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Postural sway and perceived comfort in pointing tasks

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HIGHLIGHTS

- We explored relations between postural sway and perceived comfort during pointing postures.
- Different pointing postures had no effect on postural sway.
- Perceived comfort correlated with one of the postural sway components, trembling.
- Postural sway is defined more by perceived comfort than by the actual posture.

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ABSTRACT

In this study, we explored relations between indices of postural sway and perceived comfort during pointing postures performed by standing participants. The participants stood on a force plate, grasped a pointer with the dominant (right) hand, and pointed to targets located at four positions and at two distances from the body. We quantified postural sway over 60-s intervals at each pointing posture, and found no effects of target location or distance on postural sway indices. In contrast, comfort ratings correlated significantly with indices of one of the sway components, trembling. Our observations support the hypothesis that rambling and trembling sway components involve different neurophysiological mechanisms. They also suggest that subjective perception of comfort may be more important than the actual posture for postural sway.

1. Introduction

The mechanical design of the human body allows for multiple ways of performing typical motor tasks. Selections of specific ways from many possible constitutes resolution of the problem of motor redundancy [1]. One hypothesis about the selected solutions is that they tend to maximize subjective comfort for the aspects of the task requiring greatest control, as in ending a task when more precision is required for task completion than for task initiation [2]. Consistent with this hypothesis, when standing humans point at targets in a frontal plane, they show a reproducible pattern of comfort scores across the targets (reviewed in Rosenbaum et al. [3]). We previously hypothesized that postures perceived as uncomfortable would be associated with decreased stability of the hand and body. An earlier study [4] showed that comfort scores were indeed associated with overall changes in joint configuration variance though not with changes in hand stability as reflected in the structure of variance (cf. Latash et al. [5]). In the current study, we explored whether the subjective perception of comfort is associated with varying indices of postural sway across arm postures during pointing at various targets. Our main hypothesis was that postures with lower comfort scores would show higher indices of postural sway and its components.

2. Materials and methods

2.1. Subjects

Twelve young adults (6 males and 6 females, 28 ± 3 years of age, 66.1 ± 13.0 kg of mass, 1.69 ± 0.11 m of height) volunteered

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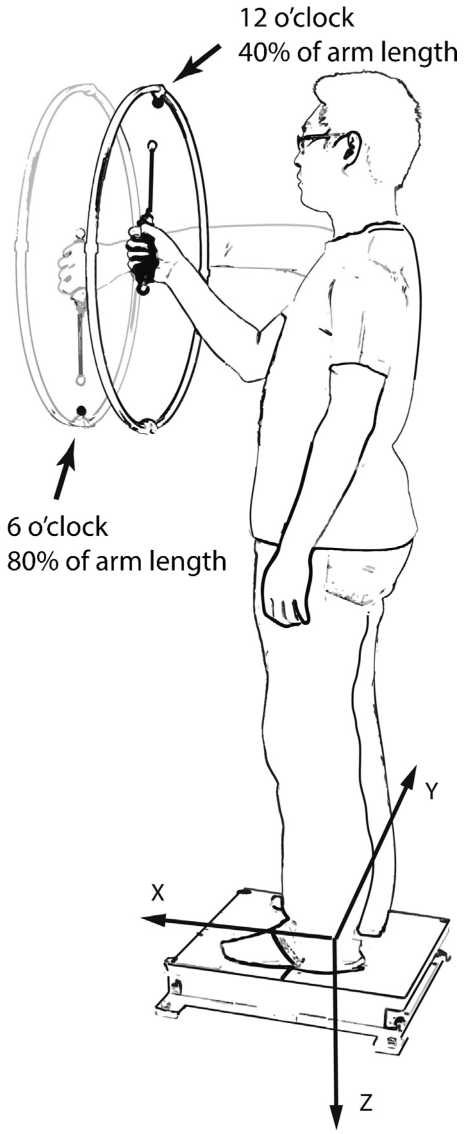

Fig. 1. The experimental setup for the pointing task. Subject stood on the force plate and maintained a pointing posture. The plastic hoop was placed at the two relative distances: 40 and 80% of the participant's arm length. A reflective target marker was placed on the inner surface of the hoop either at 3, 6, 9, and 12 o'clock positions. *X*, *Y*, and *Z*-axes represent force plate coordinate system. Figure shows an example of two pointing postures, with two target positions at two hoop distances.

for the study. All participants were healthy and none reported any vision, hearing or neurological problems. None of the subjects had a recent history of injury or chronic discomfort associated with upper extremity or trunk. All participants reported that they were right-handed. Each subject signed an informed consent form according to Pennsylvania State University policy for biomedical research.

