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Assessment of Dynamic Balance, Muscle Strength and Pain in Young Women with Generalized Joint Hypermobility

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ABSTRACT

This research aims to assess dynamic balance, muscle strength, and pain in young women with generalized joint hypermobility.

Research methods: A cross-sectional research design was used in this study. The Beighton scale was used to assess joint hypermobility; the Y test was performed to assess injury risk; a hand-held dynamometer was applied to assess upper extremities' muscle strength; the McGill tests were used for evaluation of the endurance of trunk muscles' strength; a numeric analog scale and pain map were used to assess pain intensity and localization.

Participants: Twenty-five young females (age: 22(18–28; 21,16) years; body mass index: (23, 19,2–24, 23,2) kg/m²) participated in this study.

Results: The median Beighton score value was 7 (4-9;7.48) points. The Y balance test revealed that 36% (n=9) of the participants were at risk of injury when standing on the dominant leg, and 64% (n=16) when standing on the non-dominant leg. 64% (n=16) of the young women had a normal grip strength of the dominant hand, and 56% (n=14) had normal non-dominant handgrip strength. Only 20% (n=5) of young women with joint hypermobility had an abdominal-to-back muscle strength endurance ratio within the normal range and lateral muscle endurance ratio was within the normal range only in 16% of women.

Conclusions: Our pilot study showed that young women with joint hypermobility have reduced hand muscle strength, an imbalance in trunk muscle static endurance and an increased risk of injury in more than half of the subjects. As many as 76% of the young women in this study reported experiencing pain in different areas of the body.

Keywords: increased range of movement, fitness, injury risk

INTRODUCTION

Joint Hypermobility (JH) is a clinical sign, used to define the capability that a joint (or a group of joints) has to move, passively and/or actively, beyond normal limits along physiological axes. Although JH may exist as an isolated diagnostic finding, but is often a feature of a larger syndromic diagnosis (Castori, 2017). Joint hypermobility is divided into asymptomatic or symptomatic and syndromic or non-syndromic (Tinkle, 2020). Generalized Joint Hypermobility (GJH) is defined as the simultaneous presence of JH at the four limbs and axial skeleton, with involvement of both the major and minor joints (Castori, 2017).

Joint hypermobility can be acquired as a result of sports or other special activities, or inherited – congenital. One of the causes of joint hypermobility is a physical activity emphasizing flexibility, such as ballet, yoga, gymnastics, acrobatics, figure skating, or other activities. JH predominantly determined by the tightness or laxity of ligaments, which in turn, is influenced by genetics, involving the connective tissue genes collagen, elastin, and fibrillin (Grahame, 1999). As a consequence, heritable connective tissue disorders like the Ehlers-Danlos Syndromes, Marfan Syndrome, and Osteogenesis Imperfecta, result in systemic ligamentous laxity and can present with GJH (Malek, 2021).

Age, gender, and ethnicity have been suggested to influence the prevalence of JH (Baeza-Velasco, 2011). The prevalence of JH is highest in childhood and gradually decreases in adolescence and adult life. Research studies show that JH is observed quite often in young adults, although its prevalence differs according to country (e.g., 39.5% in France, 39% in Chile, and 26.8% in Brazil). In the USA, the proportion of young adults with varying degrees of JH ranged from 12.5 to 26.2%, of whom 36.7% were women and 13.7% were men (Estrella, 2023; Bravo, 2006; Russek, 2016; Beighton, 2011). Irrespective of age, joint hypermobility is more commonly found in women than in men by a ratio of 3:1 (Skwiot, 2019). We found no studies in Lithuania examining the prevalence of JH in young adults. Only the prevalence of joint hypermobility in schoolchildren was assessed, ranging from 5.7% to 19.2% (Gocentas, 2016).

Individuals with JH have poorer balance. Decreased proprioception is strongly associated with poorer dynamic balance, reduced knee flexors and extensors strength, and the development of knee pain (Steinberg, 2021). Dynamic balance during walking in children and young adults with joint hypermobility is associated with reduced trunk stability and poorer motor control (Falkerslev, 2013). Posturographic studies performed by Turkish researchers show that young women with GHJ have a higher risk of injury compared to subjects without GHJ (Aydin, 2017).

