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FASTING PLASMA GLUCOSE AND HEMOGLOBIN A1C DIFFER BY GENDER AND RACE AMONG EMERGING ADULTS

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Healy et. al. Objective: To examine the relationship between, and disparities in, glycemic markers among emerging adults. **Methods**: A diverse group of emerging adults affiliated with a large university located in the Northeast of the US were recruited. Participants self-reported demographic information, and lipids and glycemic markers were assessed using a finger-stick screening with participants fasted for a minimum of 9-12 hours before blood sampling. **Results**: Data were collected from 217 participants (21±2 years). Regardless of gender or race, no statistically significant relationship was found between FPG and either HbA_{1C}. However, those of 'other' races were found to have significantly higher FPG and HbA_{1C} compared to non-Hispanic white participants, and gender differences in glycemic markers were only observed among non-Hispanic white participants. **Conclusions**: While limited by a relatively small sample size, findings reinforce the importance of recognizing racial differences in glycemic markers when diagnosing and treating diabetes given racial disparities were observed in otherwise healthy emerging adults.

Key Words: young adults; college students; diabetes; metabolic syndrome

INTRODUCTION

Diabetes is the seventh leading cause of death in the United States (U.S.) (Centers for Disease Control and Prevention [CDC], 2017a), and imposes a considerable financial burden on individuals and the healthcare system (American Diabetes Association [ADA], 2013). Nearly one in ten of adults in the U.S. have diabetes, a further third are considered pre-diabetic, and many more are undiagnosed (CDC, 2017b) demonstrating the importance of accurate and reliable testing.

Diabetes is most commonly diagnosed through blood glucose analyses. The two methods to test blood glucose are fasting plasma glucose (FPG) and glycated hemoglobin A1C (HbA_{1C}). FPG is the most common method and assesses short-term blood glucose levels (ADA, 2014a), whereas HbA_{1C} test is the preferred method of assessing long-term blood sugar levels. While both tests can provide an indication of whether individuals are characteristic of pre-diabetes, the nature of the relationship between HbA_{1C} and FPG remains unclear among otherwise healthy emerging adults.

Previous findings indicate that there is a linear or curvilinear relationship between FPG and HbA_{1C} among adults irrespective of race and diabetic status (Ramachandran et al., 2012; van 't Riet et al., 2010). However, it is well established that glycemic markers vary based on race (Bergenstal et al., 2017; Cavagnolli et al., 2017; Guo et al., 2014; Herman & Cohen, 2012) even among youth (Kahkoska et al., 2018; Willi et al., 2015). Such variations risk misdiagnoses of whether or not individuals have diabetes (Guo et al., 2014). Moreover, there is disagreement concerning the diagnostic criteria for FPG and HbA_{1C}. For example, HbA_{1C} diagnostic criteria, with ≥ 6.5% the most stringent criteria (ADA, 2014b), though evidence suggests that the optimal cut-off is closer to <6% (Kaur et al., 2020). At present, recommendations suggest accounting for medical history and existing medical conditions when considering glycemic goals, but race is not mentioned as a factor to consider when making decisions (ADA, 2014b).

Thus, when screening patients to diagnose diabetes, appreciation of glycemic marker variation is important for both accurate diagnoses and prescription of appropriate treatment (Sacks, 2011). Failure to acknowledge racial differences has potential to do harm (Herman, 2016; Selvin, 2016). As previous studies have mainly involved youth or older adults, it is important to examine the relationship between FPG and HbA_{1C} among otherwise healthy emerging adults. Thus, the purpose of this study was to examine the relationship between FPG and HbA_{1C} among emerging adults, and differences based on gender and race.

METHODS

Participants

Data were collected from individuals affiliated with a large university located in the Northeast of the US between September 2018 and March 2019. Students were recruited from general education health and wellness courses, with other students recruited via word of mouth (N=207). A variety of recruitment methods were required to achieve the necessary level of diversity to allow for investigation of differences based on race in a predominantly non-Hispanic white community. The remaining 10 participants were high school students, at least 18 years of age with a dual-enrollment affiliation to Pennsylvania State University, that were recruited from community outreach events. All participants provided informed written consent, and trained technicians administered tests. The Pennsylvania State University Institutional Review Board approved this study.

Protocol

Upon consenting to participate, participants completed a questionnaire that encompassed demographics and past medical history. The questionnaire served as a screening tool, before participants proceeded to the phlebotomy area where finger prick tests were administered. Participants were instructed to abstain from food and caffeine for eight hours, alcohol for 24 hours, and smoking and exercise for at least two hours prior to testing. Participants reporting one or more adverse condition that could influence red blood cell count were excluded from analyses.

Measures

Demographics. Participants self-reported their demographics, including age, gender, and race.

Medical/health history. Participants responded (yes/no) to 10 items regarding past medical/health history that may influence primary variables within the study (glucose, HbA1c). Six items pertained to whether participants had ever been told they had the following conditions that could affect red blood cell lifespan and therefore HbA1C: anemia, sickle cell anemia, iron deficiency, or hemolytic anemia, diabetes mellitus (type 1 or 2), abnormally functioning spleen (World Health Organization [WHO], 2011). Another item asked whether participants were currently receiving iron replacement therapy. Two further items asked whether they had had a recent (3 months) blood transfusion or their spleen removed. The final item asked whether they had a family history of diabetes.

Lipids and glycemic markers. Participants underwent a lipid-glucose test and HbA_{1C} test administered via finger prick. Blood was collected via fingerstick. The finger was cleaned with alcohol and allowed to air dry. Using a single use lancet, the finger was pricked and a drop of blood was allowed to form on the finger. This initial drop of blood was wiped away and 40 microliters of blood was collected into a capillary tube for lipid and fasting plasma glucose measurement with the Cholestech LDX. An additional 5 microliters of blood were collected into the A1cNow+ collection device for determination of HbA1c using this device. In participants undergoing a second HbA1c measure, an additional 1 microliter of whole blood was collected into the Seimens DCA Vantage collection device.

An Alere Cholestech LDX System analyzer (Abbot Labs, Chicago, IL) was used to perform a lipid profile, cholesterol, and glucose assessment of the bloodstream. The Cholestech machine was calibrated prior to each testing session. Additionally, a commercially available A1cNow+ System (Polymer Technology Systems [PTS] Diagnostics, Indianapolis, IN) was used to provide HbA_{1C} readings. Five months into the study, a second HbA_{1C} instrument, the DCA Vantage Analyzer (Seimens Medical Solutions USA, Inc.), was purchased with a university approved grant and incorporated as a second HbA1c measurement into the study. This DCA was included given its well-established clinical accuracy (Lenters-Westra & Slingerland, 2010). About a third of participants received all three tests (one lipid-glucose profile, and both HbA_{1C} tests), while the remainder received the initial standard protocol of one lipid-glucose and one HbA_{1C} test. Both the DCA Vantage Analyzer and PTS Diagnostics A1cNow+ instruments calculate glycosylated hemoglobin scores according to the following equation: % HbA_{1C} = (HbA_{1C} /Total Hemoglobin) x 100 (Seimens Medical Solutions USA, Inc.). Neither require calibration. A retest was conducted in instances when a value was outside of the detectable range.

Statistical Analyses

Descriptive statistics were computed to characterize the sample. Pearson correlation coefficients were computed to examine the relationship between blood glucose measures. Independent sample t-tests were used to examine differences in fasting plasma glucose, HbA_{1C} (from PTS and DCA machines), total cholesterol (TC), high-density lipoprotein (HDL), low-density lipoprotein (LDL), and triglycerides based on gender and race separately. For race, participants were grouped into those identifying as either non-Hispanic white or 'other races' due to the small sample size. All analyses were run using SPSS 26.0 (IBM, Armonk, NY), with significance levels set at $p < .05$.

RESULTS

Participant Characteristics

The mean age of the two hundred and seventeen emerging adults participated in the study was 21±2 years. The majority identified as men (N=114, 52.5%), with the remainder identifying as women (N=103, 47.5%). The largest racial group was non-Hispanic white (N=117, 54%), followed by non-Hispanic Asian (N=44, 20%), Hispanic/Latinx (N=27, 12%), non-Hispanic African American (N=12, 6%), non-Hispanic Middle Eastern (N=11, 5%), and non-Hispanic mixed (N=6, 3%).

Relationships between glycemic markers

Among all participants, very weak non-statistically significant relations between FPG and both HbA_{1C} PTS and DC, and a moderate statistically significant relation between HbA_{1C} measures were revealed. Similar results were observed with respect to the relation between FPG and HbA_{1C} measures among those identifying as non-Hispanic white, but the relation between HbA_{1C} measures was very weak and not statistically significant. Similar results were observed pertaining to the relation between FPG and HbA_{1C} measures among those identifying as other races, but the relation between HbA_{1C} measures was strong and statistically significant (Table 1).

Table 1.

Relationships (correlation coefficients) between glycemic markers separated by race

	PTS	DC
All		
FPG	0.083	0.007
PTS		.479*
Non-Hispanic White		
FPG	0.151	-0.095
PTS		0.069
Other Races		
FPG	-0.053	0.033
PTS		.749*

Note. * < 0.05

Differences based on gender and race

Compared to women, men reported significantly lower HDL (moderate to large difference), higher LDL (small to moderate difference), lower triglycerides (moderate difference), higher glucose (moderate difference), and lower HbA1C DCA (moderate difference). Similar results were observed when examining differences between men and women identifying a non-Hispanic white. By contrast, when examining gender differences among those identifying as other races, similar findings to the overall sample were observed with the exception of triglycerides, fasting plasma glucose, and HbA1C PTS for which there were no statistically significant differences between genders. The only statistically significant differences between racial groups found was that participants of other races had moderately higher HbA1C PTS and HbA1C DCA compared to non-Hispanic white participants (Table 2).

Table 2.

