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Comparison of an Acute Bout of Exercise to a Sugary Snack on Energy, Mood and Cognitive Performance

Erica Knowles

Stephen F. Austin State University, knowlese@jacks.sfasu.edu

COMPARISON OF AN ACUTE BOUT OF EXERCISE TO A SUGARY SNACK ON ENERGY, MOOD AND COGNITIVE PERFORMANCE

By

Erica Grace Knowles, Bachelor of Science

Presented to the Faculty of the Graduate School of

Stephen F. Austin State University

In Partial Fulfillment

Of the Requirements

For the Degree of

Master of Science

Stephen F. Austin State University
May, 2019

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ON ENERGY, MOOD AND COGNITIVE PERFORMANCE

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ERICA GRACE KNOWLES, Bachelor of Science

APPROVED:

Malcom T. Whitehead, Ph.D., Thesis Director

Dustin Joubert, Ph.D., Committee Member

DawnElla Rust, Ed.D., Committee Member

Casey Hart, Ph.D., Committee Member

Pauline M. Sampson, Ph.D.
Dean of Research and Graduate Studies

ABSTRACT

Low perceived energy and a decline in cognitive performance throughout the day are common issues, though exercise and food consumption are suggested to improve mood and cognition. The present study compares effects of acute exercise to consuming sugar on mood, energy, and cognitive performance. Subjects underwent blood glucose testing, completed an Abbreviated Profile of Mood States Questionnaire, and Automated Operation Span (OSPAN) and Digit Span tests to measure memory and attention. On two separate days subjects consumed candy or walked on a treadmill for 10 minutes, then measurements were repeated at 30-min, 60-min, and 120-min post. Two-way ANOVA over time revealed significant condition over time effects for the maximum digits on the forward digit span (p=0.034) and number of correct spans in the backward digit span (p=0.023). There were no significant differences for OSPAN performance, mood or perceived energy (p>0.05). This study indicates that though exercise and sugar have limited differences in their effects there is a need for greater research in this area.

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INTRODUCTION

Subjective feelings of energy are the interpretation of one's capacity to do mental or physical activity [1]. Low perceived energy is a common problem particularly in workers and college-aged students. In a survey of 29,000 employees, 38% reported experiencing low levels of perceived energy, poor sleep, or feelings of fatigue. Workplace fatigue costs employers an estimated $136 billion annually due to low productivity [2]. In addition, 50% of college students surveyed reported daytime sleepiness, and 70% are not reaching sufficient sleep which adds to their feelings of fatigue [3]. The average American spends approximately 58% of their day sedentary [4], or inactive, which is shown to increase perceived fatigue [5]. Generally speaking, a common method used to boost mood and energy levels is a sugary snack, especially during times of high-energy demand or stress such as studying or focusing at work [6,7,8]. The subsequent increase in energy is easily mislabeled as "feeling better" or "good feelings", causing repeated use of a sugar snack to improve subjective energy and manipulate feeling states such as calmness, tiredness and tension [6]. These good feelings could occur since highly concentrated glucose can stimulate the release of dopamine, a neurotransmitter that stimulates reward and pleasure in the brain [9]. Snacking has been linked to a risk of overweight and obesity in adolescents [10], and adults [11], especially since snacking typically occurs with low nutrient density foods, indicating a need for healthier alternatives. Thayer [6] questioned if bouts of exercise were as beneficial, if not more, than sugary snacks on improving energy, tiredness, and tension. Eighteen undergraduates (age 19-38) were randomly assigned to either walk rapidly for 10 minutes or ingest 1.5 oz of candy for a total of 12 testing sessions (six per intervention). The Short Form Activation-Deactivation Checklist was used to measure feeling states and was given immediately before the intervention then 30 minutes, one hour, and two hours post. These researchers found that energy was significantly higher after walking (30 minutes=14.81, 1 hour=15.03, 2 hours=13.77) than snacking (30 minutes=12.27, 1 hour=12.37, 2 hours= 11.19). Walking also caused greater improvements in tiredness and tension compared to snacking in all time points. When comparing pre-test to post-test tension levels, walking caused a significant decrease below pre-test values that remained for the full two hours post ($ts(17)=$ 2.75, 2.60, 2.27, respectively). For snacking, levels were higher at 30 minutes and two hours ($ts(17)= 1.41$, $p< .17$ & 2.06, $p< 0.05$, respectively) and highest at 60 minutes ($t(17)= 2.52$, $p< 0.02$). After walking, energy levels were significantly higher at 30 minutes (14.59) and one hour (14.56) post compared to pre-test (10.20). While the data suggests walking has greater benefits than snacking, since this study was performed there has been a lack of sufficiently controlled studies to support these findings. Moreover, dissimilarities in the research design of existing studies has not clearly demonstrated the direct effects of snacks or exercise on cognition, mood, or energy. The purpose of the present study is to compare the effects of an acute bout of exercise and a sugary snack on energy, mood, and cognitive performance. The following review of literature includes studies focusing on the acute cognitive, energy, and mood effects of consuming snacks or exercising.

LITERATURE REVIEW

Food Consumption

Long-term supplementation wherein various foods and nutrients are given at high doses for extended periods of time have been thoroughly studied, yet currently there is a notable lack in research specifically investigating the immediate short-term effects of snacks on energy and mood. Macht and Mueller [12] point out that with emotional eating, an individual consumes food in response to usually a stressful or saddening stimulus. These researchers studied chocolate consumption in the context of emotional eating and found that chocolate improved a negative mood but had no effect on positive or neutral mood states. Furthermore, when comparing palatable to non-palatable chocolates, only the palatable benefited mood; this suggests the effects are more likely related to the emotional state than the actual nutrients of chocolate. Additionally, nutrient-dependent emotional changes occur after nutrient absorption, meaning that the effects would not be felt immediately and the expectation of an emotional change is likely the biggest effector. Even so, the benefits of eating chocolate lasted only three minutes, showing this popular sugary snack is limited and relatively ineffective [12].

Benefits of Food

The most common time for snacking is in the afternoons [13]. Studies show that the timing of a meal can impact cognitive performance [14,15,16,17]. Lunch has been shown to impair reaction time and attention in university students, although this depends on the type of meal (High-carb vs high-protein; larger or smaller than normal meal) [16,18] while breakfast can benefit memory but impair concentration in adolescents [15]. Three breakfast drinks (high-carbohydrate, high-protein, or control) were compared for effects on mental workload, sleepiness and negative mood state, with no significant differences found for workload or mood [19]. However, a high-carbohydrate drink did decrease sleepiness compared to the control drink, showing the importance of breakfast in improving energy levels. Similarly, a snack can affect cognition and even benefit more than a meal. Research has demonstrated that breakfast can have a negative effect on mood while a snack after breakfast was able to reverse this effect and improve mood [20]. In addition, approximately one hour after eating lunch there is a decrease in performance that can last for an hour [17], yet a mid-day confectionery snack improved cognitive performance on both memory and attention tasks [14]. This idea is supported by Kanarek and Swinney [21] who used male college students to study mid-afternoon effects of a caloric confectionary snack (*n*=10) or a fruit-flavored yogurt snack (n=8) compared to a low-caloric snack (lemon-lime flavored non-caffeinated diet soft drink). Kanarek and Swinney [21] tested memory, attention, arithmetic and reading under four nutritional conditions: lunch with caloric snack, no lunch with caloric snack, lunch with low-calorie snack, no lunch with low-calorie snack. All breakfasts and lunches were provided on testing days and conditions were double-blinded. Reaction time on an attention task was significantly faster with the caloric snack than the lower-calorie snack (417 and 432, respectively; $p<0.05$) and recall was also significantly higher (5.0 and 4.8, $p<0.05$). Contrary to the previously mentioned findings of negative effects of lunch on cognition, results were trending towards significance ($p= 0.06$) in showing that eating lunch lead to better performance on the arithmetic task, reading faster, and lowering reaction time compared to not eating lunch, although more research is needed to confirm these results. Leidy et al. [22] found that processing speed and cognitive flexibility increased post-snack vs pre-snack, supporting the idea that snacking benefits cognition. Interestingly, having no snack lowered tension-anxiety and vigor-activity, indicating mixed effects on mood states.

