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ORIGINAL ARTICLE

Balance, Gait, Falls, and Fear of Falling in Women With the Hypermobility Type of Ehlers-Danlos Syndrome

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Objective. **To investigate balance, gait, falls, and fear of falling in patients with the hypermobility type of Ehlers-Danlos syndrome (EDS-HT).**
Methods. **Twenty-two women with EDS-HT and 22 sex- and age-matched healthy control subjects participated in the study. Each subject performed the modified Clinical Test of Sensory Interaction on Balance (mCTSIB) and the Tandem Stance test (TS) on an AccuGait force platform to assess balance by center of pressure–based postural sway measures. The GAITRite walkway system was used to record spatial–temporal gait variables during 3 walking conditions (single task, cognitive task, and functional task). Data about fall frequency and circumstances were collected by retrospective recall, and fear of falling was assessed by the modified Falls Efficacy Scale.**
Results. **Compared with healthy subjects, EDS-HT subjects showed significantly impaired balance, reflected by increased sway velocity, mediolateral and anteroposterior sway excursion, and sway area during mCTSIB and TS. Gait velocity, step length, and stride length were significantly smaller during all walking conditions, and a significant dual-task–related decrement was found for gait velocity, step and stride length, and cadence in the EDS-HT subjects compared to the control group. Ninety-five percent of the patients fell during the past year, and some fear of falling was measured.**
Conclusion. **To our knowledge, this study is the first to establish that EDS-HT is associated with balance and gait impairments, increased fall frequency, and poorer balance confidence, implying a decrease in the safety of standing in everyday life situations. Whether these deficits can be improved by appropriate exercise programs needs to be addressed in future research.**

INTRODUCTION

Ehlers-Danlos syndromes (EDS) comprise a clinically and genetically heterogeneous group of heritable connective tissue disorders sharing clinical manifestations of joint hypermobility, skin hyperextensibility, and tissue fragility (1,2). Most EDS subtypes are caused by mutations in genes encoding fibrillar collagens type I, III, or V, or genes encoding enzymes involved in the posttranslational modification of collagens. To date, the genetic background of the most frequently occurring EDS subtype, the hypermobility type of EDS (EDS-HT), remains elusive (3). Clinical diagnostic criteria for EDS-HT include generalized severe joint hypermobility and instability, recurrent joint dislocations, debilitating chronic pain, and mild skin involvement (1). Like most chronic disorders, the symptoms of EDS-HT extend beyond the defining criteria. Neuromuscular problems (4,5), fatigue (6), inactivity (7), and mood disturbances (8–10) are common associated features. In addition, it has been suggested that people with EDS-HT experience difficulties with gait and balance (11,12).

Balance or postural control is essential in everyday life. It allows performance of activities that range from maintenance of static positions to complex dynamic activities. Postural control involves on the afferent side the central processing of peripheral sensory input from visual, vestibular, and proprioceptive systems, whereas the efferent side involves coordinated motor responses in order to remain or restore the body center of mass within the base of support (13,14). Subjects with EDS-HT display impairment in knee joint proprioception (5) as well as reduction in (quadriceps) muscle strength (4,15). These deficits, but also other disease-related characteristics such as joint/

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Significance & Innovations

- Balance and gait are impaired in women with the hypermobility type of Ehlers-Danlos syndrome (EDS-HT).
- EDS-HT is associated with increased fall frequency and lowered balance confidence, implying a decrease in the safety of standing in everyday life situations.

extremity pain (16,17), fatigue (6), and limited physical activity (7), may contribute to a possible decrease in postural control in patients with EDS-HT.

Impairment in postural control generally manifests in balance problems in everyday activities such as walking and stair climbing. Walking is essentially an unstable condition with the body's center of mass projecting outside the base of support for most of the gait cycle (18). In a survey study conducted by Berglund and Nordström (12), 46% of the patients with EDS reported walking more slowly and 36% mentioned walking with some difficulty, e.g., limping, wobbling, and stumbling. Furthermore, many daily activities involve distractions, obstacles, and other secondary tasks while walking. It is possible that carrying out 2 different tasks simultaneously will increase gait decrement in patients with EDS-HT, as postural stability during gait could require more attention in this population.

