Breaking up prolonged sitting to improve cardiometabolic risk: a comparative analysis of muscle strengthening exercise and treadmill walking

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Water College of Health Professions.

By
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Under the mentorship of *Andrew Flatt, Ph.D*

ABSTRACT

Purpose: To examine the effectiveness of brief bouts of treadmill walking and bodyweight-based muscular strengthening exercises to mitigate the effects of sedentary behavior on blood pressure, blood glucose, cognitive performance, and perceived fatigue.
Methods: Healthy young adults (n = 9) completed 3 experimental trials consisting of 4-hour sedentary periods. The trials consisted of an uninterrupted sedentary period (control), treadmill walking every 30 minutes for 5 minutes, and bodyweight-based muscular strengthening exercises every 30 minutes for 5 minutes. Blood glucose was measured at baseline and every 30 minutes thereafter. Blood pressure and fatigue were measured at baseline and every hour thereafter. Cognitive performance was measured at baseline and post-trial. A standardized breakfast was consumed by each participant following baseline assessment.
Results: Main effects of time were observed for systolic blood pressure and blood glucose ($Ps < 0.05$). Systolic blood pressure was lower at baseline versus 60 and 240 min time points ($Ps < 0.05$), and blood glucose at baseline was lower than 60-120 min time points ($Ps < 0.05$). A main effect of group was observed for fatigue ($P < 0.01$). Fatigue for the aerobic condition was lower than control ($P < 0.01$).
Conclusions: Despite no significant interaction effects, aerobic exercise in the form of treadmill walking tended to more effectively mitigate fatigue and increases in systolic blood pressure.

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Honors Dean: Dr. Steven Engel

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INTRODUCTION

Cardiometabolic disease (CMD) is the leading cause of death worldwide[1]. Many common adverse events and conditions such as heart attack, stroke, and diabetes fall under the umbrella of CMD. Sedentary behavior is one of the leading modifiable cardiometabolic health risk factors[2]. Sedentary behavior refers to activities while awake that have an energy expenditure ≤1.5 metabolic equivalents (METs) such as slow walking, lying down, or watching television. It is estimated that adults spend 8 to 10 hours a day engaged in sedentary behavior[4]. There have been significant associations between sedentary behavior and CMD. For example, long durations of sedentary behavior can raise your blood pressure and increase the risk of heart attack, stroke, and kidney disease[1]. Moreover, type 2 diabetes and metabolic syndrome are prevalent in those who engage in higher sedentary behavior[4].

Recent studies have shown that regularly breaking up prolonged periods of sedentary behavior is more effective than a single continuous period of moderate to vigorous physical activity to lower postprandial glucose and insulin concentrations[4]. Despite having this knowledge, there is little research on ways to decrease sedentary behaviors that have an impact on CMD. A recent study demonstrated that walking for 5 mins every 30 mins on the treadmill over a 4-hour sedentary time period was able to mitigate the adverse effects on CMD risk factors, including increases in glucose and blood pressure[2]. However, walking is not always practical as it requires access to a treadmill or a safe walking environment. In a previous study, resistance exercises were used to disrupt prolonged sitting and a decrease in endothelin-1 concentrations among adults with overweight or obesity compared to those in a prolonged sitting position was observed[3]. However, whether resistance exercise is as effective as aerobic exercise for combating increases in blood glucose or blood pressure are unclear. Therefore, the purpose of this study was to compare the effects of brief intermittent bouts of treadmill walking and bodyweight-based muscular exercise throughout a sedentary period on markers of cardiometabolic health in young adults. We hypothesized that bodyweight-based muscular strengthening exercises would have a similar effect on CMD risk factors as treadmill walking. This would provide a potentially more accessible option for people to reduce their sedentary behavior, reduce the burden of CMD, and improve the health span in the population.

