Phase plane analysis of stability in turning movement in subjects with functional ankle instability

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INTRODUCTION

Functional ankle instability (FAI), a tendency for the foot to repeatedly sprain or give way, is a late complication in roughly 10 to 30% of acute ankle sprains. Postural control deficits during quiet standing after acute ankle sprain and in those with FAI have been frequently reported. The task of maintaining posture during quiet standing may not place adequate demands on the postural control system to detect deficits stemming from FAI. In addition, Balance Testing is commonly done using force plates and some measure of the center of pressure movement called, postural sway. Several different parameters are used to quantify postural sway, such as mean sway path, area measures, sway area and velocity measures, mean sway velocity. However, it is now obvious that physical systems are dynamic systems. Their activities are inherently nonlinear, and so nonlinear tools are required in order to understand and manage FAI. The dynamic systems approach suggests a different approach that concentrates not on the number of parameters of stability, but on the consistency of motion as a measure of stability. Our purpose deals with a phase plane analysis of COP (center of pressure) trajectory during the turning movement. This turning movement during in the standing position is one movement complicated by “giving way”. Understanding the normal control mechanisms of the turning movement, based on measuring and analyzing variations in the mechanisms of affected ankles, is a prerequisite to evaluating possible treatment outcome.

METHODS

Three subjects with unilateral FAI (mean age 25.5 years) and one control subject with a healthy ankle (age 24 year) consented to participate in this study. FAI was defined as an individual having sustained an inversion ankle sprain. The same ankle also needed to have had a feeling of “giving way”. Mechanical instability was assessed with the Anterior Drawer and Talar Tilt tests by taking at stress radiography. First, the subject stood with weight evenly distributed on the force plate. Then the subject transferred his/her body weight onto the right leg and turned that produced external pelvic perturbation relative to the weight-bearing femur. After returning to the neutral position, the subject transferred his/her weight onto the left leg and turned again. This was repeated 2 times, with each series of movements being 40 seconds in length.

Phase plane analysis of COP was performed to assess postural stability during the turning movement. Plotting the COP state variables, in this case displacement and velocity, in the medio-lateral (M/L) and anterior-posterior (A/P) direction is an informative tool for quantifying balance control. In addition, plotting the vertical floor reaction force (Fz) variables, in this case the Fz value and 1-time differentiation value, is an informative tool for quantifying the body weight transfer onto the supporting leg.

RESULTS AND DISCUSSION

On the phase plane plot in the M/L direction, difference became clear between subjects with FAI and the subject with a healthy ankle. In the subject with a healthy ankle, the trajectory on the phase plane in the M/L direction was divided into two trajectories: an acceleration trajectory in shifting weight, and a limiting cycle/ convergent trajectory above the x-axis on the phase plane for turning movement (Figure 1). These two trajectories were called Phase 1 and 2, respectively, for convenience. In subjects with FAI, two trajectory patterns on the phase plane in the M/L direction were recognized. One pattern did not show a limiting cycle trajectory for the turning movement, but rather the trajectory rapidly converged above the x-axis on the phase plane (Figure 2). The other pattern did not typically converge at one point above the x-axis on the phase plane during turning posture is maintained (Figure 2).

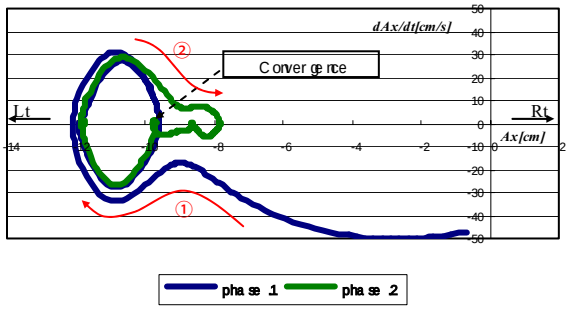

Figure 1: Phase plane in M/L direction of left healthy ankle

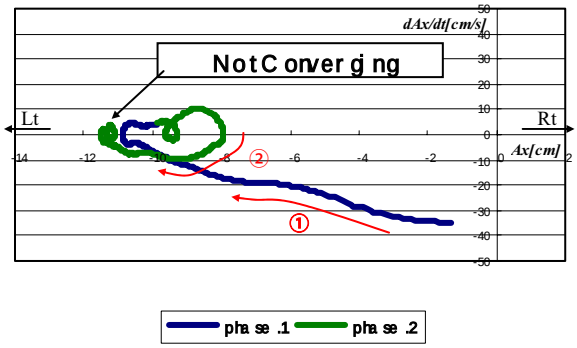

Figure 2: Phase plane in M/L direction of left FIA ankle

CONCLUSIONS

We believe that the quantity and quality of COP during the twisting motion may be connected with a person’s likelihood of “giving way”. Analysis by phase planes in the M/L direction of COP during the twisting motion could potentially be used as a screening tool for people who are at risk for FAI and as an evaluation tool to determine the success of treatments that address the causes of FAI.