Full length article

Computer interactions during walking workstation use moderately affects spatial-temporal gait characteristics

Jeffrey D. Eggleston[a,*], Emily A. Chavez[a], John R. Harry[b], Janet S. Dufek[c]

[a] Department of Kinesiology, University of Texas at El Paso, El Paso, TX, United States
[b] Department of Kinesiology and Sport Management, Texas Tech University, Lubbock, TX, United States
[c] Department of Kinesiology and Nutrition Sciences, University of Nevada, Las Vegas, NV, United States

A B S T R A C T

Background: Due to increased sedentary workstyles, active workstations have shown the ability to increase activity while only moderately affecting work ability. However, previous examinations have not examine fine motor mousing tasks on tripping descriptors.
Research Question: What affect do mousing tasks of varying target size have on tripping descriptors during walking workstation use?
Methods: Three-dimensional kinematic data were collected while participants used a walking workstation completing one baseline and three mousing conditions of varying target sizes.
Results: Target size main effects ($p < 0.001$) detected decreased stride length in all experimental conditions, which were supported by moderate effect sizes, and decreased stance width and time in double limb support ($p < 0.001$ for both comparisons). Stance width differences resulted in large effect sizes between baseline and all conditions, while only moderate effect sizes were observed between time in double limb support in baseline compared to all conditions. No changes in knee flexion range of motion were observed in response to target size ($p = 0.278$).
Significance: These results indicate that walking workstation users shorten their stride length and decrease their base of support while completing mousing tasks. The placement of the upper extremities on the workstation desk likely acted as the primary mechanism to increase stability. It is concluded that performing mousing tasks of varying target size using a walking workstation does not pose greater risk for adverse gait events.

1. Introduction

Recently, there has been an increase in time spent performing sedentary work-related activities [1], leading to increased obesity [1] and mortality rates and greater risks for developing diabetes and cardiovascular disease [2]. These health consequences are due to low levels of physical activity that result from prolonged bouts of sitting [3], also contributing to the development of musculoskeletal discomfort [4]. To combat cardio-metabolic and musculoskeletal health consequences, attempts have been made to replace sedentary workstations with active alternatives [5] by placing desks in sit-stand [6] or low-intensity exercise environments. Many types of active workstations have been presented, with the most common styles incorporating a treadmill [7–9], elliptical [10], or cycle ergometer [11,12]. Use of treadmill-, elliptical-, and cycle-based workstations have been shown to increase caloric expenditure relative to seated workstations [12]. Walking

workstations (i.e. treadmill workstations) are the most common type of active workstation [13,14]. While much attention has been given to how individuals perform normal work-related activities such as typing and mousing tasks, there is little empirical evidence how combined walking-working actions impact walking mechanics [8,9,15].

Because of dual-task demands performed during walking workstation use, a growing concern among researchers is the potential occurrence of an acute adverse gait event [9] (e.g., tripping, falling, etc.) due to the dual-task environment that creates a division of focus for the user [16]. Furthermore, significant workstation-related changes in walking mechanics have been observed, such as in stride width, vertical ground reaction force and minimum toe clearance [15], and trunk angular position during simple and complex cognitive tasks [9]. Sagittal plane knee flexion range of motion has been described as a primary characterization of individuals at higher risk for tripping in obstacle-free walking [17]. Knee joint angular positioning, in addition to hip and

ankle angular positioning, can be altered during completion of relatively simple tasks during walking workstation use before returning to near-normal mechanics after an accommodation period [8]. However, knee flexion range of motion, has yet to be examined when using a walking workstation to perform adequate representations of work-related tasks that can vary in difficulty.

Attentional division is not only a concern for potential trips or falls, as it may have a direct negative effect on work performance accuracy [16,18]. Although it was observed that walking workstation use had little effect on simple and complex work-related tasks [9], the tasks examined have ranged from pencil and paper tests [16] to mathematical reasoning and reading comprehension assessments [15] and a variety of cognitive and task complexities [9]. Relative to more skilled performances during walking workstation use, previous examinations [19] have noted decreased typing performance in comparison to sitting. Additional studies have concluded that activities requiring fine motor skill [19] were not performed as well when using a walking workstation [16]. Nonetheless, little is known with respect to whether walking mechanics are affected by mousing tasks during walking workstation use, especially given the potential for attentional division from the increased difficulty of fine motor movement.