Differences in lipids and glycemic markers based on gender and race

	Gender						Race					
	Men (n=114)		Women (n=103)		*p*	η^2	Non-Hispanic white (n=117)		Other races (n=100)		*p*	η^2
	M	SD	M	SD			M	SD	M	SD		
HDL (mg/dL)	52.3	13.7	65.1	19.9	< .001	0.12	57.9	18.2	58.9	18	.660	.00
LDL (mg/dL)	99.4	42.1	86.7	29.8	.020	0.03	91.8	36.9	95.4	37.9	.510	.00
Total cholesterol (mg/dL)	166.3	39.2	172.0	31.6	.230	0.01	165	36.4	173.6	34.9	.080	.01
Triglycerides (mg/dL)	88.3	41.9	115.8	64.4	< .001	0.06	95.5	48.5	108	61.9	.100	.01
FPG (mg/dL)	92.6	8.7	88.5	8.9	.001	0.05	89.6	9.4	91.8	8.4	.070	.01
HbA_{1C} PTS (%)	5.0	0.5	5.0	0.4	.770	0.00	4.9	0.4	5.2	0.5	< .001	.08
HbA_{1C} DCA (%)	5.3	0.2	5.4	0.2	.040	0.06	5.3	0.2	5.5	0.27	.020	.08

Notes. HDL = High Density Lipoprotein; LDL = Low Density Lipoprotein; TC = Total Cholesterol; FPG = Fasting Plasma Glucose; Hemoglobin A1C = HbA_{1C}

DISCUSSION

The purpose of this study was to examine the relationship between FPG and HbA_{1C} among emerging adults, as well as differences based on gender or race. In contrast to previous studies involving older adults (Ramachandran et al., 2012; van 't Riet et al., 2010), no relationship was found between FPG and either HbA_{1C} measure. This may be attributable to the age of the participants and/or the small sample size in the current study.

Consistent with previous research involving young adults, men had greater LDL and glucose, whereas women had greater HDL and triglycerides (Wilson et al., 2020). Men were also found to have higher levels of HbA_{1C} based on the DCA, but not the PTS, measure. However, gender differences in glycemic markers were only observed among non-Hispanic white participants, and not those identifying as other races. This may be attributable to non-Hispanic white individuals having lower HbA_{1C} levels compared to those of other races. In addition, findings indicate that disparities exist among otherwise healthy emerging adults, whereas previous research involved diabetic youth (Kahkoska et al., 2018; Willi et al., 2015).

This study is limited by a relatively small sample size and the inability to examine differences between specific racial groups, let alone disparities based on the intersection of gender and racial groups. However, given the otherwise healthy status participants in this study, findings further reinforce the importance of recognizing racial differences in glycemic markers when diagnosing and treating diabetes. Moreover, findings highlight the importance of adopting an individualized approach for diabetes diagnoses and treatment in an clinical setting (Selvin, 2016). Further research is required to further investigate the relationship between glycemic markers among young and/or healthy populations, as well as the influence that the intersection of gender and race have on glycemic markers and their relationship with one another.

CONCLUSION

While limited by a relatively small sample size, findings reinforce the importance of clinicians adopting an individualized approach to diagnoses and treatment of diabetes that facilitates recognition of racial differences in glycemic markers among emerging adults.

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REFERENCES

American Diabetes Association. (2013). Economic costs of diabetes in the U.S. in 2012. Diabetes Care, 36(4), 1033-1046. https://doi.org/10.2337/dc12-2625

American Diabetes Association. (2014a). Diagnosis and classification of diabetes mellitus. Diabetes Care, 37(Supplement 1), S81-S90.

American Diabetes Association. (2014b). Standards of Medical Care in Diabetes—2014. Diabetes Care, 37(Supplement 1), S14. https://doi.org/10.2337/dc14-S014

Bergenstal, R. M., Gal, R. L., Connor, C. G., Gubitosi-Klug, R., Kruger, D., Olson, B. A., Willi, S. M., Aleppo, G., Weinstock, R. S., Wood, J., Rickels, M., DiMeglio, L. A., Bethin, K. E., Marcovina, S., Tassopoulos, A., Lee, S., Massaro, E., Bzdick, S., Ichihara, B., Markmann, E., McGuigan, P., Woerner, S., Ecker, M., Beck, R. W., & Group, f. t. T. D. E. R. D. S. (2017). Racial differences in the relationship of glucose concentrations and Hemoglobin A1c Levels. Ann Intern Med, 167(2), 95-102. https://doi.org/10.7326/m16-2596

Cavagnolli, G., Pimentel, A. L., Freitas, P. A. C., Gross, J. L., & Camargo, J. L. (2017). Effect of ethnicity on HbA1c levels in individuals without diabetes: Systematic review and meta-analysis. PLoS One, 12(2), e0171315-e0171315. https://doi.org/10.1371/journal.pone.0171315

Centers for Disease Control and Prevention. (2017a). About underlying cause of death 1999–2017. http://wonder.cdc.gov/ucd-icd10.html

Centers for Disease Control and Prevention. (2017b). National Diabetes Statistics Report, 2017. https://www.cdc.gov/media/releases/2017/p0718-diabetes-report.html

Guo, F., Moellering, D. R., & Garvey, W. T. (2014). Use of HbA1c for diagnoses of diabetes and prediabetes: Comparison with diagnoses based on fasting and 2-Hr glucose values and effects of gender, race, and age. Metab Syndr Relat Disord, 12(5), 258-268. https://doi.org/10.1089/met.2013.0128

Herman, W. H. (2016). Are there clinical implications of racial differences in HbA1c? Yes, to not consider can do great harm! Diabetes Care, 39(8), 1458. https://doi.org/10.2337/dc15-2686

Herman, W. H., & Cohen, R. M. (2012). Racial and ethnic differences in the relationship between HbA1c and blood glucose: Implications for the diagnosis of diabetes. J Clin Endocrinol Metab, 97(4), 1067-1072. https://doi.org/10.1210/jc.2011-1894

Kahkoska, A. R., Shay, C. M., Crandell, J., Dabelea, D., Imperatore, G., Lawrence, J. M., Liese, A. D., Pihoker, C., Reboussin, B. A., Agarwal, S., Tooze, J. A., Wagenknecht, L. E., Zhong, V. W., & Mayer-Davis, E. J. (2018). Association of cace and ethnicity with glycemic control and Hemoglobin A1c levels in youth with Type 1 Diabetes. JAMA Netw Open, 1(5), e181851-e181851. https://doi.org/10.1001/jamanetworkopen.2018.1851

Kaur, G., Lakshmi, P. V. M., Rastogi, A., Bhansali, A., Jain, S., Teerawattananon, Y., Bano, H., & Prinja, S. (2020). Diagnostic accuracy of tests for type 2 diabetes and prediabetes: A systematic review and meta-analysis. PLoS One, 15(11), e0242415-e0242415. https://doi.org/10.1371/journal.pone.0242415

Lenters-Westra, E., & Slingerland, R. J. (2010). Six of eight hemoglobin A1c point-of-care instruments do not meet the general accepted analytical performance criteria. Clin Chem, 56(1), 44-52. https://doi.org/10.1373/clinchem.2009.130641

Ramachandran, A., Riddle, M. C., Kabali, C., & Gerstein, H. C. (2012). Relationship between A1C and fasting plasma glucose in dysglycemia or Type 2 Diabetes. Diabetes Care, 35(4), 749. https://doi.org/10.2337/dc11-1918

Sacks, D. B. (2011). A1C versus glucose testing: A comparison. Diabetes Care, 34(2), 518. https://doi.org/10.2337/dc10-1546

Selvin, E. (2016). Are there clinical implications of racial differences in HbA1c? A difference, to be a difference, must make a difference. Diabetes Care, 39(8), 1462. https://doi.org/10.2337/dc16-0042

van 't Riet, E., Alssema, M., Rijkelijkhuizen, J. M., Kostense, P. J., Nijpels, G., & Dekker, J. M. (2010). Relationship between A1C and glucose levels in the general Dutch population: The new Hoorn study. Diabetes Care, 33(1), 61-66. https://doi.org/10.2337/dc09-0677

Willi, S. M., Miller, K. M., DiMeglio, L. A., Klingensmith, G. J., Simmons, J. H., Tamborlane, W. V., Nadeau, K. J., Kittelsrud, J. M., Huckfeldt, P., Beck, R. W., & Lipman, T. H. (2015). Racial-ethnic disparities in management and outcomes among children with Type 1 Diabetes. Pediatrics, 135(3), 424. https://doi.org/10.1542/peds.2014-1774

Wilson, O. W. A., Kamara, K., Papalia, Z., Bopp, M., & Bopp, C. M. (2020). Changes in hypertension diagnostic criteria enhance early identification of at risk college students. Translational Journal of the American College of Sports Medicine, 5(1). https://doi.org/10.1249/TJX.0000000000000114

World Health Organization. (2011). *Use of glycated haemoglobin (HbA1c) in diagnosis of diabetes mellitus: Abbreviated report of a WHO consultation*.

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TWELVE WEEKS OF OCCLUSAL SPLINT TREATMENT REDUCES BLOOD PRESSURE RESPONSES TO HYPERTENSIVE STIMULI IN THOSE WITH SLEEP BRUXISM

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Sabella M. & Jarvis S. Sleep bruxism (SB) is associated with increased sympathetic tone, a risk for the future development of hypertension. It is unclear whether those with SB would demonstrate exaggerated responses to hypertensive stimuli and whether treatment with an occlusal splint could mitigate these responses. **Objectives**: This study compared hemodynamic responses to the cold pressor test (CPT) and static handgrip (SHG) to fatigue between controls (CON) and those with SB to determine whether those with SB have exaggerated responses. **Methods**: Nineteen subjects (9 CON, 10 SB) had heart rate (HR) and blood pressure (BP) responses measured during a CPT and SHG with post-exercise circulatory arrest (PECA). SB subjects underwent a 12-wk occlusal splint intervention followed by a repeat of the experimental protocol. **Results**: No BP differences existed with pre- (PRE) vs. post-intervention (POST) in the SB subjects. CPT induced larger ΔSBP (10±10 vs. 19±7 mmHg; $p < 0.05$) and ΔDBP (8±8 vs. 17±9 mmHg; $p < 0.05$) in SB subjects compared to CON. POST had attenuated ΔSBP (15±9 vs. 8±5 mmHg; $p < 0.03$) and ΔDBP (18±10 vs. 8±6 mmHg; $p < 0.05$) during CPT. SB subjects experienced greater ΔDBP (21±11 vs. 31±8; $p < 0.05$) during SHG which was not different during POST. **Conclusions**: SB individuals may be at increased risk for the development of hypertension based on exaggerated BP responses to hypertensive stimuli. Twelve weeks of occlusal splint treatment attenuated some of these responses.

