

# The effects of neuromuscular taping on gait walking strategy in a patient with joint hypermobility syndrome/Ehlers–Danlos syndrome hypermobility type

Filippo Camerota, Manuela Galli, Veronica Cimolin, Claudia Celletti, Andrea Ancillao, David Blow and Giorgio Albertini

## Abstract

**Objective:** In this case study, biomechanical alterations induced by neuromuscular taping (NMT) were quantified, during walking, in a patient with joint hypermobility syndrome/Ehlers–Danlos syndrome hypermobility type (JHS/EDS-HT).

**Methods:** A female JHS/EDS-HT patient underwent NMT applications over the low back spine and bilaterally to the knee. Quantitative gait analyses were collected before the NMT application and at the end of the treatment (2 weeks after the first application of NMT).

**Results:** At the end of treatment following the NMT application, left step length showed improvements in cadence and velocity, the left knee showed a reduction in its flexed position at initial contact, and the right ankle joint improved its position at initial contact and in the swing phase. Improvements were also found in kinetics, in terms of the ankle moment and power.

**Conclusions:** Results show that NMT seems to be a promising low-cost intervention for improving gait strategy in patients with JHS/EDS-HT. Further investigations are needed to assess the effects of this treatment intervention on pathological symptoms.

**Keywords:** Ehlers–Danlos syndrome, gait analysis, neuromuscular taping, rehabilitation

## Introduction

Joint hypermobility syndrome (JHS) is a relatively common, although largely under diagnosed, clinical entity characterized by congenital contortionism and musculoskeletal complaints [Steinmann *et al.* 2002]. There is significant clinical overlap between JHS and various heritable connective tissue disorders, mainly the Ehlers–Danlos syndrome(s) (EDS) [Grahame *et al.* 2000]. These similarities are so stringent that, recently, an international group of experts stated that JHS and EDS hypermobility type (HT) are the same clinical entity that should be distinguished from other types of EDS [Tinkle *et al.* 2009]. Accurate prevalence data are still lacking for JHS/EDS-HT. However, this condition seems to affect no less than 1 in 10,000 in the general population [Steinmann *et al.* 2002] and is dramatically more

common in women [Castori *et al.* 2010]. The diagnosis of JHS/EDS-HT is clinical in essence as no validated genetic test is yet available [Callewaert *et al.* 2008]. Major features include joint hypermobility, joint complications and minor skin features (e.g. skin hyperextensibility), while the presence of additional cutaneous, vascular, skeletal and ocular symptoms moves the diagnosis towards other EDS variants. Although laxity of tendons and ligaments is considered the major determinant for musculoskeletal complaints in JHS/EDS-HT, the muscle itself seems to be frequently affected in terms of hypotonia, muscle cramps and pain, fibromyalgia, and chronic fatigue [Voermans *et al.* 2010]. In these patients, poor postural control and abnormal gait can be also affected by frequent orthopaedic complications involving the lower limbs [Celletti *et al.* 2012, 2013; Cimolin *et al.* 2011; Galli *et al.*

*Ther Adv Musculoskel Dis*

2015, Vol. 7(1) 3–10

DOI: 10.1177/  
1759720X14564561

© The Author(s), 2014.  
Reprints and permissions:  
[http://www.sagepub.co.uk/  
journalsPermissions.nav](http://www.sagepub.co.uk/journalsPermissions.nav)

Correspondence to:  
**Veronica Cimolin, PhD**  
Department of  
Electronics, Information  
and Bioengineering  
Department, Politecnico  
di Milano, piazza Leonardo  
da Vinci 32, 20133 Milano,  
Italy  
[veronica.cimolin@  
polimi.it](mailto:veronica.cimolin@polimi.it)

**Filippo Camerota, MD**  
**Claudia Celletti, MD**  
Physical Medicine and  
Rehabilitation Division,  
Orthopaedic Department,  
Umberto I Hospital,  
Sapienza University,  
Rome, Italy