The lack of empirical testing on work-related tasks of varying level of difficulty during walking workstation use have exposed an important gap in the literature. As such, the purpose of this study was to examine spatial-temporal walking mechanics and tripping descriptors [17] during mousing tasks with varying target sizes (i.e., varying difficulty) during walking workstation use. It was hypothesized that the mousing tasks would invoke significant alterations in walking mechanics relative to baseline due to the nature of dual-task interference. Previously, it was observed that performing dual-tasks during walking have caused reductions in speed and stride length [20]. Additionally, it was hypothesized that the smallest target sizes would elicit the greatest change in walking mechanics and tripping descriptors, indicating a greater risk for an adverse gait event during walking workstation use.

2. Methods

2.1. Participants

An *a priori* power analysis (G*Power v3.1, Dusseldorf, Germany) was performed with stride width data from Grindle et al. [15] to determine the appropriate sample size. Based on a proposed effect size of 0.466, power of 0.90, alpha (α) of 0.05, and correlation between groups of 0.7, it was determined that a total sample of 41 participants was required for sufficient statistical power. 44 healthy young adults (21 men, 23 women; 24.14 ± 6.38 years of age; 1.67 ± 0.10 m; 71.92 ± 14.08 kg) were recruited for participation. Participants were at least 18 years of age, able to functionally ambulate on a treadmill without assistance, and free from previous injuries within the past six months that resulted in altered walking abilities. Prior to completing any laboratory activities, a detailed description of the study was provided to the participants, and written informed consent was obtained on institutionally approved documentation (IRB protocol number: 1309898-1) in accordance with the Declaration of Helsinki.

2.2. Procedures

Participants completed all laboratory activities during a single experimental session. Demographic and anthropometric data were measured and recorded, then participants changed into spandex clothing. To track segmental motion, spherical 14-mm retroreflective markers were adhered with hypoallergenic tape bilaterally to the following anatomical locations: anterior superior iliac spines, posterior superior iliac spines, iliac crests, medial and lateral femoral condyles, medial and lateral malleoli, and base of the second toes; a single marker was placed on the sacrum. Plastic shells with four non-collinear markers were placed on the lateral, mid-segment aspects of the thighs and legs using elastic wraps. Three non-collinear markers were adhered bilaterally over the heel counter of the shoes. The motions of the reflective markers were tracked using a 10-camera three-dimensional motion capture system (200 Hz; Vicon Motion Systems, Ltd., Oxford, UK) interfaced to a computer running Vicon Nexus software (version 2.7). Following calibration, participants were shown a demonstration of how to operate the walking workstation (i.e. how to adjust desk height and treadmill speed) and complete the mousing tasks. The walking workstation in the current study was a Steelcase FitWork Workstation (Steelcase Inc., Grand Rapids, MI, USA). Experimental testing began once the participants demonstrated a sufficient understanding of the functionality of the walking workstation.

Testing included one baseline and three experimental mousing conditions. In each condition, participants walked on the walking workstation at a speed of 0.894 m*s^{-1}. This speed was equal to the maximum capacity of the workstation, and all participants identified this speed as their preferred speed for each condition. Participants walked for a total of two-minutes, with one-minute of data collected after an initial 30 s, allowing them to achieve a consistent gait pattern prior to data collection. The baseline condition was completed first to ensure that the mousing task conditions did not affect baseline performance. The mousing conditions were then completed in a randomized order. Mousing conditions were categorized by the size of the targets displayed: large targets were 100 pixels in diameter (Fig. 1a), medium size targets were 50 pixels in diameter (Fig. 1b), and small targets were 20 pixels in diameter (Fig. 1c). The mousing conditions were administered from a website, aimbooster.com, where the training task 'precision' game mode was selected. Specifically, targets appeared randomly throughout a 300 by 300-pixel square grid and displayed for
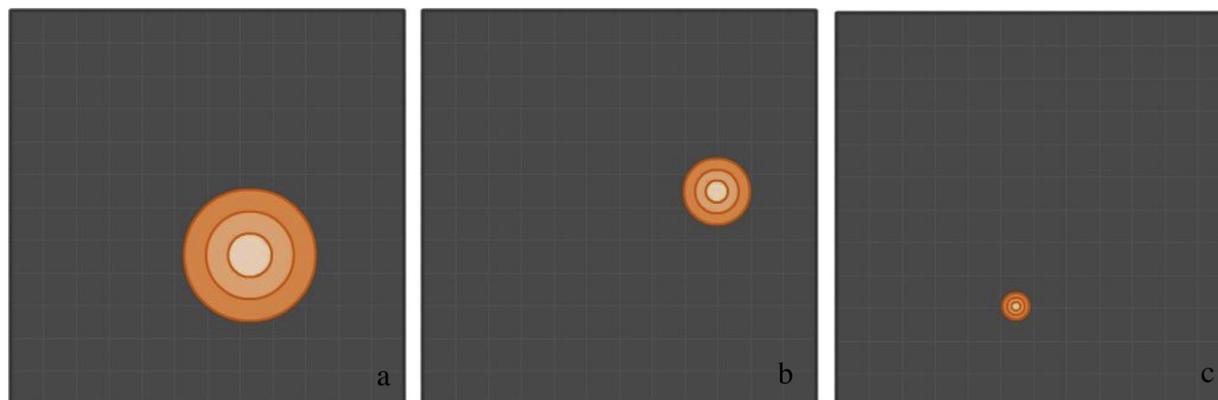

