



Published in final edited form as:

*Clin Biomech (Bristol, Avon)*. 2024 March ; 113: 106210. doi:10.1016/j.clinbiomech.2024.106210.

## Assessment of Gait Mechanics and Muscle Strength in Hypermobile Ehlers Danlos Syndrome

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### Abstract

**BACKGROUND:** Hypermobile Ehlers Danlos Syndrome, a heritable connective tissue disorder, is associated with muscle dysfunction, joint subluxations and pain. The impact of hypermobile Ehlers Danlos Syndrome on musculoskeletal mechanics is understudied. Therefore, the aim of this study was to assess the effects of hypermobile Ehlers Danlos Syndrome on lower extremity gait mechanics and muscle strength.

**METHODS:** Eleven people with hypermobile Ehlers Danlos Syndrome and 11 asymptomatic controls underwent a 3D gait analysis and isometric hip and knee muscle strength assessment. Joint subluxations were self-reported by the hypermobile Ehlers Danlos syndrome group. Independent t-tests and Mann Whitney U tests were used to analyze joint mechanics, muscle strength, and patient report outcomes ( $p < 0.05$ ).

**FINDINGS:** Both groups exhibited similar walking speeds as well as similar hip, knee, and ankle joint kinematics. The hypermobile Ehlers Danlos Syndrome group walked with a lower peak hip extensor moment (hypermobile Ehlers Danlos Syndrome:  $-0.52 \pm 0.28 \text{ Nm} \cdot \text{kg}^{-1}$ , Control:  $-0.83 \pm 0.26 \text{ Nm} \cdot \text{kg}^{-1}$ ,  $p = 0.01$ ) yet similar knee and ankle joint moments. The hypermobile Ehlers Danlos Syndrome group exhibited a 40% deficit in peak hip extensor strength (hypermobile Ehlers Danlos Syndrome:  $1.07 \pm 0.53 \text{ Nm} \cdot \text{kg}^{-1}$ , Control:  $1.77 \pm 0.79 \text{ Nm} \cdot \text{kg}^{-1}$ ,  $p = 0.04$ ). Approximately 73%, 55% and 45% of the hypermobile Ehlers Danlos Syndrome cohort self-reported hip, knee/patella and ankle joint subluxations, respectively, at least once a week.

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**INTERPRETATION:** Patients with hypermobile Ehlers Danlos Syndrome ambulated with altered hip extensor moments and exhibit hip extensor weakness. Future work should investigate the underlying mechanisms of hip extensor weakness and corresponding effects on joint health in people with hypermobile Ehlers Danlos Syndrome.

### Keywords

Ehlers Danlos Syndrome; Hypermobility; Gait; Strength; Lower Extremity

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## 1. Introduction:

Ehlers Danlos Syndrome (EDS) is a heritable connective tissue disorder, consisting of numerous subtypes that impact the cardiovascular, musculoskeletal, and nervous systems.<sup>1</sup> Approximately 10 million people in the United States have the hypermobile EDS (hEDS) subtype, representing 80 – 90% of the entire EDS population.<sup>2</sup> People with hEDS exhibit severe joint hypermobility, chronic musculoskeletal fatigue, and pain.<sup>2</sup> Although people with hEDS and joint hypermobility syndrome (JHS) both exhibit joint hypermobility, the disease manifestations in the hEDS and JHS populations are distinct. Only one or a few joints, seldom more than five, are hypermobile in most instances of JHS.<sup>3</sup> However, because hypermobility is not always accompanied by symptoms, it may not necessarily lead to a clinical presentation.<sup>3</sup> Joint hypermobility and alterations in proprioception lead to chronic joint instability in people with hEDS and may result in soft tissue injuries leading to the higher incidence rate of osteoarthritis (OA) in the hEDS population.<sup>4</sup> With approximately 1% of the hEDS population (> 100,000 people)<sup>2</sup> exhibiting signs of early onset OA<sup>5</sup>, there is a critical need to understand the impact of hEDS on joint function so that interventions can be developed to improve long-term joint health in people with hEDS.

