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Aspects of Isometric Contractions and Static Balance in Women with Symptomatic and Asymptomatic Joint Hypermobility

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Abstract

Objective: The aim of the current study was to identify the differences in strength, balance and muscle activity between women with normal mobility and those with generalized joint hypermobility (GJH) with and without symptoms.

Methods: A total of 195 women, 67 normomobile (NM) and 128 hypermobile (HM), were included in this explorative cross-sectional study, whereby 56 were classified as symptomatically hypermobile (HM-s) and 47 as asymptomatically hypermobile (HM-as). Peak force (Fmax) and rate of force development (RFD) were measured during single-leg maximal voluntary isometric contractions of the knee extensor and flexor muscles in a sitting position. Balance was investigated on a force plate by calculating the anterior-posterior and medio-lateral sway while maintaining a single-leg stance for 15 seconds. During the sway measurements, muscle activity of six leg muscles was recorded using surface electromyography. The NM and HM groups were compared using independent samples t-tests, whereas the NM, HM-s and HM-as groups were compared using one-way ANOVAs with Tukey post-hoc tests (significance level $p \leq 0.05$).

Results: While no statistically significant differences were found for Fmax, RFD and postural sway between the three groups, semitendinosus muscle activity showed a difference between the NM and HM ($p=0.019$) as well as between the NM and HM-as groups ($p=0.020$).

Conclusions: No clinically meaningful differences were found between the three groups. This might be possibly due to the fact that the performance measurements were not sensitive and the motor tasks not challenging enough to detect differences in neuromuscular behavior of the investigated groups.

Keywords: Generalized joint hypermobility; Neuromuscular abilities; Strength; Balance; Questionnaire; Subgrouping; Symptoms

Introduction

Generalized joint hypermobility (GJH) is a condition often seen in the field of rheumatology but mostly underestimated regarding complexity of diagnosis and treatment [1].

GJH depends on age, sex and ethnicity, whereby women are usually more often affected than men and, with increasing age, joint mobility is commonly reduced [2]. In a recent survey conducted by Mulvey et al. [3], the prevalence of GJH in a general population was reported to be 18% with hypermobile subjects having a 40% increased risk of reporting severe chronic widespread pain. Furthermore, recurrent joint dislocation or subluxation, arthralgia, soft tissue injuries and back pain as well as fibromyalgia, chronic fatigue syndrome or early osteoarthritis were associated with the condition [4,5].

The diagnosis of GJH is mainly based on the Beighton Score [6,7]. With the Brighton Criteria [8], which includes additional information on medical history, the Hypermobility Syndrome is identified.

Concerning the diagnosis and treatment of this complex clinical pattern, only little evidence is available, whereby most available publications were based on professional opinions, experience and theoretical knowledge [4,9,10].

The stabilization of a joint is based on both the passive and the active tone. The passive tone includes the elastic properties of the soft tissue, which provide a certain level of stiffness. In several studies, hypermobile subjects showed differences in collagen distribution and reduced stiffness as compared to people with normal mobility [4,11,12]. The active tone is defined by the neuromuscular properties and muscular strength, which has to be split into maximum strength, strength endurance and rate of force development [13].

Activities of daily life such as walking and stair climbing are based on specific strength requirements such as rate of force development [14-16]. In individuals with reduced performance of the musculoskeletal system these activities can be problematic, leading to accidents and often to restrictions in daily life [17].

Multiple authors investigated the musculoskeletal abilities in hypermobile persons and found some differences compared to normobile persons.

Mebes et al. [18] showed that hypermobile women without symptoms had a higher isometric rate of force development in the knee extensor muscles compared to normomobile women. Another study indicated that muscle strength and functional performance of the lower extremity were reduced in women with the hypermobility type Ehler-Danlos syndrome. Furthermore, these patients demonstrated a significantly lower level of physical activity than controls [19].

In other studies, reduced proprioception and impairment in knee joint position perception was linked to hypermobility [20,21].

