Laboratory 2: Static and Dynamic Postural Control

MVS 320 Sec. 003

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**Module 1: Factors impacting static postural control during standing**

*Introduction*

Static posture is described as quiet standing although there is constant input from the central nervous system making micro-adjustments, seen in the constant sway of a person’s stance, to maintain static position. This module explores how two factors: base of support and different sensory feedback affects center of pressure. The contribution of base of support to postural control will be examined by standing on a force plate with both feet, then one foot. Sensory feedback will be manipulated by standing with eyes open and then closed, as well as standing on different surfaces. Taken together, you would expect to see the greatest displacement (sway) in the antero-posterior and medio-lateral directions when base of support is reduced (i.e. standing on one foot vs. two), surface is less stable (i.e. foam vs. hard floor), and sensory feedback is impaired (i.e. eyes are closed).

*Methods*

Have the subject stand as still as possible centered on the force plate. The force plate will detect the center of pressure and its concurrent displacements for eight different scenarios, described later. Three trials, each 20 seconds in duration, will be taken for each scenario that includes manipulation of either sensory feedback information or different standing surfaces. The data will be collected on a computer with AMTI software from a computer attached to the force plate. The scenarios are as follows: both legs, eyes open/eyes closed; one leg, hip flexed to 90 degrees; one leg, eyes closed; both legs on foam surface, eyes open/closed; one leg on foam surface, eyes open/closed.

*Results*



Table 1. Mean and 1 standard deviation (SD) for center of pressure displacement for each of the eight conditions in the antero-posterior and medio-lateral directions.

Figure 1. Millimeters of COP displacement in the antero-posterior direction for the eight given conditions.

Figure 2. Millimeters of COP displacement in the medio-lateral direction for the eight given conditions.

Figures 1 and 2 represent the graphical form of the data presented in Table 1. According to Figure 1 and Figure 2, the condition with the most stable COP was the double stance, eyes open condition (1 mm displacement, 0 SD for AP; .5 displacement, 0 SD for ML). Any condition in which the eyes were closed represented greater COP displacement in both the AP and ML directions (see Figures 1 and 2—conditions grouped according to eyes open or closed). The greatest variability in COP displacement in the AP direction was for the double stance, eyes open on the foam square, as this was the piece of data with the largest standard deviation (2.52 SD). In Figure 2 however, the greatest displacement in the ML direction was for the double stance, eyes closed on the foam square and the single stance, eyes closed conditions. (1.53 SD).

*Discussion*

As the conditions increased in difficulty and parameters (i.e. from double to single stance, eyes open to closed, flat surface to foam surface), the amount of displacement in both the AP and ML directions increased. Given the eight different conditions, it was expected that the most difficult (i.e. greatest COP displacement in AP/ML directions) condition would be the single stance, eyes closed on the foam square (SS-EC-FS). This condition would be expected to be the most difficult because the base of support is narrowed by standing on one leg, the sensory feedback system is impaired because the eyes are closed, and the foam square provides an uneven standing surface that requires continual compensatory micro-adjustments. The most basic condition, the double stance, eyes open, would be expected to produce the least postural sway and thus a small COP displacement. These assumptions are asserted in the data presented in Figures 1 and 2. In Figure 1, the mean COP displacement for the SS-EC-FS is 10 mm in the AP direction, significantly higher than any of the other conditions. Concomitantly, the COP displacement for the same condition for in the ML direction is 6mm, the second highest value.

For all of the intermediate conditions, there was a steadily increasing progression in the amount of displacement as the conditions increased in difficulty (see Figures 1 and 2). Similarly, the millimeters of COP displacement in the AP or ML directions was always greater during conditions in which the subject’s eyes were closed. This result would be expected because sensory feedback, especially from the visual system, is a major determinant in postural control and maintaining balance.

There are several possible sources of error for this module. One such possibility is in quantifying the COP displacement. One person estimated millimeters of displacement for the entire lab; therefore the reported data is heavily dependent on that person’s accurate conception of a millimeter because there was no formal measuring tool, only eyeball estimation. Another possible source of error is that there may have been a small learning curve over the duration of the experiment. For example, many of the conditions had standard deviations less than 1 showing the measured values were true to the average (ex. Figure 1. DS-EO-FS; Figure 2). Furthermore, in Figure 2, the subject actually performed better (lower COP displacement in the ML direction) in the SS-EC-FS than the DS-EC-FS (6mm vs. 6.37mm, respectively).