Although people with hEDS and JHS have distinct disease manifestations, previous gait-related studies have combined people with hEDS and JHS as a single cohort.<sup>6</sup> Despite the potential limitations of combining hEDS and JHS populations into a single cohort, there is a limited amount of prior research investigating the impact of joint hypermobility on gait mechanics. Individuals with hEDS and JHS ambulate with lower hip and ankle joint stiffness compared to healthy individuals and may suggest lower hip and ankle joint stability in hEDS and JHS.<sup>7</sup> Prior work has focused on the relationship between ankle joint mechanics and the vertical ground reaction force (vGRF) during walking with self-reported fatigue in people with hEDS and JHS.<sup>6</sup> Higher self-reported fatigue levels were associated with lower peak vGRF during walking yet there was no relationship between fatigue with ankle joint mechanics in those with hEDS and JHS.<sup>6</sup> This lack of association between self-reported fatigue and ankle joint mechanics may be due to the combined hEDS and JHS cohort in this previous study<sup>6</sup> and suggests that gait mechanics should be evaluated separately in the hEDS and JHS populations. In addition, prior work has shown that people with hEDS ambulate with higher forefoot contact area and pressure compared to healthy individuals<sup>8</sup>, suggesting altered proprioception may lead to aberrant joint loadings patterns in people with hEDS during gait. In order to better understand the impact of hEDS on musculoskeletal function and gait mechanics, studies should not combine people with hEDS and JHS into a single

cohort and should solely investigate the direct impact of hEDS on lower extremity joint function and health.

People with hEDS exhibit recurrent dislocations and subluxations during activity, which leads to chronic pain and a higher risk of soft tissue overuse injury and disability.<sup>9,10</sup> The high rate of joint dislocations and subluxations may be due to the altered muscle tissue composition<sup>11</sup> in people with hEDS, resulting in abnormal muscle function and correspondingly, altered joint mechanics. More specifically, people with hEDS exhibit weaker quadriceps and hamstrings musculature, compared to healthy individuals, which may lead to increased joint instability during dynamic activity and may result in higher amounts of joint subluxations.<sup>11</sup> Prior work has shown that people with hEDS ambulate with lower hip and ankle joint stiffness<sup>9</sup>, which may be due to ligament laxity and an inability of the surrounding musculature to optimally stabilize these joints during walking. Despite the prior work indicating joint instability and lower joint stiffness in the hEDS population, the overall lower extremity gait patterns and muscle function exhibited by individuals with hEDS are not well documented. It is however, reported in prior literature that musculoskeletal fatigue has a direct relationship with muscle weakness, and changes in movement patterns in people with hEDS.<sup>9</sup> As lower muscle strength was associated with lower activity levels in the hEDS population<sup>12</sup>, understanding the association between lower extremity gait mechanics and muscle function would provide insight into biomechanical factors that lead to inactivity in the hEDS population. More specifically, a combined analysis of muscle strength and gait mechanics will provide clinicians with the clinically relevant information needed to better understand the impact of hEDS on joint function during walking. These gait and muscle related data will provide potential biomechanical- and muscular-based targets for hEDS-related interventions that seek to improve joint function and joint health as well as reduce musculoskeletal fatigue in the hEDS population.

Prior work has grouped individuals with hEDS and JHS as a single cohort despite the highly distinct clinically based classifications for diagnosis of hEDS and JHS<sup>1,13</sup> and has led to a lack of understanding of the impact of hEDS on lower extremity muscle function and joint mechanics. Current rehabilitation protocols to optimize gait mechanics and function in the hEDS population are not scientifically informed. In order to develop an effective and scientifically justified gait-related rehabilitation program for the hEDS population, we must first understand the potential gait-related abnormalities in people with hEDS. Therefore, the purpose of this study was to investigate the differences in lower extremity gait mechanics and muscle strength between people with hEDS and healthy individuals. We hypothesized that people with hEDS would exhibit altered lower extremity gait mechanics and muscle weakness compared to healthy individuals.