A study of Ferrell and colleagues reported reduced balance capability and weaker muscle reflex activity in hypermobile subjects [10]. The same group further reported that an exercise intervention program in hypermobile individuals led to improvements in balance, strength and pain and hence, to an improvement in quality of life [9]. Unfortunately, the exercises of the home-based training protocol were unclear. There is a lack of information on how symptoms and neuromuscular abilities might be linked to each other. Thus, the exact relationship between reduced neuromuscular abilities and symptoms remains unclear.

Therefore the aim of the current study was to identify the differences in strength, balance and muscle activity between women with normal mobility and those with GJH with and without symptoms.

Material and Methodology

Study design

An explorative cross-sectional design was chosen. All measurements were conducted in a single-session, except the questionnaire, which was filled in monthly over a period of six months. Inclusion criteria were checked by an independent physiotherapist. All other investigators were blinded. The study was approved by the local ethics committee and all participants provided written informed consent.

Participants and classification

Recruitment was conducted ad hoc from the staff of the University Hospital Bern, the student body of the Bern University of Applied Science and from additional sources. Prior to the invitation for the laboratory measurements, potential participants were pre-screened by phone. Inclusion criteria consisted of: women aged 18-40 years, body mass index (BMI) ranging from 18-30 kg/m^2, and no severe pain situation or disability that would restrict the measurements. Exclusion criteria were: surgeries or trauma affecting the lower extremity or lumbar spine and pregnancy within the past 2 years, diagnoses of Marfan's Syndrome, Ehlers-Danlos syndrome I and II or osteogenesis imperfecta and performing competitive sports or more than 4 hours intense training per week.

The presence of GJH was evaluated using the Beighton scoring system, whereby the women in the hypermobile group had to reach at least 6 points [7] and those in the normomobile group a maximum of 1 point. In addition, hypermobile subjects had to present a hyperextension of the right knee beyond 10 degrees and had to reach the floor easily with their palms during a forward flexion of the trunk with the knees straight. Joint mobility of the right and left knee in flexion and extension was measured with a hydrogoniometer [22-24]. Finally, a total of 195 women, 67 normomobile (NM) and 128 hypermobile (HM) were included. From the HM women 56 were further classified as symptomatically hypermobile (HM-s) and 47 as asymptomatically hypermobile (HM-as) based on a face validated follow-up questionnaire. All women who mentioned any kind of pain or disability during stair climbing within six months following the laboratory measurements were classified as symptomatic. No further classification was possible for twenty-five participants, since they did not return their questionnaires and were therefore excluded from further analyses.

Questionnaire

Symptoms were recorded monthly over a period of 6 months with a face validated questionnaire. On the date of the measurements, the Canadian Occupational Performance Measure Questionnaire (COPM) was completed by each subject [22]. The COPM was developed by occupational therapists as a tool to capture the problems of patients in daily life in a more individual way. In the semi-structured interview, the patient has to identify up to five problematic activities. Then, these activities have to be judged on a scale from 1 to 10 with regard to performance and satisfaction with the performance of each activity.

Based on the declared problem situations two problems were individually defined and additionally three generally known problems in hypermobility were included. These general problems were lifting 10 kg, descending stairs, and remaining in a position longer than 20 minutes. The questionnaire further included a general overview of their impairment, the localization, type, intensity and frequency of the problems of the participants.

Data Collection

Strength: To measure peak force (Fmax) and rate of force development (RFD) during a maximal voluntary isometric contraction (MVIC) of the knee extensor and flexor muscles, participants were seated on a custom-built chair with the knees and hips positioned in 90° of flexion. A sling was attached to the lower end of the tibia (first on the posterior side for the measurement of extension and then on the anterior side for the measurement of flexion) and connected to a one-dimensional strain gauge (KM 1500S; Megatron, Munich, Germany), which was calibrated in Newton (N).

The participants were instructed to push towards extension and flexion, respectively, as fast and as strong as possible and to maintain the force for 5 seconds. Prior to the measurements, participants were allowed to practice the task once. Each measurement was repeated three times with a break of 15 seconds in between.

