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Behavior Change Trajectories and Metabolic Syndrome Risk Factor Clustering During the Transition to College: A Feasibility Pilot Study

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ABSTRACT

International Journal of Exercise Science 15(5): 125-141, 2022. Metabolic syndrome (MetS) is typically diagnosed in adults; however, MetS risk factors are growing in prevalence during youth and young adulthood. Though the transition from high school to college is associated with adverse changes in lifestyle behaviors that may contribute to MetS risk factor development, the relationship between pre-college MetS risk status and transition-related behavior change is unknown. This prospective study aimed to describe the relationship between pre-college MetS risk status and transition-related behavior change trajectories in college-bound students. Moreover, it aimed to assess the feasibility of the study design, including acceptability to both participants and investigators, prior to implementation in a larger sample. Participants (n = 21, 18.3 ± 0.3 y/o) were assessed for MetS risk factors during their last semester of high school. Self-report behavioral data on dietary habits, physical activity, sleep, stress, and alcohol consumption were collected at baseline and during the fall and spring semesters of the first year of college. Linear mixed models revealed drastic increases in alcohol consumption (β_{11} = 0.39, p < 0.001) and apparent decreases in moderate-vigorous physical activity (β_{11} = -0.15, p = 0.185) during the college transition. Furthermore, 47.6% of students had ≥ 1 MetS risk factor at baseline and those with a greater number of risk factors experienced a more severe alcohol-related behavior change trajectory (β_{11} = 0.29, p < 0.050). These findings highlight the importance of primordial prevention strategies against early MetS risk development, given the potential relationship with future behavioral trajectories. Future research should aim to further characterize this relationship using comprehensive, longitudinal measures that span the college transition in larger, more diverse samples.

KEY WORDS: Cardiometabolic risk, lifestyle, physical activity, alcohol consumption, university students, young adults

INTRODUCTION

Approximately half of college students possess one or more metabolic syndrome (MetS) risk factor including: abdominal obesity, elevated triglycerides (TRG), low high-density lipoprotein cholesterol (HDL), hypertension, and high fasting blood glucose (24, 26). Importantly, the development of each subsequent risk factor (i.e. risk factor clustering) increases lifetime cardiovascular disease risk (32, 35, 49). Those with defined MetS, characterized by the presence of three or more risk factors, experience a two-fold greater risk of developing cardiovascular

disease (1). Whereas defined MetS is typically detected and diagnosed in adults, in whom it affects an estimated 35% of the overall US adult population, there is growing evidence that individual MetS risk factors develop much earlier in life (17, 32) and are particularly prevalent in college students (16, 22–26, 43, 47).

In addition to the high prevalence of individual MetS risk factors, the college years are associated with poor lifestyle behaviors. Racette et al. found that out of 204 first year college students, only 29% engaged in regular physical activity and 71% ate fewer than the daily recommended servings of fruits and vegetables (36). Moreover, the transition from high school to college has been characterized as a key period for suboptimal changes in lifestyle behaviors. Deforche et al. reported a decrease in fruit and vegetable intake, sport participation, and active transportation as well as an increase in alcohol consumption in students transitioning to college (12). Similarly, Sher and Rutledge noted that heavy drinking behaviors increased significantly from the end of high school to the first semester of college (39).

Though previous studies have indicated that the college transition is associated with adverse changes in lifestyle behaviors, most have relied on retrospective recall to describe pre-college behaviors, limiting the validity of transition-related data (5, 38, 44). Furthermore, while some studies have proposed that negative changes in physical activity, sleep duration, and alcohol intake are associated with weight gain during the college transition (12, 44), no research has explored the relationship between pre-college MetS risk status and lifestyle behavior change. Characterizing this relationship using ecologically valid, prospective behavior change data will help to inform primordial prevention strategies by highlighting specific behaviors and populations that might benefit from targeted, early intervention to prevent further MetS risk development.

While a large-scale, prospective longitudinal trial would provide important evidence to inform the design of behavioral interventions in this population, such studies are expensive and time consuming. Thus, it is important to first determine whether the proposed trial protocol is logistically feasible and acceptable to both investigators and participants (10, 45). A feasibility pilot study is a necessary step in the development of behavioral strategies for the prevention and treatment of chronic disease that utilizes a similar design to the eventual large-scale trial. It provides an opportunity for investigators to a) identify barriers to successful study completion, b) evaluate the acceptability of methods to participants and the investigative team, c) estimate time requirements and participant dropout rates, and d) provide overall 'proof of concept' for the study design and aims. Though such trials produce somewhat variable estimates of primary effect sizes, this information can also be used to help determine sample sizes for large-scale trials (10).