Key Words: sympathetic tone, hypertension, cold pressor test, static handgrip to fatigue, sleep bruxism, controls, post-exercise circulatory arrest

INTRODUCTION

Approximately 8% of the general adult population is affected by sleep bruxism (SB) (Lavigne, Kato, Kolta, & Sessle, 2003), a sleeping disorder characterized by nocturnal teeth grinding. SB is associated with enhanced daytime sympathetic tone (Malpas, 2010), as well as surges in sympathetic activity that precede SB episodes in the form of brief awakenings termed microarousals (Nashed et al., 2012). Microarousals can occur spontaneously or be triggered through external stimuli (Satoh & Harada, 1973). Regardless of the origin, there exists a shift in sympathovagal balance towards sympathetic dominance during these episodes (Huynh et al., 2006). Heart rate (HR) and blood pressure (BP) increase, likely due to the pressor response created by the forceful bite (Okada et al., 2009). It has been proposed that the trigeminocardiac reflex is initiated to lower sympathetic cardiovascular responses (Schames, Schames, Schames, & Chagall-Gungur, 2012). For example, manipulation of the trigeminal branches during SB lead to vagal stimulation, thus countering the sympathetic activation prior to SB (Lang, Lanigan, & van der Wal, 1991).

Individuals with elevated sympathetic activity have demonstrated exaggerated responses to tests that expose them to a hypertensive stimulus, such as the cold pressor test (Wood, Sheps, Elveback, & Schirger, 1984). These responses identify individuals that are increased risk for the future development of hypertension and cardiovascular events (Wood et al., 1984). For example, long-term follow-up studies have shown that individuals with hyper-reactive BP responses during childhood or their younger years were associated with the future development of hypertension (Chaney & Eyman, 1988; Kasagi, Akahoshi, & Shimaoka, 1995; Menkes et al., 1989; Wood et al., 1984).

Occlusal splints, commonly used to treat SB, are known to decrease electromyographic (EMG) activity in the jaw muscles that are associated with SB episodes (Amorim, Vasconcelos Paes, de Faria Junior, de Oliveira, & Politti, 2012). Occlusal splint treatment has been reported to show improvement in aspects of sleep structure, such as increased slow wave activity sleep, which is inversely related to hypertension (Fung et al., 2011; Sjoholm, Kauko, Kemppainen, & Rauhala, 2014). However, it is also unclear whether wearing an occlusal splint may inhibit the beneficial parasympathetic influence of the trigeminocardiac reflex by preventing manipulation of the mandibular branch. Use of this splint has been shown to lower maximal bite force contraction and EMG to the masseter (Amorim et al., 2012). Blood pressure rises during sustained contractions of the masseter muscle. By inhibiting the muscle mechanoreceptor response created by the masseter, the increase in blood pressure would not occur.

The relationship between SB and cardiovascular risk factors is not clearly understood. Therefore, the objective of this study was to determine the relationship between SB and BP responses to hypertensive stimuli. It was hypothesized that individuals with SB would have an exaggerated BP response to the compared to the control subjects. it was also hypothesized that SB subjects would demonstrate improvements in BP responses after 12-wks of treatment with an occlusal splint.

METHODS

Subjects

Nineteen subjects (6 men, 13 women) gave written informed consent to participate in this study which was approved by the Institutional Review Board at Northern Arizona University. The study followed the guidelines set forth in the *Declaration of Helsinki*. Subjects were divided in the SB group (n = 10) and the control (CON) group (n=9). SB subjects were initially recruited from the university campus and the nearby community using flyers and mass emails. During the medical screening the participants filled out a questionnaire assessing their daily symptoms of sleep bruxism. Symptoms included headaches upon waking, pain in the location of the temporomandibular joint upon waking, tooth sensitivity, and if they were using substances, medically or recreationally, that could have been a factor in their sleep bruxism. Decisive inclusion in the study was determined by the subject's diagnosis by a dentist and whether or not the subject needed treatment, failing to do so was exclusionary. SB subjects could also already have an occlusal splint but been inconsistent with treatment (<2 nights per week). Inclusionary criteria were: ≥18 yrs, body mass index (BMI) ≤35 kg/m^2, no evidence of depression or neurological disorders, and no smoking or living with a smoker. Also, failing to be diagnosed by a dentist or use treatment was exclusionary. During screening, a detailed medical history was obtained, and a supine 12-lead resting electrocardiogram and BP measurement was performed.

Experimental Design

24-Hr Ambulatory Blood Pressure

Subjects with SB wore a 24-hr ambulatory BP monitoring device to confirm normotensive status for the study. BP via brachial artery was taken every 30 minutes during waking hours and every hour during sleep (Oscar 2, Morrisville, NC). The 24-hr ambulatory BP monitoring was repeated after the 12-wk occlusal splint intervention.

Study visits. Subjects arrived at the lab having fasted for ≥4 hrs. Subjects also avoided strenuous physical activity for ≥12 hrs and caffeine and alcohol for ≥48 hrs prior to the visit. The study visits included a cold pressor test (CPT) and static handgrip to fatigue (SHG) with post-exercise circulatory arrest (PECA). PECA was performed by occluding blood flow to the arm by inflating a blood pressure cuff to 250 mmHg. Prior to instrumentation the subject performed three maximal voluntary contractions with his/her dominant hand. The protocol was performed in the same order and under the same lab conditions during the second study visit.

Cold Pressor Test

Subjects laid in the supine position while beat-by-beat BP (Finometer MIDI, ADInstruments, Colorado Springs, CO) and heart rate (ECG module, ADInstruments, Colorado Springs, CO) were continuously measured. Following a 1 min baseline (BL), the cold pressor test was performed by submerging the hand in a 50:50 mixture of water and ice (2-4 C°) for 2 min, followed by a 3 min recovery (REC) period. BP via electrosphygmomanometry (SunTech Tango+, Morrisville, NC) was obtained during min 1 and 2 of cold pressor test and min 1 and 3 of REC.

Static Handgrip to Fatigue with Post Exercise Circulatory Arrest

The subject was required to maintain 30% of his/her maximal voluntary contraction until fatigue. Fatigue was defined as inability to maintain 80% of the desired force. A 2-min PECA began immediately following failure by inflating a BP cuff to 250 mmHg around the upper arm.

Intervention

After the PRE measurements were obtained, the SB subjects wore a nighttime occlusal splint prescribed by a dentist for 12-wks. Occlusal splints were made of hard acrylic resin and covered the entire arch of the teeth. Soft splints and nociceptive trigeminal inhibiting splints were not permissible. Subjects were queried at weeks 4 and 8 of the intervention to assess treatment compliance and if they were experiencing difficulties using their occlusal splints. Prior to the experimental protocol, the subjects were informed of the possible beneficial uses of using an occlusal splint, such as protection from chipping or fracturing teeth and possibly relief of tension type headaches. Information regarding effects on the cardiovascular system was limited to possible overall health references and quality of life increases due to decreases in pain.

Statistical analysis

Beat-by-beat BP and HR for BL were condensed into 1 min averages. Cold pressor test and REC were condensed into 30 sec averages. Static handgrip was divided into 5 even stages [20, 40, 60, 80, and 100% (fatigue)]. PECA was reduced to 1 min averages and REC for static handgrip was reported as 1 min averages.

All values are expressed as means ± SD. A repeated measures ANOVA [group (CON, SB) × stage] was used to compare BP and HR responses. For the cold pressor test, comparisons between BL, CPT1, CPT2, and REC were made. For the static handgrip to fatigue, comparisons between BL, fatigue (100%), PECA1, PECA2, and REC were made. T-tests were used to compare BP and HR changes (Δ) from BL between CON and SB groups during CPT1, CPT2, fatigue, PECA1, and PECA2. Paired t-tests were used to compare these differences PRE vs POST in the SB subjects. Significance was defined as $p < 0.05$.

RESULTS

Subject characteristics

Eight of the initial 10 SB subjects completed both PRE and POST visits. These subjects reported occlusal splint compliance of ≥5 nights per week throughout the intervention. None of these subjects reported discomfort related to the treatment or a need for refinement from any cause, such as soft tissue interference, during the check-up or on the day of the final experimental protocol, though one subject who did not complete the follow-up protocol reported removing the mouth guard during the night due to its excessive bulk.

There was no difference in age (CON: 19±1 vs SB: 22±5 yrs.), height (172±9 vs 168±10 cm), weight (66.7±10.7 vs 69.0±13.8 kg), or body mass index (22.8±2.5 vs 24.2±3.7 kg/m^2) between the two groups of subjects.

24-Hr Ambulatory Blood Pressure Monitoring for Sleep Bruxism Subjects

SBP (120±8 vs 122±8 mmHg, P=0.03, for PRE vs POST, respectively) and DBP (70±7 vs 71±6 mmHg, p = 0.04) were both higher during the overall phase during POST testing. This was likely due to higher SBP (124±9 vs 128±10 mmHg, p = 0.02) and DBP (73±7 vs 76±7 mmHg, p = 0.04) during the awake phase after the intervention. No differences in SBP (107±9 vs 107±8 mmHg, p = NS) and DBP (59±7 vs 58±8 mmHg, p = NS) were observed between PRE vs POST during the sleep phase.

Cold Pressor Test

Heart rate. There was a trend toward a main effect of lower HR among SB subjects compared to CON ($p = 0.07$), but overall was not significant. The cold pressor test elicited the same absolute HR in the CON and SB groups. There were also no differences in HR between PRE vs POST. HR changes from BL (ΔHR) did not differ at CPT1 or CPT2 between CON and SB subject or between PRE and POST.

Blood pressure. As expected, the cold pressor test induced increases in SBP and DBP during CPT in CON and SB groups (all $p < 0.01$). SB subjects demonstrated lower SBP during the BL for cold pressor test and REC (both $p < 0.05$). However, no significant differences were seen in absolute SBP and DBP between the groups during the cold pressor test. SBP and DBP were similar between PRE and POST in SB subjects. However, ΔSBP and ΔDBP (changes from BL, Table 3) during CPT1 were larger in SB subjects than in CON (both $p < 0.05$). ΔSBP during CPT2 was also larger in SB subjects ($p < 0.05$). ΔSBP and ΔDBP during POST were attenuated compared to PRE testing during CPT1 (both $p < 0.05$) but ΔSBP was not significant during CPT2 (PRE vs POST, $p = 0.07$).