Glucose

Researchers have found evidence that the key to snack's effects on cognition and mood states lies in their correlation to blood glucose [23,24,25]. Positron emission tomography (PET scan) has shown that increased mental activity is associated with increased glucose metabolism [25]; therefore, glucose is essential for maintaining proper brain function. Although glucose can be derived from other sources, such as protein, the most likely source is dietary carbohydrates. Protein can be converted to glucose and be used to sustain brain metabolism, but only in fasting conditions where low dietary carbohydrate intake occurs. When these fasting conditions occur, cognitive performance is negatively affected; yet these effects are reversed by ingesting a small amount of glucose [26]. The pre-existing blood glucose levels do mediate this effect in that when levels are lower, glucose impacts cognition greater than when levels were already moderate to high. In addition, there is an estimated time delay of 30 minutes for glucose to have full impact [27]. The amount of cognitive load required by a task could also be a predictor of its sensitivity to enhancement through blood glucose [14]. Furthermore, although there is limited data on the influence of the glycemic index of carbohydrates on memory, the existing research suggests that even low glycemic index foods can benefit memory. Additionally, in studies focusing on cumulative impacts of high, medium, or low-carbohydrate diets, the high carbohydrate diets were associated with better mood. However, glycemic load should continue to be investigated to determine if it plays a role in mood and memory [25]. Glucose’s impact on memory is still unclear as other research counters these findings [23,24]. Mahoney provided a possible explanation on why glucose would impact cognition [28]. Acetylcholine has been tied to memory, attention and learning performance. An increase in acetylcholine synthesis occurs due to glucose metabolism, therefore increases in cognitive processes could result [29]. Again, further research is required to confirm this theory.

Exercise

It is a well-established fact that exercise has a significant direct effect on the health of an individual. Similar to snacking, there is a greater body of research on the long-term benefits of exercise than acute effects. The body of literature regarding the benefits of exercise is growing and includes improving levels of fatigue, mood states, and cognitive performance [30-40].

Debate over the value of recess and physical education (PE) for children has driven research connecting the benefits of physical activity to academic performance. Hillman et al. [30] found acute exercise significantly improved reading comprehension and accuracy during an Eriksen flanker task. Hillman also used P3 wave amplitude, a measure of neuroelectric changes that occur during information processing in the brain, as it reflects resource allocation during a task. They found that wave amplitude was higher after exercise compared to rest, showing that greater attention is given after an exercise bout. Aerobic fitness was positively correlated with test performance in elementary age children, which is supported by previous research measuring brain activity that found increased alpha activity occurs in aerobically fit versus not fit people, and there is a positive linear relationship between reaction time and VO_2, or the measure of oxygen utilization in the body during exercise [31]. Additionally, physical activity improves cerebral blood flow and production of neurotransmitters like catecholamines and endorphins which can improve cognitive performance [27].

Wollseiffen theorized that since exercise also causes an increase in motor cortex activity, productivity and mood in the workplace could be improved through exercise [32]. These researchers conducted a study of 50 office workers in a university using five separate interventions and measures of mood, arithmetic, memory, attention and electroencephalogram (EEG) to test this theory. The interventions included boxing, biking, massage chairs, no break, or the worker's usual break. In regard to mood, the usual break yielded the greatest improvements compared to the other interventions ($p<0.05$), which could be due to the social interactions typical of an office break. Boxing significantly increased decision-making task performance compared to the usual break or massage chair and was marginally significant to biking and no break ($p=0.06$). Further, EEG alpha-2 activity significantly increased after boxing and biking ($p<0.01$, $p<0.05$, respectively) while only slightly increasing after the massage chair, indicating that even brief physical activity has a greater positive effect on neurocognitive performance than physical relaxation. Expanding on these findings, one study compared six five-minute bouts of exercise throughout the day to one 30-minute single bout of exercise in the morning to determine which is more effective [33]. Interestingly, this study did not show significant improvements in cognitive performance due to exercise. Both exercise conditions had significantly greater energy levels than the sitting condition; however, the shorter bouts had sustained effects while the longer bout did not. The five-minute bouts also had significantly lower fatigue, higher vigor and better mood states.

When determining the intensity of exercise, one study suggests 40-60% of VO_2 is best for cognition [34]. However, in aerobically fit people there is evidence for cognitive improvement at high intensity (>70%) exercise [35]. Brisswalter et al. [35] suggested the cause could tie to the arousal or activation of the central nervous system, which includes the brain and spinal cord and controls activities of the body, that increases with physical activity. However, another study showed choice reaction time, a measure of cognitive performance, was improved after reaching the adrenaline threshold (the sudden increase in adrenaline in response to exercise intensity), which indicates a high level of arousal [36]. Additionally, Fontana et al. [37] found that at moderate to high intensities, speed on a decision-making task was significantly faster. Although these findings support high-intensity exercise for cognitive improvements, short-duration moderate-intensity exercise has a broader application.

Fatigue

Epidemiological studies show physical inactivity and fatigue symptoms are positively related [38]. Improvements in feelings of energy and fatigue after exercise is seen even in various diseased populations, including psychiatric, cardiovascular, cancer, and fibromyalgia [38]. Fatigue is typically a side effect of diseases, especially depression. Although the focus of research has been aerobic exercises, strength training specifically has caused greater decreases in depressive feelings than aerobic training, suggesting that fatigue and mood could be impacted by strength training. Herring and O'Connor [39] implemented a resistance training program in sedentary women (n=14) who rated their feelings of vigor and fatigue both during and after exercise. The intensities used were 70% of 1-repitition maximum (1RM), 15% 1RM, and a control group who performed no exercise. Fatigue measures were not different between groups, but vigor was highest for all exercises at 70% 1RM compared to the 15% 1RM and control groups both during and after exercise. Due to a lack of consistent research methods, these results have not been confirmed and require further studies to confirm the impact of resistance training on fatigue and mood. The benefits of exercise on fatigue is suggested to be mediated by the length of exercise bouts; for instance, 20 minutes of acute exercise reduces anxiety, but over one hour of exercise causes fatigue symptoms [40]. One possible consideration is that heat stress causes more fatigue, and when performing acute physical activity there is significantly less heat stress than when engaging in long bouts of intense exercise [27].

Research suggests that exercise can have immediate benefits by improving energy levels, mood, and cognition [6,27,30,33,37,38]. On the other hand, increased mental activity and improved mood states are associated with increased glucose metabolism, which would occur after eating a snack [25]. A high-calorie snack also yielded similar benefits while a low-calorie snack did not [21], showing the dynamic nature of this topic and need for continued research to establish guidelines for caloric and sugar intake to improve cognition and mood. In the meantime, due to the current sedentary and overweight nature of society, exercise should always be recommended for its health benefits as well as possible mood and cognitive performance improvements. Additional indirect benefits to health such as attenuating food cravings [41], reversing fatigue [1,33], and positively affecting mental health [42,43] also add to the health impact of incorporating exercise daily, especially in work or school settings.

METHODS

Participants

A total of 17 male and female sedentary adults (18-36 years old) were recruited locally through flyers and emails. Participants included college students and young adults who were considered sedentary as defined by the American College of Sports Medicine (ACSM). This means that participants did not perform at least 150 minutes of moderate intensity exercise in at least 10-minute bouts each week for the past three months [44]. A 3-Day Physical Activity Recall was used to determine activity level [45] prior to participation in this investigation. Participants completed questionnaires to exclude for learning disabilities, attention disorders, depression or other mental conditions that affect mood, dietary restrictions, cardiovascular or metabolic diseases, pregnant, or smokers. This study was approved by the Institutional Review Board at the university where research took place. All participants were informed of the purpose and risks of this study verbally and asked to sign an informed consent form prior to participating in the study. There was no compensation for participating, and participants could drop out of this investigation at any time.

Study Design

This study employed a crossover within group design. Subjects were assigned to either the snack or exercise group in a randomized order with one week between testing conditions. Prior to testing, participants came to the laboratory to be screened for physical activity, complete the Physical Activity Readiness Questionnaire (PAR-Q), and have measurements of height, weight, resting heart rate, and resting blood pressure taken. Subjects then completed a familiarization session utilizing the cognitive tests to help prevent a learned effect and asked to perform an incremental exercise test to determine intensity for subsequent testing. Subjects wore a chest strap heart rate monitor (Polar T61 Coded, Finland) fitted around the body at the base of the sternum and referred to the Borg Rate of Perceived Exertion (RPE) for subjective perceived exertion scores during testing [46]. Before the incremental exercise test participants sat quietly for five minutes in order to reach a resting heart rate.