Decrement in postural control and gait is an important factor in the incidence of falls, and falls are often the cause of injury and disability (19,20). Many people who fall, whether they get injured or not, develop a fear of falling and subsequently limit their activity, leading to reduced mobility and muscle weakness and increased risk of future falls. However, currently there is a lack of evidence regarding balance control, gait, falls, and fear of falling in EDS populations.

Therefore, the primary objective of this study was to investigate whether balance and gait are impaired in patients with EDS-HT compared to healthy subjects. The secondary objective was to examine falls and fear of falling in patients with EDS-HT.

SUBJECTS AND METHODS

Subjects. As more than 90% of patients with EDS-HT are women (1), the current study included only women. Twenty-two white women diagnosed with EDS-HT with a mean age of 39 years (range 18–55 years) participated. Patient selection was performed in the department of Centre for Medical Genetics at the Ghent University Hospital on the basis of the revised Villefranche criteria, including the presence of generalized joint hypermobility (for Beighton score, see Table 1) and/or skin hyperextensibility/fragility, in combination with recurring joint dislocations, chronic musculoskeletal pain, and/or a positive family history. Also, 22 healthy volunteers, individually matched for sex, age, and ethnicity, were included in the study. These healthy controls were recruited by local advertisement. Control subjects were excluded if they had undergone surgery of the lower extremity, a neurologic or orthopedic condition that affected their balance or gait, sight or hearing problems, a generalized disease affecting joints or ligaments, or a Beighton score >4/9. Any subject with recent inflammation of the ear or a known disorder of the organ of balance (such as Ménière's disease) was excluded. Also, pregnant women were omitted from the study.

Procedure. The study protocol was reviewed and approved by the Ethical Committee of Ghent University Hospital. Prior to data collection, the purposes and procedures were fully explained, and informed consent was obtained from the participants. Each subject was evaluated individually and tested following a standard protocol. Subject characteristics, including age, height, weight, body mass index (BMI), Beighton score, data about musculoskeletal surgery at the lower extremity, and current medication use, were collected. Pain severity was assessed by a visual analog scale (VAS), where a score of 0 indicates no pain and a score of 10 indicates unbearable pain. All subjects were randomly assigned to initial testing on either posturography or gait analysis. All test sessions took place in the same quiet room to minimize any noise or other disturbances.

Materials. *Posturography.* An AccuGait strain portable force plate (AMTI AccuGait System; 49 cm × 49 cm)

Table 1. Subject's characteristics*

Variable	EDS-HT group	Control group	*P*
Age, mean ± SD years	39 ± 10.6	39 ± 10.5	0.876
Height, mean ± SD cm	166 ± 7.9	167 ± 5.7	0.542
Weight, mean ± SD kg	73 ± 13.5	64 ± 8.9	0.016†
BMI, mean ± SD kg/m^2	26 ± 4.4	23 ± 3.0	0.004†
Beighton score, mean ± SD	6 ± 1.9	1 ± 1.0	< 0.001†
Pain severity (VAS score), mean ± SD	4 ± 2.1	0 ± 0	< 0.001†
Lower extremity surgery, no. (%)	11 (50)	0 (0)	< 0.001†
Use of analgesics, no. (%)	15 (68)	0 (0)	< 0.001†

* Descriptive statistics are shown as the mean ± SD for continuous data and as percentages or absolute frequencies for categorical data. EDS-HT = hypermobility type of Ehlers-Danlos syndrome; BMI = body mass index; VAS = visual analog scale (range 0–10).
† $P < 0.05$.

connected to the standard amplifier was used to measure postural stability. Ground reaction forces and moments along the mediolateral (ML), anteroposterior (AP), and vertical axis were sampled at 50 Hz, low-pass filtered with a cutoff frequency of 10 Hz, and transformed by computer-automated stability analysis software to obtain changes in displacement of center of pressure (COP). The following COP-based measures were determined to describe the nature of postural adaptations: mean sway velocity along the COP path (sway velocity; cm/second), SD of ML COP excursion (ML sway; cm), SD of AP COP excursion (AP sway; cm), and 95% ellipse sway area included within the COP path (sway area; cm^2). Greater sway coefficients indicate a greater amount of postural instability.

