
Metabolic and Energy Cost of Sitting, Standing, and a Novel Sitting/Stepping Protocol in Recreationally Active College Students

CHARLES J. FOUNTAINE‡¹, JOSH JOHANN†², CRAIG SKALKO*¹, and GARY A. LIGUORI‡²

¹Department of Applied Human Sciences, University of Minnesota Duluth, Duluth, Minnesota, ² Department of Health and Human Performance, University of Tennessee at Chattanooga, Chattanooga, TN

*Denotes undergraduate author, †Denotes graduate student author, ‡ Denotes professional author

ABSTRACT

International Journal of Exercise Science 9(2): 223-229, 2016. The purpose of this study was to compare the differences in metabolic and energy cost (MEC) of college students while seated, standing, and during a sitting/stepping protocol. Participants were assessed via indirect calorimetry for 20 min in each of the following conditions: 1) seated in a standard office chair, 2) standing in place, and 3) a sitting/stepping protocol in which participants performed 1 min of stepping in place at 90 bpm, sat for 9 min, then repeated the stepping and sitting sequence once more. Participants completed each of the 3 trials in the aforementioned order, preceded with a 3 min acclimation period in each condition. A significant difference in MEC was observed between the 3 conditions, $p < 0.001$. Pairwise comparisons indicated that the sitting/stepping protocol resulted in significantly greater MEC than the seated and standing conditions ($p < 0.001$). Additionally, the standing protocol resulted in significantly greater MEC than the seated protocol ($p < 0.001$). The significant differences and large effect sizes between conditions indicate that interspersing sedentary bouts with brief activity can substantially increase MEC. Broader application of these findings may provide health promotion professionals with novel strategies to reduce sedentary behavior and improve health.

KEY WORDS: Inactivity physiology, sedentary behavior, energy expenditure, postural changes

INTRODUCTION

The Centers for Disease Control and Prevention reports that less than half (48%) of all adults meet the guideline for cardiorespiratory health as recommended by the 2008 *Physical Activity Guidelines for Americans* (4). Furthermore, additional population surveillance data estimate that the average adult spends 7-10 h/d engaged in sedentary behaviors (12, 17, 23). Recent

systematic reviews and meta-analyses have provided mounting evidence on the association between sedentary behavior and all-cause morbidity and mortality, particularly the incidence of cardiovascular disease, cancer, and type 2 diabetes (3, 20, 23, 26). Especially concerning to health promotion professionals is the emergence of data suggesting the negative health effects of extended periods of sedentary behavior are independently associated with all-cause

mortality, regardless of the amount of physical activity (PA) participation (3, 19).

College students are no exception to the aforementioned lack of PA and prolonged bouts of sedentary behavior. According to the 2014 National College Health Assessment, barely half of all college students, 50.4%, are meeting recommendations for moderate and/or vigorous-intensity aerobic exercise (1). Estimates of sedentary behavior in college students are limited; however, previous studies have indicated college students dedicate 3.3 h/d to educational pursuits and an additional 2-3 h/d spent in screen time leisure-time pursuits, such as television watching, both of which are commonly used as proxy measurements for sedentary behavior (6, 7, 25). Much like working professionals, who spend nearly 75% of their workday seated (8, 18, 24), the typical temporal pattern of a college student who attends class, completes homework, and relaxes via screen-based leisure, suggests college students appear to be at a similarly high risk to the independent constructs of too little exercise and too much sitting.

Strategies to reduce physical inactivity that involve small, yet feasible behavior changes may be of benefit to combat sedentary behavior in college students. Previous studies have investigated interrupting prolonged sitting time with interventions such as hydraulic stepping, movement breaks, postural changes, or treadmill desks, all being met with modest success, but limited practicality (5, 10, 11, 13). One potential avenue to promote a more active lifestyle in college students is to explore interventions that interrupt traditional sedentary postural positions. For example, a

novel investigation of stepping in place during television commercial breaks produced favorable changes in daily steps and energy expenditure (EE) (21, 22). Specific to college students, engaging in a light PA break while studying or watching television could serve to facilitate health benefits with minimal disruption to the learning environment (11). Therefore, the purpose of this study was to compare the differences in metabolic and energy cost (MEC) in college students while studying seated, standing, and during a sitting/stepping protocol.

