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Relationship between foot sensation and standing balance in patients with multiple sclerosis

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ABSTRACT

The aims of the present study were to investigate the relationship between the foot sensations and standing balance in patients with Multiple Sclerosis (MS) and find out the sensation, which best predicts balance. Twenty-seven patients with MS (Expanded Disability Status Scale 1–3.5) and 10 healthy volunteers were included. Threshold of light touch-pressure, duration of vibration, and distance of two-point discrimination of the foot sole were assessed. Duration of static one-leg standing balance was measured. Light touch-pressure, vibration, two-point discrimination sensations of the foot sole, and duration of one-leg standing balance were decreased in patients with MS compared with controls ($p < 0.05$). Sensation of the foot sole was related with duration of one-leg standing balance in patients with MS. In the multiple regression analysis conducted in the 27 MS patients, 47.6% of the variance in the duration of one-leg standing balance was explained by two-point discrimination sensation of the heel ($R^2 = 0.359$, $p = 0.001$) and vibration sensation of the first metatarsal head ($R^2 = 0.118$, $p = 0.029$). As the cutaneous receptors sensitivity decreases in the foot sole the standing balance impairs in patients with MS. Two-point discrimination sensation of the heel and vibration sensation of the first metatarsal head region are the best predictors of the static standing balance in patients with MS. Other factors which could be possible to predict balance and effects of sensorial training of foot on balance should be investigated.

1. Introduction

Standing balance is a basic requirement of daily life [1]. The maintenance of balance depends on integration of inputs from visual, somatosensory, and vestibular systems [2]. One of the components of somatosensory system is cutaneous receptors. Plantar side of the foot contains these cutaneous receptors; Merkel's cells, Pacinian corpuscles, Meissner's corpuscles, and Ruffini endings [3]. In erect posture, only plantar side of the foot contacts with the ground. Cutaneous afferent inputs from the foot sole provide useful information to central nervous system (CNS) to generate human balance [4,5]. When cutaneous afferent inputs are not transmitting to the CNS, imbalance may occur as in MS [3]. World Health Organization (WHO) indicated that the one of the most common presenting symptoms of MS is sensory problems [6]. Several studies showed that sensation of the sole of the foot was decreased in this population [7–9]. Additionally, ability to maintain balance in standing is a marked problem in patients with MS [9–13]. Studies investigated the foot sensation and its relationship with standing balance indicated that sensory feedback originating from cutaneous receptors of the foot sole plays important role in the regulation of standing balance [4,5,14–16]. However, to our knowledge, the effects of reduced sensation of the foot sole on standing balance in patients with MS have not been investigated yet.

Therefore, the purposes of this study were to investigate the relationship between the foot sensations and standing balance in patients with MS and find out the sensation, which best predicts balance.

2. Materials and methods

All subjects were properly informed about the study and signed written informed consents prior to their participation. Ethics approval was obtained from the Local Ethical Committee. Assessments were performed in a quiet, well lightened room, in a random order.

Patients: Forty-eight patients were assessed for eligibility (34 female, 14 male). Six patients were not met inclusion criteria. Seven patients declined to participate.

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Eight patients were excluded due to logistic problems. Twenty-seven relapsing-remitting type (25 female, 2 male, 36.74 ± 7.66 years) patients were included in the study, diagnosed as MS according to Mc Donald's criteria [17], October 2010–January 2011. Disability level was determined using Expanded Disability Status Scale (EDSS) [18]. Spasticity was assessed using Modified Ashworth Scale (MAS) [19]. Ataxia was scored using Brief Ataxia Rating Scale (BARS) [20]. Mental state was assessed using Mini-Mental State Examination (MMSE) [21]. Patients with EDSS = 1–3.5, MAS $\leq$ 1, MMSE > 24 were included. Patients with diabetes mellitus, visual impairment, and any orthopaedic problem of the lower extremity, acute attacks (three months prior to the study) or patients received corticosteroid treatment (one month prior to the study) were excluded. Age and sex matched 10 volunteer (8 female, 2 male, 33.90 ± 5.78 years) were included as controls. Assessments were done bilaterally by the same physiotherapist.

Light touch-pressure sensation was assessed using a full Semmes-Weinstein Monofilament (SWM) test kit (North Coast Medical, San Jose, CA, USA) at the three regions of the foot (first metatarsal head, fifth metatarsal head, and heel). The smallest (1.65) monofilament was used firstly. Monofilaments were touched for a 1.0–1.5 s to the test locations and 1.65–3.61 monofilaments were applied three times consecutively. When the subject felt the stimulus correctly in one of the three trials, the filament representing a specific force was noted as the subject's score, 3.84 and higher filaments were applied for once [22].

Vibration sensation: Duration of vibration sensation was measured using 128-Hz frequency tuning fork (Elcon® Medical Instruments, Tuttlingen, Germany) at the first metatarsal head and medial malleol of the foot. The duration of the vibration was measured by chronometer, started when the fork touched to the subject's skin and stopped when the subject told "it has finished". The average of three trials was recorded as seconds [10,23–25].

Two-point discrimination sensation of the foot sole was evaluated using an aesthesiometer (Baseline®, White Plains, New York, USA) from trans-metatarsal, mid, and heel regions. Assessment was started at the maximum distance and gradually decreased until the subject could not able to differentiate the two points. When the subject felt two points as one in two of three trials, the distance was noted in mm [26,27].