METHODS

Study Population

The study consisted of adults aged 18-40 years. A power analysis was performed indicating a sample size of 30 participants would provide 80% power at an alpha level of 0.05. Inclusion criteria was self-reported sedentary time of >5 hours per day, be able to speak and understand English, be a non-smoker, be able to participate in light exercise, and have a BMI less than 35 kg/m². Participants who are prescribed medications with a known effect on glucose or metabolism, have a BMI ≥35 kg/m², are not able to engage in physical activity due to doctor's orders, or are deemed unfit determined by the PAR-Q+ met criteria for exclusion. All participants were informed of the risks and benefits of the study prior to providing written consent. Ethical approval for this study was granted by the Georgia Southern University Institutional Review Board (Protocol H23301).

Study Design

The study consisted of three experimental testing visits: control, treadmill walking, and bodyweight-based muscular strengthening exercises. All visits were conducted in 21 days or less and at a minimum of 48 hours apart. Each visit required the participant to spend approximately 4.5 hours in the Biodynamics and Human Performance Center at Georgia Southern University, Armstrong Campus. Participants arrived for each visit in the morning after refraining from exercise, over-the-counter medications, caffeine, alcohol, and tobacco products for 24 hours prior to laboratory visits. Upon arrival participants were instructed to sit in an upright chair and remain quiet for ten minutes prior to the start of the trial. After ten minutes, the participant's blood pressure was assessed via oscillometric means using a SphygmoCor XCEL device (AtCor Medical, Naperville, IL, USA) and their blood glucose was obtained from a fingerstick blood draw using a glucometer (Keto-Mojo, Napa, CA, USA) per manufacturer's instructions. Participants then consumed a meal that consisted of ~33% of their daily estimated energy requirements, using the Schofield equation, with a target macronutrient profile of ~15% protein, ~55% carbohydrate, and ~30% fat[5]. Participants consumed the same breakfast each visit. Once the participant began consuming their breakfast the trial timer began and they were instructed to take <15 minutes to eat.

Each trial consisted of the participant sitting for a four-hour period. Participants were allowed to participate in sitting activities such as reading and using their smartphone or computer. During the control visit, participants only rose from their chair for lavatory visits. During the treadmill walking trial, participants rose every 30 mins and walked for 5 mins at 0% grade and 2.0 mph on the treadmill, in accordance with previous studies[2,6]. During the body-weight muscular strengthening exercises, participants rose every 30 mins and performed bodyweight-based muscular strengthening exercises such as half squats, calf raises, and single knee raises with gluteal contractions for five mins[3,7]. Participants were instructed to maintain a level of 3 out of 10 intensity while completing the body-weight strengthening exercises.

During all trials blood pressure was measured at baseline and every hour while glucose was measured at baseline and every 30 mins. Fatigue, using a visual analog scale, was measured every hour. Cognitive performance, using the symbol digit modalities test (SDMT)[9], was assessed at baseline and at the end of the four-hour sedentary period. An overview of testing procedures is provided in Figure 1.