Testing Protocol

On testing days, participants came to the lab and remained for the full two hours of testing. Both testing sessions were done on the same day of the week and at the same time of day. Participants were instructed to aim for the same amount of sleep prior to each testing day, eat the same meals for breakfast and lunch on both testing days and provide the details of their meal to researchers.

Subjects began with a mood questionnaire, then blood glucose was measured followed by the cognitive tests. Measurements were repeated at 30 minutes, one hour, and two hours post. Between measurements the subjects watched a documentary provided by the researchers.

Initial Visit

Blood Glucose

Blood glucose levels were measured using a blood glucose meter (Bayer Contour, Bayer Corporation). The finger was first cleaned with an alcohol wipe then punctured with a lancet (MEDIpoint Stainless Steel, MEDIpoint manufacturing). The first drop of blood was wiped away then the next was used for testing. The test strip was inserted into the meter then lightly touched the drop of blood without touching the skin directly. After a five second countdown, the meter was read and the measurement recorded.

Mood

The Profile of Mood State (POMS) questionnaire is commonly used in clinical and research settings to measure current mood [47]. It has been adapted to a Short-Form that reduces the number of items from 65 to 30. This abbreviated version was created by the Educational and Industrial Testing Service (EDITS) and found to be more reliable at times than the original full-length POMS [48] while still measuring the same six subscales- Tension (TEN), Depression (DEP), Anger (ANG), Vigour (VIG), Fatigue (FAT), Esteem-Related Affect (ERA), and Confusion (CON). Each item uses an adjective to describe the mood state and participants rate the items on a scale from 0 (not at all) to 4 (extremely) based on their current feelings. To score the questionnaire, the ratings for each item in each subscale are added together with the ERA items reverse-scored.

OSPAN

The operation-word-span task (OSPAN) was developed by Turner and Engle [49] to measure memory and attention. OSPAN is a complex span task, meaning there is a primary (memory span) and a distracting secondary (arithmetic problems) task which allows for greater application to a variety of activities. A computer-generated OSPAN task was used for this study [50]. On the computer, subjects were given a series of basic math problems and then read a random letter after each problem (i.e. (6 / 2) - 1 =? J). First, there was a practice session of only letter spans where a series of two letters appeared one at a time on the screen then a matrix of letters were shown. The subject must recall the letters in the correct order. Next, there was math problem practice consisting of basic math problems to solve-once the subject had solved the problem, they were shown a number and must choose if this is the correct answer by clicking a “True” or “False” box on the screen. This practice session also gave an average estimated time to complete each math problem, which is then used in the actual OSPAN task. Finally, there was a short practice session of the letter span and math portions together. During the actual task, subjects were given their average time plus 2.5 SD to solve each equation or the computer automatically moved on and counted that problem as an error in order to keep participants focused on the math as much as the letters. Likewise, an 85% accuracy rate on the math problems was required to ensure the participant did not negate the problem. After each set the computer showed their percent accuracy in red on the top of the screen. Set sizes are the number of operation-letter spans and vary from 3-7 over the course of three trials, totaling 75 letters and 75 equations. Scoring includes the OSPAN score (total of all perfectly recalled sets), total number correct (total numbers recalled in correct position), and three types of errors made (math, speed, and accuracy).

Digit Span

This cognitive test measured attention as well as working memory capacity [51]. The test was performed on a computer in the lab using an open-access online version of the test. A series of digits were shown one at a time on the computer screen then participants were asked to recall the digits. The first session was a forward-span, or a recall of the digits in the order they appeared, then the second session was a backward-span, or a recall of the digits in the reverse order of which they appeared. After each correct response, the number of digits given increases by one. When an incorrect response is given (a digit is missing or given in the wrong order), the number of digits stays the same for the next trial.

The maximum number of digits correctly recalled and the correct number of trials were recorded.

Interventions

Exercise

Subjects walked on a Woodway treadmill (Woodway, Weil am Rhein, Germany) for ten minutes at a self-selected pace that they labeled a 12-13 RPE. There was no warm up prior to exercising in order to align with real-world situations in which an individual would likely immediately begin the timed walk.

Sugary Snack

Each subject was given a packet of M&Ms (1.69 oz (47.9g), 240 calories, 30g sugar, 34g total carbohydrates) as the sugar snack.

Statistical Analysis

Two-way analyses of variance (ANOVA) compared condition (walking and snack) and time (pre-test, 30 minutes post, 60 minutes post, and 120 minutes post). The dependent variables were blood glucose, POMS Total Mood Disturbance (TMD), POMS energy score, OSPAN scores (Absolute, Total, Math Accuracy Errors (MAE), Math Speed Errors (MSE)) and Digit Span (DS) scores (Forward (FWD) Max, FWD Correct, Backward (BWD) Max, BWD Correct). Separate one-way ANOVA was used as post-hoc tests. A Wilcoxon signed ranks test analyzed

Likert-scaled data from the POMS. Apriori α was set at < 0.05. Pearson correlations were used to determine the existence of relationships between blood glucose to all other dependent variables. Statistical analysis was performed using SPSS 25 (IBM SPSS Statistics, New York).

RESULTS

Participant demographic data is presented in Table 1. Results of two-way ANOVA over time revealed no significant differences in the OSPAN Absolute (Figure 1, p=0.121) or OSPAN Total scores (Figure 2, p=0.078). Math accuracy and speed errors during the OSPAN also showed no significant difference over time or between conditions (Figure 3, p=0.685; Figure 4, p=0.841, respectively). FWD Correct (Figure 5) and BWD Max (Figure 6) did not have significant differences over time or between conditions, but there was a significant main effect for conditions over time in BWD Correct (Figure 7, p=0.023) and FWD Max (Figure 8, p=0.034). For FWD Max there was a main effect for time (p=0.046). Post hoc comparisons for FWD Max indicated differences between Pre and 60 MIN and between Pre and 120 MIN post (p=0.001 & 0.014, respectively). A paired samples t-test showed a significant difference between groups at 60 MIN (Means: TW (9.35), Sugar (8.82), p= 0.046) but not 120 MIN (Means: TW (8.88), Sugar (9.18), p=0.096). Wilcoxon signed ranks test revealed no significant differences across conditions (p-values: TMD pre= 1.00; TMD 30 MIN= 1.00; TMD 60 MIN= 0.47; TMD 120= 0.535; Energy pre= 0.18; Energy 30 MIN= 0.28; Energy 60 MIN= 0.83; Energy 120 MIN= 0.83). Pearson was used to determine significant correlations between blood glucose and FWD Max, FWD Correct, TMD, OSPAN Total score, and OSPAN MAE as shown in Tables 2-9.

DISCUSSION

The results of the analysis of variance from participant performance on the OSPAN test did not reveal any significant differences in any measures across time. This finding is contrary to previous research that indicated food consumption could improve cognitive performance [21]. Moreover, an additional separate investigation found that accuracy on decision-making scenarios was not significantly different based on performance at rest or with exercise [37] which could support the lack of significance between the TW and Sugar conditions in the present investigation. Our findings are further supported by other research that did not demonstrate improvements in cognitive performance between exercise and non-exercising cohorts [33]. In a previous study performance on the backward DS task was significantly greater 15 minutes after consuming a confectionery product compared to a diet non-caffeinated soft drink [21], indicating the type of sugary snack can have different effects on cognitive performance. In the present study, the maximum number of digits reached during the forward and backward DS tests increased and decreased throughout the testing period, but only the FWD Max showed a significant change across time and between groups. Both the TW and Sugar groups showed improvement from pre-measures to 60 MIN that were significantly different at this time point. Correct spans on the backward DS test also had significant effects of condition over time.

The results obtained in the present investigation from the DS and OSPAN test performance results do not support each other, and this finding could be due to multiple factors. The OSPAN not only measures memory but also attention by adding the arithmetic as a distractor from the memorization of the letters. Therefore, memory could be affected while attention is not. This phenomenon could at least in part explain the lack of significant findings in the current investigation. In addition, an anecdotal observation from the present investigation was that participants often indicated a sense of relief upon completion of the OSPAN test and being allowed to move on to the DS task. This observation may support participants preference towards the DS test in this investigation, which may have influenced the outcomes. Specifically, this preference could have caused participants to work quickly and less carefully on the OSPAN in order to get to the ‘easier’ test, or influence the effort given on each task.