Accordingly, the aims of this feasibility pilot study were to 1) describe lifestyle-related behavior change trajectories during the transition from high school to college, 2) identify whether pre-college MetS risk status predicts the degree of behavior change during the college transition, and 3) assess the feasibility of conducting an ecologically valid, comprehensive assessment of behavioral and cardiometabolic risk trajectories in a larger sample of college-aged young adults.

Based on previous literature, we anticipated that college students would experience negative lifestyle-related behavior change during the college transition and that those with a greater number of MetS risk factors before beginning college would be more likely to experience negative behavior change.

METHODS

Participants

We conducted a prospective, longitudinal feasibility pilot study that included incoming first-year university students, see Figure 1. Recruitment strategies consisted of flyers posted in the surrounding community, postcards mailed to high school seniors, targeted social media advertisements and social media posts, and word-of-mouth advertising. Eligible participants were high school seniors aged 17-19 years old, entering their first year of college during the fall of 2019, and planning to live on campus at a four-year university in the US. Participants were excluded if they (a) were pregnant or planning on becoming pregnant, (b) had a condition known to affect metabolism, bone growth, vestibular function, or neuromuscular function, (c) experienced an injury or orthopedic limitation that inhibited the participation in regular physical activity, or (d) were unwilling or unable to come to the lab for testing visits. Written informed consent was obtained from each participant 18 years and older, whereas informed consent was obtained from a parent / guardian along with assent from the minor participant in those < 18 years, prior to enrolling in the study. All aspects of the protocol were approved by the University's Institutional Review Board, and this research was carried out fully in accordance with the ethical standards of the International Journal of Exercise Science (31).

Protocol

To assess MetS risk factors and baseline lifestyle behaviors, two in-person testing sessions were conducted during the participants' last semester of high school. Due to the rolling basis of recruitment, the timing of in-person testing varied for each participant; however, all visits were scheduled between March and June of 2019. The first visit consisted of anthropometric and blood pressure measurements as well as lifestyle-related questionnaires on dietary habits, physical activity, sleep, stress, and alcohol consumption. All questionnaires were administered via Qualtrics online survey software (Qualtrics, Provo, UT) except for the diet history questionnaire, which was completed using the Diet History Questionnaire (DHQ III) from the National Cancer Institute (29). Between seven and fourteen days later, participants returned to the lab for a second visit where blood biomarkers were measured via venipuncture and subsequent biochemical analysis.

The same set of lifestyle-related questionnaires used at baseline were administered to conduct remote follow-up assessments to identify transition-related behavioral changes. Specifically, the questionnaires were completed once per semester during the fall and spring of participants' first year of college while they resided on college campuses across the US. The investigators coordinated the distribution of questionnaires with university calendars to ensure that they were not administered during breaks, final exams, or other predictable contexts in which lifestyle behaviors may deviate from normal.

