Evaluation of Plantar Foot Sensation, Balance, Physical Performance, and Fear of Movement in Substance Use Disorders

Yıldız Erdoğanoğlu, PhD*
Çetin Sayaca, PhD*
Mahmut Çalık, MS*
Cemal Onur Noyan, MD†
Alptekin Çetin, MD†
Duygu Kaya Yertutanol, PhD†
Laçin Naz Taşçılar, MS‡
Defne Kaya, PhD*

Background: Neuropathologic changes may occur in the nervous system due to long-term substance use, leading to functional disability with altering of balance. We know little about substance-related mechanisms that can cause movement disorders. This study investigated the effects of plantar foot sensation and balance on physical performance as an effect of substance use in detoxified patients.

Methods: Twenty-three users of cannabis, volatile agents, or narcotic/stimulant agents alone or in combination for at least 1 year (mean age, 27.6 years) and 20 healthy volunteers (mean age, 24.6 years) were included. Participant evaluations were implemented immediately after the detoxification process with psychiatrist approval. Depression, state-trait anxiety, and fear of movement levels were evaluated with the Beck Depression Inventory, State-Trait Anxiety Inventory, and Tampa Scale for Kinesiophobia, respectively. Plantar foot sensations were evaluated with light touch, two-point discrimination, and vibration examinations. Balance was assessed with balance software and a balance board and force platform. Balance path, balance path distance, and center of pressure were recorded. Physical performance was evaluated with the Timed Up and Go (TUG) test in the final step.

Results: There was a significant difference in two-point discrimination of patients versus controls ($P < .05$). Significant differences were also found in balance values, particularly in the sagittal direction ($P < .05$). TUG test results of patients compared with controls showed a negative influence on physical function ($P < .05$).

Conclusions: Detailed examination should be performed to understand movement disorders in substance users. Herein, substance users had impaired two-point discrimination and sagittal balance reciprocally. Thus, customized physiotherapy approaches to substance users should be considered to improve their movement disorders. (J Am Podiatr Med Assoc 110(3): 1-7, 2020)

*Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Uskudar University, Istanbul, Turkey.

†Department of Psychology, Faculty of Humanities and Social Sciences, Uskudar University, Istanbul, Turkey.

‡Department of Physical Therapy and Rehabilitation, Faculty of Health Sciences, Okan University, Istanbul, Turkey.

Corresponding author: Yıldız Erdoğanoğlu, PhD, Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Uskudar University, Guney Campus, Altunizade Mh. Mahir Iz Cd. No: 23 PK: 34674 Uskudar, Istanbul, Turkey. (E-mail: yildiz.erdoganoglu@uskudar.edu.tr)

Long-term use of substances has been shown to have toxic effects that produce neurologic and neuropsychiatric outcomes. Sensory and motor components of the nervous system are affected in people with substance addiction.[1,2] The most common neurologic disorders are peripheral neuropathy, cerebellar dysfunction, cranial nerve damage, cortical atrophy, encephalopathy, and dementia.[2,3] Long-term cannabis use is associated with decreased white matter density in the left parietal lobe,[4] which causes long-term changes in cognitive functions.[5] Besides this, functional changes may also occur in the motor system. A history of cannabis use is related to long-term changes in the open-kinetic-chain elements of gait, but the magnitude of change is not clinically detectable.[6] Furthermore, cannabis poisoning can cause acute motor impairments, including changes in balance.[7]

Plantar foot sensation is significant for posture and gait control. In conjunction with this, balance deficiency may develop reciprocally when afferent inputs of the plantar foot are not transmitted properly to the central nervous system.[8] The central nervous system then combines cutaneous entry with visual, vestibular, and proprioceptive sensory information to protect balance.[9]

Posture and coordination controlled by nervous system changes negatively depend on the substance use, but little is known about this subject in the literature. However, possible cortical and peripheral nervous system involvement with proprioceptive and plantar foot sensation may affect balance negatively.[10,11] This reciprocal mechanism leads to changes in functionality and may cause kinesiophobia in patients with substance use disorders. This study was designed to test this hypothesis by assessing plantar foot sensation, balance, and physical performance of substance users for at least 1 year without obvious neurologic involvement and findings.