Thayer [6] also compared walking and snacking in 18 undergraduate students (age 19-38 years), finding a significant association with the increase in energy after walking compared to snacking. Snacking also appeared to produce an immediate significant increase in perceived energy followed by a subsequent decrease over time. Data from the present study does not support these findings, though; both interventions did result in a continuous decrease in energy which was not significantly different between groups. However, both studies lacked a control group for comparison of the normal rate of decline in energy over the course of the study period. To emphasize this point, previous research showed no significant improvements in mood were found when comparing a short 5-minute bout of walking on a treadmill to a one-time 30-minute exercise group, yet when compared to a non-exercising control group there was a significant improvement in mood after short duration exercise [33]. Additionally this study found no significant differences in perceived energy levels throughout the day when comparing the one-time exercise group to control, yet the group completing six bouts of 5-minute exercises throughout the day increased energy compared to both groups [33]. These findings suggest that a short-duration exercise similar to the one performed in the present study can improve energy, and although not confirmed here, this potential phenomenon warrants further investigation.

Chocolate specifically has been shown to improve mood states [12] and though our study showed a greater mood disturbance after consuming chocolate M&Ms than TW, these differences were not statistically significant ($p>0.05$) and there was a significant but weak correlation between blood glucose and TMD in the Sugar intervention. Overall correlations between blood glucose and cognitive performance measures were weak, disproving the work of previous studies suggesting glucose can improve cognitive performance [26].

Limitations

The primary limitation of the study was the inconsistency between subjects in the meals eaten prior to testing. Although each participant was given a diet log to track their food amounts and times eaten the first testing day then told to repeat exactly for the second testing day, the amount and types of food consumed varied greatly. Instructing participants not eat or drink anything but water within two hours of testing and ensuring their meals were the same both testing days helped control for this variety. Future research should control for meals by setting macronutrient guidelines and ensuring all participants eat meals at a similar time. Another limitation was the time of day the testing was performed. Previous research has suggested that the time of day can affect cognitive performance and mood, as well as the effects of snacking [6,14,15,16,17]. A timing issue also occurred in that from pre to 30 MIN, and 60 MIN to 120 MIN there were approximately 30 minutes between finishing one round of measures and beginning the next round. However, there was only a 2-10 minute gap between finishing the round of 30 MIN measures and needing to begin the 60 MIN measures due to testing taking around 25 minutes total to complete, depending on the speed of the participant. This change in rest period could affect the differences across time. Lastly, the small sample size limited the results of this study.

Conclusion

The investigation into exercise and sugar or food consumption and the comparative effects on factors such as cognition and mood is relatively new and unexplored, yet the value is undeniable as fatigue and low productivity continue. Despite much attention in common culture, there is very little research into the psychological effects of acute sugar consumption or an acute bout of low intensity exercise and even less research comparing the two. While exercise would be the preferred recommendation from a health standpoint, research is needed to support this assertion as well as provide details for exercise recommendations and the differences in types of sugary snacks. Future research should continue searching for significant differences between exercise and sugar consumption over longer periods of time, such as an entire day. Since no difference was found between sugar and exercise in the present study, it is worth recommending choosing exercise over sugar when desiring an improvement in mood or cognition. Various lengths, intensities and modes of exercise need to be studied to help define recommendations. Sugary snacks should also be compared to other types of snacks, such as healthy sweet or salty, to determine a difference based on micronutrient content or expectation biases. Additionally, it is worth investigating possible confounding factors such as the time of day testing is completed or snacks and exercise are done, and if aerobic fitness levels attenuate cognitive responses.

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Table 1. Participant Descriptives (*n=17*)

	Mean ± SD
Age (years)	23 ± 5
Height (m)	1.7 ± .1
Weight (kg)	85 ± 26
BMI (kg/m²)	30 ± 8
Walking Speed (mph)	3.1 ± 0.4

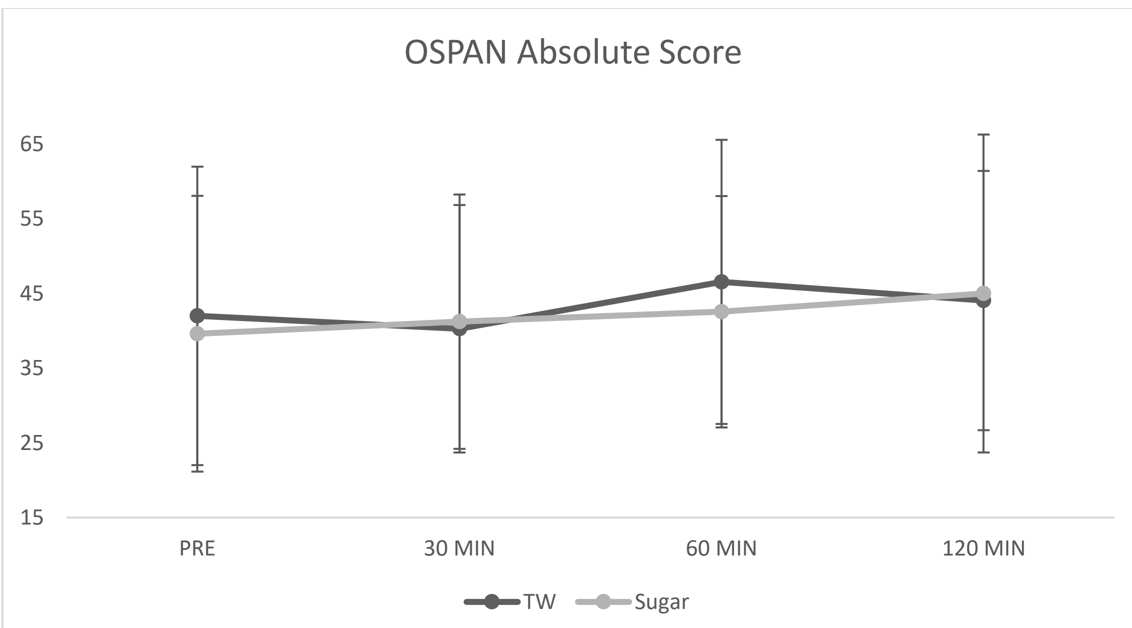

Figure 1. TW= treadmill walk. Number of letters recalled in perfect sets during the Automated Operation Span task (OSPAN). *n=17*

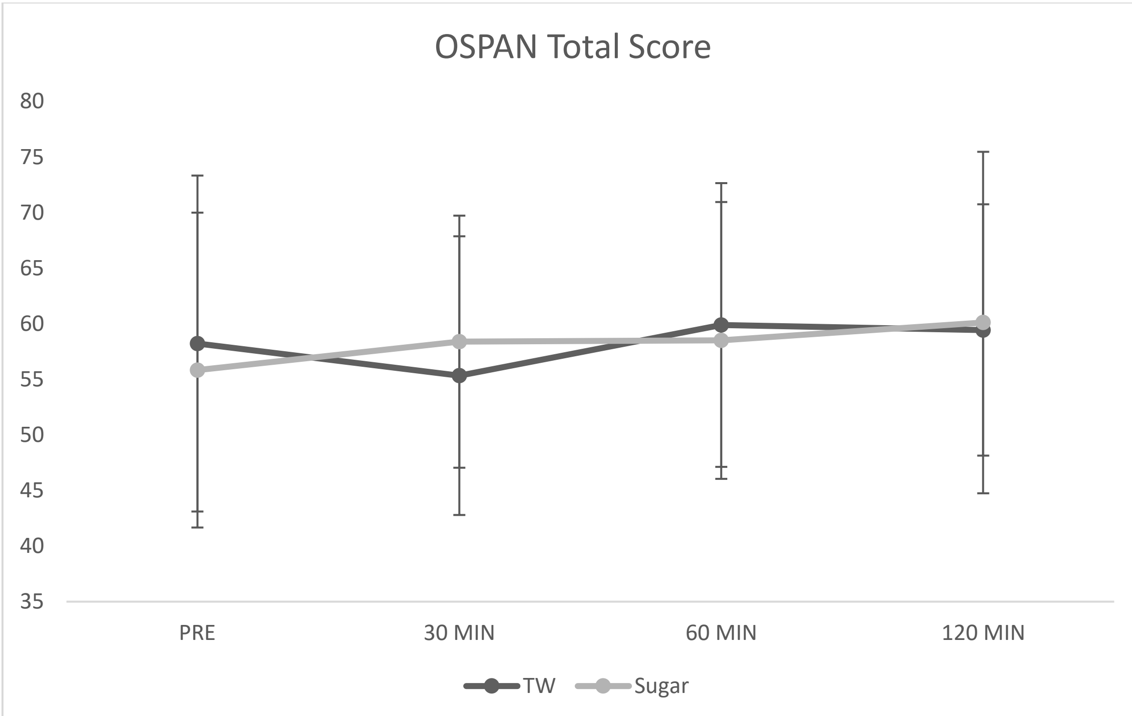

Figure 2. TW= treadmill walk. Total number of letters recalled correctly during the Automated Operation Span task (OSPAN). *n=17*