People with joint hypermobility have reduced *muscle mass and muscle strength*. This is partly due to increased tendon laxity, which is unable to transmit the force generated by muscles during movement (Kumar, 2017). When a joint is unstable, the surrounding muscles are stretched and weakened. This can trigger a reflex that causes the muscles to become less active or relaxed (Palmer, 2014). As a result, the damaged muscles may not be able to generate as much force as they would when the joint is stable, which can lead to reduced muscle strength. Joint hypermobility can indirectly affect muscle strength, increasing the risk of injury. When a joint is hypermobile, the risk of injury is increased due to increased joint instability, reduced movement control, and impaired proprioception. As a result of the injury, pain interferes with movement, making the muscles around the joint weak. Injured muscles need time to heal and during the healing process, the muscle is unable to generate as much force as when it was healthy (Keer, 2011).

Joint hypermobility can cause pain for various reasons. Pain can be caused by altered joint mechanics. The increased joint range of motion can cause excessive stress and strain on the soft tissues surrounding the joint: ligaments, tendons, and muscles leading to pain and inflammation (Tinkle, 2020). Joint hypermobility can lead to joint instability, which can cause irregular movements and further strain the soft tissues, provoking pain, especially when walking, running, jumping, or climbing stairs (Cronström, 2016). In individuals with joint hypermobility, the load on the joints can increase, which can lead to pain and degenerative changes in the joints. Reduced muscle activity also contributes to pain. When muscle activity and control are reduced, compensatory movement patterns develop, increasing the load on joints and soft tissues (Jensen, 2013). Individuals with joint hypermobility have increased sensitivity. The increased sensitivity may be due to altered central nervous system processing of sensory signals, which contributes to increased pain (Bulbena-Cabre, 2017).

There is a lack of research in Lithuania investigating joint hypermobility in young women. Therefore, in this pilot study, we aimed to assess dynamic balance, muscle strength, and pain in young women with joint hypermobility.

Study subject. Joint hypermobility, dynamic balance, muscle strength and pain in young women. The study hypothesizes that young women with joint hypermobility have poorer dynamic balance, muscle strength, and pain perception.

MATERIAL AND METHODS

Research organization.

All the procedures were carried out following ethical standards and were approved by the local research ethics committee (BEC-KZ(B)-20). The Helsinki Declaration (1964) and its later amendments were also followed. All participants were informed about the procedures of the study and signed a written informed consent form before participation. A cross-sectional research design was used in this study. As it was a pilot study therefore no representative sample size was calculated. A convenience sampling method was used. Inclusion criteria: female; young age; and diagnosed generalized joint hypermobility (≥ 4 points according to Beighton scale). Exclusion criteria: participation in sports or other specific activities that emphasize flexibility (gymnastics, acrobatics, figure skating, ballet, yoga, etc.); taking pain-relieving medication; history of an injury or musculoskeletal disorder within six months, and experiencing acute pain at the time of testing.

Participants.

Twenty-five young females (age: 22(18–28; 21,16) years; body mass index: (23, 19,2–24, 23,2) kg/m²) participated in this study.

Methods.

A questionnaire survey was carried out to assess the participants' compliance with the inclusion/exclusion criteria. A numeric rating scale (NRS) and pain assessment map were applied to gather information about perceived pain intensity and localization. NRS provides a subjective pain rating from 0 to 10.

Anthropometric measurements. Weight and height were measured with participants wearing light clothes and no shoes. Height was measured with a height measuring device while standing upright, inhaling, and holding the breath, with the head, shoulder blades, buttocks, thighs, and heels touching the device measured to the nearest 0.1 cm. Body weight was measured using a calibrated medical scale to the nearest 0.1 kg. All measurements were taken in triplicate and an average value was used for analysis. Body mass index was calculated as weight/height2 (kg/m²). Leg length was measured with a flexible measurement tape from the anterior superior iliac spine to the medial malleolus.