**Manuela Galli**  
Department of  
Electronics, Information  
and Bioengineering  
Department, Politecnico di  
Milano, Milano, Italy and  
Gait Analysis Lab IRCCS  
'San Raffaele Pisana',  
Tosinvest Sanità, Roma,  
Italy

**Andrea Ancillao, Eng**  
**Giorgio Albertini**  
IRCCS 'San Raffaele  
Pisana', Tosinvest Sanità,  
Roma, Italy

**David Blow, PT**  
NeuroMuscular Taping  
Institute, Roma, Italy

2011a, 2011b; Rigoldi *et al.* 2012, 2013; Stanitski *et al.* 2000]. As recently demonstrated in a qualitative scoring study, widespread involvement coupled with impaired proprioception [Hall *et al.* 1995; Sahin *et al.* 2008] contribute to posture and gait anomalies in JHS [Booshanam *et al.* 2011]. Proprioception refers to the sense of both static position and movement of the limbs and the body without using vision. It comprises the sense of stationary position of the limbs (limb-position sense) and the sense of limb movement (kinaesthesia). These sensations are important for controlling limb movements, manipulating objects that differ in shape and mass, and maintaining an upright posture [Kandel *et al.* 2000]. Lack of proprioception seems a prominent feature in JHS [Galli *et al.* 2011b; Sahin *et al.* 2008]. Although its relationship with the underlying joint hypermobility is still largely obscure, a handful of studies suggest that improvement of proprioception may be effective for ameliorating both the functional status, including balance, and chronic pain [Ferrell *et al.* 2004; Celletti *et al.* 2011]. However, as JHS is a systemic, progressive and chronic condition, physical therapy very probably suffers major treatment limitations, such as necessary intensive and lengthy treatment sessions and short-lasting effects.

Over the last 5 years in Europe, proprioceptive neuromuscular taping (NMT) technique has become a mainstream treatment protocol in post-operative, oncological, neurological care of patients and in sports medicine [Costantino *et al.* 2012]. This innovative taping application is based on eccentric stimulation of the skin, muscle tissue, tendons, neurological vessels, lymphatic and vascular pathways improving their functioning. Unlike other forms of taping, NMT provides passive stretching through the application, with eccentric techniques, of a tape encouraging flexibility and coordination and bettering range of movement in patients suffering with lack of muscle coordination due to different clinical conditions. It has been claimed that the effects may be due to modification of sensorimotor and proprioceptive feedback mechanisms. It has been hypothesized that the application of NMT is able to stimulate cutaneous mechanoreceptors. These receptors activate nerve impulses when mechanical loads (touch, pressure, vibration, stretch and itch) create deformation. Their activation by an adequate stimulus causes local depolarization, which triggers nerve impulses along the afferent fibres travelling toward the central nervous system. The NMT technique is applied by a physiotherapist trained in eccentric

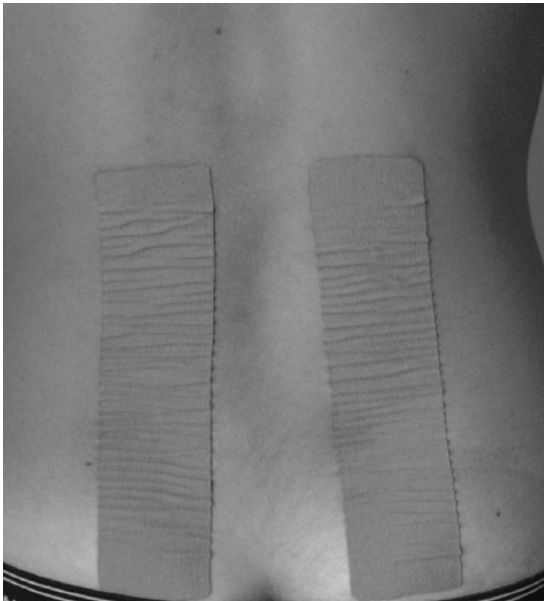
taping applications. A cotton-based elastic adhesive and paper backed tape is applied in less than 15 minutes for complex multiple applications making it a nonexpensive and noninvasive treatment option well tolerated by the patients, in particular children.