## 2. Methods

### Participants:

This cross-sectional study recruited and tested 11 people with hEDS (9 females; age =  $36.4 \pm 10.5$  yrs.; body mass index (BMI) =  $29.5 \pm 4.9$  kg·m<sup>-2</sup>) and 11 age, sex and BMI-matched healthy, asymptomatic controls (9 females; age =  $34.5 \pm 15.5$  yrs.; BMI =  $27.8 \pm 4.8$  kg·m<sup>-2</sup>) from our laboratory's healthy control database. All participants with hEDS

in this study were diagnosed using both the Beighton score criteria<sup>13</sup> and the 2017 Ehlers Danlos International Medical Criteria<sup>1</sup>. In addition, none of the participants with hEDS reported physical limitations that prohibited physical activity including walking and were cleared for participation by their physician. Study participants were excluded from this study if they had a prior lower extremity injury in the past 6 months, prior surgery on the test limb, prior diagnosis of rheumatoid arthritis, any neurological, spine, or any other lower extremity conditions that may affect gait patterns or BMI > 40 kg·m<sup>-2</sup>. The dominant limb was selected as the test limb for all study participants and was defined as the limb that the participant would use to kick a soccer ball the furthest<sup>14</sup>. This study was approved by our University's Institutional Review Board and all study participants provided written informed consent prior to testing.

### Gait Analysis:

Three-dimensional marker positions and ground reaction force (GRF) data were collected simultaneously at 250Hz and 2000Hz using a 13-camera motion capture system (Motion Analysis, Rohnert Park, CA) and an instrumented treadmill (Bertec Corp., Columbus, OH). In order to minimize the impact of footwear on gait mechanics, all study participants wore lab standardized footwear (New Balance, MZANTPC4.) A modified Cleveland Clinic markerset was used, which consisted of 46 reflective markers and were placed on anatomical landmarks in order to track segment position. To track torso position, retroreflective markers were placed on the sternal notch, the C7 vertebrae, and bilaterally on the acromion processes. Pelvis tracking was performed using markers on the anterior superior iliac spines, iliac crests, and posterior superior iliac spines. Calibration markers were placed bilaterally on the medial and lateral femoral epicondyles and malleoli, as well as the first metatarsal heads. Rigid body clusters, consisting of 4 markers each, were placed bilaterally on the lateral thighs and shanks. Foot segment tracking was performed using markers placed on the inferior and superior heel, lateral heel, second- and fifth metatarsal heads<sup>15</sup>. A three-second static calibration trial was obtained and then all calibration markers were removed.

Subjects were asked to ambulate on the instrumented treadmill at a self-selected, comfortable speed. An acclimatization period was provided to allow study participants to become comfortable walking at the self-selected speed on the instrumented treadmill. After the acclimatization period, a 20-second capture was performed, and we ensured that there was a minimum of 5 clean trials for the test limb. A clean gait trial was defined as maintaining one foot on each force belt during the stance phase of gait. The stance phase was defined as initial contact to toe-off, whereby a 20N vertical GRF threshold was used to indicate initial contact. All raw marker position and GRF data were filtered with a 4<sup>th</sup> order, low pass Butterworth filter at 8Hz and 35Hz, respectively. An 8-segment musculoskeletal model consisting of the trunk, pelvis and bilateral thighs, shanks and feet was created using each study participant's static calibration trial using Visual3D (C-Motion, v6.01.33, Germantown, MD). The hip joint centers were calculated using the CODA pelvis method<sup>16,17</sup>. Knee and ankle joint centers were estimated as the midpoint between the medial and lateral femoral condyles and malleoli, respectively. Joint angles were calculated using a Cardan sequence of X-Y'-Z'', representing the medial-lateral, anterior-posterior and superior-inferior axes, respectively. Joint angles were normalized to the standing calibration

trial. Internal joint moments were calculated and normalized by body mass ( $\text{N}\cdot\text{m}\cdot\text{kg}^{-1}$ ). Joint angle and joint moments were utilized the CODA pelvis to estimate the hip joint centers. Knee and ankle joint centers were estimated as the midpoint between the medial and lateral femoral condyles and malleoli, respectively. We assessed sagittal plane joint kinematics during the stance phase, which included the peak hip flexion and extension angles, peak knee flexion during loading response, peak ankle dorsiflexion and plantarflexion angles, hip and ankle joint range of motion (ROM) as well as knee joint excursion (peak knee flexion during loading response – knee position at initial contact). The kinetic parameters assessed during the stance phase included the peak hip flexion and extension moments, knee flexion and extension moments during the first and second halves of stance as well as the peak ankle dorsiflexion and plantarflexion moments. Hip flexion, knee flexion<sup>25</sup> and ankle dorsiflexion angles and moments were considered positive.

### Strength Testing:

Previous research demonstrates that fatigue can distort outcomes when activities are performed back-to-back without a rest period in people with hEDS.<sup>11</sup> In order to reduce the potential impact of fatigue on lower extremity muscle strength testing in the hEDS group, study participants were provided with a 20-minute rest period after completing the gait analysis. To minimize the risk of subluxations or an increase in pain in the hEDS cohort, isometric hip and knee strength testing was performed on a Biodex System 4 (Biodex Systems, Shirley, NY). Hip extensor and flexor strength assessment was performed with the participant laying supine with their hip fixed at 30° of flexion and their knee joint flexed to 90°. The dynamometer arm was secured at approximately 5cm proximal to the lateral femoral condyle. Knee extensor and flexor strength assessment was performed with the participant seated with their hips at approximately 85° of flexion and their knee joint at 90° of flexion. The dynamometer arm was secured at approximately 5cm proximal to the medial malleolus. Each participant was instructed to perform a 5-second maximal voluntary isometric contraction (MVIC) of the hip and knee extensors and flexors. Each participant was asked to perform five, 5-second maximal voluntary isometric contractions (MVIC) for the hip and knee extensor and flexor musculature. As individuals with hEDS exhibit significant muscle-related fatigue during activity<sup>9</sup>, the first MVIC for each muscle group was used as a familiarization trial and the peak torque of the remaining four MVIC was extracted and used for data analysis. A 30-second rest period was provided between each MVIC and a minimum of a 2-minute rest period was given between testing of each muscle group. All strength values were gravity corrected and normalized by body mass ( $\text{Nm}\cdot\text{kg}^{-1}$ ). It should be noted that 3 out of 11 participants with hEDS were unable to complete the hip strength testing due to severe pain or potential subluxations. For analyses involving hip strength, missing data was treated using listwise deletion.

In addition to gait analysis and evaluation of muscle strength, questionnaires were administered to the hEDS participants to obtain patient reported outcomes. More specifically, these questionnaires were used to gather additional information about each participant's medical history, physical activity level, and subluxation history. We quantified the proportion of our hEDS cohort that experienced a minimum of 1 hip, knee/patella or ankle joint subluxation on a weekly basis.

### Statistical Analysis:

Between group differences in demographic data were analyzed using independent t-tests. Gait and strength related data were tested for normality using the Shapiro-Wilk test and visually inspected using histograms. Group differences in walking speed, sagittal plane hip, knee and ankle joint kinematics and internal joint moments as well as peak isometric strength were evaluated using independent t-tests or Mann-Whitney U tests as necessary. Due to the categorical nature of the FSS and self-report joint subluxations, Spearman rho correlation coefficients ( $\rho$ ) were used to assess the relationship of statistically significant gait parameters and muscle strength with FSS scores and incidence of hip, knee, and ankle joint subluxations within the hEDS group. Cohen's d effect sizes were also calculated whereby values of 0 – 0.2, 0.21 – 0.5, and > 0.5, were considered to be small, medium, and large effect sizes, respectively<sup>18</sup>. Statistical significance for all analyses was set at the 0.05 level.