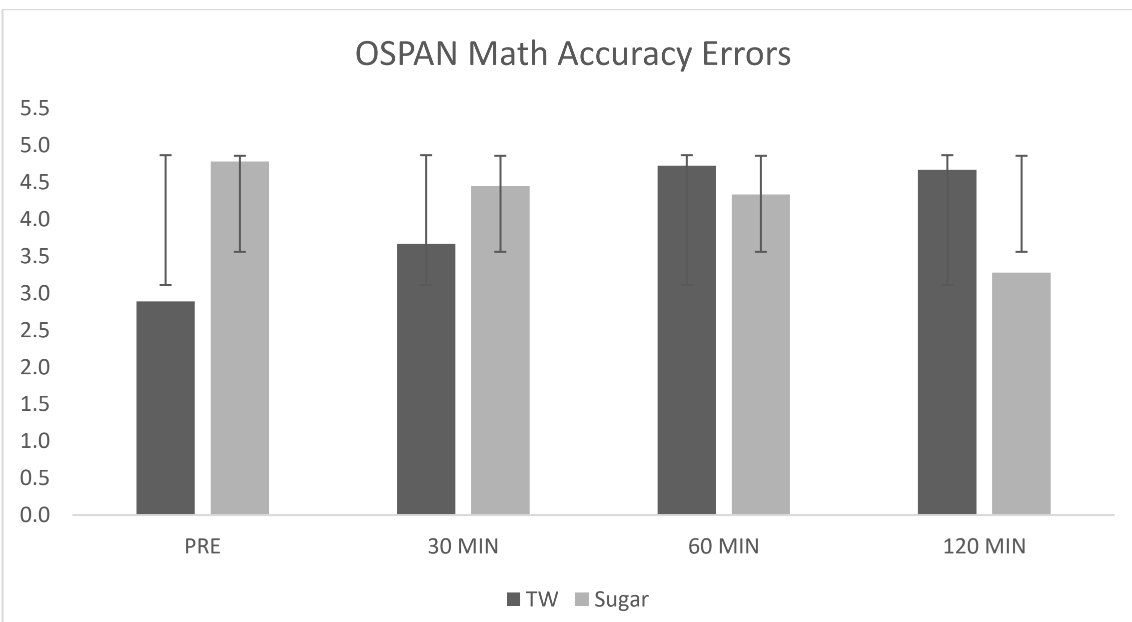

Figure 3. TW= treadmill walk. Number of incorrectly answered arithmetic problems in the Automated Operation Span task (OSPAN). *n=17*

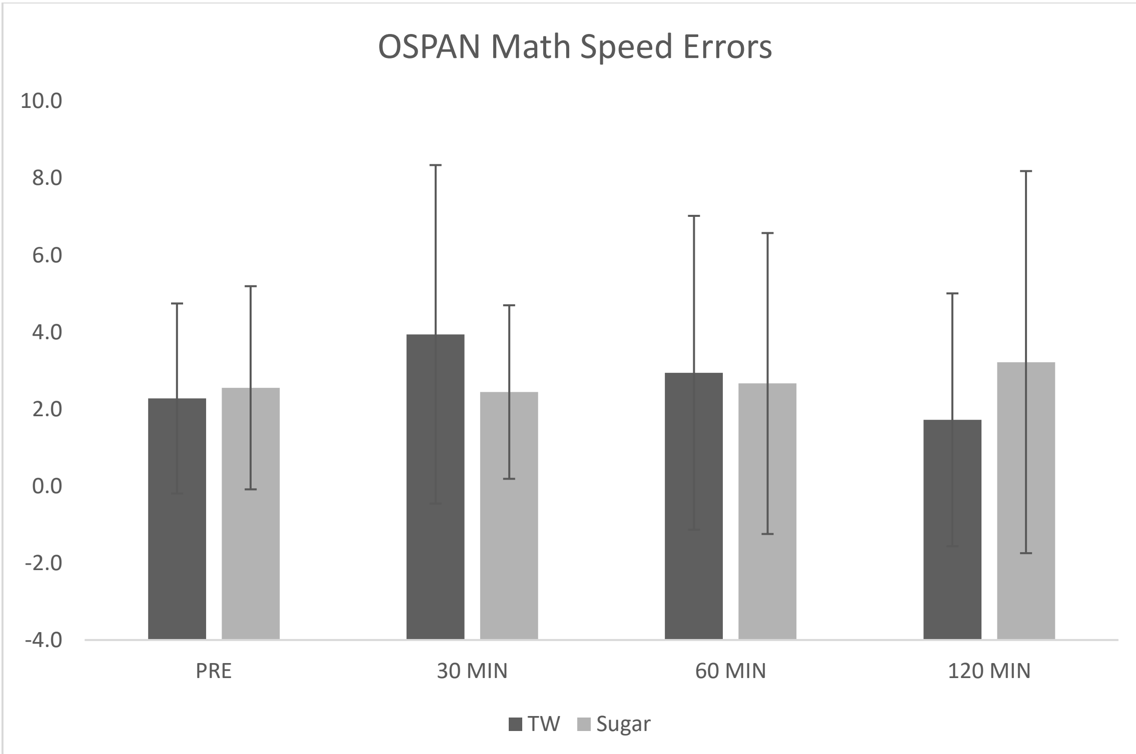

Figure 4. TW= treadmill walk. Performance on the arithmetic problems in the Automated Operation Span task (OSPAN). During a practice session before each test, the program averages the time taken to answer each math problem then sets this as a time limit to answer questions during testing. *n=17*

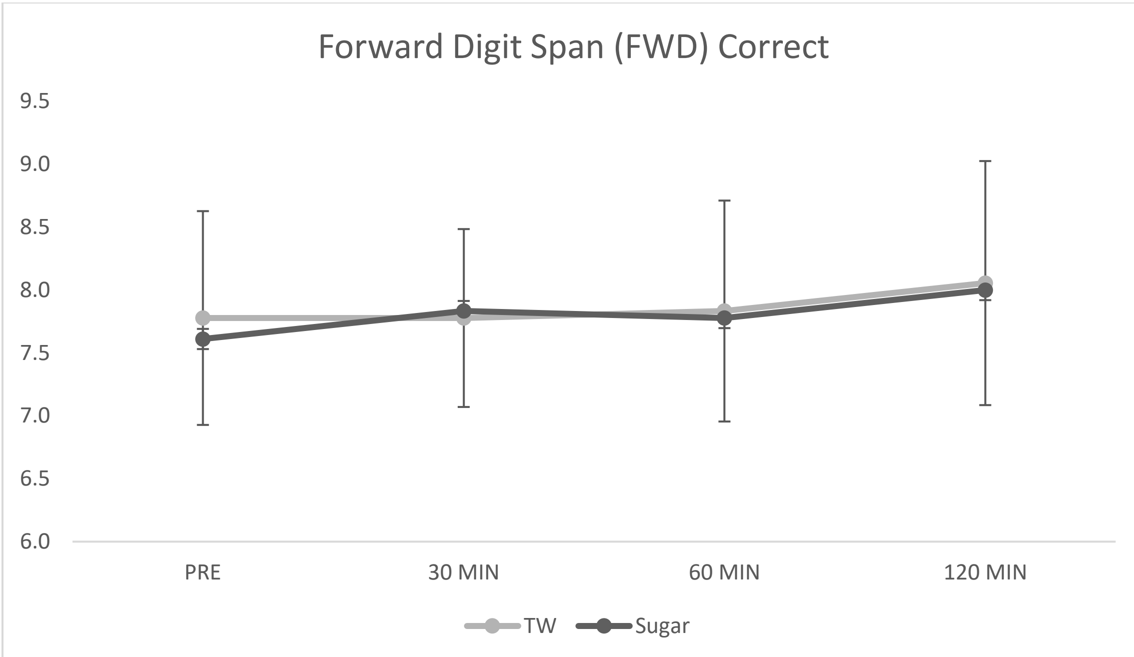

Figure 5. TW= treadmill walk. Number of correctly recalled digit spans during the forward-order recall portion of the Digit Span task. *n=17*