Each subject completed barefoot the modified Clinical Test of Sensory Interaction on Balance (mCTSIB) and the Tandem Stance test (TS) on the force platform. The mCTSIB consists of 4 conditions: eyes open on a firm surface (EO), eyes closed on a firm surface (EC), eyes open on a foam cushion (CEO), and eyes closed on a foam cushion (CEC). The TS consists of 2 conditions of standing in heel-to-toe stance with either the left foot or the right foot in front with eyes open. For the TS, the mean value for the left and right foot in front was calculated. Each condition of the mCTSIB and TS consisted of 3 successive trials of 30 seconds. During each trial, subjects were asked to stand as still as possible with their arms at their sides and looking straight forward. All subjects were guarded by an observer for safety. Test trials were eliminated if the subject fell off the force plate, which occurred in 16 CEC trials and 7 TS trials in the patient group and in 1 CEC trial in the control group.

Gait analysis. Gait was measured with the GAITRite walkway system (GR793P GAITRite Platinum, CIR Systems). The validity and reliability of the GAITRite system has been established (21,22). The GAITRite system provided spatial (distance) and temporal (time) parameters of gait via an electronic walkway connected to a computer via a serial interface cable. The walkway contained 29,952 sensor pads encapsulated in a rollup carpet with an active length of 7.93 meters (total length 8.84 meters) and an active width of 0.6 meters (total width 0.9 meters). An additional 1.5 meters at each end of the carpet was added to eliminate the effect of acceleration and deceleration. The sensors are activated by mechanical pressure and data are sampled from the carpet at a frequency of 60 Hz. The temporal–spatial parameters of specific interest were velocity, cadence, step length, stride length, swing percentage of gait cycle, and stance percentage of gait cycle. Since EDS is a systemic disease and there is no evidence that gait would be preferentially affected on one side of the body, the mean of the left and right sides was calculated.

The gait performance for each subject was measured in 3 conditions: a single-task condition, i.e., preferred walking (single task), and 2 dual-task conditions, i.e., walking while subtracting 3 backward from 100 (cognitive task) and walking while carrying a tray with glasses (functional task). Three consecutive trials were performed at each condition. For each trial, the subject was instructed to walk over the carpet at a self-selected comfortable walking speed while wearing their own flat-soled shoes.

Falls and fear of falling. Fall frequency and fall circumstances (place, cause, use of assistive devices) during the past year were assessed by retrospective recall. Falls were defined as unintentionally coming to rest on the floor or a low surface (bed, chair, etc.). Fear of falling while performing everyday activities (e.g., cleaning the house, getting dressed, simple shopping) were measured with a modified version of the Falls Efficacy Scale (mFES), which consists of 10 questions (e.g., "How fearful are you when you clean the house?"). Each item is scored on a 4-point scale: not fearful, a little fearful, moderately fearful, or very fearful of falling. Scores for the 10 items were averaged to derive the total mFES score. The FES has been found to be reliable and valid (23).

Statistical analyses. For each condition recorded, data from the trials were averaged to provide a mean value for each variable. Data analysis was performed using PASW Statistics 18 (SPSS). Descriptive statistics are shown as the mean $\pm$ SD for continuous data and as percentages or absolute frequencies for categorical data. To compare the subject characteristics and the data about fall frequency, fall circumstances, and fear of falling between groups, independent *t*-tests for means and chi-square tests for frequencies were used. Independent *t*-tests revealed a significant difference in BMI between the 2 groups ($P = 0.004$). Since BMI can influence some balance and gait components, BMI was controlled for in subsequent analyses.

Univariate analysis of covariance (ANCOVA) was conducted to determine group differences in posturography. Differential (EC $-$ EO) values as a measure of visual dependency were calculated and were compared between both groups with ANCOVA.

Repeated-measures analyses with generalized linear models were used to determine differences in gait between the groups (EDS-HT group versus control group) and between conditions (single task versus functional task and single task versus cognitive task). Dual-task decrements were calculated using the formula: decrement = (single-task score $-$ dual-task score)/single-task score $\times$ 100% (24). To determine the differences of dual-task decrements between groups, ANCOVA was used. Post hoc comparisons were made when required, and the Bonferroni procedure was used to correct for multiple testing. *P* values less than 0.05 were considered statistically significant.