### 3. Results:

The hEDS ( $0.89 \pm 0.27 \text{ m}\cdot\text{s}^{-1}$ ) and control ( $0.84 \pm 0.20 \text{ m}\cdot\text{s}^{-1}$ ) groups walked at similar speeds ( $p = 1.0$ ; Table 1). Despite a lack of between group-differences ( $p > 0.05$ ) in joint kinematics (Figure 1), the hEDS group ambulated with a lower peak hip extensor moment ( $p = 0.01$ , Cohen's  $d = -1.18$ ) compared to the control group (Figure 2). There were no significant differences in knee extensor, knee flexor or hip flexor strength yet the hEDS group exhibited approximately a 40% deficit in peak hip extensor strength ( $p = 0.04$ , Cohen's  $d = 0.69$ ) compared to the control group. In addition, 91% of the hEDS participants tested in this study reported hip, knee, or ankle joint subluxation at least once a week. When examined by a specific lower extremity joint, 73%, 55% and 45% of the participants with hEDS indicated experiencing at least one hip, knee/patella, and ankle joint subluxation, respectively, on a weekly basis. There were no significant relationships between the peak hip extensor moment or peak hip extensor strength with FSS or incidence of joint subluxations within the hEDS group ( $p > 0.05$ ).

### 4. Discussion:

Prior research combining individuals with hEDS and JHS together into a single cohort may not provide an optimal assessment of the impact of these conditions on gait mechanics and muscle function. Our study utilized a homogenous cohort consisting of individuals with clinically diagnosed hEDS, which will provide a more thorough understanding of the impact of hEDS on lower extremity joint mechanics and muscle function. According to our results, individuals with hEDS ambulated at similar speeds and utilized similar hip, knee and ankle joint kinematics as healthy individuals. However, the hEDS cohort exhibited significantly lower internal hip extensor moments and hip extensor muscle strength. The lower peak hip extensor moment observed in the hEDS cohort may be due to the hip extensor weakness in these hEDS individuals and may lead to joint pain and instability during walking. The lower hip extensor moment exhibited by the hEDS cohort may be associated with sub-optimal hip joint stability and would help to explain the high incidence (73%) of hip joint subluxations in our study cohort. Altered hip extensor function during gait may lead to increased hip joint instability, a higher incidence of tissue micro-trauma<sup>4</sup> and a higher risk of

developing hip OA in people with hEDS. These biomechanical and muscular abnormalities surrounding the hip joint suggest hip extensor muscle dysfunction in individuals with hEDS. Hip extensor dysfunction may result in hip joint pain and instability while walking in the hEDS population, which may hinder the ability of people with hEDS to carry out daily tasks or exercise and could have a negative impact on their overall general wellness. Future work should investigate the underlying cause of hip extensor muscle dysfunction in the hEDS population in order to determine potential muscular-based targets to optimize hip extensor function in the hEDS population.

Previous research has shown that when studied as a combined group, individuals with hEDS and JHS ambulate with a more plantarflexed ankle joint yet similar hip and knee joint kinematics as healthy individuals.<sup>7</sup> In contrast, the hEDS cohort in our study ambulated with similar hip, knee and ankle joint kinematics as the control cohort. Prior research demonstrated that individuals with hEDS and JHS ambulate with lower sagittal plane hip joint stiffness (change in hip moment divided by change in hip angle) during the initial 30% of the stance phase as well as a lower plantarflexor moment during terminal stance<sup>7</sup>. Although hip joint stiffness was not quantified in our study, the lower peak hip extensor moment observed in our hEDS cohort occurs during the first half of the stance phase may help to explain the lower hip joint stiffness observed in people with hEDS and JHS. Prior research has demonstrated that individuals with hEDS and JHS ambulate with a lower peak ankle plantarflexor moment compared to healthy controls<sup>7</sup> yet the hEDS group in our study did not exhibit any alterations in ankle joint moments during walking. The difference in results regarding gait mechanics may be due to the use of a more homogenous group within our study consisting of only those individuals with clinically diagnosed hEDS. In addition, the use of a short bout of walking as performed in prior work<sup>9</sup> and in our experimental protocol, may not elicit a large enough demand on the lower extremity in individuals with hEDS and use of a more dynamically challenging task, such as prolonged walking (i.e. aerobic exercise) may be more sensitive in detecting alterations in the lower extremity joint mechanics in the hEDS population.

