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ARTICLE

Cardiovascular and metabolic responses of active sitting while performing work-related tasks

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ABSTRACT

Stability balls and active-balance sitting chairs have recently emerged as a way to reduce sedentary behaviours in office settings. The purpose of this study was to determine differences in caloric expenditure and heart rate between a standard chair (SC), stability ball (SB) and active balanced sitting chair (ST) while performing work-related tasks. Participants ($n = 20$) performed a 10-minute randomised reading and typing task while sitting on the SC, SB and ST. For both the reading and typing tasks, heart rate (HR), caloric expenditure per minute and metabolic equivalents were all significantly greater (i.e. 6–13%; 19–40%; 18–39%, respectively) while using the ST when compared to the SC and SB. No significant differences were observed between the SB and SC for any of the comparisons. The ST produced a greater HR response and caloric expenditure than the SC or SB, indicating that active balanced sitting may be a feasible way to increase energy expenditure in an office setting.

Practitioner summary: The purpose of this study was to determine differences in cardiovascular and metabolic responses to various forms of office chairs. The key finding was that active sitting on a balance chair significantly increased heart rate and caloric expenditure as compared to a stability ball and standard chair.

Abbreviations: SC: standard chair; SB: stability ball; ST: active balanced chair; HR: heart rate; kcalmin: caloric expenditure per minute; MET: metabolic equivalents

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Introduction

Over the past few decades, a transition to a larger distribution of administrative, office-setting employment has innately led to a more sedentary workforce (Owen et al. 2010). According to the Bureau of Labour Statistics, as of 2015, office and administrative supportive roles account for the largest proportion of total employment. It can be reasonably assumed that many other professions spend a substantial portion of the day inactive, as an estimated 86% of workers in the United States remain seated during the workday (Lowe et al. 2015). This chronic sedentary behaviour has led to a phenomenon referred to as the 'sitting disease' in reference to the negative associations with overall health (Levine 2015). In addition to being a risk factor for obesity, prolonged periods of inactivity are often linked to diabetes mellitus, cardiovascular disease and an increased risk of mortality (Wilmot et al. 2012).

While the positive health benefits of exercise and physical activity have been well documented, the Centre for Disease Control has reported, as of 2017, that nearly half of Americans do not meet aerobic fitness guidelines. Additionally, research has indicated that even those meeting the recommended guidelines may not particularly be at a reduced risk of all cause or cardiovascular mortality if the majority of waking hours are spent sedentary (Matthews et al. 2012). Therefore, along with regular exercise, it is recommended to break up prolonged sitting with intermittent bouts of light intensity activities. For example, walking at a comfortable pace for one minute per half an hour can increase energy expenditure 3 kcal above resting values (Swartz, Squires, and Strath 2011). Additionally, Winkler et al. (2018) found that reductions in sitting at workstations, via standing or stepping, had the potential to improve cardiometabolic risk, glucose and insulin metabolism, lipid profiles, blood pressure and body composition.

In recent years, alterations to workstations have become increasingly popular to combat this sedentary lifestyle, including standing desks, treadmill/cycle desks and active sitting devices (e.g. stability balls).

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Previous studies have shown sit-to-stand desks, which allow for transitions throughout the day, are capable of increasing activity level and energy expenditure (Dutta et al. 2014; Reiff, Marlatt, and Dengel 2012). For example, in middle school children, increases in energy expenditure have been reported as high as 20.4 kcal/h (Reiff, Marlatt, and Dengel 2012); however, among adult populations, these improvements often range from negligible to modest (i.e., 4.1–7.5 kcal/h above traditional office settings; Beers et al. 2008; Burns, Forde, and Dockrell 2017; Mansoubi et al. 2015; Roemmich 2016). Therefore, active workstations, via the use of treadmills and cycles, may vary in terms of effectiveness as a means to increase heart rate and caloric expenditure (Schellewald, Kleinert, and Ellegast 2018).