The data collected here were taken from a physically active, healthy, young adult. If the same tests were performed on a person over the age of 65, you would expect to see greater displacements in both the AP and ML directions. There are a couple of possible explanations for greater sway in older age groups. One possibility is that as a person ages, their posture changes (“slumps” forward), and their center of mass moves forward out of their base of support. This would make for more imbalance and probably more compensatory responses. Compensatory responses involve activating opposing muscle groups to counteract the direction of sway. Older age groups experience gradual muscle weakness and this inability to control postural sway could account for the increased incidence of falls seen among the elderly for activities of daily living (ADLs).

**Module 2: The role of anticipatory postural responses during dynamic postural control**

*Introduction*

This module explores how postural disturbances, anticipated or otherwise, affect static postural control as a function of center of pressure (COP) displacement. If the postural disturbance is a result of some planned or anticipated movement, then one would expect opposite muscles to activate during the movement to maintain balance. Similarly, if balance is disturbed as a result of some outside acting force, muscle activation would be expected that would maintain balance by keeping the body’s center of mass within its base of support.

*Methods*

Anticipatory postural adjustments will be measured by having the subject reach out one arm to grasp an object as quickly as possible three different times. During the movement, the subject’s heels should remain on the floor. Repeat this process with two different weights attached to the subject’s wrist. To measure compensatory postural responses, the subject will stand with eyes closed while a classmate gently pushes them forward without warning. Both of these movements will use EMG recordings to measure muscle activity at the gastrocnemius. An accelerometer will be attached to the acromion process of the scapula and will be used to measure trunk displacement.

*Results*

Figure 3. Timing differences in movement onset and postural response for the weighted and unweighted anticipatory conditions, as well as the compensatory condition over three trials.

Figure 4. Peak EMG muscle activation in gastrocnemius associated with the weighted and unweighted anticipatory response conditions.

In Figure 3, the weighted and unweighted anticipatory responses both had negative differences in timing, while the compensatory had all positive differences in timing. In Figure 4, greater EMG values are recorded for the first two trials of the unweighted condition over the weighted condition. Only in Trial 3 was there a greater peak EMG for the weighted condition than the unweighted condition.

*Discussion*

During a compensatory response, the subject would be responding to some perturbation received from the external environment. In this case, we would expect to see accelerometer activity first (trunk displacement) before an EMG reading (muscle activation). Contrastly, in an anticipatory response, the subject would already have a plan for movement and activate the necessary muscles to complete that movement prior to execution. Therefore, we would expect to see EMG readings (muscle activation) prior to accelerometer readings (trunk displacement).

In Figure 3, the data fit the expected results. The anticipatory conditions (both weighted and unweighted) had negative values for difference in timing. This would be expected because in anticipatory responses-- in this case, the reaching task-- there should be muscle activation prior to trunk movement (an EMG reading before an accelerometer reading). Contrastly, in the compensatory trials, all of the difference in timing values were positive meaning there was trunk movement prior to muscle activation (accelerometer data before EMG).

Figure 4 however, did not contain the expected results. It was expected that greater peak EMG muscle activity would be recorded for the weighted anticipatory response due to the greater load on the arm. However, the results showed that for the first two out of three trials, the unweighted response had higher peak EMG muscle activity than the comparable weighted condition. Only in the third trial did the peak EMG in the weighted condition exceed the peak EMG of the unweighted condition. Possible sources of error for this anomaly in the data may have had to do with the movement itself. Each subject performed the reach task a little differently. For example, the trunk may have moved too much, there may have been too much movement at the ankle or knee joints, or the subject may have made adjustments to the way the movement was performed once the weight was added as an additional compensation.

