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Utilizing anthropometric data to improve the usability of desk bikes, and influence of desk bikes on reading and typing performance

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ABSTRACT

This study investigated the feasibility of using a desk bike in an office setting. Workstation measurements were introduced to accommodate 95% of the general U.S. population in using desk bikes. Reading and typing performances were compared at three different cycling conditions (no cycling, 10 and 25 W). Thirty healthy individuals (15 female and 15 male; Age mean: 23.1, σ: 4.19) were recruited based on 5/50/95th percentile stature. Participants were required to select preferred workstation settings and perform reading and typing tasks while pedaling. According to anthropometric measurements and variability from user preference, recommended adjustable ranges of workstation settings for the general U.S. population were derived. Repeated measures ANOVA showed that pedaling had no significant effect on reading comprehension ($p > 0.05$), but had significant effect on typing performance ($p < 0.001$). A preferred level of cycling intensity was determined (mean 17.3 W, σ: 3.69).

1. Introduction

Excess body weight is considered a risk factor for mortality and morbidity from diabetes, heart diseases and cancer (Flegal et al., 2013; Wang et al., 2011). Despite the substantial efforts from healthcare practitioners, the weight-gain epidemic continues to accelerate (Finkelstein et al., 2012; World Health Organization, 2000). Studies have shown that one of the largest contributors to the weight gain epidemic has been the trend for work environments to require less physical activity in industrialized populations (Hamilton et al., 2007).

As most working environments in developed and developing countries now require prolonged seated postures, physical inactivity has become more common in adults (Ma et al., 2009). Tudor-Locke et al. (2011) reported that workers employed in sedentary occupations (≤1.5 metabolic equivalent) were sedentary for approximately 11 h a day. In addition, more than one third of U.S. adults do not meet recommended physical activity guidelines (Hallal et al., 2012). Healthcare researchers have been emphasizing the importance of physical activity and suggest that even low intensity exercise may have beneficial health outcomes (Neuhaus et al., 2014; Tudor-Locke et al., 2014).

Despite the known health benefits of regular exercise, in terms of practicality, it is difficult for most adults to invest additional time in exercise. Researchers have also found that regardless of physical activity, prolonged sedentary behavior can be independently associated with poor health and mortality (Parry and Straker, 2013; Biswas et al., 2015). Therefore, introducing health promotion interventions to the workplace can be ideal in reducing prolonged sitting time (Carnethon et al., 2009; Van Uffelen et al., 2010).

Recent experimental studies have found that replacing excessive sedentary behavior with light physical activity may be beneficial to one's health (Levine and Miller, 2007; Dunstan et al., 2012). Carr et al. (2013) tested the practicality and feasibility of a portable pedaling exercise on middle-aged female participants working in sedentary environments. Results indicated that approximately an hour of daily sedentary time was replaced with pedaling at a moderate speed. Similarly, Rovniak et al. (2014) found that compact pedaling devices could help expend approximately 90 extra kilocalories per hour above sedentary sitting.

Although studies have been conducted to investigate the effects of simultaneous pedaling on work productivity (Elmer and Martin, 2014; Torbeyns et al., 2015), research on the ergonomic factors that may impede or facilitate use of these pedaling devices is limited. In the design of artifacts interacting with human users, the

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understanding of body dimensions and capabilities of the target population is critical in terms of maximizing fit, safety, and performance (HFES 300 Committee, 2004). Body measures have been used in various product design processes such as workstation designs, bicycle seat designs, and aircraft designs (Das and Sengupta, 1996; Garneau and Parkinson, 2011; Joslin, 2014). The concept of incorporating anthropometric measures should not be an exception for using exercise equipment in the office workplace.

The primary purpose of this study was to evaluate ergonomic factors associated with of using a desk bike in the office workplace by investigating the preferred office workstation settings (e.g., desk height and depth) with respect to anthropometric measurements and user preferences. In the authors' earlier research, the preferred workstation settings were established based on twelve undergraduate students (Cho et al., 2014). The current study is an outgrowth to that by broadening the sample to include the general U.S. adult population and increasing the sample size. Additional goals included: (a) Extending the limited literature on measuring cognitive performance when using a desk bike in the office by testing reading comprehension and typing tasks and (b) Finding the preferred exercise intensity on a desk bike while working on these tasks. The results from this study can be used to help understand the implications for and improve the usability of compact under-the-desk bikes at workstations and eventually improve health, safety and well-being.