Fig. 1. Relative size of the large (a), medium (b), and small (c) target sizes as they appeared on the 300 × 300 pixel grid. The actual length of the grid on the computer monitor was 14.5 cm.

Fig. 2. Participant utilizing the walking workstation during mousing task.

0.85 s with approximately 141 targets being displayed throughout the entirety of the two-minute trial. During the mousing tasks, participants were instructed to use the computer mouse and click on targets as they appeared on the computer screen as quickly and as accurately as possible. While completing the mousing task, participants were instructed to keep their non-mousing hand on the desk in a comfortable position (Fig. 2). After completing each condition, participants were given a two-minute rest period before beginning the subsequent condition. Although kinematic data were collected only during the middle one-minute of each condition, participants clicked on the targets for the entire two-minute duration.

2.3. Data reduction

Raw data were exported from Vicon Nexus to the Visual3D Biomechanical Software Suite (C-Motion, Inc., Germantown, MD, USA). A seven-segment model was constructed from the marker trajectories to include the pelvis and left and right thigh, leg, and foot segments. Marker trajectories were smoothed with a fourth-order low-pass Butterworth digital filter (6 Hz cutoff frequency). From the smoothed marker trajectories, sagittal plane knee joint angular positions were computed using a Cardan (*X-Y-Z*) rotation sequence where X represents the medial-lateral axis, Y represents the anterior-posterior axis, and Z represents the longitudinal axis. Data were then reduced to strides using a velocity-based algorithm [21]. Variables of interest included: right and left stride lengths, stance width, time in double limb support, and sagittal plane knee range of motion.

2.4. Statistical analysis

Mean and standard deviation values were computed per participant for each variable. From the participant means, group means and standard deviations were calculated. Statistical tests were performed in SPSS Software (v24; IBM Corp ©, Armonk, NY). One-way repeated measures analyses of variance (ANOVA) were conducted to test for significant differences (α = 0.05) among conditions for time spent in double limb support and stance width. When a significant difference

was detected in the omnibus ANOVA test, pairwise comparisons were interpreted after applying the Sidak adjustment. Two (limb; left/right) by four (target size; baseline/large/medium/small) factorial repeated measures ANOVAs were conducted to test for significant differences in stride length and knee range of motion. If a significant interaction was detected, one-way repeated measures ANOVAs with Sidak adjustments were used both unilateral comparisons among tasks, while dependent t-tests were used for between-limb comparisons within each target size. If no significant interaction was detected, limb and target size main effects were interpreted using the Sidak adjustment. Data normality was assessed using the Shapiro-Wilk test. Effect sizes (ES) were computed for each pairwise comparison to supplement the statistical tests and provide the meaningfulness of the mean differences. The ES values were computed as the ratio of the mean difference of the limbs divided by the pooled variance [22]. ES magnitudes were then interpreted with Cohen's scale [23] to determine the meaningfulness of mean differences [9,24].

3. Results

Participants completed on average a total of 92.95 (± 5.41), 94.23 (± 5.11), 94.43 (± 5.49), and 94.48 (± 5.53) strides for the baseline, large, medium, and small target sizes, respectively, collapsed across both limbs. As such, the total number of observations for each statistical test was sufficient. Mean and standard deviation values for stride length, stride width, double limb support, and knee flexion range of motion are displayed in Table 1, while ES magnitudes are displayed in Table 2.

3.1. Stride length

There was not a significant limb by target size interaction (F (3129) = 2.12, p = 0.10, η^2 = 0.05), nor was there a limb main effect (F(143) = 2.13, p = 0.152, η^2 = 0.05), however, there was a significant target size main effect (F(3129) = 10.25, p < 0.001, η^2 = 0.19). As such, pairwise comparisons revealed significant differences, regardless of limb, between baseline and all three experimental conditions (large: p = 0.004; medium: p = 0.001; and small: p = 0.003) with small ES being present among baseline and all experimental conditions, as well. In all other comparisons, ES < 0.2 were observed.