Materials and Methods

Participants

This study was conducted at NPISTANBUL Brain Hospital (Istanbul, Turkey). Twenty-three individuals who have been using cannabis, volatile agents, or narcotic/stimulant agents alone or in combination for at least 1 year (mean ± SD age, 27.608 ± 5.202 years) and 20 healthy volunteers (mean ± SD age, 24.600 ± 5.941 years) were included in this study. The exclusion criteria were schizophrenia, bipolar affective disorder, neurologic and neuropathic problems, surgical and mechanical problems of the lower extremity and body, type 1 and 2 diabetes, vertigo, and cardiovascular diseases that may alter the results.

Ethics approval for research was obtained from the Uskudar University Non-Interventional Ethics Board (Istanbul, Turkey). The procedures were conducted in accordance with the Declaration of Helsinki, and written informed consent was obtained from each individual before participation. Individuals were approved by the psychiatrist after the detoxification process.

Evaluation Methods

Plantar Foot Sensation. Light touch sensation, vibration sensation, and two-point discrimination sensation were included to asses plantar foot sensation.

Light touch sensation was evaluated with the Semmes-Weinstein monofilament test.[12] The monofilaments that were sensitive to touch-sensitive dynamic force, measured in milligrams, were used for evaluation. Diameters of monofilaments were 2.83 (0.07 g), 3.61 (0.2 g), 4.31 (2.0 g), 4.56 (4.0 g), 5.07 (10 g), and 6.65 (200 g). The evaluation started with the thinnest-diameter monofilament held at right angles to the respective zones and pressed for 1 to 1.5 sec. It was implemented in three different regions: first metatarsal head, fifth metatarsal head, and heel.[13] When the individuals felt the pressure of the monofilament, they were asked to state where the application was made. The test was performed with three repetitions, and if one of them was true, the answer was accepted as correct. The answers given 3 sec later were considered abnormal.

Duration of vibration sensation was evaluated using a 128-Hz diapason at the first metatarsal head and medial malleolus of the foot. The duration time, recorded by chronometer in seconds, started when the fork contacted the individual's skin and stopped when the individual said "it has finished"; the average of three trials was used.[14,15]

Sensation of two-point discrimination of the plantar foot was assessed with an esthesiometer at the transmetatarsal, midfoot, and heel. Measurement was started at the maximum distance and gradually decreased until the individual could not differentiate the two points. When the individual felt two points as one in two of three trials, the distance was recorded in millimeters.[16,17]

Balance. Balance evaluations were applied with a balance device (Fizyosoft, Gebze, Turkey). Standing balance was indexed by sway velocities measured with the Wii Balance Board (WBB) (Nintendo of America, Redmond, Washington) interfaced with a laptop. The tests were implemented with balance assessment software (Fizyosoft Balance System, Version 3.1.2.) using the Fizyosoft balance board and force platform. The size of the WBB is approximately 45 × 26.5 cm. Data from the WBB sensors were sampled at approximately 30 to 50 Hz. Balance path, balance path distance, center of pressure in the x and y planes (COPx, COPy), and value in the x and y planes (xVAL and yVAL) during eyes open and eyes closed states were measured with the balance device.[18,19]

Physical Performance. The individuals' physical performance was evaluated with the Timed Up and Go (TUG) test as validated by previous studies.[20] Participants were asked to stand from a sitting position, walk 3 m, turn, walk back, and sit back in the chair. The test was repeated three times, and the average of the durations was noted in seconds.[20]

Fear of Movement. Fear of movement was assessed with the Turkish version of the Tampa Scale for Kinesiophobia.[21] The scale consists of 17 questions, and the level of kinesiophobia is scored from 17 to 68 points. A score greater than 39 points is considered high kinesiophobia according to the literature.[22]

Depression. Depression levels were assessed via the Beck Depression Inventory, developed by Beck et al[23] in 1961. It consists of a 21-item self-report rating inventory that is used to assess the risk and severity of depression. Each symptom is rated on a 4-point scale ranging from none to severe, and the range of possible scores is 0 to 63. A score of 16 or more is used as the conventional cutoff value for clinical depression. The Turkish adaptation of the scale was done by Hisli in 1988.[24]