Static Handgrip to Fatigue with Post Exercise Circulatory Arrest

No differences in maximal contraction force were observed CON vs. SB (38.1±13.9 vs. 41.9±15.9 kg, $p = 0.59$). Time to fatigue was also similar between groups (167.9±17.0 vs. 201.8±42.6 sec, $p = 0.23$). Maximal force contraction did not differ PRE vs POST in SB subjects (42.2±15.0 vs. 40.3±16.5 kg, $p = 0.16$) nor did time to fatigue (199.1±46.8 vs. 208.0±56.7 sec, $p = 0.61$)

Heart Rate. No group (CON vs SB) or intervention (PRE vs POST) differences in HR existed during static handgrip to fatigue and PECA. As expected, HR increased from BL in all groups during 100% SHG (all $P<0.001$). No ΔHR differences between CON and SB or PRE vs POST were observed during static handgrip or PECA.

Blood pressure. There was no difference in SBP during static handgrip or PECA between CON vs SB or PRE vs POST. Conversely, DBP was higher in SB subjects during static handgrip and PECA (all p 0.05). All subjects demonstrated significantly higher SBP and DBP during static handgrip and PECA (CON vs SB and PRE vs POST, all $p < 0.001$). ΔSBP was similar among CON vs SB during static handgrip and PECA; however, ΔDBP was larger during static handgrip in SB subjects ($p < 0.05$) and bordered significance during PECA ($p = 0.06$). No difference was seen in ΔDBP response to static handgrip between PRE and POST SB subjects. Table 3 outlines ΔSBP did not change and ΔDBP remained elevated in SB subjects after occlusal splint intervention during static handgrip and PECA.

Table 1

Blood pressure and heart rate during the cold pressor test.

Variable	Cold pressor test			
	BL	CPT1	CPT2	REC
HR, beats/min				
Control	75 ± 15	83 ± 20	79 ± 20	67 ± 8
Sleep Bruxism	63 ± 11	69 ± 12	67 ± 11	61 ± 8
Pre-Int	62 ± 12	66 ± 7	64 ± 8	61 ± 9
Post-Int	63 ± 9	66 ± 11	63 ± 9	63 ± 7
SBP, mmHg				
Control	129 ± 12**	132 ± 16	139 ± 13*	127 ± 15**
Sleep Bruxism	116 ± 9	136 ± 10*	136 ± 10*	115 ± 7
Pre-Int	115 ± 10	134 + 10	135 ± 10	114 ± 7
Post-Int	114 ± 10	121 ± 10	129 ± 10	115 ± 8
DBP, mmHg				
Control	68 ± 5	76 ± 9	79 ± 7*	68 ± 9
Sleep Bruxism	64 ± 8	81 ± 14*	81 ± 16*	64 ± 11
Pre-Int	64 ± 8	82 ± 16	82 ± 18	64 ± 12
Post-Int	64 ± 7	71 ± 5	80 ± 9	69 ± 10

Note. Values are mean differences from baseline ± SD. HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure. Pre-Int, pre-intervention; Post-Int, post-intervention. *Difference from BL, $p < 0.05$. **Difference within stage between Control and SB, $p < 0.05$.

Table 2

Blood pressure and heart rate during static handgrip to fatigue with PECA.

Variable	BL	20%	40%	60%	80%	100%	PECA1	PECA2	REC
HR, Beats/min									
Control	66 ± 8	77 ± 14	83 ± 10	87 ± 9	91 ± 12	92 ± 16	71 ± 16	67 ± 10	65 ± 9
Sleep Bruxism	63 ± 7	73 ± 10	79 ± 6	83 ± 7	87 ± 9	95 ± 11*	68 ± 12	66 ± 13	61 ± 7
Pre-Int	62 ± 7	71 ± 9	78 ± 6	83 ± 7	87 ± 10	94 ± 12*	67 ± 13	65 ± 15	60 ± 8
Post-Int	63 ± 8	72 ± 10	76 ± 11	77 ± 10	82 ± 11	87 ± 14*	65 ± 7	63 ± 12	61 ± 7
SBP, mmHg									
Control	117 ± 14	134 ± 12	140 ± 16	145 ± 21	150 ± 25	155 ± 23*	135 ± 16*	140 ± 17*	126 ± 12
Sleep Bruxism	126 ± 21	135 ± 25	145 ± 25	154 ± 25	160 ± 23	167 ± 23*	152 ± 26*	156 ± 24*	121 ± 29
Pre-Int	130 ± 16	136 ± 21	148 ± 22	157 ± 22	163 ± 20	169 ± 20*	157 ± 24*	162 ± 21*	125 ± 26
Post-Int	131 ± 12	138 ± 14	146 ± 17	154 ± 19	158 ± 20	163 ± 21*	156 ± 19*	162 ± 19*	138 ± 16
DBP, mmHg									
Control	52 ± 8	58 ± 9	64 ± 9	67 ± 11	70 ± 11	73 ± 12* **	60 ± 7 * **	65 ± 9* **	52 ± 8
Sleep Bruxism	61 ± 16	67 ± 19	76 ± 19	82 ± 19	85 ± 21	92 ± 22*	75± 19*	81 ± 21*	59 ± 19
Pre-Int	63 ± 13	69 ± 15	78 ± 14	85 ± 15	89 ± 16	96 ± 18*	79 ± 16*	85 ± 18*	62 ± 14
Post-Int	61 ± 13	67 ± 10	76 ± 14	82 ± 15	86 ± 15	89 ± 16*	77 ± 14*	84 ± 17*	64 ± 10

Note. Values are mean differences from baseline ± SD. PECA, post-exercise circulatory arrest; HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure. Pre-Int, pre-intervention; Post-Int, post-intervention. *Difference from BL, $p < 0.05$. **Difference within stage between Control and SB, $p < 0.05$.

Table 3

Blood pressure and heart rate changes during cold pressor test and static handgrip to fatigue with PECA.

Variable	Cold pressor test		Static handgrip to fatigue	
	ΔCPT1	ΔCPT2	100%, at fatigue	PECA2
ΔHR, Beats/min				
Control	6 ± 11	4 ± 12	25 ± 14	1 ± 7
Sleep Bruxism	6 ± 10	4 ± 10	32 ± 10	3 ± 10
Pre-Int	4 ± 9	2 ± 10	32 ± 10	3 ± 12
Post-Int	3 ± 6	0 ± 7	24 ± 17	0 ± 8
ΔSBP, mmHg				
Control	3 ± 6	10 ± 10	38 ± 28	22 ± 16
Sleep Bruxism	16 ± 18*	19 ± 7*	39 ± 8	30 ± 11
Pre-Int	15 ± 9	20 ± 8	39 ± 9	32 ± 11
Post-Int	8 ± 5†	15 ± 8	32 ± 16	25 ± 11
ΔDBP, mmHg				
Control	8 ± 8	12 ± 5	21 ± 11	12 ± 8
Sleep Bruxism	17 ± 9*	17 ± 12	31 ± 8*	20 ± 8
Pre-Int	18 ± 10	18 ± 13	32 ± 8	22 ± 7

Post-Int	8 ± 6†	16 ± 6	28 ± 11	23 ± 16

Note. values are mean differences from baseline ± SD. PECA, post exercise circulatory arrest; HR, heart rate; SBP, systolic blood pressure; DBP, diastolic blood pressure. *Difference in change from baseline compared to CON, $p < 0.05$. †Difference in change from baseline compared to pre-intervention, $p < 0.05$.

DISCUSSION

The major findings of this study are SB subjects demonstrated: 1) exaggerated BP reactivity to both the cold pressor test and static handgrip compared to the CON group and 2) lowered BP responses to cold pressor test after 12-wks of occlusal splint intervention. The findings of the present study support the hypothesis that people with SB might be at increased risk for the future development of hypertension. Correspondingly, the results indicate that use of an occlusal splint may be beneficial in lowering ΔSBP responses to the cold pressor test after a 12-wk intervention. This is the first to examine a predictive measurement of BP responses to cold pressor and static handgrip before and after 12-wks of occlusal splint intervention.

SB and Responses to the Cold Pressor Test

SB subjects in this study sample had a prominently augmented mean ΔSBP increase, approximately double than that of CON subjects during cold pressor test. One advantage of cold pressor testis it is a highly reproducible test (Zhao et al., 2012). Exaggerated BP responses, such as those observed during long term studies of 20-, 28-, and 36-years, have demonstrated that these responses are strong evidence for risk of the future development of hypertension (Kasagi et al., 1995; Menkes et al., 1989; Wood et al., 1984). Consistent with Menkes et al. (1989), when the maximal SBP response to cold pressor test is augmented (≥20 mmHg), subjects are more likely to develop hypertension before the age of 45 yrs. Taken together, these studies and this one indicate that SB subjects may be at risk for future development of hypertension. It is of interest to note that the subjects in the current study were young and normotensive yet exhibited cold pressor test responses comparable to hypertensive individuals.

ΔSBP and ΔDBP during cold pressor test were reduced in POST SB subjects. These results suggest that the use of an occlusal splint was beneficial in reducing the reactivity to the cold pressor test. A possible mechanism for this reduction could be due to a decrease in the number SB episodes with occlusal splint treatment. For example, a short term (two-night study) with an occlusal splint intervention showed a 41% decrease in the number of SB episodes per hour (Dube et al., 2004). Subjects also demonstrated significantly lower bite contraction force after occlusal splint treatment (Amorim et al., 2012). Thus, wearing an occlusal splint may attenuate the BP responses that normally occur during SB episodes. The potential decrease in the number of SB episodes could have led to diminished sympathetic dominance and less exaggerated responses to the CPT. Also, the subjects did not report lifestyle changes, such as diet or exercise, or health changes that would account for the results when questioned during the follow-up visit, but BP can be altered by numerous mental and physiological conditions, such as dealing with family issues or traumatic events, which should be kept into consideration.