Force data were sampled at 1 kHz and recorded using the software "ads" (uk-labs, Kempen, Germany).

Balance and muscle activation: To evaluate each individual's balance, the sway of the center of pressure (CoP) was measured using a force plate (Kistler, Winterthur, Switzerland), while the subjects were standing still on their right leg with eyes open and the knee flexed to an angle of 20 degrees. The subjects were instructed to hold this position as steadily as possible, three times for 15 seconds.

Simultaneously, the activity of the tibialis anterior (TA), medial gastrocnemius (GM), semitendinosus (ST), biceps femoris (BF), vastus medialis (VM) as well as vastus lateralis (VL) muscles was measured using surface electromyography (EMG). Electrode placement and measurement procedure was carried out in accordance with the recommendations of SENIAM [25] and ISEK [26]. In brief, after skin preparation, two pre-gelled AgCl-surface-electrodes (Ambu Blue

Sensor N, Ambu A/S, Ballerup, Denmark) with a diameter of 5 mm and an interelectrode distance of 2 cm were placed on each of the six muscles. The conductivity criterion was a between-electrode impedance of below 5 kΩ. EMG signals were transmitted via a pre-amplifier (gain: 500; band-pass filter: 10-500 Hz) to a telemetry system (TeleMyo 2400 G2, Noraxon, Scottsdale, Arizona, USA) and sampled in sync with the GRF-data at a frequency of 1 kHz.

Signal Analysis

Several signals were analysed using the software "ads" (uk-labs, Kempen, Germany).

Strength: Force signals were filtered using a low-pass Butterworth filter with a cut-off frequency of 30 Hz. Peak force (Fmax) and rate of force development (RFD) were extracted from the force-time curves. Fmax was defined as the absolute maximal value within the five seconds of contraction and RFD calculated as the force-difference between 20% and 80% of Fmax divided by the time difference between these two points. The average of the three trials was calculated and normalized to each individual's body weight in Newton (i.e. Fmax in BW and RFD in BW/s).

Balance and related muscle activity: Anterior-posterior (ap) and medio-lateral (ml) sways were calculated and parameterized as follows: mean sway [mm], sway range [mm] and mean sway velocity [mm/s] of the 15 seconds lasting balance test.

Electromyography of all muscles measured was calculated by root-mean-square (15-seconds window) and normalized to the activity during MVC (%MVC). Median frequency (MF: Hz) of each muscles' activity was taken out of the power spectrum of raw EMG.

All balance and activity variables were averaged over the three trials.

Statistics

Statistical calculations were carried out using the software package (SPSS 20, IBMCorp., Armonk, NY, USA).

Descriptive statistics are presented as means and standard deviations for each group. Normal distribution of the variables was confirmed using the Kolmogorov-Smirnov-test.

The differences between the groups NM and HM were evaluated using independent samples t-tests, whereas the differences between the groups NM, HM-s and HM-as were explored using one-way analyses of variance (ANOVAs) with Tukey post-hoc tests. P-values ≤ 0.05 were considered statistically significant.

Results

The two (NM and HM) as well as the three groups (NM, HM-as and HM-s) were comparable in terms of height, weight and age of the participants (Table 1).