Application of this technique was found in multiple sclerosis [Costantino *et al.* 2012] and in cerebral palsy [Camerota *et al.* 2013] with encouraging results on gait pattern and upper limb functionality; no applications support the use of this type of taping method to improve the lower-limb functionality in subjects with JHS/EDS-HT. The aim of this case study presentation is to use motion analysis approach to evidence, in a quantitative way, the biomechanical improvement in gait function induced by the NMT taping intervention in a patient with JHS/EDS-HT.

### Case report

The participant is a woman aged 35 years and is affected by JHS/EDS-HT. JHS/EDS-HT was diagnosed by using published criteria [Beighton *et al.* 1998; Grahame *et al.* 2000]. The patient complained of chronic generalised joint pain with fatigue and reduced stamina; her main symptoms was referred to as difficulty and pain during walking - walking was limited to only a few minutes, and pain that was mainly localized in the lower back and knees. Clinical evaluation showed that the patient had a reduction of force in the lower limb muscles with knee pain during flexion and extension (numeric rating scale [NRS] pain 8/10), and passive motion reduction of the spine associated with muscular paraspinal lower back pain. No neurological deficit had been observed and no acute trauma had been referred.

The tape was applied in a particular way that characterized the NMT application with the aim to rise the skin in a wave, amplifying the stretching/contraction effect of the skin itself. NMT was applied by the same physical therapist during the study. According to the symptomatology referred by the patient, NMT was applied over the low back spine and bilaterally to the knee; the lumbar spine application (lumbar spine standard protocol treatment), consisted of two tapes of 25 cm in length and 5 cm width applied, with no tension applied to the tape, laterally to the spine from the intergluteal fold to the last dorsal vertebra with the patient maintaining a lumbar flexion at 45° in a standing position during the complete application [Blow, 2012] (Figure 1); for the knee application



**Figure 1.** Taping application on low back spine.



**Figure 2.** Taping application on the right knee.

(functional knee standard protocol treatment), a complex combination of two strips of 25 cm in length and 2.5 cm in width along the collateral ligament using 50% tape tension applied distally to proximal, a horizontal tape below the patella 25 cm in length and 2.5 cm in width applied with 25% tension and lastly a Y tape 30 cm in length



**Figure 3.** Taping application on the right knee.

and 5 cm in width cut with 5 cm as an initial base applied laterally to the patella with no tape tension [Blow, 2012] (Figures 2 and 3). The taping was applied constantly and changed every 3 days by the same physiotherapist for a total of five applications; the patient was invited to walk normally during this period without changing her habits. No additional rehabilitative treatment was done during this period.

The analysis consisted of a preliminary clinical examination followed by three-dimensional gait analysis (3D-GA). The analysis was conducted at the time of enrolment before the application of NMT and was repeated at the end of the treatment (2 weeks after the first application of NMT).

The 3D-GA was carried out using a 12-camera optoelectronic system (ELITE2002, BTS S.p.A., Milan, Italy) with passive markers positioned according to Davis and colleagues [Davis *et al.* 1991], for recording of movement evaluation, two force platforms (Kistler, CH), for movement kinetic evaluation, and a synchronic video system (BTS S.p.A., Milan, Italy). Anthropometric data were collected and passive markers were placed at anatomical landmarks. The patient walked barefoot at her self-selected and convenient speed along a 10 m walkway. At least seven trials were recorded during each