SB Responses to Static Handgrip to Fatigue and Post Exercise Circulatory Arrest

In our study, SB subjects had higher DBP during static handgrip and PECA, as well as a larger ΔDBP during static handgrip. DBP responses to static handgrip exercise have been previously used to predict hypertension in a 14-yr follow-up trial (Chaney & Eyman, 1988). The initial responses in our SB sample could be due to sensitized mechano- or chemo-receptors, a common trait found in hypertensive individuals (Victor, Rotto, Pryor, & Kaufman, 1989). Mechano- and chemo-receptors present in skeletal tissue are responsible for the cardiovascular pressor responses during static exercise (Victor et al., 1989). In addition to rises in HR and BP during the microarousals that precede SB episodes (Huynh et al., 2006; Nashed et al., 2012), there are further escalations in BP when the rhythmic jaw contractions occur in SB subjects (Nashed et al., 2012). For example, Okada et al. (2009) observed significant increases in BP during isometric biting at

50% of maximal bite force. Therefore, increases in BP observed in SB subjects may be the result of masseter and temporalis (muscles of mastication) contractions similar to those observed in static handgrip using the forearm muscles. The exaggerated response could also be due to the activation of chemoreceptors in the periodontal tissue (Okada et al., 2009), or a combination of both. Notably, studies in patients with heart failure and hypertensive individuals have attributed abnormally high BP responses to static handgrip to sensitized mechanoreceptors in the working skeletal muscles that lead to larger sympathetic activation than those observed in normotensive subjects (Hoel, Lorentsen, & Lund-Larsen, 1970; Middlekauff & Chiu, 2004). Thus, it is possible that SB subjects may exhibit similar characteristics as repeated rhythmic jaw contractions may also have a sensitization effect (Middlekauff & Chiu, 2004). Interestingly, Okada et al. (2009) showed attenuated BP responses during the second trial of isometric biting after administration of a nerve block to the periodontal tissue. This further supports that increases in cardiovascular variables are attributed to the pressor response (Okada et al., 2009).

Occlusal Splint

Based on the previous findings of reduced electromyographic activity and bite force, it was hypothesized that 12-wks of occlusal splint use would lead to lower BP responses to the cold pressor test and static handgrip to fatigue. There were improvements in the ΔSBP response to the cold pressor test, but not in the ΔDBP response to static handgrip. Additionally, SBP and DBP were slightly higher during 24-hr BP monitoring after the intervention. There are two possible explanations for this finding. One, it could be due to longer durations of cardiovascular responses during microarousal that would transpire in the event occlusal splints inhibit of the trigeminocardiac reflex and, consequently, its beneficial parasympathetic effects. For example, Takahashi et al. (2013) reported no reduction in microarousal occurrence, even when there were decreases in electromyography activity and the number of SB episodes (Takahashi et al., 2013). This could present a possible reason for the conflicting findings in the results of this study and increased BP after during 24-hr BP monitoring. Two, we cannot also exclude the possibility that the timing of the POST visit played a role. Most of the subjects in this study were college students and some completed their POST testing during their finals week, which may have confounded the results. However, due to the improvements seen in the cold pressor test BP reactivity, the occlusal splint showed that it may be helpful. Previous findings on the efficacy of occlusal splints have also reported conflicting results regarding its use and ability to diminish electromyographic activity (Abekura et al., 2011). The results are consistent with these previous findings of ambiguity regarding occlusal splints. Hence, the continuation of research involving occlusal splint use as treatment for SB is necessary to determine its efficacy regarding SB episodes and systemic effects.

Limitations

Identifying the specific cause of SB was a limitation in this study. The causes of SB are psychosocial factors and dopaminergic disorders malocclusion has been theorized to be a cause of for many years, but there is no valid evidence to support this claim (Manfredini, Visscher, Guarda-Nardini, & Lobbezoo, 2012). Disorder in the dopaminergic system is one of the probable causes of SB (Lobbezoo, Lavigne, Tanguay, & Montplaisir, 1997) because dopamine has motor control functions (Graybiel, Aosaki, Flaherty, & Kimura, 1994). Reductions in dopamine can cause loss of fine motor movement and possible tremors (Graybiel et al., 1994). Though all of the SB subjects were pre-screened for use of neurological drugs and medications affecting the dopaminergic system, including cigarette smoking and recreational drug use, subjects were not explicitly tested for any conditions involving the dopaminergic system. Another reason, not previously mentioned, that RMMA/SB occurs is due to gastroesophageal reflux disease (GERD) (Miyawaki et al., 2003). Chemoreceptors in the esophagus lead to micro-arousal, which then leads to RMMA and swallowing, as well as episodes of bruxing. This mechanism was not tested or quantified in this trial, but could have influenced the results by continuing microarousals regardless of treatment use (Miyawaki et al., 2003). Also, if GERD is the primary source of their SB the beneficial effects from wearing a nighttime mouth guard would likely be minimal. Therefore, the underlying cause for SB could have been due to stress related factors, disorder in the dopaminergic system, or GERD; malocclusion was ruled out as a cause due to the little evidence supporting this as a SB risk in healthy individuals, gold star diagnoses using electromyography and test to eliminate individuals with GERD or dopaminergic disorders should be done. This study compared sleep bruxers and non-sleep bruxers, as well as non-sleep bruxers before and after using an occlusal splint, however, in future studies a group of bruxers without treatment should also be compared to bruxers undergoing occlusal splint treatment.

CONCLUSION

In conclusion, this study examined BP responses to cold pressor test and static handgrip to fatigue before and after 12-wks treatment with an occlusal splint. Even young, normotensive SB subjects showed risk for the development of future hypertension based on exaggerated responses to cold pressor and static handgrip to fatigue. The risk for hypertension is likely developed from enhanced sympathetic activity. Occlusal splint use showed to be beneficial over a 12-wk duration in lowering the exaggerated SBP response to cold pressor test, likely due to decreased sympathetic tone.

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REFERENCES

Abekura, H., Tsuboi, M., Okura, T., Kagawa, K., Sadamori, S., & Akagawa, Y. (2011). Association between sleep bruxism and stress sensitivity in an experimental psychological stress task. Biomedical Journal of Scientific & Technical Research, 32(6), 395-399. doi:10.2220/biomedres.32.395

Amorim, C. F., Vasconcelos Paes, F. J., de Faria Junior, N. S., de Oliveira, L. V., & Politti, F. (2012). Electromyographic analysis of masseter and anterior temporalis muscle in sleep bruxers after occlusal splint wearing. Journal of Bodywork and Movement Therapies, 16(2), 199-203. doi:10.1016/j.jbmt.2011.04.001

Chaney, R. H., & Eyman, R. K. (1988). Blood pressure at rest and during maximal dynamic and isometric exercise as predictors of systemic hypertension. Am.J.Cardiol., 62(16), 1058-1061. doi:10.1016/0002-9149(88)90548-6

Dube, C., Rompre, P. H., Manzini, C., Guitard, F., de, G. P., & Lavigne, G. J. (2004). Quantitative polygraphic controlled study on efficacy and safety of oral splint devices in tooth-grinding subjects. Journal of Dental Research., 83(5), 398-403. doi:10.1177/154405910408300509

Fung, M. M., Peters, K., Redline, S., Ziegler, M. G., Ancoli-Israel, S., Barrett-Connor, E., & Stone, K. L. (2011). Decreased slow wave sleep increases risk of developing hypertension in elderly men. Hypertension, 58(4), 596-603. doi:10.1161/HYPERTENSIONAHA.111.174409

Graybiel, A. M., Aosaki, T., Flaherty, A. W., & Kimura, M. (1994). The basal ganglia and adaptive motor control. Science, 265(5180), 1826-1831. doi:10.1126/science.8091209

Hoel, B. L., Lorentsen, E., & Lund-Larsen, P. G. (1970). Haemodynamic responses to sustained hand-grip in patients with hypertension.Acta Medica Scandinavica,, 188(6), 491-495. doi:10.1111/j.0954-6820.1970.tb08074.x

Huynh, N., Kato, T., Rompre, P. H., Okura, K., Saber, M., Lanfranchi, P. A., . . . Lavigne, G. J. (2006). Sleep bruxism is associated to micro-arousals and an increase in cardiac sympathetic activity. Journal of Sleep Research., 15(3), 339-346. doi:10.1111/j.1365-2869.2006.00536.x

Kasagi, F., Akahoshi, M., & Shimaoka, K. (1995). Relation between cold pressor test and development of hypertension based on 28-year follow-up. Hypertension, 25(1), 71-76. doi:10.1161/01.hyp.25.1.71

Lang, S., Lanigan, D. T., & van der Wal, M. (1991). Trigeminocardiac reflexes: maxillary and mandibular variants of the oculocardiac reflex. The Canadian Journal of Anesthesia, 38(6), 757-760. doi:10.1007/BF03008454

Lavigne, G. J., Kato, T., Kolta, A., & Sessle, B. J. (2003). Neurobiological mechanisms involved in sleep bruxism. Critical Reviews in Oral Biology & Medicine, 14(1), 30-46. doi:10.1177/154411130301400104

Lobbezoo, F., Lavigne, G. J., Tanguay, R., & Montplaisir, J. Y. (1997). The effect of catecholamine precursor L-dopa on sleep bruxism: a controlled clinical trial. Movement Disorders, 12(1), 73-78. doi:10.1002/mds.870120113

Malpas, S. C. (2010). Sympathetic nervous system overactivity and its role in the development of cardiovascular disease. Physiological Reviews, 90(2), 513-557. doi:10.1152/physrev.00007.2009

Manfredini, D., Visscher, C. M., Guarda-Nardini, L., & Lobbezoo, F. (2012). Occlusal factors are not related to self-reported bruxism. The Journal of Oral & Facial Pain and Headache, 26(3), 163-167.