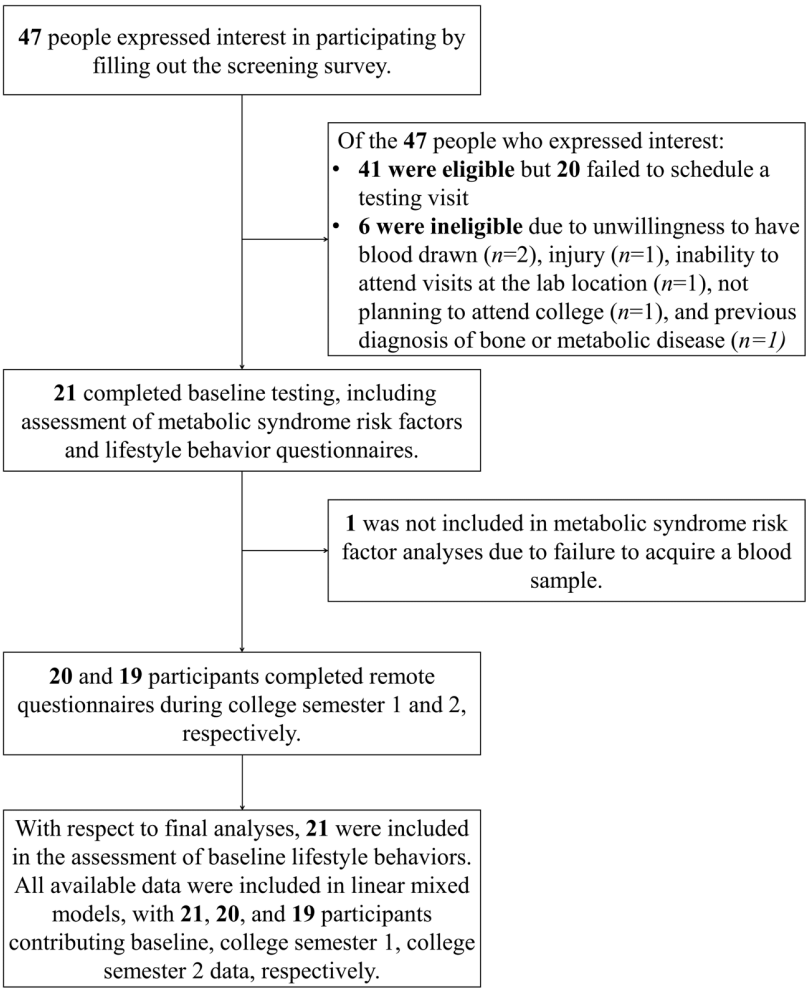

Figure 1. Flow Chart of Study Participant Inclusion

MetS Definition: In the current sample, the prevalence of metabolic syndrome and its individual risk factors were evaluated using the harmonized definition (1). Briefly, the presence of MetS was defined as having at least three of the following risk factors: waist circumference ≥ 94 cm in males and ≥ 80 cm in females or the use of population-specific cut points for non-white participants, TRG ≥ 150 mg/dL, HDL < 40 mg/dL in males and < 50 mg/dL in females, fasting glucose ≥ 100 mg/dL, and systolic blood pressure of ≥ 130 mmHg or diastolic blood pressure of ≥ 85 mm Hg.

Anthropometrics: Height and weight were measured to the nearest 0.1 cm and 0.1 kg using a standing balance scale and stadiometer (DETECTO, Webb City, MO). Waist circumference was measured in duplicate halfway between the top of the iliac crest and the most inferior palpable rib using a fiberglass no-stretch, retractable tape measure (Gulick II; MABIS Healthcare, Inc., Lake Forest, IL). Participants were instructed to stand with their feet hip-width apart and to breathe normally. If the difference between the first two measurements exceeded 0.5 cm, a third was taken. Waist circumference was assessed using the average of all measurements.

Blood Pressure: Systolic and diastolic blood pressure was taken in duplicate following a 15-minute seated resting period during two separate visits. Blood pressure was assessed using the average of the four recordings. All measurements were performed in the seated position at the upper arm with an automated blood pressure cuff (CARESCAPE V1000 Monitor, GE Healthcare, Chicago, IL).

Blood Biomarkers: A venous blood draw was used to measure HDL, TRG, and fasting blood glucose. Blood samples were collected from the antecubital space following a 12-hour overnight fast. Samples were analyzed with the Piccolo Xpress Chemistry Analyzer (Piccolo Lipid Panel Plus; Abaxis, Inc., Union City, CA). The Piccolo chemistry analyzer has been shown to have acceptable precision relative to laboratory-based testing for the assessment of a range of metabolites (28, 34).

Physical Activity and Sedentary Behavior: The International Physical Activity Questionnaire (IPAQ) assessed the number of minutes participants perceived that they engaged in moderate-to-vigorous intensity physical activity (MVPA) per day as well as the number of hours of sedentary time per day. The IPAQ includes 31-items that measure physical activity across four domains: leisure time, work, transportation, and household tasks (19). Additionally, the questionnaire asks respondents to report the amount of time they spend sitting. The IPAQ has been validated in a diverse set of populations and settings, including college-aged samples (9).

Diet Quality: The dietary habits of participants were evaluated using the DHQIII from the National Cancer Institute (29). This comprehensive dietary assessment tool, consisting of 135 food and beverage items and 26 dietary supplement questions based on adult intake data from 2007-2014 NHANES 24-hour dietary recall, has been shown to produce reliable and valid dietary patterns (40–42). To assess diet quality, DHQ III asks about the frequency with which respondents consumed certain foods, beverages, and supplements during the last month. In the present study, we reported the Healthy Eating Index 2015 (HEI) score to assess diet quality and changes in dietary habits over time. HEI was calculated according to standard scoring procedures (30).

Sleep: The Pittsburg Sleep Quality Index (PSQI) is a widely used 19-item questionnaire that quantifies sleep duration and sleep quality during the past month. PSQI produces seven component scores: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleeping medication, and daytime dysfunction. The sum of the components generates a global PSQI score, where lower scores are indicative of a healthier sleep quality and higher scores denote poorer sleep quality (7). PSQI has been validated for habitual sleep assessment in college students (14, 33) and, in this population, a score of ≥ 6 has been recommended to detect insomnia with maximum sensitivity and specificity (14).