METHODS

Participants

A convenience sample of recreationally active college students was recruited for this study. Inclusion criteria required physically active participants in good health. Students with any musculoskeletal injuries or other health problems that would inhibit the ability to sit-in-place, stand-in-place, and/or step-in-place were excluded from the study. All participants signed informed consent documents and completed a Physical Activity Readiness-Questionnaire (PAR-Q) before participation. The University of Minnesota's Institutional Review Board approved this study, and all participants completed the study with no injuries reported ($n = 18$, 10 male, 8 female, age 22.3 ± 1.4 y, body mass 74.95 ± 15.52 kg).

Protocol

Participants were assessed for 20 min in each of the following conditions: 1) seated in a standard office chair, 2) standing-in-place, and 3) a sitting/stepping protocol in which participants a) performed 1 min of stepping-in-place (stationary knee-high march via a

metronome set at 90 beats per minute (bpm), b) sat for 9 min, c) then repeated the stepping and sitting sequence once more. Participants completed each of the 3 trials during the same lab visit in the aforementioned order, preceded with a 3 min acclimation period in each condition. Participants were instructed to not drink caffeine, eat, or exercise 2 h prior to the testing session and to wear loose fitting athletic apparel appropriate for light PA. Participants were also instructed to bring homework in terms of books, magazines, or textbooks to read during the seated and standing conditions.

Oxygen consumption (VO_2) was measured breath-by-breath via portable indirect calorimetry (COSMED Fitmate PRO, Rome, Italy) and was subsequently averaged over each 20 min condition. VO_2 was converted into EE (kcal/min and kcal/h), in which 1 L $O_2 = 5$ kcal and METs, in which 1 MET = 3.5 ml $kg^{-1} min^{-1} O_2$ (2).

Statistical Analyses

All data were analyzed using IBM Statistical Package for the Social Sciences (version 21). MEC variables (VO_2 , EE, and METs) were normally distributed, as assessed by Shapiro-Wilk's test. One-way repeated measures ANOVA with Bonferroni post hoc tests were performed to determine the difference in MEC between the 3 conditions. Level of significance was set at $p \leq 0.05$. Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi^2(2) = 12.7$, $p = 0.002$, therefore degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($\epsilon = 0.646$). Partial Eta-Squared (η_p^2) effect sizes were utilized to assess the magnitude of significant ANOVA differences, in which

$\eta_p^2 = 0.01, 0.06$, and 0.14 , represented small, medium, and large effects, respectively (14).

RESULTS

Table 1 shows descriptive statistics (mean \pm SD) for VO_2 , EE, and METs, with ANOVA and post hoc differences for the three conditions. As presented in Table 1, statistically significant differences with large effect sizes were observed between all 3 conditions ($p < 0.001$). Post hoc pairwise comparisons indicated that for all MEC variables, the sitting/stepping protocol resulted in significantly greater MEC than the seated ($p < 0.001$) and standing ($p < 0.001$) conditions. Additionally, the standing protocol resulted in significantly greater MEC than the seated protocol ($p < 0.001$).

DISCUSSION

The purpose of this study was to compare differences in MEC in college students while studying when seated, standing, and during a sitting/stepping protocol. Whereas the change from sitting to standing yielded a modest 9.8% increase in MEC, the sit/step protocol was 34% greater than standing, and subsequently 47.5% greater than sitting. The significant differences and large effect sizes observed between conditions clearly indicate that college students can substantially increase MEC by interrupting sedentary bouts through either passive or active interventions, with the results of this study suggesting that active interventions may be more effective in increasing MEC.

The extrapolation of the results of this study into previous research that has investigated the homework and television viewing habits

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Table 1. Differences in oxygen consumption, energy expenditure, and METs between postural conditions.

	Sitting	Standing	Sit/Step	ANOVA <i>p</i> -value	Effect Size η_p^2
VO ₂ (ml kg ⁻¹ min ⁻¹)	4.52 ± 0.68	4.97 ± 0.75*	6.69 ± 0.84*#	<i>p</i> < 0.001	0.912
EE (kcal/min)	1.69 ± 0.43	1.86 ± 0.45*	2.50 ± 0.57*#	<i>p</i> < 0.001	0.899
EE (kcal/h)	101.69 ± 25.89	111.47 ± 26.94*	149.82 ± 34.28*#	<i>p</i> < 0.001	0.899
METs	1.29 ± 0.19	1.41 ± 0.22*	1.91 ± 0.24*#	<i>p</i> < 0.001	0.912