State-Trait Anxiety Inventory. The inventory was developed by Spielberger et al[25] in 1970 to determine state and trait anxiety levels. It is based on self-report and consists of two sections with a total of 40 items. The first part (state anxiety) aims to assess a certain moment of the person, and the second part (trait anxiety) aims to evaluate more general processes. The possible score for each scale ranges from 20 to 80. High scores indicate a high level of anxiety. It was adapted to Turkish by Öner and Le Compte in 1985.[26]

Data Analysis

Statistical analysis was performed using a statistical software program (IBM SPSS Statistics for Windows, Version 22; IBM Corp, Armonk, New York). Normal distribution of the data was determined by the Kolmogorov-Smirnov test at a confidence interval of 0.05. The descriptive mean in the study is expressed as mean ± SD. The dominant and nondominant adverse effects in the patients with substance use disorders (foot base light touch, vibration, two-point discrimination) were assessed using the paired-samples t test. Comparisons (plantar foot sensation, static balance) between the participants with substance use disorders and the control group were performed with the independent-samples t test.

Results

The demographic characteristics of the patient and control groups are given in Table 1. There were no significant differences in comparisons of foot base light touch (first metatarsal head, fifth metatarsal head, and heel midpoint) and vibration (first metatarsal head and leg medial malleolus) between patients with substance use disorders and control patients ($P > .05$). Comparisons of two-point discrimination sensation (transverse tarsal region, heel midpoint, and lateral of the plantar foot) was found to be significant between the groups ($P < .05$) (Table 2).

Among the dominant and nondominant sides of the patients with substance use disorders, light touch sensation (first metatarsal head, fifth metatarsal head, and heel midpoint), vibration sensation (first metatarsal head and medial malleolus), and two-point discrimination sensation (transverse tarsal region and heel midpoint) were not significantly different ($P > .05$) (Table 2).

Significant differences were found in balance values such as balance path, balance path distance, COPy, and yVAL during the eyes open and eyes closed states compared with the control group ($P <$ .05). On the other hand, there was no significant difference in the balance values of the patients (COPx and xVAL) during eyes open and eyes closed states ($P > .05$). In addition, dominant and nondominant balance values of the patients showed no important differences compared with among those with substance use disorders ($P > .05$) (Table 3).

In the final step, there was a significant difference in functionality (mean ± SD TUG test values) between patients with substance use disorders (5.869 ± 0.767) and control patients (4.748 ± 0.562) (independent-samples test, $P < .05$).

Discussion

Substance use is becoming a major challenge all over the world regarding not only physicosocial aspects but also organic and physical disabilities. It can cause changes in the central and peripheral nervous systems that reduce the ability of people to identify various stimuli from the environment and select appropriate reactions.[27] Particularly, sensorial deficits may delay the perception of perturbations

Table 1. Demographic and Clinical Characteristics of Patients with Substance Use Disorders and Control Patients

Characteristic	Patient Group (n = 23)	Control Group (n = 20)	*P* Value[a]
Age (years)	27.608 ± 5.202	24.600 ± 5.941	.084
Height (cm)	177.130 ± 6.982	177.550 ± 5.651	.831
Weight (kg)	78.130 ± 17.558	72.350 ± 12.436	.265
BMI	24.854 ± 5.084	22.949 ± 3.773	.176
Duration of substance use (months)	84.130 ± 55.299		
BDI score	11.826 ± 9.212		
STAI 1 score	46.956 ± 4.931		
STAI 2 score	48.913 ± 6.059		
TSK score	36.739 ± 8.164		

Note: Data are given as mean ± SD.

Abbreviations: BDI, Beck Depression Inventory; BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); STAI, State-Trait Anxiety Inventory; TSK, Tampa Scale for Kinesiophobia.