Stress: The 10-item Perceived Stress Scale (PSS-10) quantifies the "degree to which individuals appraise situations in their lives as stressful" (8). Participants are asked about aspects of their life that are unpredictable, uncontrollable, or overloaded and describe how often they think or feel a certain way using a Likert scale ranging from 0 (never) to 4 (very often). Scores range from

0 to 40, with a score of 0-13 denoting low perceived stress, 14-26 denoting moderate perceived stress, and 27-40 denoting high perceived stress. PSS-10 has been shown to be reliable and valid for use in college populations (37).

Alcohol Consumption: The Alcohol Use Disorders Identification Test (AUDIT) was used to quantify alcohol consumption and examine alcohol-related behaviors. AUDIT is a widely used 10-item questionnaire that has been previously validated for use in college students (18). Questions asking about alcohol-use during the past year were modified to only include the last three months so that changes in alcohol-related behavior throughout the college transition could be detected. AUDIT scores range from 0 to 40, with a score of 0-7 indicating a low risk for harm and/or dependency, 8-15 indicating a risky or hazardous level of consumption, 16-19 indicating high-risk or harmful levels, and 20 or more indicating high-risk with almost certain dependency (46).

Feasibility: Feasibility was assessed via several qualitative and quantitative means. Participant complaints regarding the study design, time of participation, and the behavioral monitor wear and return protocols were logged, and records of adverse events were kept. Participant retention across all three time points, as well as information regarding the volume and context of missing data were also tracked.

Statistical Analysis

All statistical analyses were performed using R, (R, Version 4.0.0) with an α-level of 0.05. First, the prevalence of individual MetS criteria and risk factor clustering (i.e. the presence of more than one MetS risk factor) were evaluated using chi-square test for independence. Second, to determine the influence of the transition from high school and the first year of college on lifestyle-related behaviors while accounting for the clustering of observations within individuals, linear growth models with random intercept and slopes were estimated using multi-level modeling, executed in the 'lme4' package (3).

Regarding lifestyle-related behaviors, separate growth models were estimated to determine the change in MVPA, sedentary time, HEI score, sleep duration, PSQI score, sleep duration, and AUDIT score across the transition from high school through the first year of college (e.g. from baseline through college semesters 1 and 2). In such models, the intercept represents the average value for the respective lifestyle-related behavior at baseline with associated *p*-values denoting significant differences among participants at baseline, and the slope represents the average per semester change in lifestyle related behavior over the transition to college. Additionally, all models examined the influence of individual MetS risk factor scores at baseline (0, 1, 2, or 3+) on growth trajectories. All model assumptions were met except for homogeneity of variance; therefore, we estimated the proposed models accounting for heteroscedastic level-1 residuals. Several lifestyle-related variables (i.e. PSQI score, MVPA, and AUDIT score) were log transformed prior to inclusion in final models due to non-normality of model residuals. A sample size of 20 or more was deemed appropriate to allow for the precise estimation of variances and effect sizes needed for planning a subsequent larger trial. In a repeated measures

design with three time points, 20 participants would provide power of at least .80 to detect moderate effect sizes (η^2 or squared partial correlations = 0.06) (20).

RESULTS

Participant Characteristics and Baseline Lifestyle-Related Behaviors: Descriptive characteristics of the study sample are presented in Table 1. All participants were recruited from the southeastern United States and were planning to start their first year of college at various US universities beginning in the fall of 2019. Of the 21 participants, 18 attended universities in the Southeast, two in the Midwest, and one in the Northeast. The mean age of the sample was 18.3 ± 0.3 years old, 66.7% were female, and 85.7% were white. On average, the BMI of participants was classified in the healthy weight range; however, two participants had a BMI that exceeded 25 kg/m^2 including one exceeding 30 kg/m^2. Taking into account sex- specific measurement cut-offs, mean MetS risk factor data indicates that, on average, participants fell within normal ranges for all MetS risk factors. Lifestyle-related behavior data can be found in Table 3. At baseline, participants reported an average daily sedentary time of approximately six hours and tended to engage in adequate levels of MVPA, averaging 98 minutes per day (13). Mean baseline sleep duration fell within the recommended seven to nine hours (21), and mean baseline PSQI scores, though not high enough to detect insomnia in young adults, were just below the threshold of > 5 for the detection of "poor" sleepers (7). Average PSS and AUDIT scores indicated that participants experienced moderate perceived stress (8) and were at a low risk for alcohol-related harm or dependency at baseline (46), respectively. Finally, mean baseline HEI scores reflected a diet that needed improvement (4).