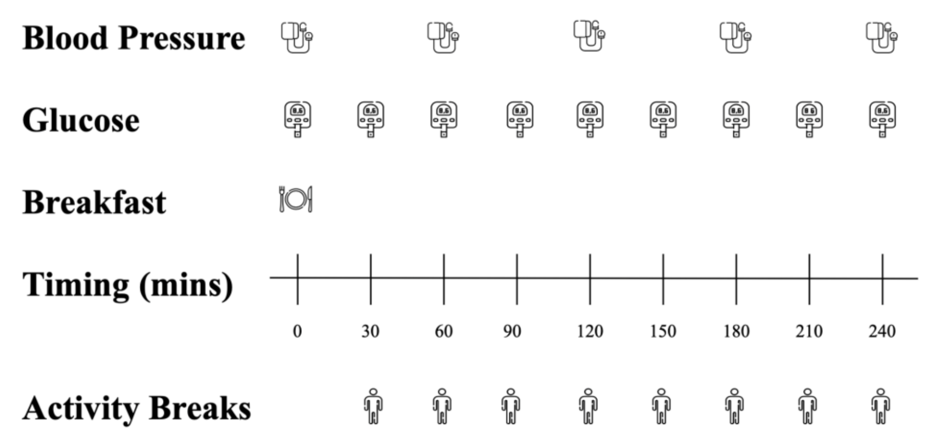


Figure 1. Study design. Participants will undergo three alike experimental testing sessions. After fasting resting glucose and blood pressure will be acquired. Each four-hour sitting session will commence with the administration of a self-prepared breakfast. Glucose will be measured every thirty minutes, and blood pressure will be measured every hour, prior to activity breaks. On the non-control days participants will partake in a five-minute activity break consisting of either treadmill walking ot simple bodyweight-based muscular strengthening exercises.

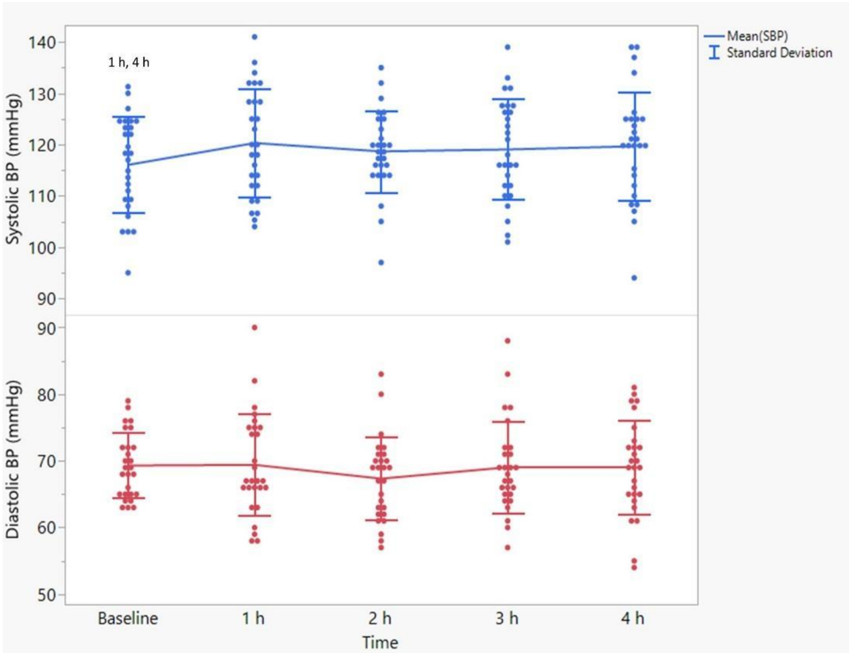
Figure 1. Schematic of the experiment study design.