[a]Independent-samples *t* test, $P < .05$.

that require fast responses, such as stumbling and falling. Reciprocally, this delayed perception might lead to a longer response time and reduce reaction ability of balance correction.[28] It has been reported that the ability to distinguish two points on the plantar foot as a preserved sensory response is associated with a lower incidence of falls[29] because afferent signals from the cutaneous receptors on the foot affect balance and stability by providing spatial and temporal information. Furthermore, actions required to maintain the upright posture via cutaneous mechanoreceptors play an important role when necessary.[30]

Although the ongoing neuropathologic process due to adverse effects of substances in the chronic phase was studied by the authors, little is known about the effects of substances in the detoxification period of the patients.[28,29] This study was conducted to investigate plantar foot sensation, balance, functional level, and kinesiophobia in patients with substance use disorders without neuropathic involvement and neurogenic findings after the detoxification process. The feedback through the tactile sensation of the plantar foot surface contributes to balance control.[31] This sensation is transmitted through the posterior column–medial lemniscus to the central nervous system. This information is integrated with the visual, vestibular, and proprioceptive senses to provide balance together. The quality of two-point discrimination sensation indicates the density in terms of skin touch receptors and is representative of somatosensory cortical

Table 2. Comparison of Sensation of Light Touch, Vibration, and Two-Point Discrimination Between Patients with Substance Use Disorders and Control Patients

	Patient Group (n = 23)		Control Group (n = 20)	*P* Value[a]	α Value[b]
Evaluation Criteria	Dominant	Nondominant	Dominant		
Foot base light touch sensation					
First metatarsal head	3.764 ± 0.551	3.957 ± 0.669	3.845 ± 0.422	.124	0.748
Fifth metatarsal head	3.980 ± 0.760	3.968 ± 0.730	3.868 ± 0.489	.862	0.547
Heel midpoint	4.467 ± 0.539	4.414 ± 0.719	4.244 ± 0.184	.874	0.080
Vibration (sec)					
First metatarsal head	10.002 ± 4.179	10.330 ± 3.582	9.344 ± 1.613	.544	0.512
Medial malleolus	9.700 ± 3.662	9.850 ± 3.160	8.371 ± 1.630	.791	0.108
Two-point discrimination (cm)					
Transmetatarsal	1.300 ± 0.990	1.400 ± 1.156	1.550 ± 1.164	.349	0.022[c]
Midfoot	3.291 ± 1.815	3.256 ± 3.256	2.550 ± 2.218	.721	0.029[c]
Heel midpoint	1.200 ± 0.938	1.500 ± 0.888	1.160 ± 0.619	.940	0.024[c]

Note: Data are given as mean ± SD.

Two-Point discrimination, light touch sensation, nonparametric Wilcoxon signed rank test.

[a]Paired-samples *t* test.

[b]Independent-samples *t* test, $P < .05$.

[c]$\alpha < 0.05$.

Table 3. Comparison of Balance Between Patients with Substance Use Disorders and Control Patients

Evaluation Criteria	Patient Group (n = 23)		Control Group (n = 20)		
	Dominant	Nondominant	Dominant	*P* Value	α Value
Balance path with eyes open	28.930 ± 26.984	30.837 ± 29.859	11.500 ± 4.850	.689	0.000[b]
Balance path distance with eyes open	2.976 ± 2.492	2.953 ± 2.389	1.800 ± 1.735	.159	0.003[b]
COPy with eyes open	–0.852 ± 2.004	–1.143 ± 1.711	–0.156 ± 1.408	.674	0.032[b]
COPx with eyes open	–0.183 ± 0.744	0.522 ± 1.069	–0.204 ± 0.697	.019[a]	0.922
xVAL with eyes open	0.023 ± 0.344	0.325 ± 0.714	0.050 ± 0.223	.090	0.646
yVAL with eyes open	–1.488 ± 3.568	–1.767 ± 2.958	–0.250 ± 2.425	.833	0.032[b]
COPx with eyes closed	–0.039 ± 1.422	0.579 ± 1.097	–0.255 ± 1.443	.144	0.615
COPy with eyes closed	–2.577 ± 1.634	–2.174 ± 1.613	–0.602 ± 1.618	.212	0.000[b]
xVAL with eyes closed	–0.130 ± 1.013	–3.695 ± 2.991	–0.250 ± 0.716	.001[a]	0.090
yVAL with eyes closed	–4.652 ± 3.127	–3.695 ± 2.991	–1.150 ± 2.852	.134	0.000[b]

Note: Data are given as mean ± SD.
Abbreviations: COP, center of pressure; VAL, value.
[a]$P < .05$, paired-samples *t* test.
[b]$\alpha < 0.05$, independent-samples *t* test.

presentation.[32] Therefore, the two-point discrimination test is a functional test that is used to assess the quality of touch sensitivity[33]; it is also considered an integrative test because it requires high-level sensory processing.[34] The results of this study show that the individuals with substance use disorders had loss in the sense of two-point discrimination of plantar foot sensation ($P < .05$), whereas there was no difference in light touch sensation and vibration sensation compared with the control group.

Similar studies showed that the reduction of plantar tactile sensation is associated with postural oscillation,[35,36] whereas some studies suggested that plantar sensitivity is moderately important to maintain balance because of the influence of decreased plantar sensation input on balance compensated for by other sensory systems.[37,38] On the other hand, clinical and laboratory tests may be able to detect only slight changes in postural stability without obvious neurologic findings. That is why the effect of plantar tactile sensation on postural stability and balance can be demonstrated by tests such platform balance, which was used in this study. Toledo and Barela[35] observed that the proprioceptive system of elderly individuals was more degenerated and that the pressure center oscillations were greater. This result reinforces the hypothesis that balance is affected by the sensorial knowledge of the plantar foot. The results of the study showed that individuals' balance results evaluated during eyes open and eyes closed states decreased in the sagittal (anteroposterior) direction ($P < .05$).

Many pathophysiologic mechanisms described in the literature assumed that cannabis use may cause unfavorable changes in normal rhythmic neural activity of locomotive circadian.[39-41] The acute effect of cannabis use has been seen before clearly,[42] but another result has shown that impaired balance may not be long-lasting.[43] The present study revealed that patients with substance use disorders showed more impairment than patients in the control group regarding physical performance in accordance with TUG test results ($P < .05$). The TUG test is a well-known and validated physical performance test that shows the functional level of the individual.[44] We think that the reciprocal mechanism between balance and physical performance may decrease functionality in patients even in the case of an obvious neurologic finding on examination. Therefore, we stated that clinical and laboratory tests are crucial to understand movement disorders in substance users.

In this article, we aimed to determine balance changes in individuals with substance use disorders. Afterward, the mechanisms underlying these changes were examined.

The mean ± SD age of individuals with substance use disorders in this study was 27.6 ± 5.2 years, and the mean ± SD duration of substance use was 84.1 ± 55.2 months. Factors such as age, depressive symptoms, memory, and cognitive changes did not seem to be likely to contribute to the outcome. Because the results of the study showed that there were no clinically significant depressive symptoms, there was state-trait anxiety in patients with substance use disorders, and their kinesiophobia level was low ($P < .05$).

The main limitation of the present study was the relatively small sample size because of singularity of the patient group. Many patients can provide more confidence about the detection of changes in substance-related movement disorders and may reveal distinct changes in balance and functional level. Although the duration of substance use in this group was certain, the amount of substance consumed during this period may have an influence on the results. The second limitation was that we could not perform functional magnetic resonance imaging and similar investigations to clarify neurodegenerative changes in the patients due to the cost of tests.

Conclusions

A decline in the two-point discrimination of plantar foot sensation and balance in the sagittal (anteroposterior) direction in patients with substance use disorders can lead to impairment of physical performance without fear of movement in accordance with this study. It is suggested that patients with substance use disorders be assessed extensively regarding movement disorders to implement proper physiotherapy and rehabilitation approaches, including proprioceptive sensation and balance.