Menkes, M. S., Matthews, K. A., Krantz, D. S., Lundberg, U., Mead, L. A., Qaqish, B., . . . Pearson, T. A. (1989). Cardiovascular reactivity to the cold pressor test as a predictor of hypertension. Hypertension, 14(5), 524-530. doi:10.1161/01.hyp.14.5.524

Middlekauff, H. R., & Chiu, J. (2004). Cyclooxygenase products sensitize muscle mechanoreceptors in healthy humans. The American Journal of Physiology-Heart and Circulatory Physiology, 287(5), H1944-H1949. doi:10.1152/ajpheart.00329.2004

Miyawaki, S., Tanimoto, Y., Araki, Y., Katayama, A., Fujii, A., & Takano-Yamamoto, T. (2003). Association between nocturnal bruxism and gastroesophageal reflux. Sleep, 26(7), 888-892. doi:10.1093/sleep/26.7.888

Nashed, A., Lanfranchi, P., Rompre, P., Carra, M. C., Mayer, P., Colombo, R., . . . Lavigne, G. (2012). Sleep bruxism is associated with a rise in arterial blood pressure. Sleep, 35(4), 529-536. doi:10.5665/sleep.1740

Okada, Y., Kamijo, Y., Okazaki, K., Masuki, S., Goto, M., & Nose, H. (2009). Pressor responses to isometric biting are evoked by somatosensory receptors in periodontal tissue in humans. The Journal of Applied Physiology, 107(2), 531-539. doi:10.1152/japplphysiol.91199.2008

Satoh, T., & Harada, Y. (1973). Electrophysiological study on tooth-grinding during sleep. Electroencephalogr. Clinical Neurophysiology, 35(3), 267-275. doi:10.1016/0013-4694(73)90238-1

Schames, S. E., Schames, J., Schames, M., & Chagall-Gungur, S. S. (2012). Sleep bruxism, an autonomic self-regulating response by triggering the trigeminal cardiac reflex. The Journal of the California Dental Association, 40(8), 670-676.

Sjoholm, T., Kauko, T., Kemppainen, P., & Rauhala, E. (2014). Long-term use of occlusal appliance has impact on sleep structure. Journal of Oral Rehabilitation, 41(11), 795-800. doi:10.1111/joor.12201

Takahashi, H., Masaki, C., Makino, M., Yoshida, M., Mukaibo, T., Kondo, Y., . . . Hosokawa, R. (2013). Management of sleep-time masticatory muscle activity using stabilisation splints affects psychological stress. Journal of Oral Rehabilitation, 40(12), 892-899. doi:10.1111/joor.12110

Victor, R. G., Rotto, D. M., Pryor, S. L., & Kaufman, M. P. (1989). Stimulation of renal sympathetic activity by static contraction: evidence for mechanoreceptor-induced reflexes from skeletal muscle. Circulation Research, 64(3), 592-599. doi:10.1161/01.RES.64.3.592

Wood, D. L., Sheps, S. G., Elveback, L. R., & Schirger, A. (1984). Cold pressor test as a predictor of hypertension. Hypertension, 6(3), 301-306. doi:10.1161/01.hyp.6.3.301

Zhao, Q., Bazzano, L. A., Cao, J., Li, J., Chen, J., Huang, J., . . . Gu, D. (2012). Reproducibility of blood pressure response to the cold pressor test: the GenSalt Study. The American Journal of Epidemiology, 176 Suppl 7, S91-S98. doi:10.1093/aje/kws294

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EXAMINING PHYSICAL ACTIVITY IN USERS OF CAMPUS RECREATION DURING CAMPUS CLOSURE DUE TO COVID-19

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Burcal K., et. al. Campus recreation facilities are a critical resource to encourage physical activity at universities. COVID-19 closures in 2020 led to the shutdown of many campuses, which included campus recreation facilities. Little is known about how the closures impacted the physical activity levels of students, faculty, and staff who relied on campus recreation for physical activity opportunities. Therefore, the purpose of this study was to determine if individuals who were users of campus recreation prior to campus closure continued to be physically active when campus closed. The survey was completed by 282 previous users (students, faculty, and staff) of campus recreation. Results indicated that 85.8% of participants were meeting physical activity recommendations following campus closure. To support physical activity off campus, survey respondents suggested online exercise classes via social media and allowing equipment rentals. Future efforts should continue identifying ways campus recreation can support physical activity both on and off campus.

Key Words: campus recreation, physical activity, college students, COVID-19, university

INTRODUCTION

Universities are an ideal setting to help students establish healthy habits that can be carried into their future after graduation (Milroy et al., 2015; Plotnikoff et al., 2015). Unfortunately, as students enter college, they find themselves with increased stress and less hours of sleep (Lund et al., 2010; Saleh et al., 2017), which has been found to lead to depression and weight gain (Hasler et al., 2004; Kahlhöfer et al., 2016; Pelletier et al., 2016; Watson et al., 2015). Faculty and staff experience many of the same health issues (Haines et al., 2007).

One health behavior that can positively impact these health behaviors is physical activity. Increasing physical activity can help with reducing stress (Pengpid & Peltzer, 2018, Van der Zwan et al., 2015), improving sleep (Wu et al. 2015), and controlling weight (Lowry et al., 2000). However, many individuals do not meet the aerobic physical activity recommendations of 150 minutes of moderate-to-vigorous or 75 minutes of vigorous intensity physical activity weekly (Department of Health and Human Services [DHHS], 2019). Studies suggest that only 30-50% of students on a standard college campus report meeting the recommendations (Fuller et al., 2015; Keating et al., 2005).

Historically, universities have designed campus recreation facilities as a convenient way to help increase physical activity by providing programs and facilities for individuals to use (Cooper & Theriault, 2008; Dalgarn, 2001; Kraus, 1971; Powers et al., 2019). Campus recreation has been found to be an especially convenient venue to get physical activity without leaving campus (Dalgarn, 2001; Feldman et al., 2019). However, few studies report how campus recreation usage specifically impacts meeting aerobic physical activity recommendations (Castle et al., 2015; Zizzi et al., 2004).

While campuses could not have foreseen the impact of COVID-19 and eventual closure of campus recreation facilities, their role in supporting physical activity through the provision of knowledge and opportunities for physical activity did not stop. Furthermore, there is limited data to show how the closure of campus recreation impacted the aerobic physical activity levels of previous users of campus recreation. Thus, the purpose of this study was to determine if individuals who were users of campus recreation prior to campus closure continued to be physically active if campus closed. This information could indicate the success of campus recreation's efforts to support the maintenance of physical activity for individuals after leaving the university (e.g., graduating students). The secondary purpose of this study was to understand how a public university campus recreation facility can help to support students, faculty, and staff to be physically active when they are not on campus. This information could be used to develop programs and resources to support current students, faculty, and staff during an ongoing pandemic as well as alumni.

METHODS

Participants

Participants in this study were undergraduate students, graduate students, faculty, and staff at a midwestern public university who either attended a group exercise class or took part in the Commit to Fit program prior to campus closure. Commit to Fit was a program offered at this specific university that allowed individuals to set structured goals for the year. In 2019, the university consisted of 17,298 individuals (12,244 undergraduate students, 2,909 graduate students, and 2,145 faculty and staff). For the 2019-2020 school year, Commit to Fit had 973 participants and Group Exercise had 462 participants. Thus, out of the total campus population during that school year, 8.16% of individuals were available to participate in the study. A sample size of 210 students, faculty, and staff was needed for this study based on a confidence level of 95% and confidence interval of +/- 5 calculated with a G*Power analysis.

Recruitment

Since this study was designed for program enhancement, approval from an Institutional Review Board (IRB) was not needed. Due to COVID-19 and campus closure, all classes moved to online learning on March 30, 2020. A link to the anonymous survey on the online survey platform, Qualtrics was sent via email on April 20th, and again on April 27th, to all possible participants. Potential participants were given roughly three weeks to complete the survey and the survey was officially closed May 12, 2020.

Demographics

Participants completed a questionnaire that included demographic questions regarding gender, GPA, ethnicity, campus living status, campus recreation usage, and age.

Campus Recreation Usage

Participants were asked the following question to determine if they were a frequent user, occasional user, or nonuser of campus recreation. The question stated, "Before COVID-19, in a typical week, how often did you use campus recreation facilities for the purpose of being physically active?". They selected one of four options that included: "I have never visited campus recreation", "less than 1 visit per week", "1-3 visits per week", and "4 or more visits per week". This question was structured after a similar survey regarding campus recreation usage (Ellis et al., 2002). "User" was defined as using campus recreation facilities on average 4+ times per week, "occasional user" was defined as using campus recreation facilities 1-3 times per week, and "nonuser" was defined as using it less than once per month (Ellis et al., 2002).

To gain an understanding of what activities participants used to participate in prior to COVID-19, participants were asked "What physical activities were you doing at campus recreation before COVID-19?". Example responses included group exercise, weight rooms, cardio equipment, gym space, classes, and "other" with the option to provide a response. Additionally, to gain an understanding of where participants were active outside of campus recreation, participants were asked "Where else did you obtain your physical activity?" included responses gym, outdoors, home, and "other" with the option to provide a response.

An additional open-ended question was used to identify ways campus recreation could support students, faculty, and staff during campus closure. This question stated, "How can campus recreation support you to be physically active when you are not on campus?".

Physical Activity

The International Physical Activity Questionnaire (IPAQ) contains seven questions and has been widely used in universities to determine levels of physical activity (Dinger et al.,2006). The IPAQ has been validated against accelerometers utilizing pooled coefficients with 0.3 criterion validity (Fogelholm et al., 2006). Further, correlation coefficients that ranged from 0.71 – 0.89 indicating moderate to high reliability, and the time spent in vigorous physical activity from the IPAQ was significantly correlated with steps/day from the accelerometer and pedometer, as well as all count variables (ρ: 0.30 – 0.47, $p < 0.01$) (Dinger et al.,2006). A sample question includes "During the last 7 days, on how many days did you do vigorous physical activities like heavy lifting, digging, aerobics, or fast bicycling?".

Stage of Change

The Stages of Change questionnaire is based on the Transtheoretical Model and classifies people into the stages of change, which include pre-contemplation, contemplation, preparation, action, and maintenance (McConnaughy et al., 1983). This questionnaire consists of four questions and has strong construct validity when used with college students (Schumann et al., 2002). Further, it shows adequate test-retest reliability based on a two-week interval with an intraclass correlation coefficient of 0.8 (Cengiz et al., 2010). When used directly with physical activity, the test-retest reliability has a correlation of 0.59 (Donovan et al., 1998). Example questions include "I am currently physically active" and "I intend to become more physically active in the next 6 months". Participants respond by selecting "yes" or "no" to each question.