**Module 3: Clinical methods used to assess postural control**

**Paper: Posture Control in Vestibular Loss Patients | Thomas Mergner, Georg Schweigart, Luminous Fennell, and Christoph Maurer**

*Introduction*

This paper attempts to find the common underlying causes of the balance loss experienced by vestibular loss (VL) patients; specifically in relating the functions of the vestibular system to the observed deficits in VL patients, primarily postural control. Although it is known that the major function of the vestibular system is maintaining balance, it is not known how exactly the vestibular system contributes to posture control. Chronic bilateral loss vestibular patients provide a rare insight into determining the function of the vestibular system as it relates to posture control. The major avenue in which VL patients make up their balance deficits is by gaze stabilization and sensory cues, mainly through the visual system. The researchers identified three main types of sensory cues for VL patients: vision, joint angle proprioception from muscle spindle receptors, and ground reaction forces from the lean angle.

*Methods*

Subjects were 25-41 years old and healthy aside from diagnosed vestibular deficits. The tests took place over several years. Conducted tests were similar to the ones we performed in lab in which subjects stood on a force plate and COP displacement was recorded. Subjects were instructed to keep their eyes closed which led to inevitable falls in the VL patients. In addition to COP displacement, rotation about the ankle, knee, shoulder, trunk, and neck joints were also recorded. Ears were plugged to prevent auditory stimuli, as well.

*Results*

This paper had several small experiments in the context of a larger one and the main points from each are presented here. Firstly, in the conditions in which VL patients had to stand on a compliant surface, the task always resulted in a complete loss of balance and falling. A very specific series of events led to the “inevitable fall sequence.” First, VL subjects typically experienced body sway in the forward AP direction. The subjects would then compensate for this forward sway by pressing the front of the foot down with greater force, but the compliant surface would give way, causing them to sway forward further still. Proprioceptive feedback interpreted the forward foot pressure as a compensatory response for falling backwards so more forward sway was induced to counteract the perceived falling backwards which actually only served to further exacerbate the forward imbalance until the subject fell.

The second major finding was from the experiments involving perturbations to a subject’s stationary balance with the eyes closed. Results indicated that a VL patient experienced an exaggerated movement twice as large in amplitude as a normal person. This larger amplitude was further increased when eyes were closed. Lastly, “stiffer” shoulder-hip coordination was observed when VL patients tried to correct posture after experiencing external perturbations.

*Discussion*

Ultimately, the authors’ hypothesis for this paper was proven to be wrong. They posited that VL patients would be able to make up for vestibular deficits in balance and sensory feedback (from having the eyes closed) by deconstructing the force components from body sway (the normal force from gravity and the active force from the direction of body sway). However, it was found that by far the most important components for maintaining balance were in fact sensory visual feedback and proprioception. This was demonstrated by the inevitable falling that resulted when VL patients had to have their eyes closed under the different conditions and the inability to use proprioceptive feedback to maintain their balance once there was a loss of visual feedback.

However, there are many more interesting things to discuss in just the results that were found that are relatable to our own discussions of balance and proprioception from lecture and lab. For example, when VL patients were placed on an uneven, compliant surface, the complete loss of balance was so total, the authors of the paper described it as “inevitable.” Because of the loss of vestibular function and the information about angular and linear acceleration that the semi-circular canals and otolith organs provide, there is a greater reliance on visual sensory feedback. In the laboratory setting however, because the subjects were required to have the eyes closed, the primary balance information had to come from elsewhere. The clinical scenario was described above. For the same situation, in a healthy adult with eyes closed on a compliant surface, forward body sway may still have resulted in increased downward pressure from the foot. Instead of mistakenly interpreting this front muscle activation as a compensatory response to falling backward and further activating front muscles, proprioceptive feedback would allow a healthy subject to activate opposing muscles in the back of the body to prevent further forward sway at all the necessary joints. Essentially, that the center of mass needs to return within the base of support to ultimately maintain balance.

Furthermore, the VL subjects in the study experienced improved results (less COP displacement) when eyes were opened and they were allowed to fixate on a point. This is in line with our own data from a healthy subject. Although VL patients still had higher overall COP displacement, the improvement still existed between the two conditions. This fact again attests to the powerful role visual feedback provides in maintaining balance and postural control. Interestingly, VL patients experienced “inevitable falling” when the eyes were open, but they were required to fixate on a moving target as opposed to a stationary one. The vestibular system is responsible for the ability to stare at an object and move our eyes to follow an object while still keeping our own balance; thus, the aforementioned result is not surprising. In healthy subjects, the vestibular system would act in the place of the deficits experienced above by VL patients.