Statistical Analysis

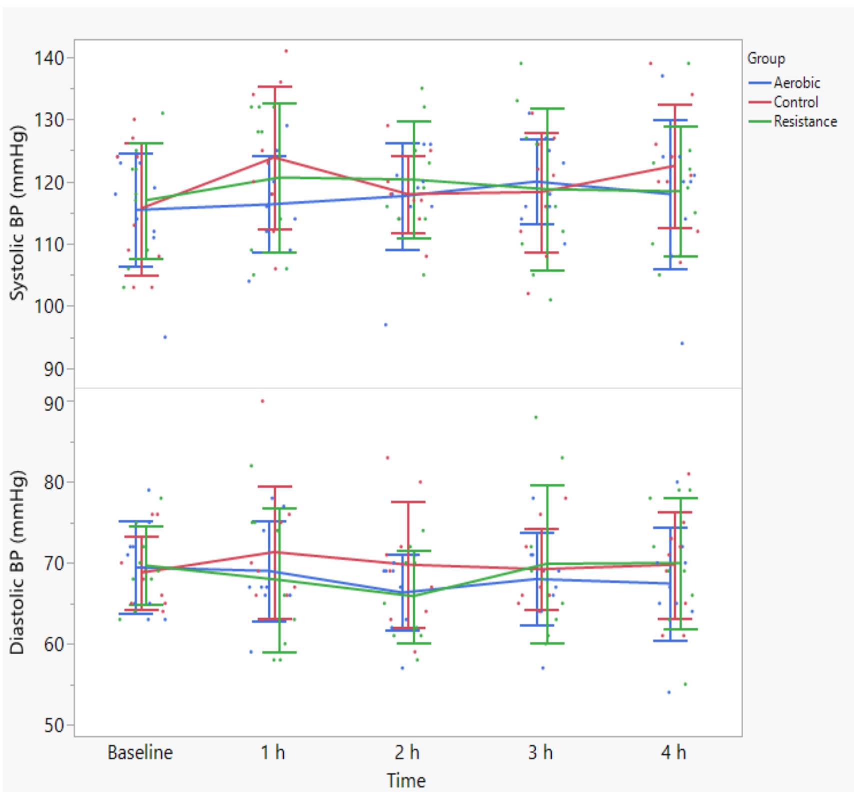
Mixed effects linear models were used to examine potential variation in outcome variables. Condition (control, treadmill walking, and bodyweight-based muscle strengthening exercise), time (baseline and all follow-up time points), and the condition × time interaction were included as fixed effects. Subject identification was included as a random effect. Post-hoc analyses were conducted using Tukey's Honest Significant Difference tests. Shapiro-Wilk tests were used to assess normality of model residuals. Variables are reported as mean ± standard deviation. P values < 0.05 were considered statistically significant. Analyses were performed using JMP 16 (SAS Institute, Cary, North Carolina, USA).

RESULTS

Nine young adults (56% female, age = 23.6 ± 4.2 years, height = 171.9 ± 7.7 cm, body mass = 75.1 ± 21.5 kg, body mass index = 25 ± 5.5 kg/m^2) participated in this study. A significant main effect of time was observed for systolic blood pressure (P = 0.019). Post-hoc analysis showed that systolic blood pressure at baseline was significantly lower than 1 h (P = 0.014) and 4 h (P 0.048) time points. No condition (P 0.439) or condition × time interaction (P = 0.292) effects were observed. No significant condition (P = 0.373), time (P = 0.599), or condition × time interaction (P =0.522) effects were observed for diastolic blood pressure. Systolic and diastolic blood pressure values are presented in Figure 2.



a.



b.

Figure 2. Time (a) and condition × time (b) plots for systolic and diastolic blood pressure (BP).

A significant main effect of time was observed for glucose (P <0.0001). Post-hoc analysis showed that glucose at 30 min was significantly higher than baseline, 150 min, 180 min, 210 min, and 240 min (Ps ≤0.0001). In addition, baseline was significantly different than 30 min, 60 min, 90 min, and 120 min (Ps <0.0001 – 0.030). Furthermore, glucose at 60 min was significantly different than 180 min, 210 min and 240 min (Ps <0.0001 – 0.046). Lastly, glucose at 90 min was significantly different from 240 min (P <0.001), and 120 min was significantly different than 240 min (P = 0.001). No condition (P 0.681) or condition × time interaction (P = 0.895) effects were observed. Glucose data for the effect of time are presented in Figure 3.