RESULTS

Subject characteristics. Descriptive characteristics of all subjects are shown in Table 1. The groups were homogenous with respect to age, sex, and height. Weight and BMI were significantly higher in EDS-HT patients than in control subjects. All 22 patients (100%) reported pain on the day of testing, 20 of whom had pain in the lower extremities with a mean $\pm$ SD pain severity score of 4 $\pm$ 2.1 on the VAS. Eleven patients (50%) underwent surgery at the lower extremity and 15 patients (68%) used analgesics on the day of testing, in contrast to the surgery-, medication-, and pain-free control subjects.

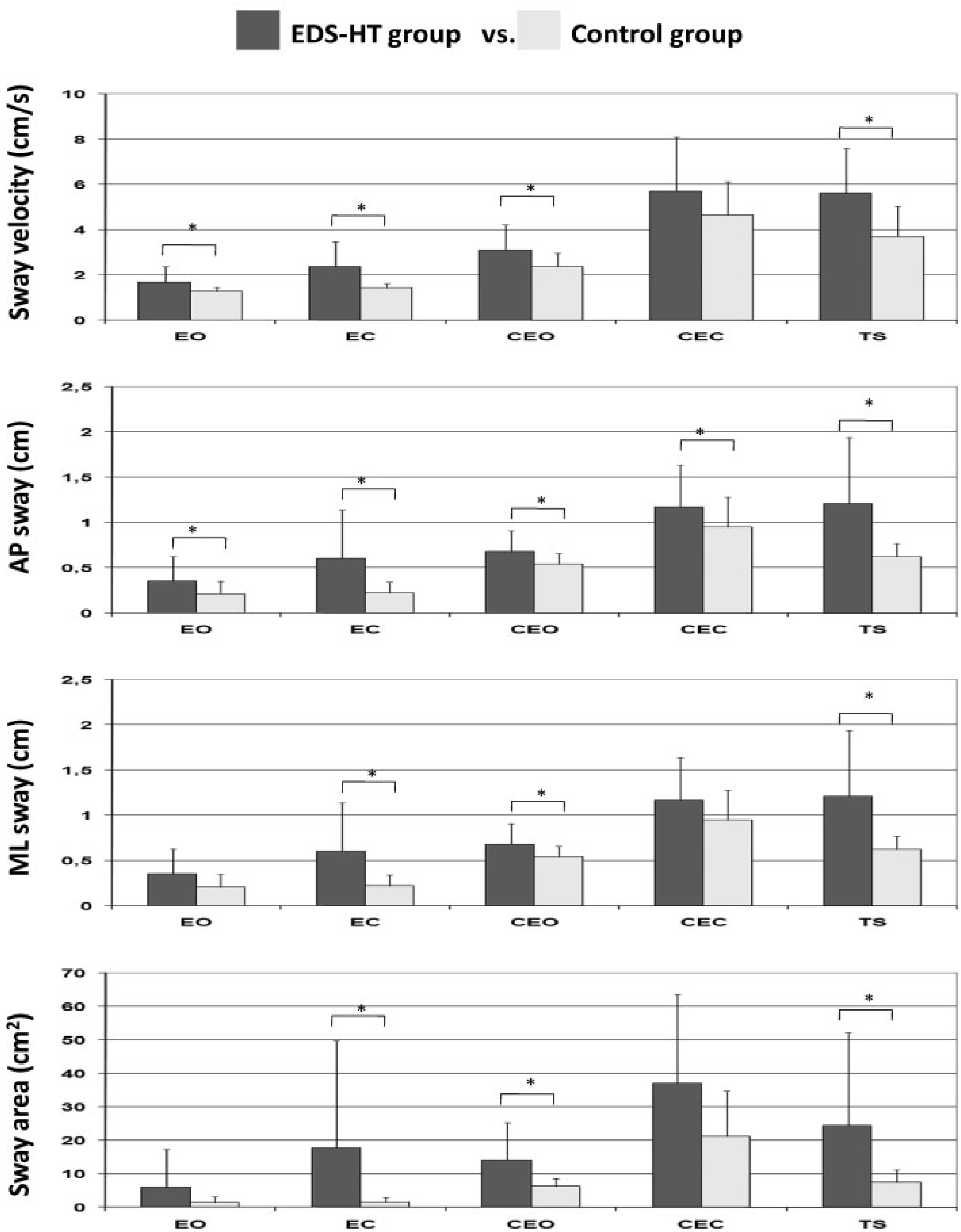

Figure 1. Balance in the hypermobility type of Ehlers-Danlos syndrome (EDS-HT) versus control group. Data are shown as the mean ± SD. Analysis of covariance adjusted for body mass index. * = $P < 0.05$; EO = eyes open; EC = eyes closed; CEO = cushion eyes open; CEC = cushion eyes closed; TS = tandem stance (heel to toe); sway velocity = mean center of pressure (COP) velocity; AP sway = SD of anteroposterior COP excursion; ML sway = SD of mediolateral COP excursion; sway area = 95% ellipse sway area included within the COP path.

Balance. Results of the balance tests are detailed in Figure 1. Compared with the healthy subjects, EDS-HT subjects showed significantly impaired balance, reflected by increased sway velocity, AP excursion, ML excursion, and sway area during the mCTSIB and TS.

Specifically, the mean sway velocity was significantly higher in the patient group compared to the control group when standing with EO ($P = 0.029$) and EC ($P = 0.002$), when standing with CEO ($P = 0.015$), and when heel-to-toe standing (TS; $P = 0.005$). Regarding the AP COP ex-

Table 2. Between-group and between-task gait differences*

Gait variable	EDS-HT group, mean ± SD			Control group, mean ± SD		
	Single task	Cognitive task	Functional task	Single task	Cognitive task	Functional task