Joint hypermobility was assessed with a Beighton score. The Beighton Score is a set of maneuvers in a nine-point scoring system, used as the standard method of assessment for GJH. GJH is considered positive if the individual scored four or more from nine criteria, requiring both upper and lower limbs to be involved in the following: hyperextension of the little finger beyond 90°, apposition of the thumb to the forearm, forward flexion of the trunk, as well as hyperextension of the elbows and knees (Malek, 2021).

The Y balance test was used for dynamic stability and risk of injury assessment. During the test, the individual needed to reach the maximum possible distance in the anterior, posteromedial and posterolateral directions stably without leaving the posture indicated by the evaluator. Normalized (according to limb length) distances of each direction for each lower limb, the asymmetry between the limbs, and a composite score of the whole test were calculated. Asymmetries with a value equal to or higher than 4 cm and/or composite score below 94% are related to neuromotor deficit suggesting a greater probability of injuries in the lower limbs (Neves, 2017). For leg dominance three tests were performed: kicking a ball at a target, picking up five marbles arranged in a vertical line and putting them in a box standing on one foot, and stomping out an imaginary fire displayed on a sheet of paper standing on one foot (van Melick, 2017).

The measurements of the handgrip strength were determined using the JAMAR dynamometer (JA Preston Corporation, New York, USA). Each participant was introduced to the correct handling and positioning of the instruments: Participants were asked to sit straight, with the upper arm in a neutral position and a 90° elbow flexion. The forearm was held in a neutral position and the wrist at a 0 to 30° extension. The instrument was held freely: neither the hand nor the forearm was allowed to rest on a surface. To minimize signs of fatigue, resting periods were included after each trial (Neumann, 2017). Handgrip strength was assessed in both hands. Hand dominance was ascertained by asking each subject which hand they used to perform well-learned skills such as writing. The results were interpreted according to N. Steiber (Steiber, 2016).

Trunk muscle static strength endurance was assessed according to McGill (McGill, 2002). McGill testing battery is a series of 4 isometric (flexion, extension, right lateral flexion, and left lateral flexion) trunk exertions held to failure. Tests were performed as described in the Werner et al. study (Werner, 2021).

Statistical analysis.

Data analysis was performed using the SPSS version 29 (IBM; Armonk, USA). The Shapiro-Wilk test was used to determine the normal distribution of the data when the sample is equal to or greater than 25. The non-parametric Wilcoxon criterion (Z) was used to compare the two dependent samples when the sample size was small, and the Student's criterion (t) was used to compare the variables that followed a normal distribution. Quantitative data are presented as median Xme (minimum value (Xmin) – maximum value (Xmax) and mean (X)), and qualitative data as percent. The relationship between quantitative variables was estimated by Spearman's correlation coefficient (not normal distribution) or Pearson's correlation coefficient (in the case of normal distribution). A correlation coefficient of $|r|\leq 0.3$

was considered low, $0.3<|r|\leq 0.7$ was considered moderate, and $|r|>0.7$ was considered a strong correlation. The significance level was set at $p<0.05$.

RESULTS

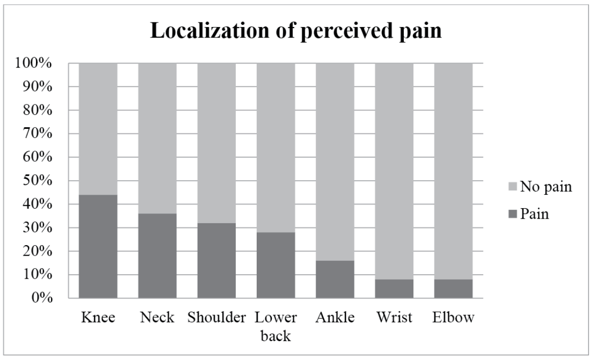
Results of joint hypermobility assessment. The Beighton score showed that 28% (n=7) of the participants scored the maximum score (9 points), 52% (n=13) scored 7–8 points, and 20% (n=5) 4–6 points. The median Beighton score value was 7 (4-9;7.48) points.