**Table 1.** Gait parameters and descriptors.

Gait parameter	Description
<i>Spatiotemporal parameters</i>	
Percentage stance (percentage gait cycle)	Percentage of gait cycle that begins with initial contact and ends at toe-off of the same limb.
Step length (mm)	Longitudinal distance from one foot strike to the next one
Cadence (step/min)	Number of step for minute
Velocity (m/s)	Mean velocity of progression
Step width (mm)	Transversal distance between the right and left foot
<i>Kinematics (degrees)</i>	
Mean PT	The mean value of pelvic movement on the sagittal plane (Pelvic Tilt graph) during the gait cycle
PO-ROM	The Range Of Motion at pelvis on the frontal plane (Pelvic Obliquity graph) during the gait cycle, calculated as the difference between the maximum and minimum values of the plot
PR-ROM	The Range Of Motion at pelvis on the transversal plane (Pelvic Rotation graph) during the gait cycle, calculated as the difference between the maximum and minimum values of the plot
HIC	Value of Hip flexion–extension angle (hip position on the sagittal plane) at Initial Contact, representing the position of hip joint at the beginning of gait cycle
HmSt	Minimum of Hip flexion (hip position on sagittal plane) in Stance phase, representing the extension ability of hip during this phase of gait cycle
HFE-ROM	The Range Of Motion at hip joint on the sagittal plane (Hip Flex–Extension graph) during the gait cycle, calculated as the difference between the maximum and minimum values of the plot
HAA-ROM	The Range Of Motion at hip joint on the frontal plane (Hip Abduction–Adduction graph) during the gait cycle, calculated as the difference between the maximum and minimum values of the plot
KIC	Value of Knee flexion–extension angle (knee position on sagittal plane) at Initial Contact, representing the position of knee joint at the beginning of gait cycle
KmSt	Minimum of Knee flexion (knee position on sagittal plane) in mid-Stance, representing the extension ability of knee during this phase of gait cycle
KFE-ROM	The Range Of Motion at knee joint on the sagittal plane (Knee Flex–Extension graph) during the gait cycle, calculated as the difference between the maximum (KMSw) and minimum (KmSt) values of the plot;
AIC	Value of the Ankle joint angle (on sagittal plane) at the Initial Contact, representing the position of knee joint at the beginning of gait cycle
AMSt	Peak of Ankle dorsiflexion (on sagittal plane) during Stance phase, representing the dorsiflexion ability of ankle joint during this phase of gait cycle
AmSt	Minimum value of the Ankle joint angle (on sagittal plane) in Stance phase, representing the plantarflexion ability of ankle joint at toe-off
AMS <sub>w</sub>	Peak of Ankle dorsiflexion (on sagittal plane) during Swing phase, representing the dorsiflexion ability of ankle joint in this phase of gait cycle
ADP-ROM	The Range Of Motion at ankle joint on the sagittal plane (Ankle Dorsiflexion–Plantarflexion graph) during the stance phase of the gait cycle, calculated as the difference between the maximum (AMSt) and minimum (AmSt) values of the plot
<i>Kinetics</i>	
AMM (N*m/kg)	The Maximum value of Ankle plantarflexion Moment during terminal stance
APM (W/kg)	The Maximum value of generated Ankle Power during terminal stance (maximum value of positive ankle power during terminal stance), representing the push-off ability of the foot during walking

session. The data were computed according to Davis and colleagues using Euler angles [Davis *et al.* 1991]. Some parameters were identified and calculated from kinematic and kinetic data (ankle moment and power): spatiotemporal parameters, joint-angle values at a specific instant of the gait cycle and peaks in ankle moment and power graphs (Table 1).

The mean values (standard deviation) of kinematic and kinetic parameters are shown in detail in Table 2 in pre- and post-sessions as well for an age-matched normal (control group [CG]) [Rigoldi *et al.* 2012]. The control group database refers to a group of 20 subjects (age range 30–45 years) acquired with the 3DGA using the same