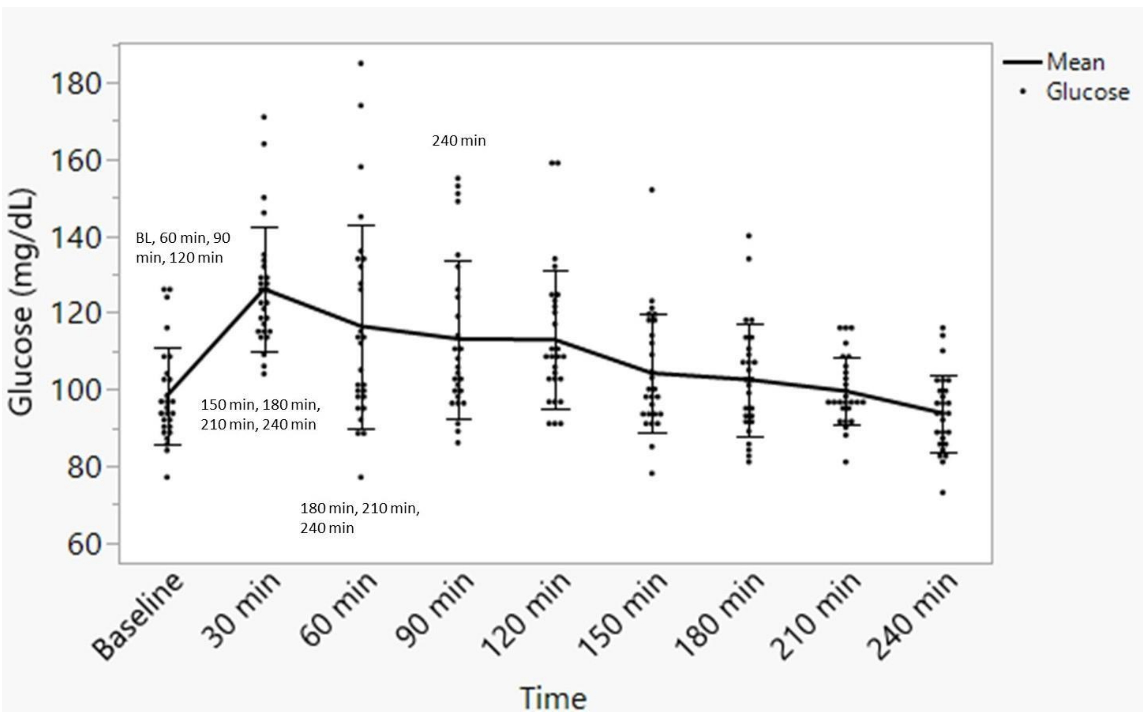


Figure 3. Time plot for blood glucose.

No significant condition (P = 0.178), time (P = 0.655), or condition × time interaction (P =0.887) effects were observed for cognitive performance. Cognitive performance for each condition is presented in Figure 4.

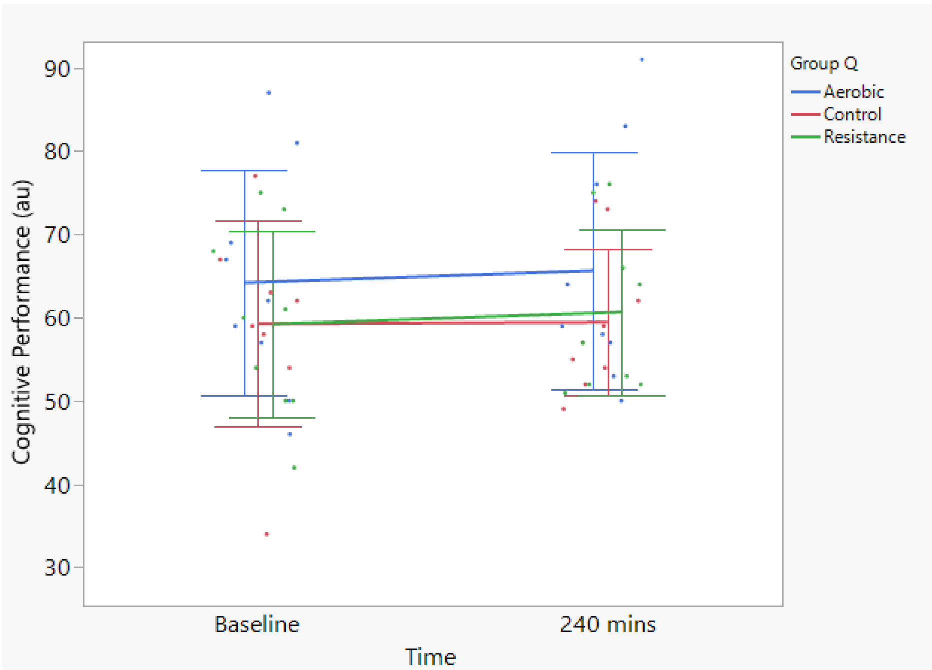


Figure 4. Condition × time plot for cognitive performance.