2.2. Experimental setup and procedures

During the experiment, subjects stood on a force plate (46.4 cm × 50.8 cm, model OR6-7-1000, Advanced Mechanical Technology, Inc., MA, USA) with eyes open or closed and feet at a self-determined comfortable width. The chosen position of the feet was marked on the force plate and was kept unchanged for all trials. A plastic hoop (diameter = 0.65 m) was placed parallel to the subject's frontal plane (Fig. 1). The hoop's center was aligned with the subject's vertical midline and adjusted to the subject's shoulder height. The hoop was placed at two relative distances from the subject: 40% and 80% of the subject's arm length. Arm length was measured from the tip of the longest finger to the anterior boundary of the armpit. During the experiment, subjects held a pointer with a power grip. The pointer was a rubber handle with a wooden rod attached to it (total length = 0.29 m, diameter of the handle = 0.03 m, total mass = 0.18 kg). Participants were asked to hold the pointer firmly, but to avoid fatigue, without excessive force.

A spherical marker, representing the target, was placed in the inner surface of the hoop at four different positions: 3, 6, 9 or 12 o'clock. The orders of target placement and relative distance were randomized between subjects. Before the experiment, participants were asked to maintain different pointing postures by first moving the right hand into the middle of the hoop and then by pointing at targets with the tip of the pointer while keeping the hand in the center of the hoop. Next, participants rated the perceived comfort of each of these postures, on a scale of 1–5, with 1 being "least comfortable" and 5 being "most comfortable." Participants were informed the first time they gave comfort ratings that the aim was to familiarize them with the range of comfort ratings they could use. They were encouraged to use the entire comfort-rating range and then to do the tasks one more time, assigning ratings afresh, without feeling compelled to give the same ratings again, to the extent they remembered those ratings for the individual tasks. Because it was important for participants to generate ratings afresh, and because we did not want to our participants to get fatigued, we used just two trials per task. This general procedure for collecting comfort ratings has led to remarkably orderly data patterns in many previous studies, as reviewed by Rosenbaum et al. [3].

Trials started with participants standing up, while their arms hung naturally by their sides. On a signal from the experimenter, subjects moved the dominant hand into the middle of the hoop, pointed at the target with the tip of the pointer and maintained this pointing posture for the duration of 60 s. It was during this time that force plate data were collected. For the eyes-closed condition, subjects were asked to close their eyes after reaching the pointing posture. After 60 s, while still maintaining the pointing posture, participants were asked to open their eyes and for the second time to rate the perceived comfort of that posture. We quantified sway under the closed-eyes condition for two reasons. First, if the subjects had their eyes open, the change in the visual field by itself could affect sway. Second, standing with one's eyes closed leads to larger sway, which may be expected to have more room for comfort-related effects. During the second round of ratings, participants were told not to feel constrained to give the same ratings. Only data from this second round of ratings were analyzed. Immediately after participants rated the pointing posture, the experimenter asked them to return to the initial position. Approximately two minutes of rest were given between trials during which the experimenter changed the location of the target marker. This procedure was repeated sixteen times, once for each of the eight target locations (3, 6, 9 or 12 o'clock at 40% and 80% of arm length) in the eyes-open or eyes-closed conditions. Trials were presented in blocks such that the participant pointed to all four target-marker positions (in random order) at either 40% or 80% arm-length and then again at the other distance. Half of the participants started with the 40% distance. The other half started with the 80% distance. Subjects did not report any signs of fatigue during the experiment.

2.3. Force data analysis

The force plate coordinate system was defined with the *x*-axis pointing forward, along the anterior-posterior (AP) direction, the *y*-axis pointing to the right, along the medio-lateral (ML) direction, and the *z*-axis pointing downwards. The origin of the coordinate system was located at distance d_z = 4.13 cm below the top surface