While most advancements in desk stations have proceeded to allow for the individual to be in a standing position, this is not always feasible. Therefore, active sitting has been proposed as a way to combat inactivity in workplaces or schools via specialised devices (e.g. stability balls and multi-directional balance chairs). This form of sitting allows the user to remain active while seated, particularly in response to maintaining balance and constant postural adjustments. Thus, in work settings, active sitting is typically a more viable option than standing or walking. With the comparison to traditional desk chairs, studies have demonstrated that utilising a stability ball increases caloric expenditure between 4.1–16.5 kcal/h (Beers et al. 2008; Dickin, Surowiec, and Wang 2017). As a result, stability balls have become a popular alternative to desk chairs and commonly viewed as a simple way to increase daily energy expenditure.

Although most of the literature has focussed on stability balls, a variety of products have emerged to specifically promote active sitting. While developers claim that these products increase daily energy expenditure and heart rate, little evidence supports these claims. Of the small portion of available research, even fewer studies observe significant improvements in energy expenditure (Dickin, Surowiec, and Wang 2017; Synnott et al. 2017). Regardless, there is not sufficient proof to make definitive claims regarding the effectiveness of active sitting devices. Therefore, the purpose of this investigation was to determine the metabolic and cardiovascular responses to sitting on a novel active sitting chair compared to a stability ball and a traditional chair.

Materials and methods

Participants

A convenience sample of five men and 15 women from the Department of Health Sciences and Kinesiology were recruited via word of mouth and email to participate in this study. All participant descriptive are reported in Table 1. The sample size utilised in this investigation was of a sufficient *n* and an *a priori* power analysis was performed using G* Power software (G Power, Heinrich-Heine University of Dusseldorf, Dusseldorf, Germany). The power analysis determined that 18 individuals were needed using a power level of 0.8, alpha level of 0.05, and moderate effect size of 0.5 (Dickin, Surowiec, and Wang, 2017; Noonan et al., 2019; Reiff, Marlatt, and Dengel, 2012). In order to participate, individuals had to meet the following inclusion criteria: (1) between the ages of 18–45 and (2) no pre-existing cardiovascular, metabolic or neurological disorders that would otherwise affect the results of this study or negatively impact the safety of the participant. This study was approved by the university institutional review board and written informed consent was obtained from each participant prior to any and all testing.

Table 1. Demographic data of participants.[a]

Age (y)	26.8 ± 7.9
Height (cm)	168.1 ± 8.2
Weight (kg)	69.9 ± 15.2
BMI (kg/m^2)	24.5 ± 3.9
Baseline HR (bpm)	73 ± 10

[a]Data are reported as mean ± SD.

BMI: body mass index; Baseline HR: heart rate at rest.

Experimental design

To complete this randomised cross-over experimental trial, all participants were asked to report to the human performance laboratory for two sessions, each consisting of approximately 45 min, for a total testing period of 1.5 h. Over the course of two visits, individuals were asked to perform two different workplace tasks (i.e. reading and typing) while sitting on various chairs (i.e. standard desk chair, stability ball and active balance chair) for 10 min each. All tasks and chair conditions were randomised via computer for both visits and participants were given time to familiarise themselves with all the chairs prior to data recording. On the first session, prior to testing, participants completed an informed consent, health history, physical activity readiness and 24-hour history questionnaire. After written consent was received, height and weight were assessed using a stadiometer and digital scale (Detecto 339, Detecto®, Webb City, MO), respectively. Once all anthropometric data was collected, participants completed the typing or reading tasks.

During all testing, caloric expenditure and heart rate were monitored using the K5 Wearable Metabolic

Technology system (COSMED USA Inc., Concord, CA) and a Garmin heart rate monitor (Garmin Ltd., Olathe, KS). The K5 was appropriately calibrated between each participant and secured in a harness on the participants back. The three types of chairs utilised in this study consisted of a standard desk chair (SC), stability ball (SB) and an active balance chair (ST; SitTight^{TM}, SitTight, Inc., Las Vegas, NV). During both the SC and SB conditions, participants were asked to keep feet firmly on the floor and attempt to maintain proper posture (Figures 1–3); however, while seated on the ST, participants were asked to keep both feet resting on the outer ledge of the chair base and encouraged to balance their centre of mass as per the manufacturer's recommendations (i.e. keep the bottom edge of the chair from touching the ground; Figure 4). The height of the ST was adjusted by each participant to allow for a comfortable sitting position during the trials. The pressure in the SB was consistent with manufacturer regulations and maintained throughout the trials.