3.2. Stance width

Stance width was significantly affected by target size, F (3129) = 81.24, p < 0.001, η^2 = 0.65, with post-hoc comparisons revealing that significant differences existed between baseline and each of the experimental conditions (p < 0.001 in all comparisons). There was a moderate ES between the baseline and large target sizes, whereas there were large ES observed between the baseline and medium and small target sizes. Further significant differences were observed between the large and medium target sizes (p = 0.025; small ES) and large and small target sizes (p < 0.001; small ES), however, no significant differences were observed between the medium and small target sizes (p = 0.962).

Table 1
Mean and Standard Deviation Values of Kinematic Parameters Among Experimental Conditions.

	Baseline	Large	Medium	Small
Left Strides (m)	1.063 (0.061)	1.046 (0.055)*	1.046 (0.059)*	1.046 (0.060)*
Right Strides (m)	1.063 (0.061)	1.046 (0.054)*	1.046 (0.059)*	1.046 (0.060)*
Stance Width (m)	0.113 (0.023)	0.097 (0.021)*	0.093 (0.022)*^{a}	0.093 (0.022)*^{a}
Left Knee RoM (deg)	64.610 (4.125)	64.061 (4.109)	64.269 (4.320)	63.977 (4.233)
Right Knee RoM (deg)	65.104 (4.125)	64.868 (4.418)	64.761 (4.310)	64.406 (4.165)
Double Limb Support (s)	0.433 (0.032)	0.424 (0.029)	0.423 (0.032)	0.420 (0.30)

Note: * = significant difference (p < 0.05) from baseline; ^{a} = significant differences (p < 0.05) from large target sizes. RoM = range of motion.

Table 2

Effect Size Magnitudes for Post-hoc Mousing Task Target Size Comparisons.

	Baseline vs Large	Baseline vs Medium	Baseline vs Small	Large vs Medium	Large vs Small	Medium vs Small
Left Stride Length	0.29*	0.28*	0.29*	0.01	0.00	0.01
Right Stride Length	0.29*	0.28*	0.29*	0.01	0.00	0.01
Stance Width	0.68[a]	0.83[b]	0.80[b]	0.17	0.21*	0.03
Left Knee RoM	0.13	0.15	0.08	0.05	0.02	0.07
Right Knee RoM	0.06	0.17	0.08	0.02	0.11	0.08
Double Limb Support	0.30*	0.40*	0.29*	0.01	0.12	0.10

Note: * = small effect size (ES $\geq$ 0.2); [a] = moderate effect size (ES < 0.8, ES > 0.2); [b] = large effect size (ES $\geq$ 0.8). RoM = range of motion.

3.3. Double limb support

The results of the repeated measures ANOVA found that time in double limb support was affected by target size, F(3129) = 18.80, $p < 0.001$, $\eta^2 = 0.30$. Post-hoc comparisons revealed a significant difference between baseline and the experimental conditions ($p < 0.001$ in all comparisons) and small ES (in all comparisons). Furthermore, a significant difference was observed between the large and small target sizes ($p = 0.024$), although ES for this comparison resulted in ES < 0.2. Significant differences were not observed between the large and medium target sizes ($p = 1.00$; ES < 0.2) nor between the medium and small target sizes ($p = 0.27$; ES < 0.2).

3.4. Knee flexion range of motion

There was not a significant limb by target size interaction (F (3129) = 1.30, $p = 0.278$, $\eta^2 = 0.03$), nor was there a significant limb or target size main effect (F(143) = 1.20, $p = 0.28$, $\eta^2 = 0.03$, and F (3129) = 2.98, $p = 0.06$, $\eta^2 = 0.07$, respectively). Likewise, ES < 0.2 were revealed in all comparisons.

4. Discussion

The purpose of the current study was to examine spatial-temporal walking mechanics and tripping descriptors during mousing tasks with varying target sizes while using a walking workstation. Previously, it was shown that performing work-related tasks during walking workstation use resulted in acute alterations in gait mechanics [8,9]. Metrics, such as stance width, stride length, among others, were significantly affected when using walking workstations, though the magnitudes of those variables remained within normal ranges [15]. What has lacked from these studies is the inclusion of varying target sizes in mousing tasks, and the effect of the levels on walking mechanics. Although the findings from the current study are not aligned with the previous investigation from Harry et al. [9] in that significant differences were observed in lower extremity kinematics among the conditions, the only main difference in their study was trunk angular position. However, the findings of the current study are more closely aligned with previous studies [8,15] where significant differences were observed in spatial-temporal gait characteristics. While our initial hypothesis that the mousing tasks would elicit changes in walking mechanics relative to baseline was mostly supported by the findings, our secondary hypothesis that the hardest mousing task would bring the greatest change in walking mechanics, was only strongly supported by the stance width data.

