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, PhDr†  
Laçin Naz Taşcılar, 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)

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 NPİSTANBUL Brain Hospital (İstanbul, 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 (İstanbul, 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 assess plantar foot sensation.

Light touch sensation was evaluated using 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.\textsuperscript{18,19}

**Physical Performance.** The individuals' physical performance was evaluated with the Timed Up and Go (TUG) test as validated by previous studies.\textsuperscript{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.\textsuperscript{20}

**Fear of Movement.** Fear of movement was assessed with the Turkish version of the Tampa Scale for Kinesiophobia.\textsuperscript{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.\textsuperscript{22}

**Depression.** Depression levels were assessed via the Beck Depression Inventory, developed by Beck et al\textsuperscript{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.\textsuperscript{24}

**State-Trait Anxiety Inventory.** The inventory was developed by Spielberger et al\textsuperscript{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.\textsuperscript{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 \(t\) 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.\textsuperscript{27} Particularly, sensorial deficits may delay the perception of perturbations...
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.\textsuperscript{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\textsuperscript{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.\textsuperscript{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.\textsuperscript{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.\textsuperscript{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 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\textsuperscript{a} |
| Age (years)                     | 27.600 ± 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    | 72.350 ± 12.436    | .265            |
| BDI score                       | 11.826 ± 9.212     | 46.956 ± 4.931     | .831            |
| STAI 1 score                    | 48.913 ± 6.059     | 36.739 ± 6.164     | .176            |
| STAI 2 score                    | 36.739 ± 8.164     | 36.739 ± 8.164     | .176            |

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.

\textsuperscript{a}Independent-samples t test, P < .05.

| Table 2. Comparison of Sensation of Light Touch, Vibration, and Two-Point Discrimination Between Patients with Substance Use Disorders and Control Patients |
|---------------------------------|-----------------|-----------------|-----------------|
| Evaluation Criteria             | Dominant        | Nondominant     | Dominant        | P Value\textsuperscript{a} | \textsuperscript{\textsuperscript{\textsuperscript{a}}\textsuperscript{a}} Value\textsuperscript{b} |
| 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           |
| Two-point discrimination (cm)   |                 |                 |                 |                 |                 |
| Transmetatarsal                 | 1.300 ± 0.990   | 1.400 ± 1.156   | 1.550 ± 1.164   | .349            | 0.022\textsuperscript{c} |
| Midfoot                         | 3.291 ± 1.815   | 3.256 ± 3.256   | 2.550 ± 2.218   | .721            | 0.029\textsuperscript{c} |
| Heel midpoint                   | 1.200 ± 0.938   | 1.500 ± 0.888   | 1.160 ± 0.619   | .940            | 0.024\textsuperscript{c} |

Note: Data are given as mean ± SD.

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

\textsuperscript{a}Paired-samples t test.

\textsuperscript{b}Independent-samples t test, P < .05.

\textsuperscript{c}\alpha < 0.05.
presentation. Therefore, the two-point discrimination test is a functional test that is used to assess the quality of touch sensitivity; it is also considered an integrative test because it requires high-level sensory processing. 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, 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. 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 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. The acute effect of cannabis use has been seen before clearly, but another result has shown that impaired balance may not be long-lasting. 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. 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.

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

<table>
<thead>
<tr>
<th>Evaluation Criteria</th>
<th>Patient Group (n = 23)</th>
<th>Control Group (n = 20)</th>
<th>P Value</th>
<th>( \alpha ) Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balance path with eyes open</td>
<td>Dominant 28.930 ± 26.984</td>
<td>Nondominant 30.837 ± 29.859</td>
<td>.689</td>
<td>0.000&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>Dominant 11.500 ± 4.850</td>
<td>Nondominant 1.800 ± 1.735</td>
<td>.159</td>
<td>0.003&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Balance path distance with eyes open</td>
<td>Dominant 2.976 ± 2.492</td>
<td>Nondominant 2.953 ± 2.389</td>
<td>.837</td>
<td>0.032&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>COPy with eyes open</td>
<td>Dominant -0.852 ± 2.004</td>
<td>Nondominant -1.143 ± 1.711</td>
<td>.019</td>
<td>0.922</td>
</tr>
<tr>
<td>COPx with eyes open</td>
<td>Dominant -0.183 ± 0.744</td>
<td>Nondominant 0.522 ± 1.069</td>
<td>.014&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.922</td>
</tr>
<tr>
<td>xVAL with eyes open</td>
<td>Dominant 0.023 ± 0.344</td>
<td>Nondominant 0.325 ± 0.714</td>
<td>.090</td>
<td>0.646</td>
</tr>
<tr>
<td>yVAL with eyes open</td>
<td>Dominant -1.488 ± 3.568</td>
<td>Nondominant -1.767 ± 2.958</td>
<td>.833</td>
<td>0.032&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>COPy with eyes closed</td>
<td>Dominant -0.039 ± 1.422</td>
<td>Nondominant 0.579 ± 1.097</td>
<td>.144</td>
<td>0.615</td>
</tr>
<tr>
<td>COPx with eyes closed</td>
<td>Dominant -2.577 ± 1.634</td>
<td>Nondominant -2.174 ± 1.613</td>
<td>.212</td>
<td>0.000&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>xVAL with eyes closed</td>
<td>Dominant -0.130 ± 1.013</td>
<td>Nondominant -3.695 ± 2.991</td>
<td>.001&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.090</td>
</tr>
<tr>
<td>yVAL with eyes closed</td>
<td>Dominant -4.652 ± 3.127</td>
<td>Nondominant -3.695 ± 2.991</td>
<td>.134</td>
<td>0.000&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Note: Data are given as mean ± SD.
Abbreviations: COP, center of pressure; VAL, value.

\( aP < .05 \), paired-samples t test.

\( b\alpha < 0.05 \), independent-samples t test.
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 (antero-posterior) 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.

Financial Disclosure: None reported.
Conflict of Interest: None reported.

References