Results of dynamic balance and injury risk assessment. The Y balance test's composite score for the dominant leg was 97.3(74-106; 95.77) and in the non-dominant leg, it was 95(81–113; 94.43). No statistically significant difference was found when comparing the composite score of the two legs (t=1.082; p=0.145). The results showed that 36% (n=9) of the participants were at risk of injury when standing on the dominant leg and 64% (n=16) when standing on the non-dominant leg.

Results of handgrip muscle strength assessment. The following results were obtained: the median handgrip strength of the dominant hand was 28(12–35; 27.08) kg, and that of the nondominant hand was 26(12–32; 24.72) kg. A statistically significant difference was found when comparing the grip strength of the two hands (t=4.821; p<0.001). Only 64% (n=16) of the young women had a normal grip strength of the dominant hand, and 56% (n=14) had normal non-dominant handgrip strength.

Results of trunk muscle static strength endurance assessment. The median *abdominal* muscles endurance was 67(13–186;79.12) s and the median back muscles' endurance was 119(65–203;124.28) s. It was observed that the *back extensor muscles* endurance was twice the endurance of the abdominal muscles. A statistically significant difference (t=-6.102; p=0.001) was found when comparing the endurance of the abdominal and back muscles of the subjects. The median abdominal and back muscle endurance ratio was 0.57(0.14–1.22;0.62). The results revealed that only 20% (n=5) of young women with joint hypermobility had an abdominal-to-back muscle strength endurance ratio within the normal range. The median static strength endurance of the right lateral trunk muscles was 41(7–105; 45.64) s, and of the left lateral trunk muscles, 41(5–97; 42.96) s. No statistically significant difference was found when comparing the endurance of lateral trunk lateral muscles (t=1.505; p=0.07). The median strength endurance ratio of trunk lateral muscles was 1.08(0.45-1.80;1.07). The results showed that only 16% of young women with joint hypermobility had a lateral muscle endurance ratio within the normal range.

In young women with joint hypermobility, as many as 76% (n=19) complained of pain. In terms of pain intensity, 28% (n=7) of women reported mild pain, 32% (n=8) reported moderate pain and 16% (n=4) reported severe pain. The median pain score of participants was 3(0–6;3.08) points. The figure 1 shows the frequency of pain by body location.



DISCUSSION

For dynamic balance, the Y test was used to calculate a composite score to determine the risk of lower limb injury. After assessing the dynamic balance of young women with joint hypermobility, we found that more than half of the subjects had poor balance when standing on the non-dominant leg and were at risk of injury, and one-third – standing on the dominant leg. In a study conducted in 2023, which included subjects with joint hypermobility, poorer performance on this test was observed compared with subjects without joint hypermobility (Hou, 2023).

Handgrip strength is an important predictor of healthy aging, future morbidity, and mortality in both younger and older people. Therefore, measurement of hand grip strength is quite often used as a simple but effective tool for health risk screening (Steiber, 2016). The scientific literature suggests that hand grip strength is related to and reflects the muscular strength of the whole body. This has been supported by Trosclair et al. who suggest that the handgrip strength of individuals can be used to predict the strength and endurance of the body's muscles (Trosclair, 2011). Our study echoes the evidence that individuals with joint hypermobility have reduced muscle strength (Jindal, 2016; Mitchell, 2021; Scheper, 2016), as static grip strength of the non-dominant arm was associated with health risk in almost half of our female subjects, while that of the dominant arm was associated with health risk in more than one-third of participants.

About 80% of participants in our study had an imbalance of trunk muscle endurance, i.e., the static endurance of the abdominal muscles was significantly lower than that of the back. Work by other researchers has shown that young subjects with JH have reduced strength in all muscle groups (Scheper, 2014), but no studies have been found that assessed the abdominal-back strength endurance ratio in young subjects with joint hypermobility.

In our study, we found that young women with GHJ had also an imbalance of the lateral trunk muscles, as 84% of the subjects had an abnormal ratio of the lateral trunk muscles. Other authors have suggested that in subjects with joint hypermobility, the function of the lateral trunk muscles is partially impaired due to a reduction in the thickness of the transversus abdominis muscle. Impaired function of the transversus abdominis muscle and external oblique muscles is also observed in individuals with GHJ, but the authors did not clarify whether this is actually due to impaired systemic muscle function (Mitchell, 2022; Nanagre, 2020).