Data Analysis

Following the collection of the questionnaires, incomplete responses and "nonusers" were removed prior to analysis. The IPAQ data was scored according to the protocol into both a categorical variable (low, moderate, or high) and a continuous variable (MET minutes) (Forde, 2018; Sjostrom et al., 2005). A high score on the IPAQ indicates participants were vigorously active on 3+ days per week or obtained 7 days of combined activity. A moderate score on the IPAQ indicated participants were vigorously active 3 days per week, moderately active 5 days per week, or obtained 5+ days of combined activities. A low score on the IPAQ indicates a participant obtained neither of those requirements. Following protocol, periods of activity less than 10 minutes in duration were not scored. Additionally, moderate-to-vigorous physical activity (MVPA) was determined utilizing the MET minutes from the IPAQ data. The Stages of Change questionnaire was scored according to protocol (Marcus & Forsyth, 2009) and each participant was categorized into one of the five stages of precontemplation, contemplation, preparation, action, or maintenance.

SPSS was used to run descriptive analyses for age, gender identity, race, position in school, grade point average, campus recreation usage, and status of living (on or off of campus). Independent t-tests were run to measure differences between minutes of moderate to vigorous physical activity (MVPA) and all demographic variables. Summative content analysis was used to evaluate the open-ended question. Summative content analysis identifies certain words in the text portions of the open-ended questions to help interpret the answers to the questions through keywords (Hsieh & Shannon, 2005). First, the lead author reviewed all answers and developed codes based on the responses. Next, the senior author reviewed the codes and documented any coding disagreements. Then they met to discuss all discrepancies until consensus was reached.

RESULTS

After removing incomplete questionnaires and all "nonusers", 282 responses were used for analysis fulfilling the power analysis requirement. Most of the participants were white (76.8%) and between the ages of 18-24 years old (68.4%, M = 1.63, SD = 1.1). (See Table 1).

Table 1

Student, Faculty, and Staff Demographics

Demographic		n=282	%
Age	18-24	193	68.4
	25+	89	31.6
Gender	Male	115	40.8
	Female	162	57.4
	Other	5	1.8
Race	White	215	76.2
	Hispanic	27	9.6
	Black	20	7.1
	Asian	16	5.7
	American Indian/Alaska Native	2	0.7
	Pacific Islander	2	0.7
GPA	3.5-4.0	152	54.0
	<3.49	130	46.0
Grade/Position	Freshman	35	12.4
	Sophomore	59	20.9
	Junior	48	17.0
	Senior	52	18.4
	Graduate	38	13.5
	Faculty/Staff	50	17.7
Campus Living Status	On-Campus	70	23.8
	Off-Campus	210	76.2
Before COVID-19 Usage of Campus Recreation	1-3 visits per week	112	39.7
	4 or more visits per week	170	60.3

Campus Recreation Usage and Physical Activity

Overall, 39.7% of participants were occasional users and 60.3% were frequent users of campus recreation. Physical activity results from the IPAQ revealed that without access to campus recreation facilities, 85.8% of individuals were still meeting the aerobic physical activity recommendations. When examining the results by level of activity, 54.2% scored high, 31.6% scored moderate, and 14.2% scored low levels of physical activity. Further, comparing physical activity by campus recreation usage, results revealed that frequent users obtained more mean minutes of MVPA per week compared to occasional users (p = 0.031). There were no other significant differences between any of the demographic variables and minutes of MVPA, including gender (p = 0.051), age (p = 0.548), race (p = 0.436), credit hours (p = 0.993), GPA (p = 0.440), and campus living status (p = 0.617).

Stages of Change

The Stages of Change questionnaire found that most participants (59.9%) were in the maintenance stage. The minutes of MVPA increased with each stage until maintenance. All stages, except precontemplation, were meeting the guidelines for physical activity. More information is available in Table 2.

Table 2

Minutes of Physical Activity Per Week

Stage of Change	Average Minutes Per Week	n=282	Percentage (%)
Precontemplation	0.0	1	0.4
Contemplation	155.37	67	23.8
Preparation	158.4	25	8.9
Action	399.0	20	7.1
Maintenance	308.8	169	59.9

Campus Closure Activity Options

When asked what activities users of campus recreation used most often prior to campus closure, responses included weight rooms (64.2%), cardio equipment (59.2%), and group exercise (45.7%). When asked where participants do most of their physical activity other than campus recreation (prior to COVID-19), responses included “outdoors, other gyms, and at home”. These responses were given as part of the “other” option in the questionnaire.

When asked “How can campus recreation best support faculty/staff/students to be physically active when they are not on campus in regard to physical activity?”, a variety of responses were given (see Table 3). The highest categories of response were suggestions for online exercise options (33.3%). 6.4% of participants desired the reopening of campus recreation, while others (4.3%) suggested rental options for equipment (e.g., borrow weights).

Table 3

Campus Recreation Support

Campus Recreation Support Categories	n=282	Percentage (%)	Examples
Social Media/Online/Home Exercise Options	94	33.3	“Classes online”
Reopening Campus Recreation	18	6.4	“Open the gym”
Rent Equipment Options	12	4.3	“Rental options”
Incentives	9	3.2	“Money incentive”
No Suggestions/NA	132	46.8	“None”
Other	17	6.0	“Other gym options”

DISCUSSION

The purpose of this study was to determine if individuals who were users of campus recreation prior to campus closure continued to be physically active if campus closed. A secondary purpose of this study was to understand how a public university campus recreation facility can help support students, faculty, and staff to be physically active when they are not on campus. The results of this study confirmed that the students, faculty, and staff, who were users of campus recreation facilities before COVID-19 campus closures, remained physically active when campus was closed. Of those in this study, 85.8%

were meeting the physical activity recommendations.

The major finding of this study came from comparing recreation user status with minutes of physical activity. There was a significant difference when comparing minutes of MVPA and campus recreation user status, suggesting that the more often individuals used campus recreation prior to campus closure, the more active they were when campus was closed. This is similar to other research which has found more frequent "users" of campus recreation, compared to "nonusers", were more physically active (Castle et al., 2015; Zizzi et al., 2004). In our study, frequent users obtained a mean of 168 minutes of MVPA per week while occasional users of campus recreation obtained a mean of 138.17 minutes of MVPA each week. This suggests that those who were more frequent users of campus recreation may have developed skills for maintaining and/or increasing their physical activity when campus recreation facilities were open. Frequent users could have had increased self-efficacy skills for physical activity due to previous participation that allowed them to meet the physical activity guidelines. Future research is needed to look at the differences between users of and nonusers of campus recreation to further explore the impact of campus recreation.

This study found no significant differences on most demographic factors with minutes of MVPA per week including gender, age, race, credit hours, GPA, and campus living status. This is contrary to other research which has found differences in MVPA based on demographic factors (Castle et al., 2015; Mettling et al., 2017; Zizzi et al., 2004). For example, several studies in university settings have found significant differences in MVPA between genders, with males being more physically active than females (Castle et al., 2015; Mettling et al., 2017; Zizzi et al., 2004).

Further, Castle et al. (2015) found significant differences based on where students lived, suggesting that living on campus and/or closer to campus recreation facilities increased campus recreation usage (Castle et al., 2015). The lack of significance in our study may be due to the fact that participants had been active in campus recreation facilities. Future research should look at usage of campus recreation and the location of where students, faculty, and staff live in relation to campus recreation facilities.

Participants in this study listed a variety of ways they were physically active outside of campus recreation with the outdoors (45%) being most popular. This was followed by other gyms (34.8%) and home workouts (23.8%). Some participants wrote in "other" options, including local community centers, and yoga studios. Future research could look further into the various places that students, faculty, and staff do their physical activity to further understand if campus recreation is used more often than other options, which can then lead to improving what is offered from campus recreation to encourage usage. Research should also look more in depth at how long students, faculty, and staff spend on campus per week to determine if there is any connection between time on campus and campus recreation use.

When looking at the Stages of Change data, 7.1% of individuals in the study were in the action stage and 59.9% of individuals were in the maintenance stage. Interestingly, those in contemplation and preparation still reported meeting the aerobic physical activity guidelines. Typically, those in contemplation and preparation do not report meeting the physical activity recommendations (Garber et al., 2008). While this does not follow the expected pattern of activity, the surveyed population in this study were all users of campus recreation, so they had either been using campus recreation for physical activity or were familiar with campus recreation facilities to begin with. Regardless, campus recreation should continue or develop programs to not only help existing users, but also non-users, to utilize campus recreation facilities and programming through stage-matched strategies.

Participants also provided a variety of ways they felt campus recreation could support them while off campus. The most popular responses included "social media" and "online". Following the campus closure, campus recreation has started using social media and online resources to give students, faculty, and staff a chance to continue to be active while away from campus. However, it is unclear how many of the participants in this survey were aware of these efforts. Thus, to best support students, faculty, and staff to be physically active when they are not on campus, universities could focus on building their social media presence and following. This can be done by both posting workouts for people to do on their own time and/or having virtual exercise classes live via online access.

Strengths and Limitations

The biggest strength of this study is that it is one of the first to describe the physical activity levels of previous campus recreation users during the closure of campus due to the pandemic. An additional strength of this study is the response rate. 384 original responses out of the 1,435 who received a link to take the survey is a 26.8% response rate. When compared to other campus recreation studies, this response rate is higher than other studies of a similar population (Mettling et al., 2018; Zizzi et al., 2004). An additional strength is that most of the previous research has focused only on the student population (Castle et al., 2015; Mettling et al., 2018; Zizzi et al., 2004). This study adds to the literature by including faculty and staff.

There were several limitations to this study. First, the survey was administered less than a month following campus closure. Administering a survey so close to campus closure limits the understanding of how students, faculty, and staff adapted to the campus closure. Second, participants in the study were already affiliated with campus recreation and thus more likely to have been physically active. Additional research is needed to determine how to best support non-users of campus recreation. Third, this survey was only sent to group exercise users and Commit to Fit participants, so there is a variety of students, faculty, and staff that use campus recreation that were not included in this study. Fourth, this survey was only conducted at one specific university and may not be generalizable to other university settings. Finally, this study used a self-report questionnaire and previous research has found that participants are likely to overreport their physical activity levels via self-report (Sallis & Saelens, 2000). Thus, additional studies, using objective measures of physical activity are needed so there is potential for false reports from participants.

CONCLUSION

Campus recreation facilities are a helpful resource to promote physical activity in college students, faculty, and staff. This study adds to the research of the impact of COVID-19 and helps campus recreation facilities further understand how to support student, faculty, and staff physical activity when they are not on campus. Results revealed that a majority of previous users of campus recreation were physically active during campus closure and individuals desire a larger social media presence and options for equipment rentals. Future research should continue to examine how to support students, faculty, and staff's physical activity who do not regularly use campus recreation facilities.

