Gait & Posture 59 (2018) 117–121

Contents lists available at ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Full length article

Constraints specific influences of vision, touch and surface compliance in postural dynamics

I-Chieh Lee*, Matheus M. Pacheco, Karl M. Newell

Motor Behavior Laboratory, Department of Kinesiology, University of Georgia, USA

ARTICLE INFO

Keywords:
Quiet stance
Correlation dimension
Task constraints

ABSTRACT

Studies that have manipulated vision and touch in posture usually emphasize the prescriptive closed-loop function of the information to reduce the amount of postural motion. In contrast, we examine here the hypothesis that the standard sensory manipulations to maintain quiet stance also change in specific ways the constraints on the task goal and the emergent movement organization. Twelve participants were instructed to maintain quiet postural stance under three sensory factors: surface compliance (foam/no foam), visual information (open/closed eyes) and tactile information (finger touch/no finger touch). The standard deviation of center of pressure (COP) motion decreased with the presence of vision, touch and rigid surface. The correlation dimension showed that the manipulation of touch and vision produced different attractor dynamics that also interacted with surface compliance. Vision decreased the correlation dimension in the foam surface while the touch manipulation increased dimension in the rigid surface. The sensory information manipulations changed the qualitative properties of the attractor dynamics as well as the quantitative properties of the amount of postural motion providing evidence for the specific nature of the postural organization across information conditions.

1. Introduction

There is a common assumption in studies of quiet standing that a general behavioral form is performed in multiple instances of postural control (e.g., with/without vision availability). The expectation is that the observed changes in behavior (usually from COP measures) are caused by changes in the sensory input [1]. For example, in the inverted pendulum model, the system is acting in terms of maintaining the center of mass (COM) above the pivot point with the sensory system detecting COM deviations from this point. Under different conditions, the qualitative behavior would be the same (minimization of postural sway), with the information available to the sensory system scaling the output in each condition [2,3]. There are different views on the sensory-motor linkage (e.g., optimal control [4]; PID control [3]) but this approach can be characterized by the idea that sensory systems are additive (non-interactive) and there is a common qualitative behavior for all tasks.

From this assumption, a large dispersion of postural sway in quiet stance reflects “poor” postural control due to a lack of sufficient information. The dispersion would be, in effect, a proxy of instability [5]. This implies a cause-effect direction in which information drives posture. However, for this to be the case, the system must be acting in terms of the same goal or exhibiting the same qualitative behavior. In many situations, participants are not explicitly instructed to maintain the COP at a given location. The instruction might also be to attend to other aspects of the task while maintaining the quiet stance. In these cases, the postural system is not necessarily acting in terms of maintaining the COP in relation to a reference point [6].

Several studies have shown that, indeed, the behavior could change independently of information availability – by means of instructions (task demands) [6]. These studies argue that postural changes could occur to facilitate achieving a goal. For instance, minimizing postural sway could occur to facilitate a precise level of touching [6] rather than touching providing information to minimize postural sway [7,8]. Postural control would be dependent on the task constraints (cf., [9]). This implies qualitative changes in behavior when specifics of the task are changed – an opposite view to the prevailing assumption of a common postural organization.

From the dynamical systems approach, the movement system gravitates around preferred states where it has maximal stability and minimal energy consumption [10]. These states emerge from the confluence of constraints from the task, individual, and environment [9] and are stable for a range of conditions changing only quantitatively. These states lose stability and ‘allow’ qualitatively different attractor

---

* Corresponding author at: Department of Kinesiology, 339 Ramsey Student Center University of Georgia, 330 River Road Athens, GA, 30602, USA.
E-mail address: il69903@uga.edu (I.-C. Lee).

http://dx.doi.org/10.1016/j.gaitpost.2017.09.014
Received 9 May 2017; Received in revised form 29 August 2017; Accepted 15 September 2017