For the typing tasks, participants were instructed to type out three pre-made excerpts on a laptop positioned at a natural, self-selected distance from the participant. Participants were asked to avoid resting their wrists on the computer and table while typing, as doing so could potentially provide additional stabilisation and effect the current results. Each typing task was performed for 10min with the excerpts and chair conditions randomised between participants. For the reading tasks, three pre-made articles of various topics were given in a randomised fashion for each trial. Participants were instructed to hold the articles at a comfortable position and to read through as many times as possible within a 10min limit while heart rate and energy expenditure were assessed continuously.

Statistical analyses

All statistical analyses were performed using IBM SPSS statistics software (SPSS Version 25.0, IBM Corp., Armonk, NY) and all data are expressed as

Figure 2. Stability ball.

Figure 1. Standard chair.

Figure 3. Active-balance chair.

Figure 4. Balanced active sitting chair.

Table 2. Comparison of HR, $kcal_{min}$ and METs while sitting on a SC, SB and ST.

	Reading			Typing		
	Mean ± SD	p Value, effect size		Mean ± SD	p Value, effect size	
	HR	v. SB	v. ST	HR	v. SB	v. ST
SC	75 ± 12	.18, 0.08	<.001, 0.31	78 ± 14	.22, 0.04	<.01, 0.15
SB	73 ± 12	–	<.001, 0.38	77 ± 13	–	<.01, 0.18
ST	84 ± 15	–	–	82 ± 14	–	–
	$kcal_{min}$			$kcal_{min}$		
SC	1.64 ± 0.28	.23, 0.09	<.001, 0.71	1.85 ± 0.36	1.0, 0.05	<.01 0.39
SB	1.69 ± 0.26	–	<.001, 0.70	1.81 ± 0.39	–	<.01, 0.42
ST	2.73 ± 0.71	–	–	2.27 ± 0.59	–	–
	METs			METs		
SC	1.44 ± 0.28	.21, 0.1	<.001, 0.75	1.59 ± 0.28	1.0, 0.02	<.01, 0.45
SB	1.50 ± 0.33	–	<.001, 0.71	1.60 ± 0.26	–	<0.01, 0.45
ST	2.35 ± 0.49	–	–	1.94 ± 0.40	–	–

HR: heart rate; $kcal_{mi}$: kilocalories expended per minute; METs: metabolic equivalent task; SC: standard chair; SB: stability ball; ST: active balanced chair.

mean ± standard deviation (SD). All data was tested for normality prior to analysis using tests for skewness, kurtosis and a Shapiro–Wilks test. Heart rate (HR), caloric expenditure per minute ($kcal_{min}$) and metabolic equivalents (METs) were compared between sitting conditions (i.e. SC, SB and ST) during each task (i.e. typing and reading) using multiple repeated measures analysis of variance (ANOVA). A Bonferroni *post hoc* was used for a follow-up procedure for significant findings. Additionally, paired samples t-tests were used to compare the previously stated independent variables between tasks (e.g. typing versus reading) for each sitting condition (e.g. SC typing compared to SC reading). Statistical significance was set at $p = .05$ for all comparisons. Cohen's *d* (Cohen 1992) statistics were calculated to determine the magnitude of differences for all significant comparisons using Hopkins' scale of magnitude (Hopkins et al. 2009). Whereas, an effect size (ES) of 0–0.19 was considered trivial, 0.2–0.59 was small, 0.6–1.19 was moderate, 1.2–1.9 was large and ≥2 was very large.