A significant main effect of condition was observed for fatigue (P = 0.007). Post-hoc analysis showed that fatigue for the aerobic condition was significantly lower than control (P = 0.005). Data for fatigue between conditions is presented in Figure 5.

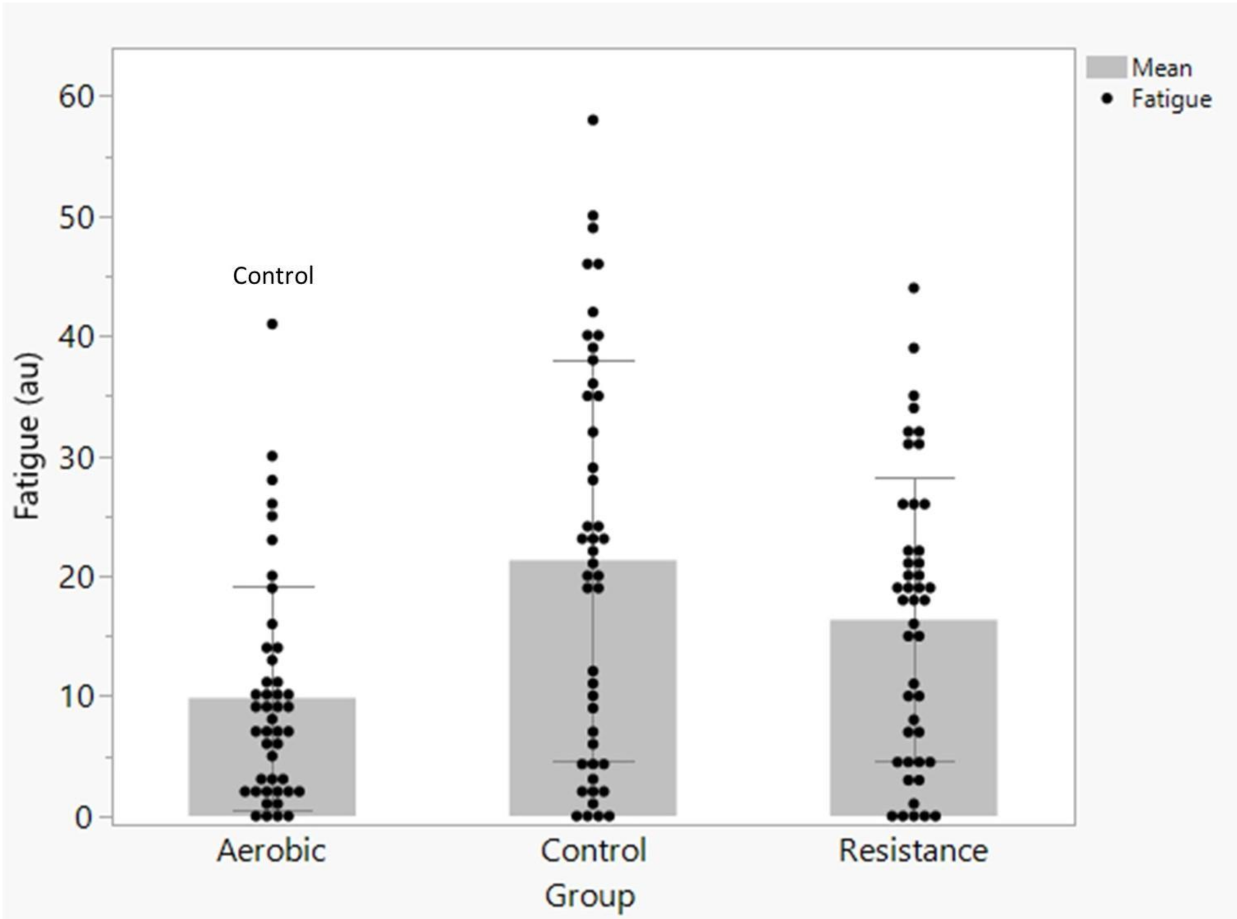


Figure 5. Bar graph displaying differences in fatigue between conditions.