Variables	NM	HM	NM/HM	HM-s	HM-as	NM/HM-s/HM-as	NM/HM-s	NM/HM-as	HM-s/HM-as
	(N=67)	(N=128)	p-value	(N=56)	(N=47)	p-value	p-value	p-value	p-value
Age [years]	24.8 (5.4)	25.8 (5.4)	0.234	25.3 (5.4)	25.7 (5.3)	0.701			
Height [cm]	165.7 (5.7)	166.7 (5.9)	0.267	166.9 (6.2)	167.1 (5.4)	0.378			
Mass [kg]	60.1 (6.9)	61.2 (8.2)	0.352	60.2 (7.6)	61.6 (7.6)	0.529			
BMI [kg/m^2]	21.9 (2.4)	22.0 (2.7)	0.748	21.6 (2.5)	22.1 (2.5)	0.644			
Right knee flexion [°]	152.1 (5.6)	154.5 (5.3)	0.005	155.6 (4.8)	153.3 (5.5)	0.002	0.001	0.505	0.077
Right knee extension [°]	4.1 (2.2)	11.6 (2.8)	<0.001	12.2 (3.5)	11.0 (1.8)	<0.001	<0.001	<0.001	0.054
Left knee flexion [°]	149.8 (5.7)	152.4 (6.1)	0.004	153.4 (5.8)	151.6 (6.3)	0.004	0.002	0.22	0.289
Left knee extension [°]	4.2 (2.2)	11.5 (2.8)	<0.001	12.0 (3.5)	10.9 (1.7)	<0.001	<0.001	<0.001	0.089
Beighton Score [points]	0.3 (0.5)	7.8 (1.0)	<0.001	7.8 (0.9)	7.7 (1.0)	<0.001	<0.001	<0.001	0.74

Table 1: Group characteristics for the normomobile (NM), hypermobile (HM) and symptomatic (HM-s) and asymptomatic hypermobile (HM-as) participants, presented as mean values (standard deviations) and related significance tests (T-Test and Oneway ANOVA with Tukey post hoc tests).

Strength

Fmax and RFD of the knee extensors and flexors showed neither a significant difference between NM and HM women nor between the three groups (NM, HM-as and HM-s) (Table 2).

Balance and muscle activation

No significant differences were found for the measurements of mean sway, sway range and sway velocity between the groups NM and HM or for NM, HM-as and HM-s (Table 3).

Variables	NM	HM	NM/HM	HM-s	HM-as	NM/HM-s/HM-as
	(N=67)	(N=128)	p-value	(N=56)	(N=47)	p-value
Fmax [BW] flexors	0.33 (0.10)	0.34 (0.09)	0.741	0.34 (0.10)	0.34 (0.09)	0.83
Fmax [BW] extensors	0.70 (0.14)	0.71 (0.14)	0.597	0.73 (0.14)	0.71 (0.12)	0.406
RFD [BW/s] flexors	1.15 (0.55)	1.29 (0.83)	0.208	1.24 (1.11)	1.32 (0.50)	0.495
RFD [BW/s] extensors	3.57 (1.11)	3.60 (1.18)	0.849	3.50 (1.37)	3.66 (1.01)	0.769

Table 2: Peak force (Fmax) and rate of force development (RFD) during a maximal voluntary isometric contraction (MVIC) of the knee extensor and flexor muscles for the groups normomobile (NM), hypermobile (HM) and symptomatic (HM-s) and asymptomatic (HM-as). All variables are normalized to each individual's body weight (BW) and presented as mean values (standard deviations) and related significance tests (T-Test and Oneway ANOVA).

Variables		NM	HM	NM/HM	HM-s	HM-as	NM/HMs/HM-as
		(N=67)	(N=128)	p-value	(N=56)	(N=47)	p-value
Sway (mean) [mm]	ap	6.0 (1.3)	5.8 (1.2)	0.251	5.9 (1.1)	5.8 (1.3)	0.63
	ml	5.9 (1.2)	5.8 (0.9)	0.607	5.9 (1.0)	5.7 (0.9)	0.504
Sway (range) [mm]	ap	30.3 (6.3)	29.9 (5.9)	0.702	30.4 (5.6)	29.6 (6.0)	0.724
	ml	27.8 (4.7)	27.8 (3.9)	0.918	28.3 (3.6)	27.3 (3.9)	0.502
Sway (velocity) [mm/s]	ap	35.1 (10.1)	34.7 (8.4)		33.8 (7.7)	34.4 (7.7)	0.72
	ml	44.2 (10.4)	44.0 (8.6)		44.4 (7.6)	43.5 (8.6)	0.881

Table 3: Mean sway (mm), sway range (mm) and mean sway velocity (mm/s) in anterior-posterior (ap) and medio-lateral (ml) directions during 15-seconds of single-leg stance for the groups normomobile (NM), hypermobile (HM) and symptomatic (HM-s) and asymptomatic (HM-as) groups, presented as mean values (standard deviations) and related significance tests (T-Test and Oneway ANOVA).