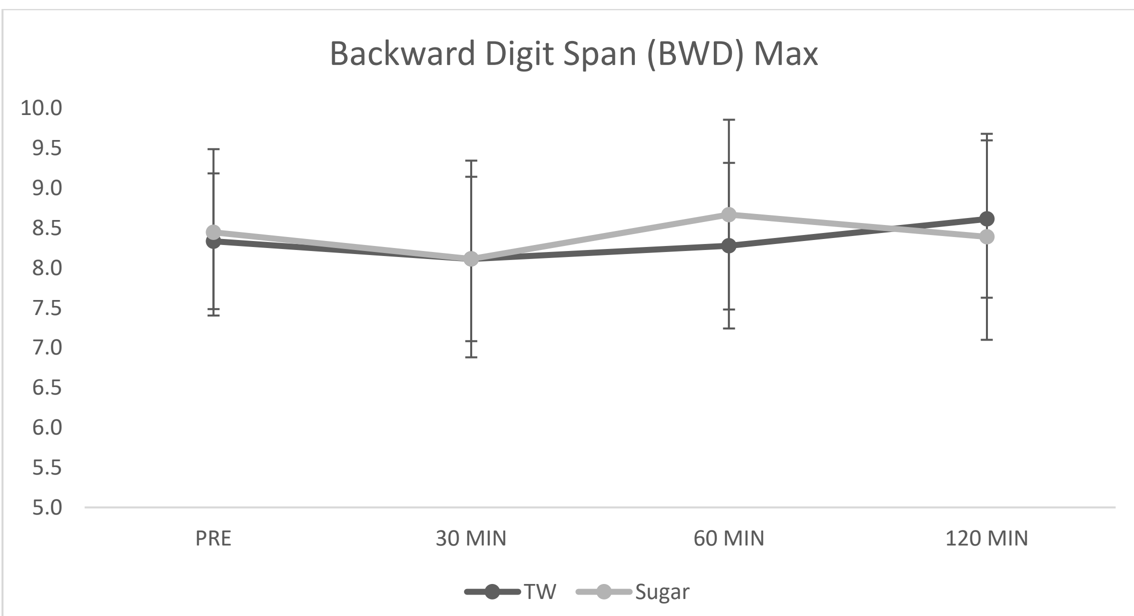

Figure 6. TW= treadmill walk. Maximum length of the digit span reached during the reverse-order recall portion of the Digit Span task. *n=17*

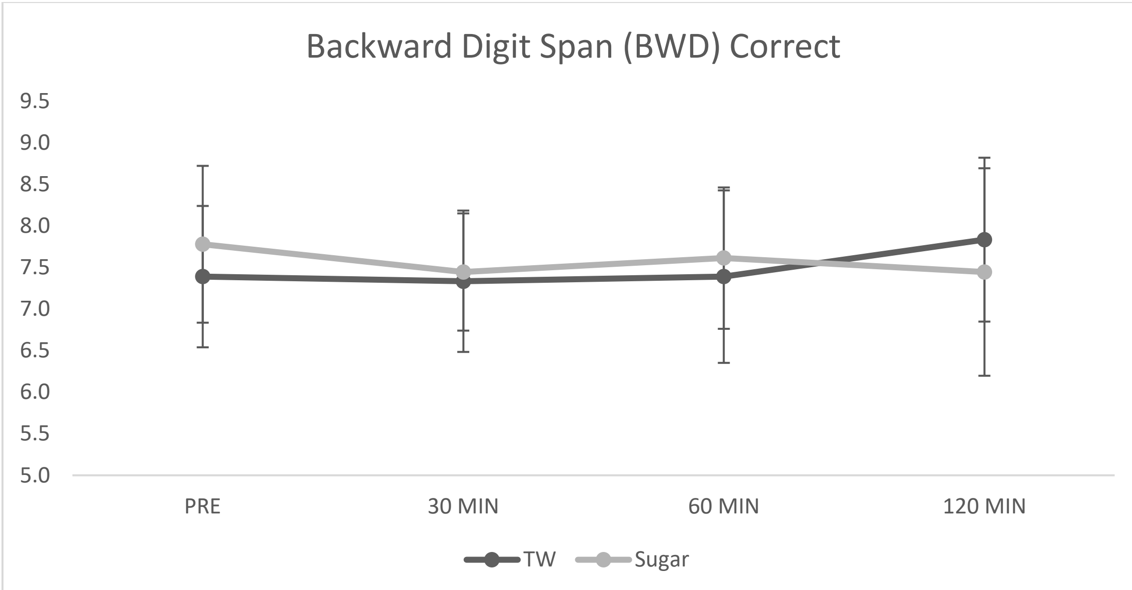

Figure 7. TW= treadmill walk. Number of correctly recalled digit spans during the reverse-order recall portion of the Digit Span task. *n=17*

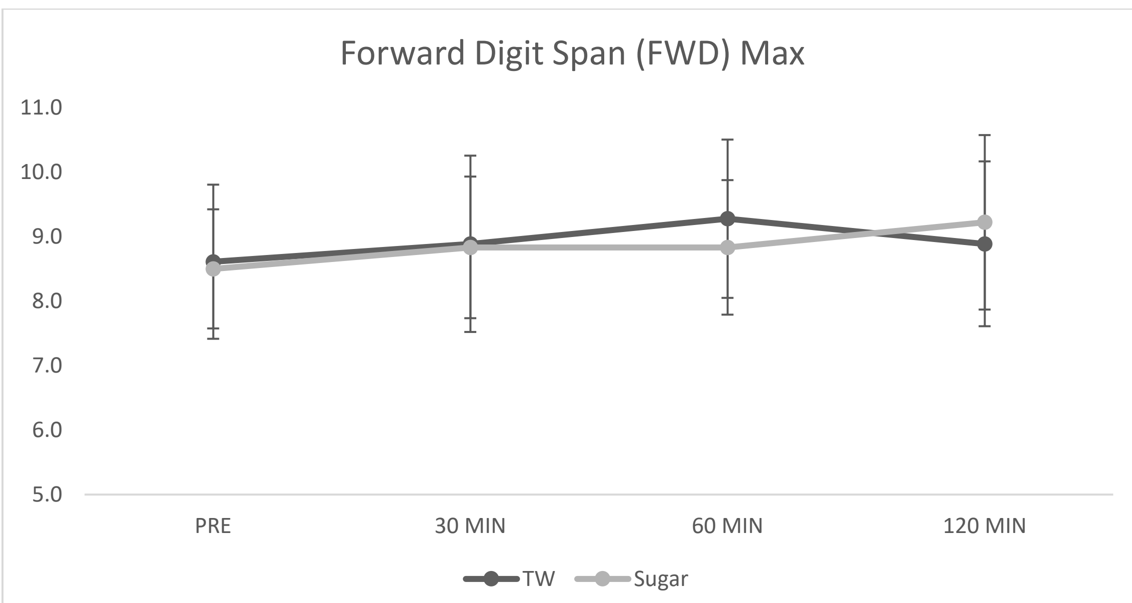

Figure 8. TW= treadmill walk. Maximum length of the digit span reached during the forward-order recall portion of the Digit Span task. *n=17*