Results

All participants completed both trials and were used for statistical analyses. Means ± SD for all values for both the reading and typing tasks are provided in Table 2. Mauchly's test of sphericity was violated for HR, $kcal_{min}$ and METs for the reading trials and HR and METs for the typing trials. Therefore, a Greenhouse-Geisser correction was utilised to determine overall significance. During the reading task, results indicated that the ST produced a significantly greater mean HR response, $kcal_{min}$ and MET level when compared to the SC and SB. There were no differences between the SC and the SB for any of the variables measured. In regard to the typing task, HR, $kcal_{min}$ and METs were all significantly greater while using the ST when compared to the SC and SB. However, no statistical differences were found between the SC and SB for any measured variables.

When comparing workplace tasks between the same type of chair condition, there were no statistically significant mean differences in HR between reading and typing tasks for the SC ($p = .1$, ES = 0.15), the SB ($p = .1$, ES = 0.15) and the ST ($p = 0.82$, ES = .03). The SC, however, expended significantly greater $kcal_{min}$ ($p < .01$, ES = 0.29) and METs ($p < .01$, ES = 0.25) during the typing task when compared to the reading. In contrast, these metrics were significantly lower ($kcal_{min}$: $p < .01$, ES = 0.29; METs: $p < .01$, ES = 0.36) while typing on the ST. There were no observed differences between tasks while sitting on the SB ($kcal_{min}$: $p = .19$, ES = 0.21; METs: $p = .1$, ES = 0.2).

Discussion

The purpose of this study was to compare the metabolic and cardiovascular responses to office work-related tasks while sitting on different styles of chairs. The major findings indicate that the ST elicited significantly higher HR and caloric expenditure compared to both the SC and SB. These results support previous literature examining the physiological responses to various active workstations (Cox et al. 2011; Dickin, Surowiec, and Wang 2017; Reiff, Marlatt and Dengel 2012; Schellewald, Kleinert, and Ellegast 2018; Synnott et al. 2017). Moreover, the SB did not appear to elicit any advantage when compared to the SC.

Examining ways to promote physical activity in the workplace has become increasingly more important, as the vast majority of workers spend the largest portion of their work day sitting and do not meet the recommendations for physical activity (Lowe et al. 2015). This sedentary behaviour has led to the introduction of standing, walking or active workstations in traditional office settings to promote employee health and encourage more movement throughout the day, with varying levels of success (Beers et al. 2008; Burns, Forde, and Dockrell 2017; Roemmich 2016). For instance, Roemmich (2016) found that energy expenditure increased by 7.5 kcal/h when participants were standing versus sitting while performing clerical work; however, Burns, Forde, and Dockrell (2017) demonstrated no significant differences in energy expenditure during typing or reading tasks between a sitting and standing posture.

Another key finding of the current study was that no differences between the SC and SB for HR or caloric expenditure were observed. Although, the metabolic findings are consistent with previous literature showing a similar energy expenditure during work-related tasks while using a SB (1.69–1.81 $kcal_{min}$; Beers et al. 2008; Dickin, Surowiec, and Wang 2017). While the SB provided no additional benefit as compared to a SC, active sitting, using the ST, resulted in upwards of 19–40% greater caloric expenditure per minute. If factored out to an eight-hour work day, this increase would result in an additional ~500 kcals compared to the other chairs used in this study. While no research has yet to investigate the ST, this increase in energy expenditure is inconsistent with previous literature examining active workstations (Beers et al. 2008; Dickin, Surowiec, and Wang 2017; Noonan et al. 2019; Reiff, Marlatt, and Dengel 2012). For example, Beers et al. (2008) found that the use of a stability ball increased caloric expenditure by ~6% compared to sitting; while, Dickin, Surowiec, and Wang (2017) found increases only up to ~10.4%. The significant caloric increases, while utilising the ST, may be attributed to the specific need to control one's centre of mass. Sitting on the SB requires the individual to keep both feet planted on the ground while attempting to maintain postural control without a backrest. However, the ST requires the individual to place both feet on the base of the chair; therefore, the only point of contact with the ground is the inflatable bladder (Figure 4). This reduction in points of contact may require increased metabolic demand and it has been previously reported that an unstable sitting surface compels an individual to adjust one's balance through the activation of trunk and back musculature. Ultimately, this could lead to an increased caloric expenditure during similar work-related tasks (Koepp, Moore, and Levine 2016).