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REFERENCES

Castle, J., Alman, R., Kostelnik, R., & Smith, S. (2015). Factors that affect the usage of fitness and recreation centers by students on College campuses. *Journal of Physical Education and Sports Management*, *2*(2), 100-119. http://dx.doi.org/10.15640/jpesm.v2n2a8.

Cengiz, C., Aşçı, F. H., & İnce, M. L. (2010). " Exercise Stages of Change Questionnaire": its reliability and validity. *Türkiye Klinikleri Spor Bilimleri*, *2*(1), 32-37.

Cooper, N., & Theriault, D. (2008). Environmental correlates of physical activity: implications for campus recreation practitioners. *Recreational Sports Journal*, *32*(2), 97-105. https://doi.org/10.1123/rsj.32.2.97.

Dalgarn, M. K. (2001). The role of the campus recreation center in creating a community. *Recreational Sports Journal*, *25*(1), 66-72. https://doi.org/10.1123/nirsa.25.1.66.

Department of Health and Human Services (DHHS). (2019). Physical Activity Guidelines for Americans, 2nd edition. Retrieved from https://health.gov/paguidelines/second-edition/pdf/Physical_Activity_Guidelines_2nd_edition.pdf

Dinger, M. K., Behrens, T. K., & Han, J. L. (2006). Validity and reliability of the International Physical Activity Questionnaire in college students. *American journal of health education, 37*(6), 337-343.fuller. https://doi/org/10.1080/19325037.2006.10598924.

Donovan, R. J., Jones, S., Holman, C. D. A. J., & Corti, B. (1998). Assessing the reliability of a stage of change scale. *Health Education Research*, *13*(2), 285-291. https://doi.org/10.1093/her/13.2.285.

Ellis, G. D., Compton, D. M., Tyson, B., & Bohlig, M. (2002). Campus recreation participation, health, and quality of life. *Recreational Sports Journal*, *26*(2), 51-60. https://doi.org/10.1123/rsj.26.2.51

Feldman, S. S., Cochran, R. A., & Mehta, T. (2019). Predictors of weight change: findings from an employee wellness program. *Frontiers in endocrinology*, *10*, 77. https://doi.org/10.3389/fendo.2019.00077

Fogelholm, M. I. K. A. E. L., Malmberg, J. A. R. M. O., Suni, J., Santtila, M. A. T. T. I., Kyröläinen, H., Mäntysaari, M., & Oja, P. (2006). International physical activity questionnaire: Validity against fitness. *Medicine & Science in Sports & Exercise*, *38*(4), 753-760. https://doi.org/10.1249/01.mss.0000194075.16960.20.

Forde, C. (2018). *Scoring the international physical activity questionnaire (IPAQ)*. University of Dublin.

Fuller, J., Gonzales, M., & Rice, K. (2015). Physical activity levels among on campus and online college students. In *International Journal of Exercise Science: Conference Proceedings* (Vol. 8, No. 3, p. 21).

Garber, C. E., Allsworth, J. E., Marcus, B. H., Hesser, J., & Lapane, K. L. (2008). Correlates of the stages of change for physical activity in a population survey. *American journal of public health*, *98*(5), 897-904. https://doi.org/10.2105/AJPH.2007.123075.

Haines, D. J., Davis, L., Rancour, P., Robinson, M., Neel-Wilson, T., & Wagner, S. (2007). A pilot intervention to promote walking and wellness and to improve the health of college faculty and staff. *Journal of American College Health*, *55*(4), 219-225. https://doi.org/10.3200/JACH.55.4.219-225

Hasler, G., Buysse, D. J., Klaghofer, R., Gamma, A., Ajdacic, V., Eich, D., ... & Angst, J. (2004). The association between short sleep duration and obesity in young adults: a 13-year prospective study. *Sleep*, *27*(4), 661-666. https://doi.org/10.1093/sleep/27.4.661.

Hsieh, H. F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research*, *15*(9), 1277-1288. https://doi.org/10.1177/1049732305276687.

Kahlhöfer, J., Karschin, J., Breusing, N., & Bosy-Westphal, A. (2016). Relationship between actigraphy-assessed sleep quality and fat mass in college students. *Obesity*, *24*(2), 335-341. https://doi.org/10.1002/oby.21326.

Keating, X. D., Guan, J., Piñero, J. C., & Bridges, D. M. (2005). A meta-analysis of college students' physical activity behaviors. *Journal of American College Health*, *54*(2), 116-126. https://doi.org/10.3200/JACH.54.2.116-126.

Kraus, R. (1971). *Recreation and leisure in modern society*. TACC.

Lowry, R., Galuska, D. A., Fulton, J. E., Wechsler, H., Kann, L., & Collins, J. L. (2000). Physical activity, food choice, and weight management goals and practices among US college students. *American Journal of Preventive Medicine*, *18*(1), 18-27. https://doi.org/10.1016/s0749-3797(99)00107-5

Lund, H. G., Reider, B. D., Whiting, A. B., & Prichard, J. R. (2010). Sleep patterns and predictors of disturbed sleep in a large population of college students. *Journal of Adolescent Health*, *46*(2), 124-132. https://doi.org/10.1016/j.jadohealth.2009.06.016.

Marcus, B. H., & Forsyth, L. H. (2009). *Motivating people to be physically active.* Human Kinetics.

McConnaughy, E. A., Prochaska, J. O., & Velicer, W. F. (1983). Stages of change in psychotherapy: Measurement and sample profiles. *Psychotherapy: Theory, Research & Practice*, *20*(3), 368. https://doi.org/10.1037/h0090198.

Mettling, S., Lee, J. M., Blount, A., & Dinkel, D. (2018). A Needs Assessment for Physical Activity Programming Based on the Transtheoretical Model. *Recreational Sports Journal*, *42*(2), 202-216. https://doi.org/10.1123/rsj.2017-0019.

Milroy, J. J., Orsini, M. M., D'Abundo, M. L., Sidman, C. L., & Venezia, D. (2015). Physical activity promotion on campus: Using empirical evidence to recommend strategic approaches to target female college students. *College Student Journal*, *49*(4), 517-526.

Pelletier, J. E., Lytle, L. A., & Laska, M. N. (2016). Stress, health risk behaviors, and weight status among community college students. *Health Education & Behavior*, *43*(2), 139-144. https://doi.org/10.1177/1090198115598983.

Pengpid, S., & Peltzer, K. (2018). Vigorous physical activity, perceived stress, sleep and mental health among university students from 23 low-and middle-income countries. *International Journal of Adolescent Medicine and Health*. *32*(2). /j/ijamh.2020.32.issue-2/ijamh-2017-0116/ijamh-2017-0116.xml.https://doi.org/10.1515/ijamh-2017-0116.

Plotnikoff, R. C., Costigan, S. A., Williams, R. L., Hutchesson, M. J., Kennedy, S. G., Robards, S. L., ... & Germov, J. (2015). Effectiveness of interventions targeting physical activity, nutrition and healthy weight for university and college students: a systematic review and meta-analysis. *International Journal of Behavioral Nutrition and Physical Activity*, *12*(1), 45. https://doi.org/ 10.1186/s12966-015-0203-7.

Powers, S. L., Trauntvein, N. E., Barcelona, R. J., & Hartman, C. L. (2019). Constraints and Negotiations to Student Recreational Sport Center Usage. *Journal of Amateur Sport*, *5*(2), 18-38. https://doi.org/10.17161/jas.v5i2.8439.

Prochaska, J. O., Redding, C. A., & Evers, K. E. (2015). The transtheoretical model and stages of change. In K. Glanz, B. K. Rimer, & K. "V." Viswanath (Eds.), *Health behavior: Theory, research, and practice* (pp. 125–148). Jossey-Bass/Wiley. Saleh, D., Camart, N., & Romo, L. (2017). Predictors of stress in college students. *Frontiers in Psychology*, *8*, 19. https://doi.org/10.3389/fpsyg.2017.00019.

Sallis, J. F., & Saelens, B. E. (2000). Assessment of physical activity by self-report: status, limitations, and future directions. *Research Quarterly for Exercise and Sport*, *71*(sup2), 1-14. https://doi.org/10.1080/02701367.2000.11082780

Schumann, A., Nigg, C. R., Rossi, J. S., Jordan, P. J., Norman, G. J., Garber, C. E., ... & Benisovich, S. V. (2002). Construct validity of the stages of change of exercise adoption for different intensities of physical activity in four samples of differing age groups. *American Journal of Health Promotion*, *16*(5), 280-287. https://doi.org/10.4278/0890-1171-16.5.280.

Sjostrom, M., Ainsworth, B., Bauman, A., Bull, F., Hamilton-Craig, C., & Sallis, J. (2005). Guidelines for data processing analysis of the International Physical Activity Questionnaire (IPAQ)-Short and long forms.

Van der Zwan, J. E., de Vente, W., Huizink, A. C., Bögels, S. M., & de Bruin, E. I. (2015). Physical activity, mindfulness meditation, or heart rate variability biofeedback for stress reduction: a randomized controlled trial. *Applied Psychophysiology and Biofeedback*, *40*(4), 257-268. https://doi.org/10.1007/s10484-015-9293-x.

Velicer, W. F., Prochaska, J. O., Fava, J. L., Norman, G. J., & Redding, C. A. (1998). Detailed overview of the transtheoretical model. *Homeostasis*, *38*, 216-233. https://doi.org/10.4278/0890-1171-12.1.38.

Watson, N. F., Badr, M. S., Belenky, G., Bliwise, D. L., Buxton, O. M., ... & Kushida, C. (2015). Joint consensus statement of the American Academy of Sleep Medicine and Sleep Research Society on the recommended amount of sleep for a healthy adult: methodology and discussion. *Sleep*, *38*(8), 1161-1183. https://doi.org/10.5665/sleep.4716.

Wu, X., Tao, S., Zhang, Y., Zhang, S., & Tao, F. (2015). Low physical activity and high screen time can increase the risks of mental health problems and poor sleep quality among Chinese college students. *PloS one*, *10*(3), e0119607. https://doi.org/10.1371/journal.pone.0119607.

Zizzi, S., Ayers, S. F., Watson, J. C., & Keeler, L. (2004). Assessing the impact of new student campus recreation centers. *NASPA Journal*, *41*(4), 588-630.

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