**Table 2.** Gait analysis parameters of the case study and the control group (CG).

	JHS/EDS-HT patient				Control Group
	Pre-session		Post-session		
	Right side	Left side	Right side	Left side	
<i>Spatiotemporal parameters</i>					
Percentage stance (percentage gait cycle)	58.7 (0.6)	57.7 (0.6)	57.7 (0.6)	58.3 (3.1)	59.65 (3.19)
Step length (mm)	646.0 (47.3)	656.7 (42.5)	696.3 (35.2)	739.0 (44.2)	889.7 (21.5)
Step width (mm)	130.7 (3.8)		131.0 (2.6)		123.29 (27.84)
Cadence (step/min)	103.3 (2.1)		117.0 (3.6)		115.7 (4.6)
Velocity (m/s)	1.1 (0.1)		1.4 (0.1)		1.3 (0.2)
<i>Kinematics (degrees)</i>					
Mean PT	5.8 (1.1)	6.2 (1.2)	9.3 (1.5)	11.4 (0.2)	6.53 (6.97)
PO-ROM	11.7 (1.0)	11.5 (0.2)	15.1 (0.2)	14.8 (0.1)	6.01 (2.53)
PR-ROM	16.4 (2.0)	17.1 (1.9)	15.4 (0.2)	16.8 (0.9)	10.72 (5.32)
HIC	28.5 (0.4)	31.6 (1.1)	29.7 (2.0)	34.2 (0.3)	27.23 (9.57)
HmSt	-14.8 (0.7)	-15.6 (2.7)	-18.3 (1.7)	-15.4 (2.4)	-14.83 (9.60)
HFE-ROM	46.5 (1.2)	48.7 (1.5)	44.2 (7.1)	47.5 (3.2)	43.52 (4.76)
HAA-ROM	11.9 (1.7)	15.0 (0.5)	14.2 (2.3)	13.5 (1.1)	10.71 (3.06)
KIC	8.6 (1.4)	11.2 (2.6)	2.6 (0.1)	4.8 (2.2)	4.39 (6.53)
KmSt	-1.2 (1.8)	-0.6 (1.9)	-2.6 (3.0)	-1.5 (0.6)	0.12 (3.82)
KFE-ROM	65.3 (2.8)	65.9 (3.9)	64.9 (5.3)	66.4 (4.8)	59.07 (6.31)
AIC	-5.2 (1.8)	-2.3 (2.7)	0.2 (0.6)	-3.6 (0.6)	1.81 (6.87)
AMSt	9.6 (2.5)	6.1 (2.4)	10.2 (2.5)	5.1 (1.0)	21.04 (5.16)
AmSt	-11.6 (2.1)	-12.2 (1.9)	-12.5 (1.7)	-17.5 (3.4)	-9.73 (9.40)
ADP-ROM	21.2 (3.3)	19.3 (0.8)	22.7 (0.9)	22.6 (4.1)	25.72 (6.56)
AMSw	-0.8 (2.8)	-0.2 (3.4)	4.5 (3.3)	0.3 (1.6)	7.89 (9.93)
<i>Kinetics</i>					
AMM (N*m/Kg)	1.1 (0.01)	1.0 (0.2)	1.7 (0.1)	1.5 (0.1)	1.5 (0.2)
APM (W/Kg)	1.9 (0.1)	1.7 (0.2)	3.1 (0.1)	(0.5)	3.2 (0.9)

Data are expressed as mean (standard deviation).  
ROM, range of motion; PT, pelvic tilt; PO, pelvic obliquity; HIC, hip at initial contact; HFE, hip flex-extension; HAA, hip abduction-adduction; KIC, knee at initial contact; KFE, knee flex-extension; AIC, ankle at initial contact; ADP, ankle dorsiflexion-plantarflexion; St, stance; Sw, swing; M, maximum value; m, minimum value; AM, ankle moment; AP, ankle power.

experimental set-up described previously and using the same equipment of the same laboratory.

