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Design, Development and Evaluation of the Basin of Stability Chair

Martin L. Tanaka, Engineering and Technology Dept, Western Carolina University, mtanaka@wcu.edu
Walter D. Fox, Engineering and Technology, Western Carolina University, wdfox2@catamount.wcu.edu

Introduction

In many cases the cause of low back pain is easily identified using radiographic procedures, however, there are also many cases where the cause of low back pain is unknown (idiopathic). Many researchers have suspected spinal instability to be the cause of this idiopathic low back pain and have evaluated torso dynamics using unstable sitting devices [1-3]. They have quantified these movements using kinematic variability and dynamic stability parameters, but to date, no parameter have been found that are able to predict or explain the cause of idiopathic low back pain.

A new approach to evaluate torso dynamics was proposed that considers the relationship between the basin of stability (BoS) and the kinematic variability of the torso [4]. The theory is that a BoS exists that surrounds the vertical torso position and if the kinematic variability remains within this region, no injury will occur. Reduced order mathematical models were used to simulate torso dynamics. Finite time Lyapunov exponents were calculated at each location in state space and from this state space map, Lagrangian Coherent Structures (LCS) were found. These LCS are co-dimension one boundaries that separate the stable region from the unstable region in state space and define the edge of the basin of stability. Although LCS had been found on the mathematical models, no actual human subject testing had been performed due to limitations of the existing devices.

Methods

The current research describes a new device that is able to achieve the large angles needed to detect basin of stability for the human torso. In order to detect LCS, trajectories must be allowed to evolve and diverge over time. Previous devices had a limited range of movement (~±15°), too small for BoS detection. The new BoS chair allows approximately ±45° of movement, sufficiently large for trajectory evolution.

Figure 1. Basin of Stability Chair

Performance of the device was evaluated by measuring the threshold of stability (ToS), the maximum difficulty level that a subject is able to maintain balance. Twelve subjects were recruited and all signed IRB approved informed consent prior to study participation. Subjects balanced in a kneeling position on the chair using small torso movements. After balancing for 60 seconded without falling, the trial was considered "passed" and the difficulty level was increased by moving the restorative springs closer to the central pivot point. The critical spring distance was determined for each subject based on the minimum passing spring distance. Data was normalized by dividing the critical distance by a normalization factor, d_{eq}, which accounted for height and weight of the test subject.

Results

The mean critical distance (Figure 2) for females (4.98") was found to be no different ($p=0.166$) than that of males (5.52"). Equilibrium distance was found to be larger ($p=0.004$) for males (10.064") than females (8.312"). Following normalization, there was no difference in balance capability between genders ($p=0.107$), with mean d_{norm} values for females and males being 0.60 and 0.55, respectively. Normalization proved to be necessary and effective. Prior to normalization the performance parameter d_{crit} was found to be correlated with subject weight ($p=0.002$). However after normalization, correlations with weight ($p=0.370$) or height ($p=0.091$) were removed. During falls, deflection angles exceeding 30° in the anterior direction and 40° in the posterior direction were achieved (Figure 3).

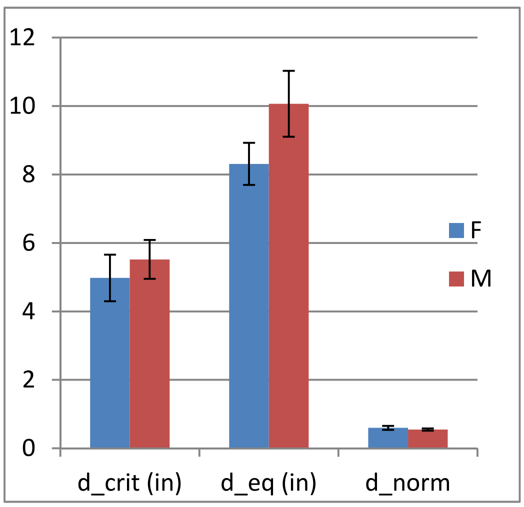

Figure 2. Mean values and gender differences ToS parameters

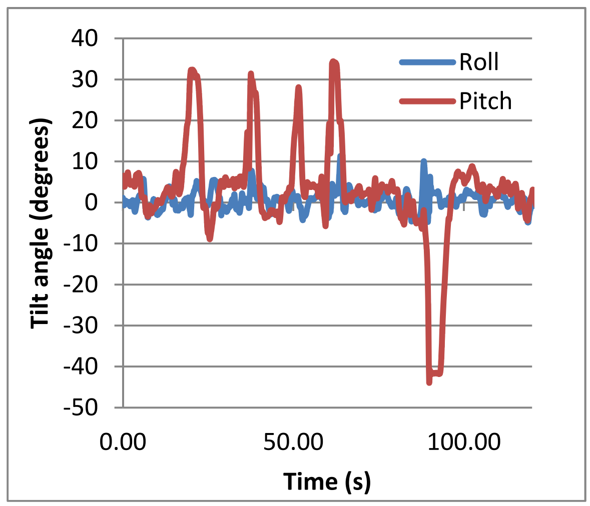

Figure 3. Large deflection angles achieved during testing

Discussion

The BoS chair is as a durable and flexible tool for measuring torso stability. Values of the ToS obtained using the BoS chair were similar to those obtained in previous experiments using the wobble chair [4]. Moreover, the BoS chair was effective at measuring torso stability and achieve angles exceeding 40 degrees showing its potential to detect basin of stability. We intend to use this new device to improve our understanding of torso stability and low back pain.

Acknowledgments

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