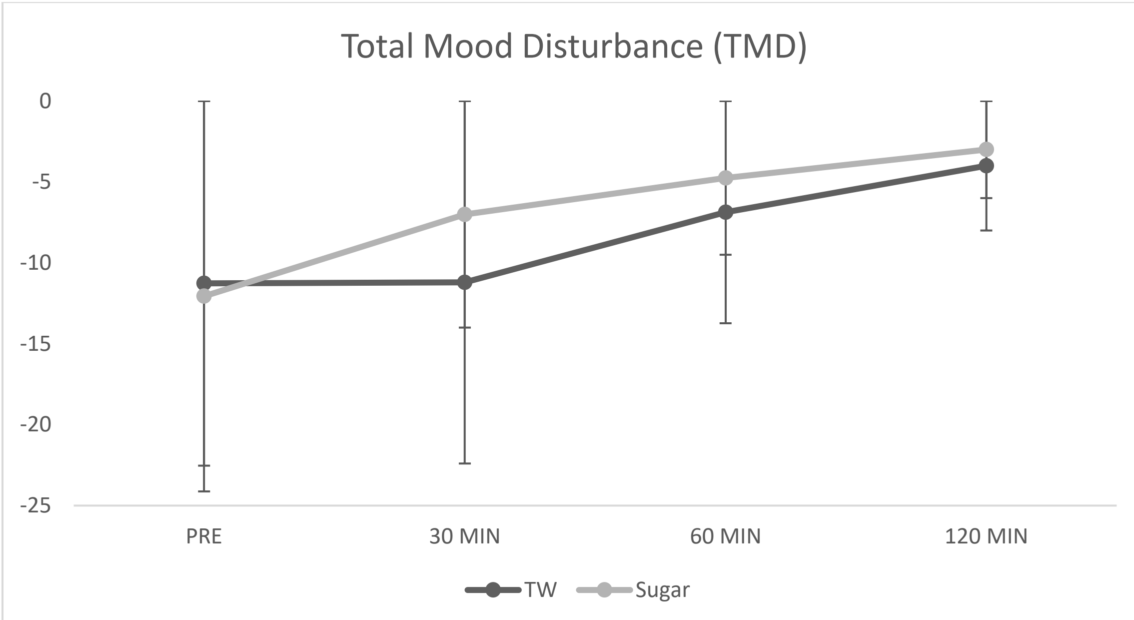

Figure 9. TW= treadmill walk. Total Mood Disturbance (TMD) measured by the Short-Form Profile of Mood State Questionnaire (POMS). *n=17*

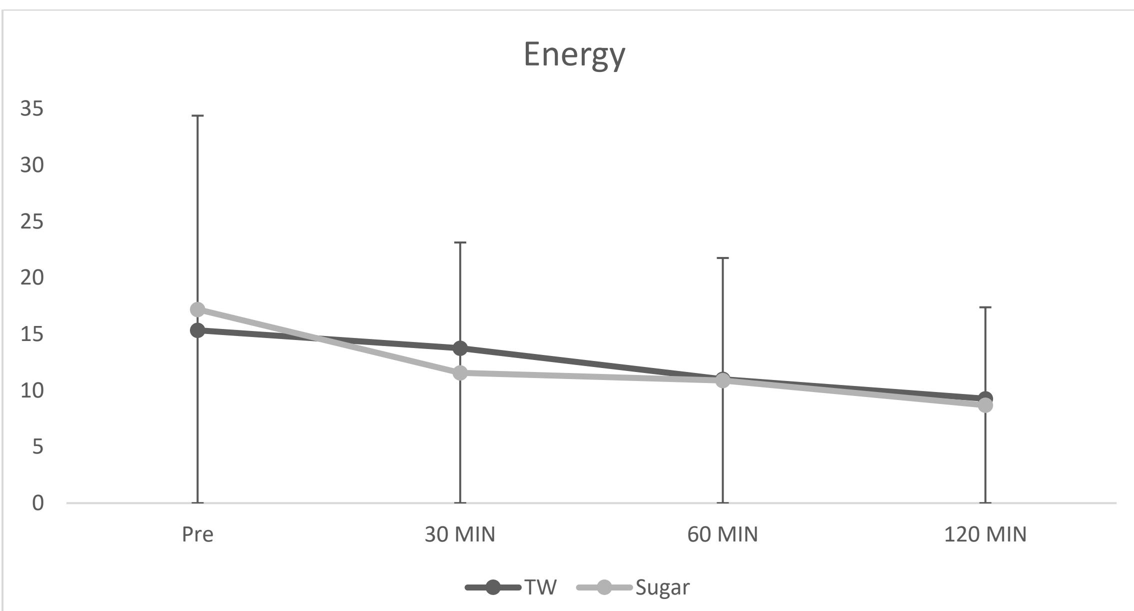

Figure 10. TW= treadmill walk. Perceived energy levels as measured by the difference in positive mood scores and fatigue scores in the Short-Form Profile of Mood State Questionnaire (POMS). *n=17*

Table 2. Results of Pearson Correlation Analysis of measurements pre 10-minute treadmill walk (*n=17*)

	AB	TO	MAE	MSE	FM	FC	BM	BC	TMD	Energy
GLU	-0.171	-0.055	-0.263	-0.106	-0.280	-0.457	0.262	-0.053	0.151	-0.208
ABS	-	0.089**	-0.351	0.473	0.566*	0.382	0.595*	0.648**	0.126	-0.138
TO	-	-	-0.488*	0.370	0.273	0.137	0.541*	0.507*	0.078	-0.152
MAE	-	-	-	0.201	-0.141	-0.041	-0.630**	-0.385	-0.501*	0.466
MSE	-	-	-	-	0.156	-0.048	0.424	0.261	-0.391	0.368
FM	-	-	-	-	-	0.743**	0.380	0.548*	0.334	-0.138
FC	-	-	-	-	-	-	0.187	0.615**	0.264	-0.125
BM	-	-	-	-	-	-	-	0.646**	0.330	-0.288
BC	-	-	-	-	-	-	-	-	0.033	0.077
TMD	-	-	-	-	-	-	-	-	-	-0.938**

GLU=blood glucose; AB=OSPAN Absolute Score; TO=OSPAN Total Score; MAE=OSPAN Math Accuracy Errors; MSE=OSPAN Math Speed Errors; FM=Forward Maximum digits; FC=Forward Correct; BM=Backward Maximum digits; BC=Backward Correct; TMD=Total Mood Disturbance. *-correlation is significant at the 0.05 level. **-correlation is significant at the 0.01 level

Table 3. Results of a Pearson Correlation Analysis of measurements pre sugar consumption (*n=17*)

	AB	TO	MAE	MSE	FM	FC	BM	BC	TMD	Energy
GLU	-0.236	-0.276	0.134	0.109	-0.271	-0.359	0.131	0.037	-0.337	0.284
AB	-	0.893**	-0.444	-0.109	0.492*	0.647**	0.456	0.268	0.170	-0.198
TO	-	-	-0.426	0.159	0.622**	0.716**	0.609**	0.125	0.096	-0.073
MAE	-	-	-	0.145	-0.054	-0.069	-0.418	-0.174	-0.478	0.383
MSE	-	-	-	-	-0.045	-0.093	0.185	-0.465	-0.098	0.251
FM	-	-	-	-	-	0.815**	0.516*	0.554*	-0.302	0.242
FC	-	-	-	-	-	-	0.330	0.322	-0.206	0.078
BM	-	-	-	-	-	-	-	0.402	-0.054	0.226
BC	-	-	-	-	-	-	-	-	-0.316	0.371
TMD	-	-	-	-	-	-	-	-	-	-0.895**

GLU=blood glucose; AB=OSPAN Absolute Score; TO=OSPAN Total Score; MAE=OSPAN Math Accuracy Errors; MSE=OSPAN Math Speed Errors; FM=Forward Maximum digits; FC=Forward Correct; BM=Backward Maximum digits; BC=Backward Correct; TMD=Total Mood Disturbance. *-correlation is significant at the 0.05 level. **-correlation is significant at the 0.01 level

Table 4. Results of Pearson Correlation Analysis of measurements 30-minutes post 10-minute treadmill walk (*n=17*)

	AB	TO	MAE	MSE	FM	FC	BM	BC	TMD	Energy
GLU	-0.022	-0.009	0.138	-0.194	-0.224	-0.288	-0.126	-0.188	0.120	-0.147
AB	-	0.959**	-0.330	-0.167	0.440	0.591*	0.533*	0.471	0.107	-0.296
TO	-	-	-0.329	-0.086	0.399	0.547*	0.510*	0.407	0.092	-0.283
MAE	-	-	-	0.339	-0.206	-0.438	-0.485*	-0.500*	-0.329	0.335
MSE	-	-	-	-	-0.230	-0.210	-0.109	0-.206	0.018	0.064
FM	-	-	-	-	-	0.888**	0.465	0.434	0.098	-0.103
FC	-	-	-	-	-	-	0.546*	0.453	0.196	-0.266
BM	-	-	-	-	-	-	-	0.865**	0.152	-0.097
BC	-	-	-	-	-	-	-	-	0.212	-0.146
TMD	-	-	-	-	-	-	-	-	-	-0.943**

GLU=blood glucose; AB=OSPAN Absolute Score; TO=OSPAN Total Score; MAE=OSPAN Math Accuracy Errors; MSE=OSPAN Math Speed Errors; FM=Forward Maximum digits; FC=Forward Correct; BM=Backward Maximum digits; BC=Backward Correct; TMD=Total Mood Disturbance. *-correlation is significant at the 0.05 level. **-correlation is significant at the 0.01 level