Although joint hypermobility may be asymptomatic, as many as 76% of the young women in this study reported experiencing pain in various areas of the body. The most common areas of pain were the knees (44%), the neck (36%) and the shoulders (32%), In a study conducted in 2022, young adults with hypermobility spectrum disorder reported that the most common areas of pain were the neck and back (Akkaya, 2022). In a study conducted in 2014, individuals with joint hypermobility reported, in descending order, the most frequent areas of pain were the knees, back, neck and shoulders (Al-Jarallah, 2014. The results of this study are broadly in line with the findings of other researchers). Other authors have suggested that individuals with JH who experience pain have also reduced isometric strength, suggesting that a deficit in muscle strength is associated with pain (Radaelli, 2022).

The absence of a control group, i.e., individuals without joint hypermobility, could be identified **as a weakness of this study**, as it would have made it easier to compare the data and indicators between individuals with and without joint hypermobility.

CONCLUSIONS

Our pilot study showed that young women with joint hypermobility have reduced hand muscle strength, an imbalance in trunk muscle static endurance and an increased risk of injury in more than half of the subjects. As many as 76% of the young women in this study reported experiencing pain in different areas of the body. We believe that further, comprehensive studies are needed to address the problem of joint hypermobility in young women and that it is particularly relevant to assess complex interventions to improve physical performance and reduce pain.

REFERENCES

Aydın, E., Metin Tellioğlu, A., Kurt Ömürlü, İ., Polat, G., & Turan, Y. (2017). Postural balance control in women with generalized joint laxity. Turkish journal of physical medicine and rehabilitation, 63(3), 259–265. https://doi.org/10.5606/tftrd.2017.160

Akkaya K.U., Burak M., Erturan S., Yildiz R., Yildiz A., Elbasan B. (2022). An investigation of body awareness, fatigue, physical fitness, and musculoskeletal problems in young adults with hypermobility spectrum disorder. *Musculoskeletal Science and Practice*; 62:102642. https://doi.org/10.1016/j.msksp.2022.102642

Al-Jarallah, K., Shehab, D., Al-Jaser, M. T., Al-Azemi, K. M., Wais, F. F., Al-Saleh, A. M. et al. (2014). Prevalence of joint hypermobility in Kuwait. *Int J Rheum Dis, 20*(8), 935. https://doi.org/10.1111/1756-185X.12556

Baeza-Velasco, C., Gely-Nargeot, M. C., Vilarrasa, A. B., Fenetrier, C., Bravo, J. F. (2011). Association between Psychopathological Factors and Joint Hypermobility Syndrome in a Group of Undergraduates from a French University. *Int J Psychiatry Med*, *41*(2), 187–201. https://doi.org/10.2190/PM.41.2.g

Beighton, P.H., Grahame, R., Bird, H. (2011). Hypermobility of joints 4th edition. Springer Science & Business Media, p. 136.

Bravo, J. F., Wolff, C. (2006). Clinical study of hereditary disorders of connective tissues in a Chilean population. *Arthritis Rheum, 54*:515–523. https://doi.org/10.1002/art.21557

Bulbena-Cabre, A., Salgado, P., Rodriguez, A., Bulbena, A. (2017). Joint hypermobility: A potential biomarker for anxiety disorders in bipolar patients. *Journal of psychosomatic research, 97*:141. DOI:10.1016/j.jpsychores.2017.03.217

Castori, M., Tinkle, B., Levy, H., Grahame, R., Malfait, F., & Hakim, A. (2017). A framework for the classification of joint hypermobility and related conditions. American journal of medical genetics. Part C, Seminars in medical genetics, 175(1), 148–157. https://doi.org/10.1002/ajmg.c.31539

Cronström, A., Creaby, M.W., Nae, J., Ageberg, E. (2016) Modifiable Factors Associated with Knee Abduction During Weight-Bearing Activities: A Systematic Review and Meta-Analysis. *Sports Medicine, 46*(11), 1647–1662. https://link.springer.com/article/10.1007/s40279-016-0519-8