Velocity, cm/second	109.49 ± 16.68†	92.83 ± 28.07‡	106.05 ± 18.83†	122.82 ± 19.18	120.54 ± 23.4	125.16 ± 20.13
Cadence, steps/minute	104.86 ± 8.46	92.68 ± 20.64‡	105.72 ± 10.59	107.83 ± 12.23	104.57 ± 16.06	111.58 ± 11.41
Step length, cm	62.41 ± 6.00†	59.61 ± 9.26†	59.88 ± 6.77‡	68.20 ± 6.10	69.00 ± 7.22	66.97 ± 5.98§
Stride length, cm	125.03 ± 11.98†	119.2 ± 18.8†	120.06 ± 13.82‡	136.57 ± 12.13	138.35 ± 14.41	134.21 ± 11.9§
Swing % of gait cycle	36.81 ± 2.20	35.62 ± 3.30	36.22 ± 2.14	37.57 ± 2.44	37.82 ± 3.04	38.08 ± 1.68
Stance % of gait cycle	63.18 ± 2.20	64.39 ± 3.30	63.79 ± 2.14	62.55 ± 2.44	62.19 ± 3.04	61.94 ± 1.68

* Analysis of covariance adjusted for body mass index. EDS-HT = hypermobility type of Ehlers-Danlos syndrome.
† Significant between-group differences ($P < 0.05$).
‡ Significant between-group differences ($P < 0.05$) and significant within-group differences (single task ↔ cognitive task, single task ↔ functional task; $P < 0.05$).
§ Significant within-group differences (single task ↔ cognitive task, single task ↔ functional task; $P < 0.05$).

cursion, subjects in the EDS-HT group displayed significantly greater body sway compared to subjects in the control group during all test conditions (EO: $P = 0.005$, EC: $P = 0.007$, CEO: $P = 0.004$, CEC: $P = 0.034$, and TS: $P = 0.044$). Subjects with EDS-HT also swayed significantly more than the control subjects in the ML direction during EC ($P = 0.017$), CEO ($P = 0.029$), and TS ($P = 0.038$). Significant differences between groups regarding the sway area were found during EC ($P = 0.046$), CEO ($P = 0.012$), and TS ($P = 0.040$).

In both groups, the mean balance scores increased when the conditions became more difficult, indicating more postural instability. Specifically, stability deteriorated significantly more in patients than control subjects when deprived of visual information (differential sway velocity: $P = 0.022$, differential AP sway: $P = 0.041$, and differential ML sway: $P = 0.048$).