The metabolic cost of typical office tasks (e.g. reading, typingand paper sorting) has been previously suggested at <1.5 METs (Ainsworth et al. 2000; Burns, Forde, and Dockrell 2017; Schellewald, Kleinert, and Ellegast 2018), which are consistent with the current findings for the SC and SB. However, the ST resulted in a significantly greater metabolic cost (1.94–2.35 METs) than previously established. These findings are similar to work-related tasks using active walking (1.6 km/h) workstations (Cox et al. 2011). While standing/walking workstations have been shown to increase metabolic expenditure, they often induce fatigue and soreness, particularly in the feet and low back (Gregory and Callaghan 2008; Noonan et al. 2019; Ringheim et al. 2015). Given the similarity of metabolic demands and HR responses to active walking workstations, ST may provide comparable health benefits in a more space-efficient and potentially less fatiguing or pain inducing, manner.

Similar to measures of metabolic expenditure, HR increases proportionately with intensity of activity (Strath et al. 2013). The ST elicited an average HR of approximately 84 bpm during the simulated office tasks, roughly 6–13% greater than the SB and SC. The HR response from the SB in the current study was similar to previous findings using a similar protocol (Beers et al. 2008). However, the significant increases in HR that were observed with the ST were higher than previously studied chairs, but were similar to responses seen with standing/walking workstations (Cox et al. 2011). Furthermore, the ST produced HR responses above those demonstrated via dynamic cycling work stations such as the Deskbike© (77 ± 5 bpm; Schellewald, Kleinert, and Ellegast 2018). The ST may provide greater instability than other active sitting apparatuses. The subsequent corrective responses could result in increases in the level of muscle recruitment from lower extremities and postural control musculature which may influence cardiovascular response and total energy expenditure.

The short duration of the office work-related tasks (i.e. 10 min each) in the current study limits the applicability of the findings to long term use of the ST as a workplace modality. It is possible that an individual may become familiarised with the ST with chronic usage; thereby, establishing a learning effect. As the individual increases postural control and balance on the ST, a decrease in muscular activation and subsequent metabolic expenditure may occur. Additionally, muscle activity was not monitored within this study; thus, future studies should examine electromyographical patterns of postural and stabilisation musculature. Furthermore, due to the prevalence of overweight and obesity in the office setting, future studies should assess the viability and metabolic efficacy of the ST during work-related tasks in an obese population. The sample included in this study was predominately college-aged and healthy, which may have resulted in better stabilisation than various other populations (e.g. overweight, aging). Although no participants in this study lost control while on the ST, it should be noted that individuals with balance issues or inadequate core strength may potentially be at an increased risk of falling. Finally, during the typing task, participants were instructed to avoid resting their wrists on the computer. Although this was done to prevent stabilisation, it is possible that this created an unfamiliar body orientation while typing and constrained participants movement. Lastly, only the ST chair was adjustable as compared to the SB and SC. Thus, the SB and SC may have favoured individuals of certain anthropometrics (e.g. thigh and shank length) and further research is warranted to determine postural alignment on standardised versus adjustable chairs.

The increase in technological advances and transition of the workforce to more sedentary office jobs have been associated with a rise in adult obesity for those attempting to achieve a negative energy balance. Therefore, active work stations may aid in the promotion of incorporating physical activity throughout the day. While, stability balls and standing desks have been introduced, the results of increased caloric expenditure remain unclear. However, the current results support the use of active sitting, via the ST, which demonstrated significantly greater measures of metabolic expenditure and cardiovascular responses compared to the SC and SB. Thus, it is possible that the ST may provide improvements in the health and wellbeing of office workers, without requiring major alterations to their schedule or work stations. However, given the short duration of the testing (i.e. 10 min), further research is warranted to determine longitudinal variations over a work day and across time (i.e. months).

Disclosure statement

The results of the current study do not constitute endorsement of SitTight™ by the authors or Ergonomics. No potential conflict of interest was reported by the authors.

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