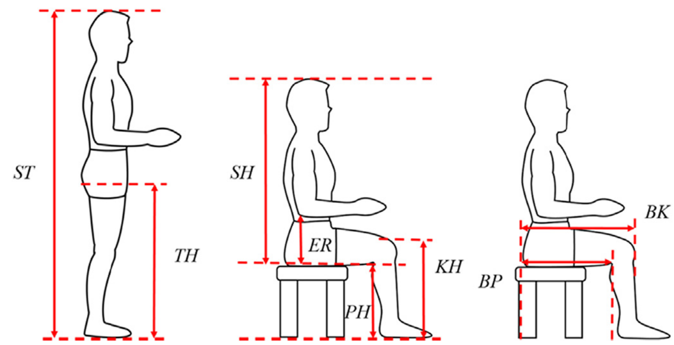

Fig. 1. Representation of the anthropometric measures.

Stature (*ST*): The vertical distance between the floor and the top of the head.
Trochanterion height (*TH*): The vertical distance between the floor and the trochanterion (upper side of the thigh).
Sitting height (*SH*): The vertical distance between the sitting surface and the top of the head.
Elbow rest height (*ER*): The vertical distance from the sitting surface and the olecranon (bottom of the tip of the elbow).
Popliteal height (*PH*): The vertical distance from the footrest and the posterior surface of the knee.
Knee height (*KH*): The vertical distance from the footrest surface and the suprapatella (top of the knee).
Buttock-popliteal (*BP*): The horizontal distance from the posterior point of the buttock to the popliteal fossa (back of the knee).
Buttock-knee (*BK*): The horizontal distance from the posterior point of the buttock and the anterior point of the knee.
Weight (*WT*): Body mass measured to the nearest 0.1 kg on a digital scale.

2. Methods

2.1. Participants

Thirty participants (15 female) were recruited from The Pennsylvania State University and Centre County of Pennsylvania, U.S. All participants were healthy with an average age of 23.1 ($\sigma = 4.19$). Participants were recruited based on 5th, 50th and 95th percentile stature according to NHANES 2007-2010 (each with 5 participants for each gender; Fryar et al., 2012). All participants reported some experience in using a computer mouse and keyboard. The study was approved by the Human Subject Research Institutional Review Board at The Pennsylvania State University. All participants read and signed the informed consent prior to participation in the study and received compensation ($14 for 2 h).

2.2. Anthropometric measurements

The nine anthropometric measurements in this study adopted the standards from the Anthropometric Survey of U.S. Army Personnel (Gordon et al., 1989, Fig. 1).

The measurements were collected using an anthropometer (Model 101, GPM, Switzerland) on the right side of participants (with the exception of *ST* and *WT*). For *ST* and *TH*, participants were standing erect looking straight ahead without shoes. Other measures were taken with participants seated on a horizontal surface, elbows and knees flexed 90° (verified with a goniometer), and feet set parallel to thighs on a height adjustable flat horizontal surface (footrest) in a relaxed and upright posture. The weight factor was evaluated by calculating the Body Mass Index (*BMI*) based on *ST* and *WT*.

2.3. Experimental setup

An office workstation with a standard computer (Windows 7) and a 24 inch monitor (16:9 ratio and resolution of 1920 × 1080 at 60 Hz) was set up in a controlled lab (54.1 m^3; 3.6 × 4.7 × 3.2 m) with the temperature set to 23.3 °C (Fig. 2). The simulated workstation consisted of an office chair (Aeron Chair, Herman Miller, Zeeland, MI, USA) and a customized workstation desk (two adjustable industrial workstations connected with a flat plywood table top; 2.2 × 125 × 70 cm).

The desk bike DeskCycle (3D Innovations LLC., Greeley, CO, USA; Fig. 3) was used in this study and was set to the intensity level of 2. Participants were required to pedal at 10 and 25 W, which is approximately 45 and 90 RPM, respectively.

Participants were able to adjust the seat height pneumatically, while the desk height and depth were adjusted by the facilitators according to participants' request. Fig. 4 shows the dimensions of the workstation that were measured.

2.4. Reading comprehension and typing task outcomes

Reading accuracy and times were measured through reading comprehension problems. Participants were required to read a passage (approximately 280 words) and answer five multiple-choice questions (each with four choices) on the computer. Eight passages were prepared with all written at the average U.S. adult reading level (Kirsch, 1993).

Typing speed (adjusted words-per-minute; AWPM) was measured using TypingMaster Pro Lite (TypingMaster Inc., Helsinki, Finland). Participants were required to copy a passage presented on the screen for 2 min as quickly and as accurately as possible. To ensure that the difficulty is consistent across the typing passages, eight passages with a syllabic intensity of approximately 1.3 was prepared (Straker et al., 2009).

2.5. Subjective ratings

The intensity of cycling condition was evaluated subjectively with the Borg Rating of Perceived Exertion (Borg RPE; Borg, 1982). Two additional questions were asked at the end of the study to assess the desk bike: