The Effect of Ankle-Foot Orthoses on Balance Impairment: Single-Case Study

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ABSTRACT

Computerized Dynamic Posturography was performed with and without ankle-foot orthoses (AFOs).

With no orthoses the patient had falls performing most of the tests.

Bilateral orthoses improved his balance: a derived composite balance score increased four times.

In view of these findings, AFOS, in addition to correcting the patient's foot placement during locomotion, could also be expected to improve the maintenance of balance during quiet stance or dynamic perturbation.

Key Words: Diabetic neuropathy, balance, ankle-foot orthosis.

The remarkable ability of the body to maintain balance is based on the efficient detection and integration of information from the vestibular, visual, and somatosensory systems. Dysfunction in any one these three sensory systems (which may happen when information from one or more of the perceptual systems is in conflict with the information from the other perceptual systems) results in spatial disorientation, varying degrees of unsteadiness, or imbalance. When either the visual field or support surface is moving, the somatosensory and visual systems dominate the control of balance. This happens because the vestibular system is less sensitive to slow and quick changes of environment than the visual or somatosensory systems. The vestibular system acts as an internal reference for inaccuracies that may result from operating both the somatosensory and visual systems. The challenge of equilibrium maintenance increases considerably and depends more on vestibular input when both visual and somatosensory information are compromised. The most serious consequences of errors in the vestibular, visual, and proprioceptive perception of the environment are faulty or delayed corrective responses leading to falls. In particular, sensory deprivation studies have shown that deficit of the proprioceptive perception (i.e., seen in patients with peripheral neuropathy and associated with a loss of distal sensation) is associated with increased risk of falls.[1-3]

One of the major complications associated with diabetic neuropathy is bilateral loss of somatosensory information in the hands and feet. Such a somatosensory deficit in the feet compromises functional postural stability of patients with diabetic neuropathy and might place them at a higher risk of falling when performing more challenging daily tasks.[1-6] It was also shown that diabetic subjects with peripheral neuropathy have demonstrated a significant loss of ankle movement perception,[7] have larger ranges of postural sway, [4,8] and are more likely to use hip control balance strategy. Because of the percentage of individuals diagnosed with diabetes who develop polyneuropathy after 20 years reaches 50%,[10] the number of balance studies involving diabetic patients is growing.[3,5,6]

AFOs are prescribed to control and limit movement at the ankle and knee, thus improving gait abnormalities in patients with hemiplegia, and peroneal and tibial nerve paralysis. AFOs are also prescribed to have an impact on speed and energy cost of hemiparetic ambulation.[11] The importance of orthotic use is well documented.[12-16] In particular, it was demonstrated in a single-subject design study that standing balance of a 4.5-year-old boy with cerebral palsy improved while using an AFO.[17] In particular, improvements were noted in duration of independent standing during with-orthoses condition, in the symmetry of the stance pattern, and in the ease with which the subject maintained independent standing. The effect of wearing ankle orthoses has also been shown in healthy volunteers tested while upright standing on a statokinesimetric platform with and without orthoses.[18] The study provided information about the prophylactic effect of bilateral orthoses for subjects with major variations in postural equilibrium. However, objective functional measurement of dynamic balance of diabetic patients with and without AFOS has not been reported.

The purpose of the study is to assess the effect of AFOs on balance impairment using computerized dynamic posturography. Dynamic posturography provides information on the use of sensory cues to maintain postural stability and on the automatic postural responses to maintain stability after translation or rotation of the support surface.[19]

Methodology

The subject was a 48-year-old male with a 23 year history of insulin-dependent diabetes mellitus. The subject had peroneal nerve palsy and impaired sensations of both hands and feet. His light touch was impaired below the ankles and below the wrists bilaterally. He also was without proprioception and had diminished vibratory sense in these areas. Motor tone was normal in all extremities, and reflexes were normal, with the exception of absent ankle jerks and diminished knee jerks. Romberg test was positive and the patient was unable to perform tandem gait. He was unable to stand on either the right or left foot for more than one second without losing his balance. Gait without AFOS revealed that the patient during initial stance and midstance exhibited bilateral equino varus ankle-foot deformity followed by excessive pronation during terminal stance. He also exhibited hyperextension of both knees during mid- and terminal-stance phase. Steppage gait was observed during swing phase.

Four days prior to the study, the patient was provided with a bilateral rigid polypropylene AFOS (thickness of plastic was 3/16 in) with the trim line medially and laterally at the apex of the malleoli, proximally 1 in below fibular head and distally at the toe sulcus and the ankle set at 2° of dorsiflexion (Figure 1). The orthoses were beneficial in correcting the patient's gait deviations, providing limitation of plantar flexion and dorsiflexion by its biomechanical configuration. Gait evaluation with orthoses revealed that the ankle and knee control improved, the patient no longer exhibited bilateral equino varus at the ankle. He had heel-to-toe gait without hyperextension at the knees, and steppage gait was not observed. The patient had no complaints of dizziness or balance difficulty and was independent in ambulation with the orthoses without any assistive devices.

In the dynamic posturography, the subject stands on a dual forceplate enclosed by visual surround. Both the forceplate and the surround can be made to move with the subject's anterioposterior sway or independent of the sway, thus enabling programmed disturbances of the equilibrium. The dual forceplate records the vertical forces between feet and ground as well as shear forces, therefore allowing estimation of the position of the swaying body and the pattern of sway in terms of hip or ankle strategy.

Dynamic posturography was performed with and without AFOS. The subject was placed on the dual forceplate and secured with a harness to prevent a fall. The Sensory Organization Test (SOT) was performed in a clinically routine manner. The SOT included six tests conditions (Figure 2). The first three involved the patient standing on a fixed platform with eyes open (SOT 1), eyes closed (SOT 2), and using sway-referenced vision (SOT 3). Changes in platform sway referencing (SOT 4, 5, 6) introduced changes in somatosensory input while alterations in vision were similar to previous three series.

Posturography scores-range from 0 to 100, with 0 representing a fall (protected by harness), and 100 representing perfect stability-were based on the data base established by the initial users' group. In all trials, the position of the subject on the dual forceplate was the same: the medial malleolus of each foot were centered directly over the stripe on the dual forceplate in such a way that the distance between two feet (measured as the distance between the midlines of the two heels) was 0.15 m (or 8.5% of standing height of the subject) which corresponds to the recommended foot placement for balance testing.[20] The experimenter checked the positioning of the subject during all parts of the experiment to make sure that feet position and the sway-referenced stimuli were equivalent for both orthotic and nonorthotic trials.

Results

Figure 3 represents equilibrium scores of the patient measured with a computer dynamic posturography techniques. The scores reflect how much the patient swayed during each trial of the six sensory conditions. The equilibrium scores were calculated by comparing the patient's anterioposterior sway during each trial to a theoretical sway stability limit of 12.5°. In the first test with no orthoses, the subject demonstrated scores over 75 in three trials. However, only 19% of the trials were successful (he fell in 13 of 16 trials), and as a result, the composite score (calculated by averaging the scores for all conditions) reached a value of only 14 (Figure 3a). Because of the harness, there was no danger of falling for the patient even though equilibrium was lost. In contrast, during the second test with bilateral orthoses the patient was more stable: in 73% of trials (11 of 15), the patient showed normal posturography patterns (Figure 3b) resulting in improvement of integral composite score nearly 4 times higher while using orthoses. The composite score for the second test reached the magnitude of 59, which is still below the magnitude established for healthy subjects, but above the magnitude which is considered to be abnormal.

Discussion

The results of the study show that the overall balance test performance of the patient with severely reduced foot sensation could be improved by using AFOS. Both experimental series were performed under the same conditions, except that the subject was wearing AFOS in the second series. The patient had falls performing most of the sensory organization test conditions without orthoses and improved his performance while wearing orthoses.

It appears reasonable that the patient with loss of afferent function could rely on more proximal cues provided by the orthoses. Indeed, it is widely known that stability of posture increased while an ambulatory aid such as a cane, walker, etc. is used.[21] The ambulatory devices, in addition to providing an extended base of support,[22] may furnish somatosensory information to the proximal parts of the body that are still functioning normally.[23]

It has been shown that somatosensory stimulation from contact of the feet with the support surface plays an important role in maintaining upright stance.[24] Also, touch and pressure cues from any part of the body in contact with a stable external surface positively influence apparent body orientation.[25] Even a very slight finger contact with a stable surface attenuates body sway in blind individuals.[26]

In view of these findings, AFOS, in addition to correcting the patient's foot placement during locomotion, could also be expected to improve the maintenance of balance during quiet stance or dynamic perturbation. It is quite possible that mechanical connection of the intact parts of the body to the surface area could help in getting somatosensory feedback necessary for balance control. This is consistent with the finding.[27] that peripheral neuropathy patients improved their unipedal proprioception while using a firm lateral knee pad during a stance test.

Conclusion

This study provides information about the prophylactic effect of wearing AFOS by a patient with severely reduced foot sensation due to diabetic neuropathy. The orthoses were beneficial not only in correcting the patient's gait and providing independence in ambulation, they also changed for better his balance performance: improvement of the overall balance score performance measured with the Computerized Dynamic Posturography test was seen with bilateral orthoses as compared with results of the test with no orthoses.

This single-subject research design supports the efficiency of AFOs in improving standing balance for a patient with diabetic neuropathy but does not provide information for making any statistical statement. Our findings, nevertheless, encourage us to pursue future research to statistically document the effectiveness of using orthoses on balance improvement.

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