Before the treatment, the patient showed a limited step-length bilaterally, with low cadence and velocity in comparison with CG. In terms of kinematics, pelvic movements on the transversal (PR-ROM index) and frontal plane (PO-ROM index) were higher than in healthy subjects. The hip joint showed a physiological gait pattern. Left knee position at initial contact (KIC index) was flexed comparing with the CG. The ankle joint showed a plantar flexed position at the initial contact on the right side (AIC index), and a bilateral low dorsiflexion ability during stance (AMSt index) and swing phase (AMSw index). In terms

of ankle kinetics, we observed a limited maximum of plantar flexion moment and of ankle power at the terminal stance. After NMT intervention, spatiotemporal parameters improved (left step length, cadence and velocity) reaching values closer to GC. With regards to kinematics, mean pelvic tilt increased its value towards the anterior position, remaining inside the normal range; a slight increase of ROM at pelvic rotation was observed after the intervention. The left knee improved its flexed position at initial contact and some changes were displayed at the right ankle joint, which improved its position at initial contact and in swing phase. Improvements were also found in kinetics, in particular in ankle moment and ankle power (both showed increased values). Patients reported a reduction of knee pain (NRS

3/10) and more stamina particularly during walking.

### Discussion

This case report aimed to quantify the effects of NMT in the walking strategy in a patient with JHS/EDS-HT. Our results showed a general gait ability improvement when NMT was used. In particular, our data showed that, after treatment, spatiotemporal parameters improved, in particular the step length, the cadence and the velocity. Positive changes were observed in terms of kinematics, especially at ankle joint, which after NMT removal was in a more normal position and the kinetics showed an improvement in push-off ability during terminal stance. A slight worsening was observed in terms of PR-ROM. This modification, with a worsening at proximal joints and improvements at distal ones, may be due to the initiation of a new control strategy after the intervention: the modifications at distal joints, directly connected to treatment, probably induce adjustment at the pelvis.

NMT application was also shown to be effective as follows. It is noninvasive and is not a time-consuming procedure; thus, it is cost-effective while not requesting specific patient collaboration. Its hypothetical mechanism of action, if merely speculative, should be that NMT may play a role as a sensitive input that is integrated by the central nervous system and used for assisting motor program execution process known as sensorimotor integration.

It has recently has been hypothesized that taping seems to stimulate cutaneous mechanoreceptors resulting in physiological changes in the taping area [Yoshida *et al.* 2007]; mechanoreceptor stimulation may improve proprioceptive inputs for muscles to perform task-specific functions [Kaya Kara *et al.* 2014].

We cannot compare our result with other literature results because this study represents a first-case attempt to quantify NMT effects on gait improvement in a patient with JHS/EDS-HT. However, encouraging effects on gait after this kind of intervention were found in NMT applied in patients with multiple sclerosis [Costantino *et al.* 2012] while other taping methods were used in children with cerebral palsy [Iosa *et al.* 2010] and on healthy subjects [Halseth *et al.* 2004; Murray and Husk, 2001]. No studies to our

knowledge use 3D-GA assessments to evaluate the NMT effects in patients with JHS/EDS-HT.

This case report could be considered an observational pilot study with the prospect to inform clinical practice. Further randomized controlled investigations on more subjects are certainly needed to assess effectively the effects of NMT intervention on movement and on the generalized debilitating symptoms associated with the pathology. In addition, it would be interesting to assess whether the improvements are maintained over time. The limitations of this study are related to having data only for one subject and only using the 3D-GA test. The lack of clinical scales pre- and post-treatment is a limitation of this study, which was mainly focused on the quantification of the improvement of gait walking for this subject. Pain during walking and generalized fatigue represented the major underlying symptoms for this patient. Another limit is related to the 3D-GA in that this study did not include electromyography (EMG) signal evaluation. EMG signal evaluation could be useful in the description of muscle activity modification during the gait and to better explain the observed improvements in terms of kinematics and kinetics. Future studies should also investigate NMT evaluating not only the gait characteristics but also, with the use of clinical scales, the modification of functional abilities, reduction of pain and improvements of quality-of-life issues. Nevertheless, the fact that walking strategy improved after the treatment period suggests that NMT seems to be a promising intervention for improving gait strategy in patients with JHS/EDS-HT.

### Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

### Conflict of interest statement

None of the authors have any conflicts of interest to declare.

### References

- Beighton, P., De Paepe, A., Steinmann, B., Tsipouras, P. and Wenstrup, R. (1998) Ehlers–Danlos syndromes: revised nosology, Villefranche, 1997. Ehlers–Danlos National Foundation (USA) and Ehlers–Danlos Support Group (UK). *Am J Med Genet* 77: 31–37.
- Blow, D. (2012) *NeuroMuscular Taping: From Theory to Practice*. Milano: Edi Ermes.

- Booshanam, D., Cherian, B., Joseph, C., Mathew, J. and Thomas, R. (2011) Evaluation of posture and pain in persons with benign joint hypermobility syndrome. *Rheumatol Int* 31: 1561–1565.
- Callewaert, B., Malfait, F., Loeys, B. and De Paepe, A. (2008) Ehlers–Danlos syndromes and Marfan syndrome. *Best Pract Res Clin Rheumatol* 22: 165–189.
- Camerota, F., Galli, M., Cimolin, V., Celletti, C., Ancillao, A., Blow, D. *et al.* (2013) Neuromuscular taping for the upper limb in cerebral palsy: a case study in a patient with hemiplegia. *Dev Neurorehabil* Oct 2. [Epub ahead of print]
- Castori, M., Camerota, F., Celletti, C., Grammatico, P. and Padua, L. (2010) Ehlers–Danlos syndrome hypermobility type and the excess of affected females: possible mechanisms and perspectives. *Am J Med Genet A* 152(A): 2406–2408.
- Celletti, C., Castori, M., Galli, M., Rigoldi, C., Grammatico, P., Albertini, G. *et al.* (2011) Evaluation of balance and improvement of proprioception by repetitive muscle vibration in a 15-year-old girl with joint hypermobility syndrome. *Arthritis Care Res (Hoboken)* 63: 775–779.
- Celletti, C., Galli, M., Cimolin, V., Castori, M., Albertini, G. and Camerota, F. (2012) Relationship between fatigue and gait abnormality in joint hypermobility syndrome/Ehlers–Danlos syndrome hypermobility type. *Res Dev Disabil* 33: 1914–1918.
- Celletti, C., Galli, M., Cimolin, V., Castori, M., Tenore, N., Albertini, G. *et al.* (2013) Use of the Gait Profile Score for the evaluation of patients with joint hypermobility syndrome/Ehlers–Danlos syndrome hypermobility type. *Res Dev Disabil* 34: 4280–4285.
- Cimolin, V., Galli, M., Vismara, L., Grugni, G., Camerota, F., Celletti, C. *et al.* (2011) Gait pattern in two rare genetic conditions characterized by muscular hypotonia: Ehlers–Danlos and Prader–Willi syndrome. *Res Dev Disabil* 32: 1722–1728.
- Costantino, C., Licari, O., Granella, F. and Sghedoni, S. (2012) Neuromuscular taping in multiple sclerosis. A pilot study. *Acta Biomed* 83: 103–107.
- Davis, R., Ounpuu, S., Tyburski, D. and Gage, J. (1991) A gait analysis data collection and reduction technique. *Hum Mov Sci* 10: 575–587.
- Ferrell, W., Tennant, N., Sturrock, R., Ashton, L., Creed, G., Brydson, G. *et al.* (2004) Amelioration of symptoms by enhancement of proprioception in patients with joint hypermobility syndrome. *Arthritis Rheum* 50: 3323–3328.
- Galli, M., Cimolin, V., Vismara, L., Grugni, G., Camerota, F., Celletti, C. *et al.* (2011a) The effects of muscle hypotonia and weakness on balance: a study on Prader–Willi and Ehlers–Danlos syndrome patients. *Res Dev Disabil* 32: 1117–1121.