Despite similar hip flexor and knee joint strength, our hEDS cohort exhibited significantly weaker hip extensor musculature compared to the healthy control cohort and may suggest hip extensor muscle dysfunction. The only gait-related alteration that was exhibited by our hEDS cohort was the lower peak hip extensor moment and may be associated with hip extensor muscle dysfunction. The suggested hip extensor muscle dysfunction may be due to altered muscle composition in people with hEDS. More specifically, people with hEDS exhibit a disorder of the collagen network within connective tissues, such as muscle, and also exhibit impaired connective tissue repair mechanisms<sup>19</sup>, which would lead to fibrotic transformation of the muscle's extra cellular matrix. The joint moment is an indirect measure of muscle function during activity and these potential alterations in the extra cellular matrix would impact the transfer of force<sup>20</sup> within the hip extensor musculature. These alterations in muscle compensation would help to explain the weaker hip extensor musculature and correspondingly, lower peak hip extensor moment during walking observed in our hEDS cohort. These alterations in muscle composition may more severely affect the hip extensor musculature, compared to other muscle groups, in individuals with hEDS and may help to explain the lack of differences in hip flexor, knee flexor and knee

extensor peak strength and moments. Future work combining measures of hip extensor muscle composition and gait analysis would provide insight into the potential underlying compositional factors associated with hip extensor muscle dysfunction that lead to altered hip extensor moments in the hEDS population.

There are a few limitations that should be considered when interpreting the results of our study. Firstly, the majority (over 80%) of the participants with hEDS in our study were female; however, this reflects the distribution of the diagnosis in the population. Previous work<sup>9,21</sup> has indicated that approximately 80 – 93% of people with hEDS are female. Secondly, our study used a short bout of walking to assess gait mechanics and may not provide an accurate assessment of gait-related abnormalities that are associated with inactivity in the hEDS population. We recognize that our sample size is limited, and in part due to a small percentage of individuals with hEDS as it is a rare genetic condition. Despite this fact, future studies should try to recruit a larger cohort of patients with hEDS. We also recognize that our results are slightly underpowered (post-hoc power: 0.75) and recruiting a larger cohort should help to increase study-related power. As chronic pain and joint instability in people with hEDS is more evident after walking for at least 30 minutes<sup>22</sup> future work should include gait analysis during a longer duration of walking ( > 30 minutes), to assess the impact of aerobic exercise (i.e. prolonged walking) on gait mechanics in the hEDS population. In addition, we did not investigate muscle activity during gait and future work should utilize electromyography to assess the impact of hEDS on muscle activation during walking.

## 5. Conclusion:

In our study, individuals with hEDS exhibited a 37% lower peak hip extensor moment during walking and also demonstrated a 40% deficit in hip extensor muscle strength, when compared to healthy controls. Our findings may help clinicians establish an understanding of potential biomechanical- and muscle-related targets for interventions to improve gait mechanics and to help increase physical activity, optimize joint function and reduce risk of joint degeneration in the hEDS population.

## Funding Sources

This research was supported in part by the University of Kentucky Department of Kinesiology and Health Promotion Graduate Student Research Funding, Pediatric Exercise Physiology Lab Endowment and NIH (K01-AG073698, K01-HL149984)

