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Evaluating the effect of four different pointing device designs on upper extremity posture and muscle activity during mousing tasks

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ABSTRACT

The goal of this study was to evaluate the effect of different types of computer pointing devices and placements on posture and muscle activity of the hand and arm. A repeated measures laboratory study with 12 adults (6 females, 6 males) was conducted. Participants completed two mouse-intensive tasks while using a conventional mouse, a trackball, a stand-alone touchpad, and a rollermouse. A motion analysis system and an electromyography system monitored right upper extremity postures and muscle activity, respectively. The rollermouse condition was associated with a more neutral hand posture (lower inter-fingertip spread and greater finger flexion) along with significantly lower forearm extensor muscle activity. The touchpad and rollermouse, which were centrally located, were associated with significantly more neutral shoulder postures, reduced ulnar deviation, and lower forearm extensor muscle activities than other types of pointing devices. Users reported the most difficulty using the trackball and touchpad. Rollermouse was not more difficult to use than any other devices. These results show that computer pointing device design and location elicit significantly different postures and forearm muscle activities during use, especially for the hand posture metrics.

1. Introduction

As computer usage increases both at home and in the workplace, the incidence of musculoskeletal disorders (MSDs) associated with computer usage has also risen (Cook et al., 2000). Many attribute these increases to a rise in hours mouse use, as the association between MSDs (specifically of the hand, arm, and shoulder) and mouse usage is stronger than the association between hours of keyboard activity and MSD outcomes (Gerr et al., 2004; Ijmker et al., 2007). The specific design and placement of pointing devices, such as a mouse, has been evaluated to determine the effects on upper limb posture and muscle activity (Burgess-Limerick et al., 1999; Dennerlein et al., 2006; Jensen et al., 1998). Specifically, prolonged mouse use is associated with ergonomic risk factors including sustained muscle load and non-neutral postures related to extreme ulnar deviation, wrist extension and forearm pronation (Burgess-Limerick, 1999; Jensen, 1998; Karlqvist et al., 1998; Sjøgaard and Søgaard, 1998).

Most of the previous studies have focused on wrist and shoulder postures, along with forearm and shoulder muscle activities. For instance, several studies have shown that placement of the mouse closer to the center line of the operator reduces non-neutral shoulder and wrist postures as well as reducing muscle activity of both the forearm and the shoulder (Sommerich et al., 2002; Dennerlein, 2006; Kumar and Kumar, 2008, Harvey, 1997). Other studies have shown that the design of the pointing device has little effect on neck and shoulder posture and muscle activity; however, they do have an effect on forearm muscle activity (Lee, 2005, 2008). Despite all of this work, few studies have investigated hand postures. Those that did investigated hand postures related only to the button design and placement (Lee et al., 2007) or the size of notebook mice (Oude Hengel et al., 2008). Overall, very little has been done to explore the effects of different pointing devices on hand or finger posture to provide a better link between the design of the device and effects on forearm muscle activity.

Therefore, the goal of this study was to investigate the consequences of using four different computer pointing devices during typical computer tasks on the postures of the shoulder, wrist, and hand, as well as the muscle activity of the forearm and user perceptions of the devices. In a repeated measures experiment

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conducted in a laboratory environment, we evaluated four distinct device designs (a conventional mouse and three alternative pointing devices: a trackball mouse, a touchpad, and a rollermouse) placed on the work surface according to the users standard practices. We hypothesized that users would experience more non-neutral shoulder, wrist and finger postures, along with sustained forearm muscle load with some of the devices compared to the others.

2. Methods

Twelve right-handed adult participants (6 females, 6 males) with no history of neck or upper extremity musculoskeletal disorders volunteered and provided written informed consent for this repeated measure laboratory study. The mean anthropometric measures for the participants were typical of the average United States population (Table 1). Harvard School of Public Health Office of Regulatory Affairs and Research Compliance approved all protocols and informed consent forms. All participants completed the full study protocol using all four computer pointing devices to complete the two designed computer tasks, while having their posture and muscle activity recorded real time continuously.

2.1. Independent variables: pointing device conditions

Each participant completed a series of standardized mousing tasks four times, each with a different pointing device: a generic mouse (Lenovo 06P4069 Black 3-Button Wired Optical Mouse), a trackball (Logictech TrackMan Marble), a standalone touchpad device (ADESSO Smart Cat 4-Button Touchpad), and a roller-style device (Contour Rollermouse Free 2). All devices were set to the same pointer speed at 6 of the 11- point scale in Microsoft Windows XP® with the acceleration function disabled. The setting requires a 100 mm lateral mouse movement (or a 100 mm-equivalent of trackball rotation along one axis) to move the cursor across a 520 mm wide computer screen (24” size) based on a 1600x1200 resolution setting. Similarly, such a cursor-moving distance required the users to move their fingers laterally for 100 mm on the touchpad or rotate the roller bar on the roller mouse for an arc length of 100 mm. During the experiment, the mouse and the trackball were placed to the right side of the keyboard; whereas, the touchpad and the rollermouse were placed in between the participant and the keyboard, at the center of the table which are the conventional placement of these devices (Fig. 1). For all conditions, the participants sat at the same workstation, which consisted of a chair with arm rests, a monitor, and a generic keyboard with no number keypad. The height of the chair was adjusted such that the participant's feet could remain on the floor and the thighs would be parallel with the floor throughout the experiment. The height of the desk was set such that the j-h key of the keyboard was at resting elbow height. The height of the monitor was customized for each participant such that the upper edge of the screen display was at each participant's eye level. For each subject, the location of the monitor and the keyboard were kept constant for all conditions.

Table 1
Anthropometric measures of means (standard deviations) across all participants.

	Males ($N = 6$)	Females ($N = 6$)	All
Age (yrs)	30.5 (8.5)	24.7 (1.5)	27.6 (6.6)
Height (cm)	173.2 (6.6)	166.7 (1.3)	169.9 (5.7)
Weight (kg)	68.8 (11.3)	60.0 (4.1)	64.4 (9.4)
Hand length (cm)	18.1 (0.6)	17.5 (0.9)	17.8 (0.8)
Hand breadth (cm)	9.1 (0.49)	8.5 (0.6)	8.8 (0.6)
Thumb CMC to tip (cm)	6.3 (0.6)	6.3 (0.4)	6.3 (0.5)

2.2. Independent variables: tasks

Participants completed two distinctive computer tasks with each of the four devices. The first task involved 3 min of playing Solitaire and the second involved 5 min of web browsing, which required reading and answering specific reading comprehension questions. Playing solitaire, which requires point-and-click and point-and-drag tasks in various areas of the computer screen, familiarized participants with cursor operations using different devices. The customized web browsing tasks involved both cursor operations (cursor movement, point-and click and click-and-drag) along with intermittent keyboard operations (typing) to simulate office work that requires interactions with both the keyboard and the designated pointing device. The web browsing task required approximately 90% mousing and 10% typing operation. The order of different pointing device conditions presented to participants was counter-balanced, with a 2-min break provided between tasks.

2.3. Dependent variables: posture

An optical three-dimensional motion analysis system (Optotrak Certus, Northern Digital, Ontario, Canada) recorded hand and upper limb posture. Infrared light-emitting diodes (IRLEDs) were mounted on each fingertip and proximal interphalangeal joint (PIP) of the participant's right hand. A rigid body cluster consisting of three IRLEDs attached to a metal structure was attached to the back (dorsal) side of the hand over the 3rd metacarpal bone between the wrist and knuckle. Three additional rigid bodies were attached to the forearm, upper arm, and chest. Locations of bony landmarks (right and left acromion, sternal notch, lateral and medial epicondyle of the right elbow, radial and ulnar styloid of the right wrist, metacarpophalangeal joints for digits II-IV of the right hand) were palpated, digitized and tracked according to their corresponding body segment IRLED cluster. Location data for each IRLED and digitized point were subsequently filtered through a low-pass, fourth-order Butterworth filter with a 10 Hz cutoff frequency and used to define local coordinate systems for each segment (Asundi et al., 2010, 2012; Winter, 2005).

Using the anatomical position and the vertical as reference, joint angles for the shoulder and wrist were defined by the rotation matrices describing the orientation of the distal segment relative to the proximal segment. Specifically, from the local coordinate systems, rotation matrices were calculated to obtain the upper arm orientation relative to the torso (shoulder), the forearm relative to the upper arm (the elbow), and the hand/wrist orientation relative to the forearm (the wrist). With these local rotation matrices, Euler angles for all body segments of interest were calculated to describe flexion, extension, abduction, adduction, and rotation (internal or external) of the right shoulder, elbow, and wrist (Asundi et al., 2010, 2012; Winter, 2005).

The results present these calculated joint angles relative to a reference posture similar to the 90-90-90 recommended postures for computer users (OSHA, 2003). For shoulder flexion/extension and ab-adduction the reference posture was with the torso vertical with the upper arms vertical next to the torso. For shoulder internal and external rotation, the reference posture is with the upper arm vertical, the elbow flexed 90° such that the forearm is horizontal and is perpendicular to the coronal plane. For the elbow the reference posture is with the upper arm vertical the elbow is flexed such that it is horizontal. For the wrist flexion/extension and ab-adduction the reference posture is with the same as the anatomical position with the 3rd metal carpal aligned with the long axis of the forearm. For supination and pronation the reference posture is with the upper arm vertical, the elbow flexed at 90°, the hand is fully pronated such that the palms are flat on the table.