Muscles	NM	HM	NM/HM	HM-s	HM-as	NM/HM-s/HM-as	NM/HM-s	NM/HM-as	HM-s/HM-as
	(N=67)	(N=128)	p-value	(N=56)	(N=47)	p-value	p-value	p-value	p-value
Tibialis anterior	10.0 (5.7)	9.7 (4.7)	0.701	9.5 (3.9)	9.6(4.8)	0.843			
Gastrocnemius medialis	11.2 (4.4)	11.5 (4.4)	0.684	11.2 (3.6)	11.6 (4.9)	0.586			
Semitendinosus	8.3 (5.9)	6.3 (4.6)	0.02	5.6 (3.3)	6.5 (5.3)	0.019	0.133	0.019	0.668
Biceps femoris	12.0 (9.6)	14.3 (4.8)	0.669	10.1 (6.4)	18.9 (62.6)	0.425			
Vastus medialis	15.5 (7.7)	14.8 (7.2)	0.487	14.8 (6.5)	13.6 (6.2)	0.291			
Vastus lateralis	15.7 (6.4)	16.1 (8.2)	0.741	15.5 (6.6)	16.4 (9.6)	0.86			

Table 4: Activation levels (%MVC) of the six measured lower extremity muscles measured during 15-seconds of single-leg stance for the groups normomobile (NM), hypermobile (HM) and symptomatic (HM-s) and asymptomatic (HM-as), presented as mean values (standard deviations) and related significance tests (T-Test and Oneway ANOVA with Tukey post hoc tests).

In terms of muscle activity, the semitendinosus muscle revealed a significant decrease of mean activation level in the NM compared to the HM group (p=0.020) as well as between the HM-as and NM groups (p=0.019). No further statistically significant difference was found (Tables 4 and 5).

Muscles	NM	HM	NM/HM	HM-s	HM-as	NM/HM-s/HM-as
	(N=67)	(N=128)	p-value	(N=56)	(N=47)	p-value
Tibialis anterior	67.0 (7.7)	65.5 (7.5)	0.195	64.3 (6.9)	66.5 (7.7)	0.161
Gastrocnemius medialis	63.2 (6.8)	64.1 (6.2)	0.388	63.9 (5.7)	63.2 (6.3)	0.842
Semitendinosus	64.9 (9.4)	62.6 (8.9)	0.098	63.4 (8.4)	61.6 (9.5)	0.154
Biceps femoris	41.8 (25.2)	37.3 (25.3)	0.231	36.4 (26.6)	35.9 (25.7)	0.37
Vastus medialis	53.8 (5.3)	53.3 (5.8)	0.567	52.9 (5.5)	53.7 (5.1)	0.674
Vastus lateralis	55.9 (6.4)	54.3 (8.5)	0.162	54.1 (6.5)	54.1 (10.8)	0.356

Table 5: Median frequency of the electromyographic signal spectrum (Hz) of the six lower extremity muscles measured during 15-seconds of single-leg stance for the groups normomobile (NM), hypermobile (HM) and symptomatic (HM-s) and asymptomatic (HM-as), presented as mean values (standard deviations) and related significance tests (T-Test and Oneway ANOVA).

Discussion

The main aim of the current study was to identify differences between NM, HM-s and HM-as in terms of strength measurements (RFD, MVC), balance and related muscle activity. The results indicated that there was no difference between the three groups concerning strength (RFD and MVC) and sway parameters. In the measurement of EMG of the six muscles of the lower extremity only the value of ST was significantly different between the three groups. The reasons for this fact are multifaceted:

Strength measurements might not have been challenging enough and hence, a more demanding test setting including drop jumps and side-cutting manoeuvres should be created [27,28], to incorporate the results of one study, which stated that neural activation played an important role in the improvement of RFD [29].