Table 5. Results of a Pearson Correlation Analysis of measurements 30-minutes post sugar consumption (*n=17*)

	AB	TO	MAE	MSE	FM	FC	BM	BC	TMD	Energy
GLU	0.356	0.338	-0.520*	-0.324	0.016	-0.243	-0.062	-0.062	0.279	-0.268
AB	-	0.930**	-0.404	-0.105	0.444	0.365	0.427	0.092	0.202	-0.258
TO	-	-	-0.285	-0.068	0.581*	0.449	0.343	0.036	0.023	-0.134
MAE	-	-	-	0.263	0.036	0.186	-0.119	-0.010	-0.314	0.321
MSE	-	-	-	-	-0.119	0.106	0.145	0.289	-0.020	0.092
FM	-	-	-	-	-	0.765**	0.362	0.173	-0.121	0.028
FC	-	-	-	-	-	-	0.511*	0.230	0.012	-0.081
BM	-	-	-	-	-	-	-	0.674**	0.071	0.057
BC	-	-	-	-	-	-	-	-	-0.092	0.124
TMD	-	-	-	-	-	-	-	-	-	-0.936

GLU=blood glucose; AB=OSPAN Absolute Score; TO=OSPAN Total Score; MAE=OSPAN Math Accuracy Errors; MSE=OSPAN Math Speed Errors; FM=Forward Maximum digits; FC=Forward Correct; BM=Backward Maximum digits; BC=Backward Correct; TMD=Total Mood Disturbance. *-correlation is significant at the 0.05 level. **-correlation is significant at the 0.01 level

Table 6. Results of Pearson Correlation Analysis of measurements 60-minutes post 10-minute treadmill walk (*n=17*)										
	AB	TO	MAE	MSE	FM	FC	BM	BC	TMD	Energy
GLU	-0.186	-0.090	0.414	0.099	-0.550*	-0.666**	-0.156	-0.012	-0.040	.052
AB	-	0.981**	-0.259	-0.128	0.483*	0.360	0.408	0.262	0.468	-0.446
TO	-	-	-0.150	-0.097	0.481	0.308	0.446	0.289	0.492*	-0.452
MAE	-	-	-	0.557*	-0.336	-0.265	-0.272	-0.377	-0.363	0.469
MSE	-	-	-	-	-0.223	-0.207	-0.230	-0.258	-0.369	0.288
FM	-	-	-	-	-	0.689**	0.536*	0.381	0.147	-0.305
FC	-	-	-	-	-	-	0.441	0.188	0.040	-0.177
BM	-	-	-	-	-	-	-	0.746**	0.380	-0.415
BC	-	-	-	-	-	-	-	-	0.436	-0.461
TMD	-	-	-	-	-	-	-	-	-	-0.754**

GLU=blood glucose; AB=OSPAN Absolute Score; TO=OSPAN Total Score; MAE=OSPAN Math Accuracy Errors; MSE=OSPAN Math Speed Errors; FM=Forward Maximum digits; FC=Forward Correct; BM=Backward Maximum digits; BC=Backward Correct; TMD=Total Mood Disturbance. *-correlation is significant at the 0.05 level. **-correlation is significant at the 0.01 level

Table 7. Results of a Pearson Correlation Analysis of measurements 60-minutes post sugar consumption (n=17)										
	AB	TO	MAE	MSE	FM	FC	BM	BC	TMD	Energy
GLU	0.333	0.490*	-0.255	-0.343	-0.101	-0.220	0.214	0.177	0.541*	-0.460
AB	-	0.891**	-0.194	0.238	0.458	0.621**	0.258	0.423	-0.133	0.040
TO	-	-	-0.213	0.019	0.321	0.425	0.172	0.246	0.164	-0.194
MAE	-	-	-	0.192	-0.249	-0.127	-0.259	-0.239	-0.266	0.329
MSE	-	-	-	-	0.091	0.208	-0.133	0.221	-0.381	0.315
FM	-	-	-	-	-	0.727**	0.616**	0.720**	-0.023	-0.066
FC	-	-	-	-	-	-	0.543*	0.505*	-0.291	0.250
BM	-	-	-	-	-	-	-	0.737**	0.124	-0.065
BC	-	-	-	-	-	-	-	-	0.084	-0.113
TMD	-	-	-	-	-	-	-	-	-	-0.937**

GLU=blood glucose; AB=OSPAN Absolute Score; TO=OSPAN Total Score; MAE=OSPAN Math Accuracy Errors; MSE=OSPAN Math Speed Errors; FM=Forward Maximum digits; FC=Forward Correct; BM=Backward Maximum digits; BC=Backward Correct; TMD=Total Mood Disturbance. *-correlation is significant at the 0.05 level. **-correlation is significant at the 0.01 level

Table 8. Results of Pearson Correlation Analysis of measurements 120-minutes post 10-minute treadmill walk (*n=17*)										
	AB	TO	MAE	MSE	FM	FC	BM	BC	TMD	Energy
GLU	-0.308	-0.329	0.275	0.200	-0.506*	-0.447	-0.136	-0.262	-0.346	0.115
AB	-	0.894**	-0.196	-0.421	0.619**	0.502*	0.235	0.430	0.462	-0.491*
TO	-	-	-0.402	-0.460	0.484	0.332	0.181	0.386	0.367	-0.369
MAE	-	-	-	0.630**	-0.280	-0.030	0.080	-0.006	0.126	-0.112
MSE	-	-	-	-	-0.390	-0.032	0.251	0.174	-0.018	0.077
FM	-	-	-	-	-	0.742**	0.438	0.562*	0.460	-0.430
FC	-	-	-	-	-	-	0.672**	0.594*	0.648**	-0.628**
BM	-	-	-	-	-	-	-	0.795**	0.479	-0.592*
BC	-	-	-	-	-	-	-	-	0.265	-0.348
TMD	-	-	-	-	-	-	-	-	-	-0.896**

GLU=blood glucose; AB=OSPAN Absolute Score; TO=OSPAN Total Score; MAE=OSPAN Math Accuracy Errors; MS=OSPAN Math Speed Errors; FM=Forward Maximum digits; FC=Forward Correct; BM=Backward Maximum digits; BC=Backward Correct; TMD=Total Mood Disturbance. *-correlation is significant at the 0.05 level. **-correlation is significant at the 0.01 level

Table 9. Results of a Pearson Correlation Analysis of measurements 120-minutes post sugar consumption (n=17)										
	AB	TO	MAE	MSE	FM	FC	BM	BC	TMD	Energy
GLU	-.183	-.166	-.320	-.079	-.483*	-.527*	-.266	-.239	.100	-.168
AB	-	.952**	-.066	-.489*	.704**	.484*	.369	.232	.217	-.355
TO	-	-	.008	-.505*	.633**	.470	.397	.236	.197	-.303
MAE	-	-	-	.282	-.173	-.074	-.343	-.494*	-.493*	.443
MSE	-	-	-	-	-.426	-.398	-.307	-.004	-.104	.103
FM	-	-	-	-	-	.815**	.444	.452	.205	-.320
FC	-	-	-	-	-	-	.142	.196	.123	-.179
BM	-	-	-	-	-	-	-	.835**	.429	-.393
BC	-	-	-	-	-	-	-	-	.435	-.406
TMD	-	-	-	-	-	-	-	-	-	-.945**

GLU=blood glucose; AB=OSPAN Absolute Score; TO=OSPAN Total Score; MAE=OSPAN Math Accuracy Errors; MSE=OSPAN Math Speed Errors; FM=Forward Maximum digits; FC=Forward Correct; BM=Backward Maximum digits; BC=Backward Correct; TMD=Total Mood Disturbance. *-correlation is significant at the 0.05 level. **-correlation is significant at the 0.01 level

VITA

After completing her work at Lampasas High School, Lampasas, Texas, in 2013, Erica Knowles entered Stephen F. Austin State University at Nacogdoches, Texas. She received the degree of Bachelor of Science in Kinesiology from Stephen F. Austin State University in December 2016. In August 2017, she entered the Graduate School of Stephen F. Austin State University within the Department of Kinesiology, and worked as a Graduate Assistant in the department for two years. She received the degree of Master of Science in May 2019.

Permanent Address: 823 CR 3150
Kempner, TX 76539

Journal style: Physiology & Behavior

This thesis was typed by Erica G. Knowles