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References

1. Giesen ES, Deimel H, Bloch W: Clinical exercise interventions in alcohol use disorders: a systematic review. J Subst Abuse Treat **52:** 1, 2015.
2. Strong DR, Redwine L, Norman SB, et al: An exercise-based program for veterans with substance use disorders: formative research. J Psychoactive Drugs **47:** 248, 2015.
3. Zschucke E, Heinz A, Ströhle A: Exercise and physical activity in the therapy of substance use disorders. ScientificWorldJournal **2012:** 901741, 2012.
4. Matochik JA, Eldreth DA, Cadet, JL, et al: Altered brain tissue composition in heavy marijuana users. Drug Alcohol Depend **77:** 23, 2005.
5. Solowij N, Pesa N: "Cannabis and Cognition: Short- and Long-term Effects," in *Marijuana and Madness*, 2nd Ed, edited by D Castle, RM Murray, DC D'Souza, p 91, Cambridge University Press, Cambridge, UK, 2011.
6. Pearson-Dennetta V, Todda G, Wilcoxa RA, et al: History of cannabis use is associated with altered gait. Drug Alcohol Depend **178:** 215, 2017.
7. Ramaekers JG, Kauert G, van Ruitenbeek P, et al: High-potency marijuana impairs executive function and inhibitory motor control. Neuropsychopharmacology **31:** 2296, 2006.
8. Kars HJ, Hijmans JM, Geertzen JH, et al: The effect of reduced somatosensation on standing balance: a systematic review. J Diabetes Sci Technol **3:** 931, 2009.
9. Machado AS, da Silva CB, Rocha ES, et al: Effects of plantar foot sensitivity manipulation on postural control of young adult and elderly. Rev Bras Reumatol Engl Ed **57:** 30, 2017.
10. Perry SD: Evaluation of age-related plantar-surface insensitivity and onset age of advanced insensitivity in older adults using vibratory and touch sensation tests. Neurosci Lett **9:** 62, 2006.
11. Pattison LP, McIntosh S, Sexton T, et al: Changes in dopamine transporter binding in nucleus accumbens following chronic selfadministration cocaine: heroin combinations. Synapse **68:** 437, 2014.
12. Jerosch-Herold C: Assessment of sensibility after nerve injury and repair: a systematic review of evidence for validity, reliability and responsiveness of tests. J Hand Surg Br **30:** 252, 2005.
13. Baraz S, Zarea K, Shahbazian HB, et al: Comparison of the accuracy of monofilament testing at various points of feet in peripheral diabetic neuropathy screening. J Diabetes Metab Disord **13:** 19, 2014.
14. Temlett JA: An assessment of vibration threshold using a biothesiometer compared to a C128-Hz tuning fork. J Clin Neurosci **16:** 1435, 2009.
15. Buchman AS, Wilson RS, Leurgans S, et al: Vibratory thresholds and mobility in older persons. Muscle Nerve **39:** 754, 2009.
16. Nolan MF: Limits of two-point discrimination ability in the lower limb in young adult men and women. Phys Ther **63:** 1424, 1983.
17. Dellon AL, Mackinnon SE, Crosby PM: Reliability of two-point discrimination measurements. J Hand Surg Am **12:** 693, 1987.
18. Duarte M, Freitas SM: Revision of posturography based on force plate for balance evaluation. Rev Bras Fisioter **14:** 183, 2010.
19. Goble DJ, Cone BL, Fling BW: Using the Wii Fit as a tool for balance assessment and neurorehabilitation: the first half decade of "Wii-search." J Neuroeng Rehabil **11:** 12, 2014.
20. Wall JC, Bell C, Campbell S, et al: The Timed Get-up-and-Go test revisited: measurement of the component tasks. J Rehabil Res Dev **37:** 109, 2000.
21. Ylmaz ÖT, Yakut Y, Uygur F, et al: Tampa Kinezyofobi Ölçeği'nin Türkçe versiyonu ve test-tekrar test güvenirliği. Fizyoterapi Rehabilitasyon **22:** 44, 2011.
22. Domenech J, Sanchis-Alfonso V, López L, et al: Influence of kinesiophobia and catastrophizing on pain and disability in anterior knee pain patients. Knee Surg Sports Traumatol Arthrosc **21:** 1562, 2013.
23. Beck AT, Ward CH, Mendelson M, et al: An inventory for measuring depression. Arch Gen Psychiatry **4:** 561, 1961.
24. Hisli N: Beck depresyon envanterinin geçerliği üzerine bir çalışma. Psikoloji Dergisi **6:** 118, 1988.
25. Spielberger CD, Gorsuch R, Lushene RE, et al: *Manual for Stait-Trait Anxiety Inventory*, Consulting Psychologists Press, Palo Alto, CA, 1970.