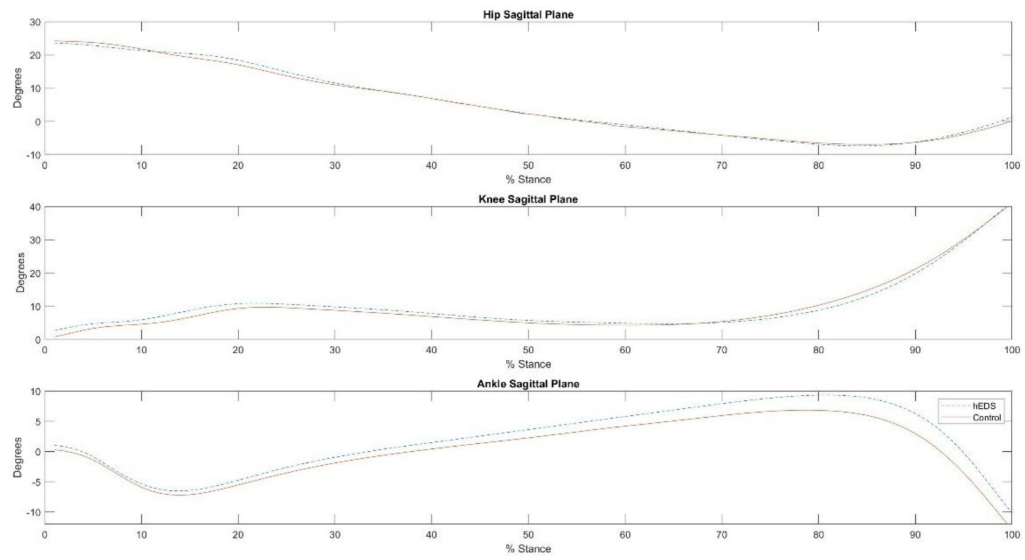
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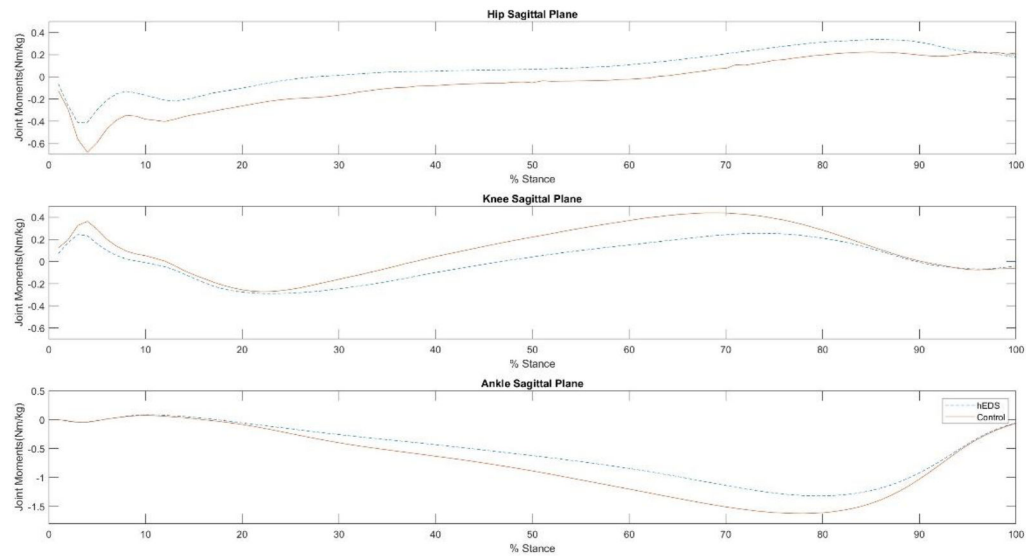
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**Highlights:**

- Hypermobile Ehlers Danlos Syndrome alters muscle function but is not well understood
- The impact of Hypermobile Ehlers Danlos Syndrome on gait mechanics is understudied
- People with Hypermobile Ehlers Danlos Syndrome exhibit hip extensor muscle weakness
- People with Hypermobile Ehlers Danlos Syndrome walk with lower hip extensor moments



**Figure 1:** Joint Kinematics for the hypermobile Ehlers Danlos group (hEDS; dashed) and healthy control group (solid) during the stance phase.



**Figure 2:** Joint Kinetics for the hypermobile Ehlers Danlos group (hEDS; dashed) and healthy control group (solid) during the stance phase.

**Table 1:**

Results are reported as mean  $\pm$  standard deviation for the control and Hypermobility Ehlers Danlos Syndrome (hEDS) groups. Positive joint angles and moments represent hip flexion, knee extension, and ankle dorsiflexion.

	Control	hEDS	p-value	Effect Size (Cohen's d)
<b>Demographics</b>				
N	11 (9 F: 2 M)	11 (9 F: 2 M)		
Age (years)	34.5 $\pm$ 15.5	36.4 $\pm$ 10.5	0.34	X
BMI (kg·m <sup>-2</sup> )	27.8 $\pm$ 4.8	29.5 $\pm$ 4.9	0.14	X
Walking Speed (m·s <sup>-1</sup> )	0.84 $\pm$ 0.2	0.89 $\pm$ 0.27	0.45	X
Joint Subluxation %	X	91% sublux regularly	X	X
	X	Hip: 73%	X	X
	X	Knee: 55%	X	X
	X	Ankle: 45%	X	X
<b>Peak Joint Angles &amp; Range of Motion (RoM)</b>				
Peak Hip Extension	-7.50 $\pm$ 4.68	-7.56 $\pm$ 3.93	0.98	0.01
Peak Hip Flexion	24.6 $\pm$ 2.48	23.8 $\pm$ 6.68	0.71	0.16
Knee Flexion (Initial Contact)	-0.78 $\pm$ 5.16	-2.66 $\pm$ 8.46	0.54	0.27
Knee Flexion (Loading Response)	-10.20 $\pm$ 6.47	-11.4 $\pm$ 7.21	0.68	0.18
Peak Ankle Dorsiflexion	7.24 $\pm$ 3.50	10.24 $\pm$ 4.37	0.09	-0.76
Peak Ankle Plantarflexion	-7.48 $\pm$ 2.91	-7.35 $\pm$ 3.02	0.92	-0.05
Hip RoM	32.1 $\pm$ 6.73	31.3 $\pm$ 5.78	0.70	0.12
Knee Excursion	6.57 $\pm$ 7.53	5.07 $\pm$ 5.50	0.60	0.22
Ankle RoM	22.2 $\pm$ 5.28	23.84 $\pm$ 3.60	0.41	-0.36
<b>Peak Joint Moments (Nm·kg<sup>-1</sup>)</b>				
Peak Hip Extensor	-0.83 $\pm$ 0.26	-0.52 $\pm$ 0.28	<b>0.01</b> **	-1.18
Peak Hip Flexor	0.42 $\pm$ 0.21	0.39 $\pm$ 0.25	0.52	0.15
Peak Knee Flexor (1 <sup>st</sup> half of stance)	-0.51 $\pm$ -0.34	-0.32 $\pm$ 0.17	0.12	-0.70
Peak Knee Flexor (2 <sup>nd</sup> half of stance)	-0.46 $\pm$ -0.46	-0.28 $\pm$ -0.26	0.44	-0.46
Peak Knee Extensor (1 <sup>st</sup> half of stance)	0.34 $\pm$ 0.21	0.34 $\pm$ 0.22	0.93	-0.04

	Control	hEDS	p-value	Effect Size (Cohen's d)
Peak Knee Extensor (2 <sup>nd</sup> half of stance)	0.11 ± 0.05	0.13 ± 0.09	0.64	-0.21
Peak Ankle Plantar-Flexor	-1.66 ± 0.53	-1.34 ± 0.26	0.12	-0.77
Peak Ankle Dorsi-Flexor	0.10 ± 0.05	0.12 ± 0.09	0.58	-0.24
<b>Joint Strength (Nm·kg<sup>-1</sup>)</b>				
Hip Extensor	1.77 ± 0.79	1.07 ± 0.53	<b>0.04<sup>**</sup></b>	0.69
Hip Flexor	0.97 ± 0.32	0.88 ± 0.36	0.33	0.34
Knee Extensor	2.34 ± 0.61	1.93 ± 0.69	0.11	0.65
Knee Flexor	0.93 ± 0.30	0.82 ± 0.28	0.21	0.29

<sup>\*\*</sup> indicates statistical significance