Further, it is notable that the SDs of the means of the patient group were 2–7 times higher than those of the control group in all conditions, suggesting a high degree of variability in balance impairment in the EDS-HT sample.

Gait. *Between-group differences.* Spatiotemporal characteristics of gait are shown in Table 2. During the single task, the EDS-HT group walked with decreased speed, with shorter step length, and with shorter stride length compared to the healthy control group. There were no significant differences between both groups regarding swing percentage and stance percentage of gait cycle and cadence. The dual-task walking conditions displayed the same significant differences, except for cadence during the cognitive-task condition.

Between-task differences. As shown in Table 2, EDS-HT patients showed significant decreases in walking velocity ($P = 0.006$) and cadence ($P = 0.016$) when performing the cognitive task compared to the single task. There were no significant differences in gait between these conditions in the control subjects. When comparing the functional task with the single task, both EDS-HT patients and control subjects showed significant gait decrease regarding step length ($P = 0.004$ and $P = 0.042$, respectively) and stride length ($P = 0.005$ and $P = 0.047$, respectively). There were no significant differences with respect to the remaining gait variables.

Dual-task–related gait decrement. Table 3 shows the gait decrements between the single task and dual tasks. When comparing both cognitive- and functional-task–related gait decrement between groups, the analysis revealed significant increases in percent decrement of walking velocity ($P = 0.006$ and $P = 0.019$, respectively), cadence ($P = 0.027$ and $P = 0.048$, respectively), step length ($P = 0.045$ and $P = 0.024$, respectively), and stride length ($P = 0.044$ and $P = 0.025$, respectively) in EDS-HT patients compared to healthy subjects.

Falls and fear of falling. Nearly all patients fell at least once during the past year. More specifically, 2 patients (9.1%) reported falling ≥1 time/week, 10 patients (45.5%)

Table 3. Dual-task–related gait decrement*

Gait variable, %	EDS-HT group, mean ± SD		Control group, mean ± SD	
	Cognitive task	Functional task	Cognitive task	Functional task
Velocity	15.70 ± 20.88†	3.22 ± 9.50†	2.05 ± 11.35	−2.13 ± 8.71
Cadence	11.75 ± 17.79†	−0.76 ± 5.15†	2.97 ± 11.64	−3.80 ± 6.77
Step length	4.72 ± 11.03†	4.10 ± 5.31†	−1.17 ± 5.71	1.76 ± 3.19
Stride length	4.92 ± 11.18†	4.05 ± 5.45†	−1.31 ± 5.73	1.68 ± 3.15
Swing % of gait cycle	2.99 ± 9.65	1.56 ± 3.45	−0.76 ± 6.51	−1.73 ± 8.00
Stance % of gait cycle	−2.01 ± 6.18	−0.98 ± 2.09	0.51 ± 3.90	0.82 ± 4.27

* Gait decrement was calculated using the formula: decrement = (single-task score − dual-task score)/single-task score × 100%. Analysis of covariance adjusted for body mass index. EDS-HT = hypermobility type of Ehlers-Danlos syndrome.
† Significant between-group differences ($P < 0.05$).

reported falling ≥1 time/month, and 9 patients (40.9%) reported falling ≥1 time/year, whereas only 1 patient (4.5%), and all of the control subjects, reported no falls. The falls occurred equally inside and outside the house. Most patients (n = 18) did not know why they fell. Nonetheless, 15 patients (68.2%) mentioned balance problems such as feeling unsteady, stumbling readily, and swaying, and 18 patients (81.8%) reported having difficulties with walking, 8 of whom regularly used an assistive device.

Regarding fear of falling, significant higher mFES scores were found in the EDS-HT group (mean ± SD 1.1 ± 0.55, range 0.2–1.8) compared to the control group (mean ± SD 0.0 ± 0.0, range 0.0–0.5; $P < 0.001$), indicating poorer balance confidence in the patient group. Four patients (18.2%) reported being not fearful, 12 patients (54.5%) reported being a little fearful, 6 patients (27.3%) reported being moderately fearful, and no one reported being very fearful of falling. The highest scores (most fearful) in the patient group were observed in activities such as taking a bath or shower, walking up/down the stairs, and taking a walk. The lowest scores (least fearful) were assessed for activities such as preparing a simple meal and getting in/out of a chair. In addition, fear of falling was significantly higher in patients who regularly fell (mean ± SD 1.3 ± 0.47) compared to those who did not (mean ± SD 0.7 ± 0.62; $P = 0.015$).