Estrella, E., Frazier, P. A. (2023). Healthcare experiences among adults with hypermobile Ehlers-Danlos syndrome and hypermobility spectrum disorder in the United States. *Disabil Rehabil, 46*(4), 731–740. doi: 10.1080/09638288.2023.2176554

Falkerslev, S., Baagø, C., Alkjær, T., Remvig, L., Halkjær-Kristensen, J., Larsen, P. K., Juul-Kristensen, B., & Simonsen, E. B. (2013). Dynamic balance during gait in children and adults with Generalized Joint Hypermobility. *Clinical biomechanics (Bristol, Avon)*, *28*(3), 318–324. https://doi.org/10.1016/j.clinbiomech.2013.01.006

Gocentas, A., Jascaniniene, N., Pasek, M., Przybylski, W., Matulyte, E., Mieliauskaite, D., Kwilecki, K., & Jaszczanin, J. (2016). Prevalence of generalised joint hypermobility in school-aged children from east-central European region. *Folia morphologica*, *75*(1), 48–52. https://doi.org/10.5603/FM.a2015.0065

Grahame, R. (1999). Joint hypermobility and genetic collagen disorders: are they related? *Archives of disease in childhood, 80*(2), 188–191. https://doi.org/10.1136/adc.80.2.188

Hou, Z., Ao, Y., Hu, Y., Jiao, C., Guo, Q., Li, N. et al. (2023). Balance training benefits chronic ankle instability with generalized joint hypermobility: a prospective cohort study. *BMC musculoskeletal disorders*, *24*(1),71. https://doi.org/10.1186/s12891-023-06179-2

Jensen, B. R., Olesen, A. T., Pedersen, M. T., Kristensen, J. H., Remvig, L., Simonsen, E. B. et al. (2013). Effect of generalized joint hypermobility on knee function and muscle activation in children and adults. *Muscle & nerve, 48*(5),762–769. https://doi.org/10.1002/mus.23802

Jindal, P., Narayan, A., Ganesan, S., MacDermid, J. C. (2016). Muscle strength differences in healthy young adults with and without generalized joint hypermobility: a cross-sectional study. *BMC Sports Sci Med Rehabil, 8*(1), 1–9. https://doi.org/10.1186/s13102-016-0037-x

Keer, R., & Simmonds, J. (2011). Joint protection and physical rehabilitation of the adult with hypermobility syndrome. *Current opinion in rheumatology, 23*(2), 131–136. https://doi.org/10.1097/BOR.0b013e328342d3af

Kumar, B., Lenert, P. (2017). Joint Hypermobility Syndrome: Recognizing a Commonly Overlooked Cause of Chronic Pain. *Am J Med, 130*(6), 640–647. https://doi.org/10.1016/j.amjmed.2017.02.013

Malek, S., Reinhold, E. J., & Pearce, G. S. (2021). The Beighton Score as a measure of generalised joint hypermobility. *Rheumatology international, 41*(10), 1707–1716. https://doi.org/10.1007/s00296-021-04832-4

McGill S. (2002) Low Back Disorders: Evidence-Based Prevention and Rehabilitation. Champaign, IL: Human Kinetics.

van Melick, N., Meddeler, B. M., Hoogeboom, T. J., Nijhuis-van der Sanden, M. W. G., & van Cingel, R. E. H. (2017). How to determine leg dominance: The agreement between self-reported and observed performance in healthy adults. *PloS one, 12*(12), e0189876. https://doi.org/10.1371/journal.pone.0189876

Mitchell, U. H., Johnson, A.W., Adams, L., Kho, J., Belavy, D. L., Owen, P. J. (2021). Muscle Contraction is Impaired in Hypermobile People: A Study of The Lateral Abdominal Muscles. 10.21203/rs.3.rs-200491/v1

Mitchell, U. H., Johnson, A. W., Adams, L., Kho, J., Pace, N., Owen, P.J. (2022). Lateral abdominal muscles of adults with hypermobility may be partially impaired during contraction. *BMJ Open Sp Ex Med, 8*(3), e001343. doi: 10.1136/bmjsem-2022-001343