Post hoc testing: * indicates significant difference from sitting (*p* < 0.001); # indicates significant difference from standing (*p* < 0.001)

of college students yields some intriguing possibilities as per the potential impact of postural changes on physical activity and subsequent MEC. For example, previous research from the authors found college students spend on average, 96 min/d engaged in homework and an additional 60 min/d watching television (7). If we assume that the student was sedentary via sitting (1.0 - 1.5 METs) for the majority of these ~150 min, the results of the present study suggest approximately 254 kcal will be expended (1.69 kcal/min × 150 min). However, if the same individual were to implement either of the protocols investigated in this study, EE would increase to 279 kcal by simply standing (1.80 kcal/min × 150 min), whereas the sit/step protocol would expend 375 kcal (2.42 kcal/min × 150 min) and equally important, an additional 1350 steps over baseline (15 1-min stepping breaks over 150 min at 90 steps/min). Broader applications of our findings to the home, school, or workplace may provide health promotion professionals novel, yet viable interventions to break up long interrupted bouts of sedentary behavior.

Our findings agree with previous research that transitioning from a seated position via standing or stepping in place is a viable method for increasing EE and PA. In a study of healthy adults, Judice et al. investigated

the differences in MEC between sitting, standing, and sit/stand transitions (9). While our study interrupted sitting with 1 min of stepping, Judice et al. instructed participants to stand up from the seated position and return to the seated position in one single action movement every minute for 10 min (9). As observed in our study, significant differences (*p* < 0.001) in MEC were observed between all 3 conditions, as EE from sit to stand increased 5-8%, whereas the metabolic cost of a single sit/stand transition was 35% above sitting (9). Likewise, in a laboratory-based pilot study, researchers attempted to quantify the EE and number of steps participants took during 60 min of television watching (22). In a crossover design, EE was assessed for 60 min in two conditions - television (TV) watching while seated versus TV watching while seated, but stepping in place during each commercial break (22). The EE of the commercial stepping protocol (148 kcal/h) was significantly greater (*p* < 0.001) than the seated condition (81 kcal/h), while accumulating 2111 steps/h, measurements that closely mirror our findings if extrapolated across a 60 min block of time (22). TV commercial stepping was further investigated by Steeves et al. when comparing 90 min of stepping during TV programming to 30 min of continuous walking in overweight and obese adults (21). Over a 6-month trial, the total steps

between stepping in place for 90 min/d during TV commercials (7605 steps/d) was not significantly different than that of 30 minutes/day of walking (7865 steps/d), leading the authors to conclude that PA performed when watching TV can provide an alternative approach to achieving recommended levels of PA during more traditionally planned leisure time pursuits (21). Similarly, McAlpine et al. assessed the effect of utilizing a hydraulic stepping-device to increase EE of office workers (13). Participants' EE was assessed in the following conditions: lying, sitting, standing, walking, and while using an under-desk stepping-device while seated in an office chair. Whereas the seated (77 kcal/h) and standing (86 kcal/h) positions of lean participants yielded similar EE to our study, the stepping device condition at a self-selected stepping rate of ~40 steps/min resulted in an EE of 312 kcal/h, which was 115% greater when compared to the sit/step protocol we utilized (13). Collectively, the results of our study in conjunction with previous investigations of stepping protocols provide further evidence that both intermittent and continuous stepping can interject physical activity and subsequently, increases in energy expenditure over baseline levels.

Limitations of this study include the recruitment of healthy, recreationally active college students; therefore, generalizations of our findings towards less active or non-healthy populations should proceed with caution. Also, although our study sample size was modest, the statistically significant differences coupled with large effect sizes demonstrate high statistical power. Additionally, this study utilized indirect calorimetry via the COSMED Fitmate to

estimate energy expenditure. Whereas previous research has established both the validity and reliability of this device in the measurement of oxygen consumption (15, 16), subsequent energy expenditure measures are derived from the use of previously established metabolic equations (2) and are duly noted as estimations. Finally, this study did not utilize a randomized order of each condition and instead performed the sitting, standing, and stepping conditions sequentially. However, pilot testing and post-hoc analysis of the VO_2 measures indicated the inclusion of the 3 min acclimation period was sufficient to allow the participant to return to resting baseline measurements, thus reducing the likelihood that any condition confounded the next.

In conclusion, the results of this study determined that replacing sedentary behavior with either standing or intermittent bouts of stepping resulted in significant and substantial increases in acute MEC. Future studies may be well served to examine the long-term impact of similar interventions in terms of impact upon body mass, body composition, and similar comorbidities negatively associated with prolonged sedentary behavior. Additionally, future investigations are encouraged to explore the practicality and subsequent compliance of implementing stepping breaks for college students in more ecologically valid free-living environments. Implications of this study may encourage health promotion professionals who work with a variety of populations to consider recommending our sit/step protocol for clientele who seek to counter prolonged bouts of sitting throughout the day.

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