The moderate differences observed for stride lengths indicate that stride length may not have a large effect on the user, and might not be severe enough to warrant concern. However, moderate and large changes in stance width were detected among all experimental conditions compared to baseline and between the large and medium and small target sizes, respectively. Thus, smaller targets motivated users to alter stance width to maintain a safer walking environment. Individuals in this sample reduced their stance width rather than widening it, indicating a decrease their base of support and compromised stability and

balance. This may be due to the slow speed of the treadmill being not normal to participants at baseline then, when faced with the mousing tasks, their focus was primarily on the task (i.e. increased cognitive demand) which resulted in more normal stance widths. Similarly, a moderate, though non-significant, decrease in time in double limb support was observed during the experimental conditions relative to baseline. Again, this difference could be partially due to the unnatural speed of the treadmill at baseline, but with a cognitive task walking mechanics were more natural. These results may be influenced by weight bearing compensations due to resting the upper extremity on the desk during the task. Participants might have utilized their upper extremities to increase their balance and diminish the demand placed on the lower extremity to maintain balance. Collectively, as mousing task target size decreased, participants displayed compromised stability and balance as evidenced by a narrower stance width and decreasing the time spent in double limb support. While participants may have increased the risk of experiencing a trip or fall due to compromised balance qualities [25] in the lower extremities, the risk may be mitigated due to the potential use of the upper extremity-desk interaction for the maintenance of balance and stability.

It was previously determined that knee flexion range of motion differentiates trippers from non-trippers in obstacle-free walking, with trippers displaying decreased knee flexion range of motion [17]. However, the current participants did not demonstrate any significant changes in knee flexion range of motion, indicating no change in the risk for tripping. This finding is crucial because it demonstrates that completing mousing tasks on targets of varying sizes does not pose a greater chance of tripping. Given previous conclusions that mousing might cause individuals to have a greater division in focus while using a walking workstation [16], the findings from the current study illustrate that previous conclusions may be accurate since altered lower extremity kinematics were observed. These findings, taken collectively from previous studies [8,9,15,17] exhibit that walking workstations can be used without increased fall or trip risks, and that a small degradation [7] of work performance may be outweighed by the increased metabolic expenditure of users [26].

The main limitation of the current study is the speed of the treadmill of 0.894 m*s^{-1}. Treadmill speed may not have been normal for many participants and may have caused unintentional alterations in their walking mechanics. The authors feel this limitation is minimized as the treadmill speed was constant throughout all participants and all experimental conditions, similar to a control speed used in similar gait analyses during treadmill use [27]. Additionally, the current study did not include movement trajectories of the mousing hand, and thus, no conclusions can be made relative to participants' performance on the clicking task. Furthermore, due to the random appearance location of the targets within the grid, the actual difficulty of the tasks could not be determined. An additional limitation was the use of healthy college-aged sample since many of the individuals may have had prior experience walking and/or running on a treadmill. Nevertheless, the findings still reveal important information that completing mousing tasks of varying target size while using a walking workstation are not likely to invoke an adverse gait events. Furthermore, while the target population for an intervention such as this is sedentary individuals or

individuals who are obese, the authors felt compelled to initially examine this type of intervention on individuals with minimal risks for adverse gait events prior to subjecting individuals with increased risks to the intervention.

In conclusion, this study revealed that completing varying levels of mousing tasks while using a walking workstation significantly affects stride length, stance width, and time in double limb support, relative to baseline. While each of these variables decreased in the experimental conditions, only stance width was classified as a large mean difference. Observing decreases in these variables would indicate a decreased ability to maintain stability during walking. This, however, was likely mitigated by the upper extremities on the desk while walking. The upper extremity could have provided enough support from being on the desk that participants did not feel uncomfortable enough to increase stride length, stance width, or increased time in double limb support. Furthermore, participants in this sample did not display a decrease in knee flexion range of motion, which has been found in individuals with increased risk for tripping. This study, similar to previous studies, illustrates the ability of individuals to utilize a walking workstation while perform their work-related duties and not greatly increasing their risk of tripping or falling during use.

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Declaration of Competing Interest

The authors have no conflicts of interest to disclose.

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