DISCUSSION

To our knowledge, the results of this study are the first to describe objective deficits in balance and gait in multiple conditions in patients with EDS-HT compared to age- and sex-matched controls. In addition, this is the first study that demonstrates a high incidence of falls and lowered balance confidence in an EDS-HT population.

In balance testing, the EDS-HT group clearly shows postural instability, as evidenced by increased sway amplitudes of velocity, AP and ML excursion, and area during multiple conditions of mCTSIB and TS. Our findings are in agreement with a very recent published study by Galli et al, who demonstrated higher values of ML and AP sway during EO and EC condition in patients with EDS-HT compared to healthy controls (25). In addition, in patients with joint hypermobility syndrome (JHS), which closely resembles EDS-HT (26), Ferrell et al showed higher ML and AP excursions in the JHS group compared to the control group during standing with eyes open on a wobbling balance board (27). To our knowledge, there are no other studies of hypermobile subjects with which to compare our results.

Furthermore, our results point out that visual dependency for postural control is substantially higher in the EDS-HT patients than in the control subjects. This relatively high reliance on visual information and the considerable postural instability while standing CEO indicate a lack of afferent sensory information from the lower extremities in EDS-HT patients. This is consistent with a study by Rombaut et al, who showed a significant decrease in knee joint reposition acuity of 32 EDS-HT patients compared to matched healthy controls, indicating an impairment of proprioception in the knee joint of EDS-HT patients (5).

In contrast to the identified proprioceptive impairment, our findings may lend no support for deficits in vestibular input, as we could not find significant sway differences between both groups during CEC, except for AP sway. However, it is possible that the CEC condition did not succeed in discriminating between EDS-HT and healthy subjects, as the condition represents a high level of difficulty to both the patient and the healthy subject. Moreover, 16 trials in the patient group and 1 trial in the control group during CEC were excluded from the analysis due to falls. Consequently, due to this high dropout frequency, only the best performances were analyzed, which could not demonstrate significant differences between both groups.

It is likely that several other mechanisms, in addition to impaired proprioception, may be responsible for the balance impairment observed within the EDS-HT group. Lower extremity muscle weakness, especially of the quadriceps, appears to be an important determinant of postural instability in rheumatoid arthritis (RA) and fibromyalgia (FM), which are both chronic musculoskeletal disorders displaying some clinical similarities with EDS-HT (28,29). In addition, muscle fatigue has been shown to affect the control of posture in patients with lower leg arthritis (30). As muscle fatigue and lower extremity muscle weakness are frequent problems in EDS-HT (4,6,15), it is reasonable that both factors can contribute to the alterations in balance in this population.

Furthermore, lower extremity musculoskeletal pain, which was present in almost every EDS-HT patient in our study, could influence balance control. Pain may increase pain-induced reflex inhibition of the muscles around the knee joint (31), which could compromise effective and timely motor responses to maintain posture. In addition, pain may result in reduced loading of the affected joints (32), which could undermine the maintenance of the COP within the base of support.

With regard to the gait analysis, our results reveal that patients with EDS-HT walked more slowly and with shorter step and stride length than the healthy control subjects when comparing normal walking without second task. These findings are in accordance with reported gait changes in patients with RA and FM (33–36). In contrast to most of these studies, we found no significant group differences for cadence. An explanation may be that cadence at preferred speed is determined by pendular properties of the leg, which is dependent on stature, and which did not differ between our groups (37). To our knowledge, at the moment there are no studies concerning gait in EDS or JHS with which to compare our results.

Several factors can be responsible for gait changes in patients with EDS-HT. Decreased postural stability and muscle weakness together with fatigue and joint laxity may be important contributors. In addition, gait in EDS-HT may be affected by foot deformities and foot pain (38). Thereby, walking may require greater effort and more attention in EDS-HT patients. Furthermore, fear of falling has been shown to influence gait characteristics, including reduced walking velocity, reduced stride length, and reduced step width (39).