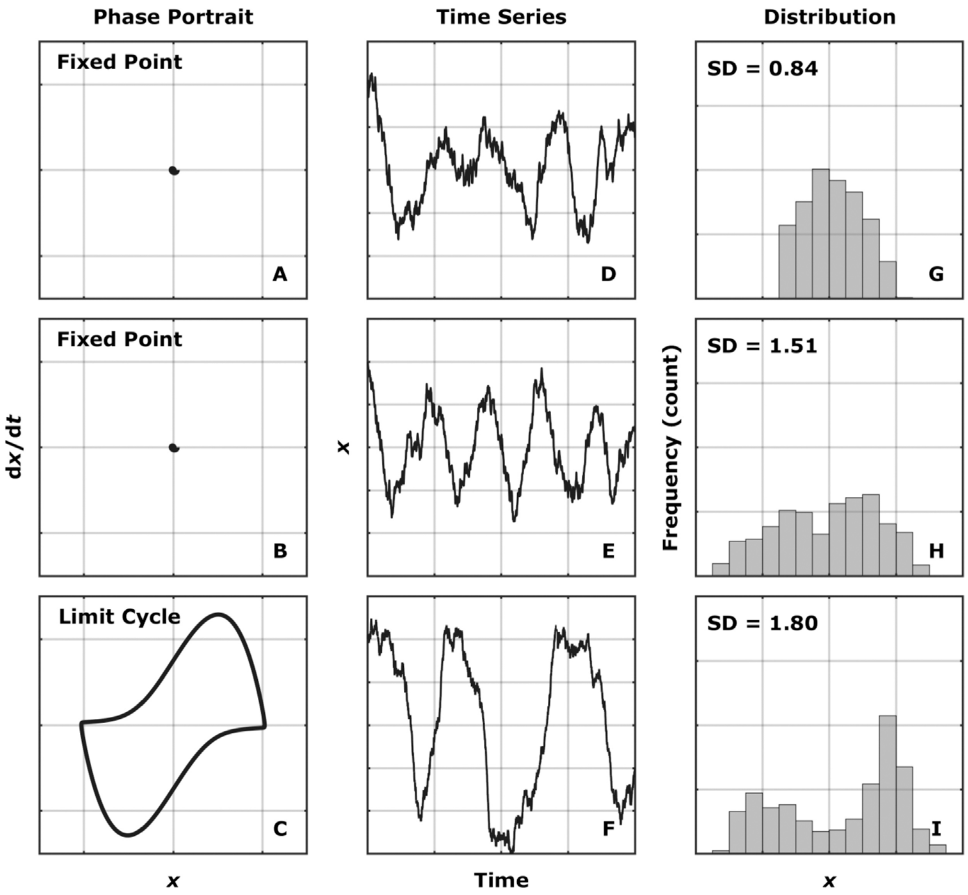

Fig. 1. Schematic of different attractor dynamics. Figures A–C provide the phase portrait (plotting the derivative of a given variable x as a function of its value) of a fixed point (A and B) or a limit cycle attractor (C). Figures D–F provide the time series (perturbed with Gaussian white noise) respective to A–C. Figures G–I provide the histogram respective to D–F. The fixed-point attractors time series were generated using a linear mass-spring model ($\ddot{x} + b\dot{x} + cx = 0$) with different values of b for A and B. A is more stable than B in the sense that its convergence rate is faster. The limit-cycle attractor was generated using a van der pol oscillator ($\ddot{x} - b(1 - x^2)\dot{x} + x = 0$). It is noticed that the standard deviation (SD) increased as the stability of the fixed-point attractor decreased (from A to B). Nevertheless, the standard deviation also increased when the stability was the same but qualitative organization of the attractor changed (from A to C) making it an unreliable measure of stability.

dynamics when critical values are reached (e.g., [11]). The behavior might be qualitatively the same in a certain range of task manipulations within quiet stance if these tasks are similar, but it is also possible that the qualitative behavior of postural control might change.

To investigate the constraint specific influences of sensory input on postural control, a direct measure of the qualitative organization of the system is required. The emerging organization of the body is available in kinematic properties generated by the attractor dynamics. There are distinct attractor dynamics reflecting different qualitative states (stable node, limit cycle, etc.) and these can be measured in terms of dimensionality (see Fig. 1). Indeed, studies have used properties of the attractor dynamics to determine how the system modulates the postural behavior (e.g., Fixed point [12]; Saddle node and Limit cycle [13]) and, in clinical settings, these measures have been shown to differentiate between health and disease states in posture [14].

Two questions arise from this discussion. The first is in terms of the cause-effect relation between posture and task. From the experiments that changed the task instructions, the cause-effect direction cannot be inferred; instructions can influence the pick-up of information as well the task demands, leaving room for both explanations. Even if we assume that qualitative changes occurred when task demands were changed, we are still to understand whether common manipulations in quiet stance reflect quantitative changes in output from information or qualitative changes in behavior provided new task demands. The hypothesis of the present study is that qualitative changes will occur for some manipulations but not for all. The comparison between traditional measures (i.e., standard deviation – SD) and measurement of dynamics can show when a new variation of the paradigm reflects quantitative or qualitative changes in behavior.

We investigated quiet stance under traditional manipulations: availability of vision, tactile information, and surface compliance. These factors have shown individually significant influences on postural sway [1,15,16]. A specific hypothesis for each manipulation would be speculative given the literature has been limited in measurement of attractor dynamics in the quiet standing paradigm. Thus, we maintain our guiding hypothesis that for a range of manipulations, the qualitative organization of the system will be the same, but in some cases, the system will show qualitative change. We expand on this in the Discussion section.

2. Methods

2.1. Participants

Six females and six males (age: 23–35 yrs) participated in this experiment. All participants provided informed written consent, reported having no neuromuscular disorder or injury, and had normal or corrected to normal vision. The Institutional Review Board of the University of Georgia approved all procedures.

2.2. Apparatus

Kinetic data of postural motion were recorded in the anterior-posterior (AP) and mediolateral (ML) directions using a force platform (AMTI, Watertown, MA). The COP time series was calculated based on the ground reaction force and moments in 3 orthogonal directions. Data were recorded at a sampling rate of 50 Hz. A white square sticker with 2 cm length was fixed on a wall at the eye level located 3 m away from the participants. The touched surface was a cloth curtain (61×107 cm^2) that was suspended vertically on a customized tripod located in front of the participant (height: 170 cm). The curtain was not attached to the ground to ensure the participant would not receive the mechanical support for posture, regardless of how the curtain was pushed. Foam on the surface of support was used to make balance more