One-leg standing balance: Subjects tried to stand on one-leg as long as possible. Test was performed eyes open and bare foot at both sides. One trial was given before the test. The duration of the standing on one-leg was measured using a chronometer. No verbal stimulus was given during the test. The chronometer was stopped when the elevated foot touched to the ground or subject lost the balance position. If a subject could stand for 180 s on one-leg, the test was accepted as completed [7]. Lower extremity dominance was determined by asking 'which leg do you prefer for kicking a ball'.

2.1. Statistical analysis

All data were analyzed using the Statistical Package for the Social Sciences (SPSS®, Chicago, IL, USA, version 11.5). Data normality was tested using Kolmogorov–Smirnov test. Data were expressed as mean (±SD) unless otherwise stated. Demographic data of MS patients and controls were compared using Independent sample *t*-test and expressed 95% confidence interval (CI). Gender difference was compared using Chi-Square Test. Only dominant sides of the MS patients were used for analysis. Since data (light touch-pressure, vibration, two-point discrimination, and one-leg standing balance) were not normally distributed, comparisons were performed using Mann–Whitney *U* test and expressed median and interquartile range (IQR). Spearman correlations were calculated to assess whether foot sensation was associated with EDSS and one-leg standing balance in MS patients. Predictors of the static balance were determined using stepwise multiple regression analysis. Statistical significance was set at $p < 0.05$.

3. Results

There were no significant differences in age, gender, weight, height, and body mass index (BMI) between MS patients and controls ($p > 0.05$, Table 1). There were no side to side differences in threshold of the light touch-pressure, duration of the vibration, and distance of two-point discrimination sensations of the foot in MS patients ($p > 0.05$). The duration of one-leg standing balance between the right and left side was similar in MS patients ($p > 0.05$, Table 2). The thresholds of light touch-pressure sensation of the foot sole were higher in MS patients compared with controls ($p < 0.01$, Table 3). The thresholds of light touch-pressure sensation of MS patients were higher (24 patients (88.89%) in first metatarsal head; 23 patients (85.19%) in fifth metatarsal head; 21 patients (77.78%) in heel) than the 95%CI of the controls (Table 4). The duration of vibration sensation at first metatarsal head and medial malleol regions were shorter in MS patients compared with controls ($p < 0.05$, Table 3). The duration

Table 1
Demographic and clinical characteristics of the MS patients and controls.

Characteristics	MS patients (mean ± SD)	Healthy controls (mean ± SD)	p
Age, years	36.74 ± 7.66	33.90 ± 5.78	0.395
Gender			
Female/Male, n (%)	25 (92.6)/2 (7.4)	8 (80)/2 (20)	0.273
Height, cm	163.26 ± 7.97	167.50 ± 5.32	0.449
Weight, kg	65.41 ± 13.95	66.20 ± 9.40	0.367
BMI, kg/m^2	24.68 ± 4.76	23.65 ± 3.59	0.295
Duration of illness, years	4.98 ± 4.55	–	
			MS (n), %
No medication			(3) 11.1
Interferon β-1a			(18) 66.7
Interferon β-1b			(6) 22.2
Spasticity (0–4)			(7) 25.9
BARS			(9) 33.3
Gait (0–8)			
Knee-tibia test (0–4)			(9) 33.3
Finger to nose test (0–4)			(10) 37.0
Dysarthria (0–4)			(0) 0
Oculomotor (0–2)			(2) 7.4

$p < 0.05$; BMI = Body Mass Index; BARS = Brief Ataxia Rating Scale.

Table 2
Comparisons of light touch-pressure, vibration, two-point discrimination sensations and one-leg standing balance at the right and left sides in patients with MS.

	Multiple sclerosis		p
	Right Median (25th–75th IQR)	Left Median (25th–75th IQR)	
Light touch-pressure threshold			
First metatarsal head	3.61 (3.33–3.84)	3.61 (3.22–3.84)	0.979
Fifth metatarsal head	3.61 (3.22–4.08)	3.61 (3.22–3.84)	0.784
Heel	3.84 (3.61–4.17)	3.84 (3.61–4.31)	0.541
Vibration (s)			
First metatarsal head	8.71 (7.40–11.01)	9.24 (6.97–9.88)	0.659
Medial malleol	7.68 (6.42–9.54)	7.77 (6.38–9.55)	0.836
Two-point discrimination (mm)			
Trans-metatarsal	21 (15–27)	19 (15–33)	0.938
Mid foot	22 (16–29)	22 (17–27)	0.621
Heel	22 (17–29)	21 (17–30)	0.876
One-leg standing balance (s)	28.26 (3.64–120)	17.14 (2.97–67)	0.406

$p < 0.05$; IQR = interquartile range.

Table 3
Light touch-pressure, vibration, two-point discrimination sensations and one-leg standing balance of MS patients and healthy controls.

	MS patients	Healthy controls	p
	Median (25th–75th IQR)	Median (25th–75th IQR)	
Light touch-pressure threshold			
First metatarsal head	3.61 (3.33–3.84)	2.44 (1.65–2.93)	0.001
Fifth metatarsal head	3.61 (3.22–4.08)	2.44 (2.18–2.93)	0.001
Heel	3.84 (3.61–4.17)	3.22 (2.44–3.67)	0.002
Vibration (s)			
First metatarsal head	8.71 (7.40–11.01)	11 (9.97–12.11)	0.018
Medial malleol	7.68 (6.42–9.54)	9.74 (7.85–10.95)	0.022
Two-point discrimination (mm)			
Trans-metatarsal	21 (15–27)	12 (8.75–13.25)	0.001
Mid foot	22 (16–29)	13.5 (11.75–14.25)	0.001
Heel	22 (17–29)	12.5 (11.5–20)	0.005
One-leg standing balance (s)	28.26 (3.64–120)	180	0.001

p <0.05; IQR = interquartile range.