In several other studies it was specified that hypermobile individuals have problems with proprioception and muscle activation [10,19] but the exact relationship to symptoms still remains unclear. In another study, asymptomatic hypermobile women showed a significantly higher value for RFD of the right leg than normomobile women measured while isometric contraction [18].

Measurement of balance may not be stressful enough for these women. One possible way to apply a more demanding balance test is to create a more instable base that the participants have to stand on for the measurement. Another possibility is to execute a more provoking test such as a jump with measurement of time to stabilization. This test used in a previous study indicated that the medio-lateral sway in hypermobile people was significantly larger than in normomobile people [18].

In terms of muscle activity, the semitendinosus muscle revealed a significant decrease of the mean activation level. But in general, the EMG values were very low compared to the activation during maximal contraction and showed a high variance. In all groups, the mean activation level of the BF muscle was higher than the one of the ST muscle. The clearest decrease could be observed between the NM and HM-as groups. A possible explanation for the higher mean activation levels of the flexor muscles in the HM-s group could be that the presence of symptoms led to the development of protective strategies.

Possibly the measurement should be more sensitive, such as the measurements of reflex activation taken in the study by Ferrell and colleagues [10] or by specifically measuring the H-reflex [30]. Hypermobile subjects showed a significantly different reflex response to that of normomobile people. Their reflex activity was slower and less powerful compared to controls with normal mobility [10].

Moreover, a not unimportant part of the activation of the EMG could be interference when holding the position of 20° flexion in the right knee while standing on the force plate.

Size and homogeneity of the groups were considered strengths of the study, whereas the inclusion of only women was considered a limitation. However, women are considerably more often affected by GJH and thus the greater interest in terms of finding adequate diagnosis and treatment. The grouping of the participants was conducted solely based on the Beighton score, which is possibly not discriminating enough. Besides the good intertester and good to very good intratester reliability, there is a lack of evidence regarding the validity of this screening tool [7]. Moreover, an important limitation of the Beighton Score is that the test movements evaluated rely only on angular movements at the end of the movement range. Therefore, the Beighton score is mainly based on passive properties and does not include active muscular stabilization or accessory (i.e. translatory) movements of the joint. An additional limitation was the inclusion of relatively healthy women, who were not actually seeking medical advice. Thus, participants were asymptomatic at the time of inclusion and able to complete the various tests in the test setting. Therefore, this may represent a sample of hypermobile women who are better able to manage their symptoms than others. However, several of these women had symptoms during the six months following the measurements, meaning that pain and disability may not be constant but rather a sort of on-off phenomenon in this population.

Retrospectively, there were some unclear instructions as how to fill in the questionnaire, especially concerning all the linked questions, and this led to missing data. However, to our knowledge, no validated questionnaire for symptoms like pain and disability in patients with hypermobility in German has been published.

The classification of the three groups based on this questionnaire is disputable. The questionnaire should be revised and validated to be applied to hypermobile subjects. In other studies it was possible to build clusters in the heterogeneity of hypermobility [8]. In these two studies the criteria to establish the subgroups were based more on anamnestic information such as psychosocial health and non-musculoskeletal disorders.

Therefore, the screening procedure and the face validated questionnaire should be more specific in order to find the finely graduated differences that enable the definition of subgroups. In addition, the measurements of strength and balance might have to be more sensitive or demanding in order to identify possible significant differences between the groups.

Conclusion

No clinically meaningful differences were found between the three groups (NM, HM-as, HM-s). This might be possibly due to the fact that the performance measurements were not sensitive and the motor tasks not challenging enough to detect differences in the neuromuscular behavior of the investigated groups. Future research should focus on the identification of additional objective parameters allowing a clear discrimination of hypermobile individuals with and without symptoms as well as normomobile individuals. Being able to establish subgroups in this complex clinical picture might make a more individual treatment possible.

Trial Registration

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Conflict of Interest Statement

The authors declare that there are no conflicts of interest.

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