Since many daily living tasks involve simultaneous movements, measurements of dual-task influences are important. During the buttoning dual task, EDS-HT patients significantly decreased in walking velocity and cadence, whereas the healthy controls did not. This pattern in EDS-HT of marked deterioration when dividing attention to a secondary cognitive task is thought to represent increased attentional resources on balance and gait, due to the impairments described above. Under normal circumstances, gait is almost automatically controlled, like in the control group. In concordance, significant cognitive dual-task gait decrement in walking velocity, cadence, and step and stride length was revealed in EDS-HT patients compared to the control subjects.

During the tray-carrying dual task, our results show that significant gait changes, including shortened step and stride length, are present in both healthy subjects and EDS-HT patients. The dual-task interference may be due to the fact that the tray carrying obstructs visual control, which is important to judge distance and to maintain stability during standing and walking (24). Furthermore, EDS-HT patients display a significantly higher increase of functional-task–related decrement compared to the healthy controls, but less marked than the cognitive-task decrement. As determined in balance testing, EDS-HT patients are more visually dependent than healthy subjects. Consequently, due to visual interference with tray carrying, their functional-task–related gait decrement increased to a larger extent.

Falling is a problem for adult women with EDS-HT. Ninety-five percent of our sample fell during the previous year. This percentage is extremely high, compared to approximately 30–40% of patients reported among adult RA patients and older healthy persons (40,41). Decrements in postural control and gait are important factors in the incidence of falls (19,20). This may also be true in EDS-HT, as a large number of our patients reported to have balance and walking problems, which were objectively confirmed by the postural control and gait measurements. Besides this, we should also consider that orthostatic intolerance, which possibly occurs in EDS-HT (42), could affect the frequency of falling.

Furthermore, fear of falling is strongly associated with the probability of a fall (41). Fear of falling may lead to self-limited activity, resulting in further muscle weakness, postural instability, and walking deficits, and consequently, in increased risk of future falls, which in turn can lead to increasingly being fearful of falling. However, even though fear of falling was higher in patients who regularly fell compared to those who did not, it is striking that more than 70% of the total EDS-HT group reported no or a little fear of falling.

The findings of this study have important clinical implications for the understanding and management of patients with EDS-HT. It may be appropriate for clinicians to consider interventions to improve balance and gait, and consequently to reduce falls and fear of falling in EDS-HT. There are a few studies in patients with RA, FM, and JHS that showed that aquatic training and muscle strength training improved balance performance and gait stability (27,29,43,44). However, whether patients with EDS-HT could benefit from exercises directed at improving balance and gait needs to be investigated in future research.

The present results must be viewed within the limitations of the study. First, several potential deficits may be responsible for the balance and gait problems observed within the EDS-HT group, but the design of our study prohibits the ability to determine their relative contribution. Second, fall frequency and circumstances surrounding the fall conducted in this study are potentially limited by retrospective recall bias. Real-time fall reporting, including "real falls" but also "near falls," in which patients catch themselves on furniture or other surfaces after a loss of equilibrium, would be more accurate. Third, the current study did not evaluate the potential impact of lower leg surgery and pain medication on balance and gait. However, as lower leg surgery and use of analgesics are typical for patients with EDS-HT and the reports in the current study are in line with previous studies (11,45), the current results are clinically relevant, even if lower leg surgery and pain medication use would contribute to the balance and gait deficits.

In conclusion, the present study established that EDS-HT is associated with balance and gait impairments, increased fall frequency, and poorer balance confidence, implying a decrease in the safety of standing in everyday life situations. Further research is needed to develop appropriate exercises aimed at improving balance and gait and reducing falls in patients with EDS-HT.

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AUTHOR CONTRIBUTIONS

All authors were involved in drafting the article or revising it critically for important intellectual content, and all authors approved the final version to be published. Ms Rombaut had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Acquisition of data. Rombaut, Malfait, De Wandele, Thijs, Palmans, De Paepe, Calders.

Analysis and interpretation of data. Rombaut, Malfait, De Wandele, Thijs, Palmans, De Paepe, Calders.

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