Nanagre, A. H., Chotai, K. T. (2020). Relationship between Trunk Muscle Enduranceand StaticDynamic Balance in Physically Active Individuals. *Indian Journal of Public Health Research & Development, 11*(5), 38–43. https://doi.org/10.37506/ijphrd.v11i5.9287

Neumann, S., Kwisda, S., Krettek, C., & Gaulke, R. (2017). Comparison of the Grip Strength Using the Martin-Vigorimeter and the JAMAR-Dynamometer: Establishment of Normal Values. *In vivo (Athens, Greece), 31*(5), 917–924. https://doi.org/10.21873/invivo.11147

Neves, L.F., Souza, C.Q.D., Stoffel, M, Picasso, C.L.M. (2017) The Y Balance Test – How and Why to Do it?. *Int Phys Med Rehab J 2(4)*: 00058. doi: 10.15406/ipmrj.2017.02.00058

Palmer, S., Bailey, S., Barker, L., Barney, L., & Elliott, A. (2014). The effectiveness of therapeutic exercise for joint hypermobility syndrome: a systematic review. *Physiotherapy, 100*(3), 220–227. https://doi.org/10.1016/j.physio.2013.09.002

Radaelli, R., Brusco, C. M., Machado, C. L. F., Martins, D., Sakugawa, R. L., Diefenthaeler F. et al. (2022). Muscle function and muscle balance in lower limbs are not impaired in individuals with general joint hypermobility. *Sport Sci Health, 18*(2), 455–462. DOI: 10.1007/s11332-021-00824-w

Russek, L. N., Errico, D. M. (2016). Prevalence, injury rate and, symptom frequency in generalized joint laxity and joint hypermobility syndrome in a "healthy" college population. *Clin Rheumatol, 35,* 1029–1039. https://doi.org/10.1007/s10067-015-2951-9

Scheper, M., Rombaut, L., De Vries, J., De Wandele, I., Van, Der, Esch, M., Visser, B. et al. (2016). The association between muscle strength and activity limitations in patients with the hypermobility type of Ehlers–Danlos syndrome: the impact of proprioception. *Disabil Rehabil, 39*(14), 1391. https://doi.org/10.1080/09638288.2016.1196396

Scheper, M., de Vries, J., Beelen, A., de Vos, R., Nollet, F., & Engelbert, R. (2014). Generalized joint hypermobility, muscle strength and physical function in healthy adolescents and young adults. *Current rheumatology reviews*, *10*(2), 117–125. https://doi.org/10.2174/1573397111666150120112925

Skwiot, M., Śliwiński, G., Milanese, S., Śliwiński, Z. (2019). Hypermobility of joints in dancers. *PLoS*

One, 14(2), e0212188. https://doi.org/10.1371/journal.pone.0212188

Steiber N. (2016). Strong or Weak Handgrip? Normative Reference Values for the German Population across the Life Course Stratified by Sex, Age, and Body Height. *PloS one, 11*(10), e0163917. https://doi.org/10.1371/journal.pone.0163917

Steinberg, N., Tenenbaum, S., Zeev, A., Pantanowitz, M., Waddington, G., Dar, G. et al. (2021). Generalized joint hypermobility, scoliosis, patellofemoral pain, and physical abilities in young dancers. *BMC Musculoskelet Disord, 22*(1), 161. https://bmcmusculoskeletdisord.biomedcentral.com/articles/10.1186/s12891-021-04023-z

Tinkle, B. T. (2020). Symptomatic joint hypermobility. *Best practice & research. Clinical Rheumatology, 34*(3), 101508. https://doi.org/10.1016/j.berh.2020.101508

Trosclair, D., Bellar, D., Judge, L., Smith, J., Mazerat, N., Brignac, A. (2011). Hand-Grip Strength as a Predictor of Muscular Strength and Endurance. *Journal of Strength and Conditioning Research, 25*, 99. 10.1097/01.JSC.0000395736.42557.bc

Werner, D. M., & Barrios, J. A. (2021). Trunk Muscle Endurance in Individuals With and Without a History of Anterior Cruciate Ligament Reconstruction. *Journal of strength and conditioning research*, *35*(1), 118–123. https://doi.org/10.1519/JSC.0000000000002395

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