26. Öner N, Le Compte A: *Durumluk Sürekli Kaygı Envanteri El Kitabı*, Boğaziçi Üniversitesi Yayınları, İstanbul, Turkey, 1985.
27. Franco PG, Bohrer RCD, Rodacki ALF: Intra-observer reproducibility of the feet soles two-point discrimination test in asymptomatic elderly and young individuals. Rev Bras Fisioter **16:** 523, 2012.
28. Gauchard GC, Jeandel C, Tessier A, et al: Beneficial effect of proprioceptive physical activities on balance control in elderly human subjects. Neurosci Lett **273:** 81, 1999.
29. Melzer I, Benjuya N, Kaplanski J: Postural stability in the elderly: a comparison between fallers and non-fallers. Age Ageing **33:** 602, 2004.
30. Perry SD, McIlroy WE, Maki BE: The role of plantar cutaneous mechanoreceptors in the control of compensatory stepping reactions evoked by unpredictable, multi-directional perturbation. Brain Res **877:** 401, 2000.
31. Palluel E, Nougier V, Olivier I: Do spike insoles enhance postural stability and plantar-surface cutaneous sensitivity in the elderly? Age **30:** 53, 2008.
32. O'Sullivan S: *Physical Rehabilitation*, 5th Ed, p 136, F.A. Davis Co, Philadelphia, 2007.
33. Silva PG, Jones A, Araujo PM, et al: Assessment of light touch sensation in the hands of systemic sclerosis patients. Clinics **69:** 585, 2014.
34. Boscheinen-Morin J, Conolly WB: *The Hand: Fundamentals of Therapy*, 3rd Ed, p 1, Butterworth-Heinemann, Oxford, UK, 2001.
35. Toledo DR, Barela JA: Sensory and motor differences between young and older adults: somatosensory contribution to postural control. Rev Bras Fisioter **14:** 267, 2010.
36. Peters RM, McKeown MD, Carpenter MG, et al: Losing touch: age-related changes in plantar skin sensitivity, lower limb cutaneous reflex strength, and postural stability in older adults. J Neurophysiol **116:** 1848, 2016.
37. Meyer PF, Oddsson LI, De Luca CJ: The role of plantar cutaneous sensation in unperturbed stance. Exp Brain Res **156:** 505, 2004.
38. Billot M, Handrigan GA, Simoneau M, et al: Short term alteration of balance control after a reduction of plantar mechanoreceptor sensation through cooling. Neurosci Lett **535:** 40, 2013.
39. El Manira A, Kyriakatos A, Nanou E., et al: Endocannabinoid signaling in the spinal locomotor circuitry. Brain Res Rev **57:** 29, 2008.
40. Oliviero A, Arevalo-Martin A, Rotondi M, et al: CB1 receptor antagonism/inverse agonism increases motor system excitability in humans. Eur Neuropsychopharmacol **22:** 27, 2012.
41. Romero J, Hillard CJ, Calero M, et al: Fatty acid amide hydrolase localization in the human central nervous system: an immunohistochemical study. Brain Res Mol Brain Res **100:** 85, 2002.
42. Zuurman L, Roy C, Schoemaker RC, et al: Effect of intrapulmonary tetrahydrocannabinol administration in humans. J Psychopharmacol **22:** 707, 2008.
43. Pearson-Dennetta V, Todda G, Wilcoxa RA, et al: History of cannabis use is associated with altered gait. Drug Alcohol Depend **178:** 215, 2017.
44. Stienen MN, Maldaner N, Joswig H, et al: Objective functional assessment using the "Timed Up and Go" test in patients with lumbar spinal stenosis. Neurosurg Focus **46:** E4, 2019.