DISCUSSION

The purpose of this study was to compare the effects of brief intermittent bouts of treadmill walking and bodyweight-based muscular exercise throughout a sedentary period on markers of cardiometabolic health in young adults. We hypothesized that bodyweight-based muscular strengthening exercises would have a similar effect on CMD risk factors as treadmill walking. The main finding was that in disagreement with our hypothesis, no significant condition × interactions were observed for any outcome parameter, suggesting that neither intervention significantly affected cardiometabolic parameters. Nevertheless, magnitude-based assessment revealed some superiority of the aerobic exercise intervention which is discussed below.

With all groups combined (main effect of time), systolic blood pressure was shown to be significantly lower at baseline than at the 60 min mark and 240 min mark. The increase in blood pressure at the 240 min mark supports the previous findings showing that sedentary behavior raises blood pressure[10]. This result reinforces the need to find a way to help mitigate cardiometabolic risks involved with sedentary behavior. Lack of statistical significance notwithstanding, potentially clinically relevant reductions in systolic blood pressure were noted for the treadmill walking group at the 60 min time point relative to control (-7.5 mmHg) and resistance exercise (-4.4 mmHg) as shown in Figure 2b. Thus, further research with a larger sample size should be conducted to determine if this trend reaches statistical significance, as this would provide beneficial information for those who engage in prolonged sitting. One possible reason why a significant interaction effect was not observed is because the study population involved relatively healthy young adults who were normotensive. The benefits of aerobic exercise and strength exercise breaks may be greater in older populations or those with poor cardiometabolic health.

Blood glucose significantly increased post-baseline and progressively returned to fasting levels throughout the observation period. The rise in blood glucose can be explained by the fact that participants consumed a meal within 15 mins after the beginning of each trial. Therefore, the blood glucose taken at the 30 min mark would be heavily influenced by the participants' breakfast. Time-related analysis shows that the glucose levels rise after meal ingestion and then progressively fall throughout each trial condition, with no significant effect of either intervention in attenuating the postprandial excursion. This finding contrasts with previous studies showing that blood glucose levels was significantly lowered when treadmill walking breaks occurred every 30 mins for 5 mins over an 8-hour sedentary period compared to control[2], and with short walking bouts of $<$2 mins paired with standing throughout sedentary periods[4].

Perceived fatigue was significantly lower during the treadmill walking condition versus the control condition. This finding suggests that individuals who add aerobic exercise into their daily routine may experience reduced feelings of fatigue, potentially contributing to a more productive day. Benefits of reduced fatigue may apply to work settings, daily life, or physical exercise, potentially contributing to higher levels of cardiovascular health. Despite no statistical significance, the resistance condition exhibits a decrease in fatigue compared to the control condition, but not as low compared to the aerobic condition. One could utilize this information by adding aerobic exercise into their bouts of prolonged sitting to decrease fatigue.

There were no significant differences in cognitive performance. A statistically non-significant trend shows that a higher score was achieved during the aerobic condition. A greater score indicates better cognitive performance. This could be due to the significant decrease in fatigue during aerobic conditions compared to the control condition, as greater fatigue is known to promote a decrease in cognitive performance[11]. Future research with a larger sample size is needed to support this observation.

CONCLUSION

Although further confirmation is required, the current findings seem to suggest that breaking up prolonged sitting with aerobic exercise may be more beneficial than strength training exercise breaks for decreasing perceived fatigue and systolic blood pressure in apparently healthy young adults.

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