- Galli, M., Rigoldi, C., Celletti, C., Mainardi, L., Tenore, N., Albertini, G. *et al.* (2011b) Postural analysis in time and frequency domains in patients with Ehlers–Danlos syndrome. *Res Dev Disabil* 32: 322–325.
- Grahame, R., Bird, H. and Child, A. (2000) The revised (Brighton 1998) criteria for the diagnosis of benign joint hypermobility syndrome (BJHS). *J Rheumatol* 27: 1777–1779.
- Hall, M., Ferrell, W., Sturrock, R., Hamblen, D. and Baxendale, R. (1995). The effect of the hypermobility syndrome on knee joint proprioception. *Br J Rheumatol* 34: 121–125.
- Halseth, T., McChesney, J., De Beliso, M., Vaughn, R. and Lien, J. (2004) The effects of kinesio taping on proprioception at the ankle. *J Sports Sci Med* 3: 1–7.
- Iosa, M., Morelli, D., Nanni, M., Veredice, C., Marro, T., Medici, A. *et al.* (2010) Functional taping: a promising technique for children with cerebral palsy. *Dev Med Child Neurol* 52: 587–589.
- Kaya Kara, O., Atasavun Uysal, S., Turker, D., Karayazgan, S., Gunel, M. and Baltaci, G. (2014) The effects of kinesio taping on body functions and activity in unilateral spastic cerebral palsy: a single-blind randomized controlled trial. *Dev Med Child Neurol*. DOI: 10.1111/dmcn.12583 [Epub ahead of print].
- Kandel, E., Schwartz, J. and Jessell, T. (2000) *Principles of Neural Science*, 4th edn. New York: Elsevier.
- Murray, H. and Husk, L. (2001) Effect of kinesio taping on proprioception in the ankle. *J Orthop Sports Phys Ther* 31: 37.
- Rigoldi, C., Cimolin, V., Camerota, F., Celletti, C., Albertini, G., Mainardi, L. *et al.* (2013) Measuring regularity of human postural sway using approximate entropy and sample entropy in patients with Ehlers–Danlos syndrome hypermobility type. *Res Dev Disabil* 34: 840–846.
- Rigoldi, C., Galli, M., Cimolin, V., Camerota, F., Celletti, C., Tenore, N. *et al.* (2012) Gait strategy in patients with Ehlers–Danlos syndrome hypermobility type and Down syndrome. *Res Dev Disabil* 33: 1437–1442.
- Sahin, N., Baskent, A., Cakmak, A., Salli, A., Ugurlu, H. and Berker, E. (2008) Evaluation of knee proprioception and effects of proprioception exercise in patients with benign joint hypermobility syndrome. *Rheumatol Int* 28: 995–1000.
- Stanitski, D., Nadjarian, R., Stanitski, C., Bawle, E. and Tsipouras, P. (2000) Orthopaedic manifestations of Ehlers–Danlos syndrome. *Clin Orthop Relat Res* 376: 213–221.
- Steinmann, B., Royce, P. and Superti-Furga, A. (2002) The Ehlers–Danlos syndromes. In: Steinmann,


B. and Royce, P. (eds), *Connective Tissue and its Heritable Disorders*. Wilmington, DE: Wiley-Liss, Inc.

Tinkle, B., Bird, H., Grahame, R., Lavalley, M., Levy, H. and Silience, D. (2009) The lack of clinical distinction between the hypermobility type of Ehlers–Danlos syndrome and the joint hypermobility syndrome (a.k.a. hypermobility syndrome). *Am J Med Genet A* 149(A): 2368–2370.

Voermans, N., Knoop, H., van de Kamp, N., Hamel, B., Bleijenberg, G. and van Engelen, B. (2010) Fatigue is a frequent and clinically relevant problem in Ehlers–Danlos syndrome. *Semin Arthritis Rheum* 40: 267–274.

Yoshida, A. and Kahanov, L. (2007) The effect of kinesio taping on lower trunk range of motions. *Res Sports Med* 15: 103–112.

Visit SAGE journals online  
<http://tab.sagepub.com>

 SAGE journals