Table 1. Participant Characteristics (*n* = 21)

Anthropometrics	
Height (cm)	170.0 ± 10.6
Weight (kg)	64.5 ± 12.0
BMI (kg/m^2)	22.2 ± 3.3
MetS Risk Factors	
Waist Circumference (cm)	73.1 ± 8.5
Systolic Blood Pressure (mm/Hg)	124.0 ± 10.1
Diastolic Blood Pressure (mm/Hg)	73.0 ± 7.3
HDL (mg/dL)	57.0 ± 10.7
Triglycerides (mg/dL)	79.1 ± 25.3
Fasting Blood Glucose (mg/dL)	94.8 ± 6.9

Note. Values are written as mean ± SD. BMI, body mass index; MetS, metabolic syndrome; HDL, high-density lipoprotein cholesterol.

Metabolic Syndrome Risk Prevalence: Metabolic syndrome risk factor prevalence and clustering are presented in Table 2. Nearly half of the sample (47.6%) had one or more metabolic syndrome risk factors. The presence of defined metabolic syndrome was rare, with only one participant possessing three or more risk factors. The most common risk factor was hypertension (23.8%) followed by low HDL and elevated fasting blood glucose (both 14.3%).

Table 2. MetS Risk Factors and Risk Factor Clustering (*n = 21)*

Individual MetS Risk Factors	Prevalence (%)
Abdominal Obesity* (males: ≥ 94 cm; females: ≥ 80 cm)	9.5%
Hypertension (systolic ≥ 130 mmHg; diastolic ≥ 85 mmHg)	23.8%
Low HDL (males: < 40 mg/dL; females: < 50 mg/dL)	14.3%
Elevated Triglycerides (≥ 150 mg/dL)	0.0%
Elevated Fasting Blood Glucose (≥ 100 mg/dL)	14.3%
MetS Risk Factor Clustering	
At least one risk factor	47.6%
At least two risk factors	9.5%
Three or more risk factors (defined MetS)	4.8%

Note. *Abdominal obesity cut-off values were specific to race. HDL, high-density lipoprotein cholesterol; MetS, metabolic syndrome.

Lifestyle-Related Behavior Change: Results of linear mixed models for each lifestyle-related factor are presented in Table 3. Briefly, baseline values of all lifestyle-related factors varied significantly among participants (all $p < 0.001$). Cumulative lifestyle-related behavior change data can be found in Figure 2. The majority of lifestyle-related factors did not change meaningfully over time, however, there were apparent decreases in MVPA. Relative to baseline, average MVPA had decreased by a total of 27.7% by college semester 1 and a total of 24.6% by college semester 2 (β_{10} = -0.15, p = 0.185, 95% CI -0.37–0.07), with a slight (3.1%) increase between semesters. Importantly, AUDIT scores were omitted from Figure 2 due to the magnitude with which they changed, with average scores increasing by 189.5% by college semester 1 and a further 39.1% by college semester 2 (β_{10} = 0.39, $p < 0.001$, 95% CI 0.22–0.57), relative to baseline. By the end of the first year of college, 26.3% of the sample possessed "harmful or hazardous" drinking behaviors. To further explore the results of the linear mixed model with regard to alcohol consumption, cross-level interactions were run with the number of MetS risk factors at baseline included as an interaction term. Results suggested that the number of MetS risk factors at baseline predicted the trajectory of behavior change (Figure 3), with participants that had greater number of risk factors experiencing a steeper alcohol-related behavior change trajectory (β_{11} = 0.29, p = 0.023, 95% CI 0.04–0.54).

Feasibility: No complaints were registered regarding the study design or testing time requirements. However, several participants reported that the wearable monitor was uncomfortable and caused redness/chafing at the wrist. Four adverse events occurred during or immediately following the venous blood draw, including one instance of minor edema and bruising at the draw site, one instance of dizziness that remedied within 2 minutes of transitioning to a supine position, and two instances of syncope during or immediately following the blood draw. Though one instance of syncope prevented the acquisition of a viable blood sample, both participants recovered quickly without need for external assistance. Participant retention was excellent, with one participant lost to follow-up during college semester 1 (4.8% of sample) and a second participant lost to follow-up by college semester 2 (9.5% of sample), thus, overall retention was 19 of 21 (90.5%). The study team were unable to contact the participants that dropped out, so no reason was provided for attrition. Finally, complete data for all outcomes were available for 20 of 21 participants at baseline and college

semester 1, with one participant providing complete data other than the biochemical outcomes due to the previously described inability to acquire a blood sample. At college semester 2, one participant failed to complete their lifestyle-related questionnaires.

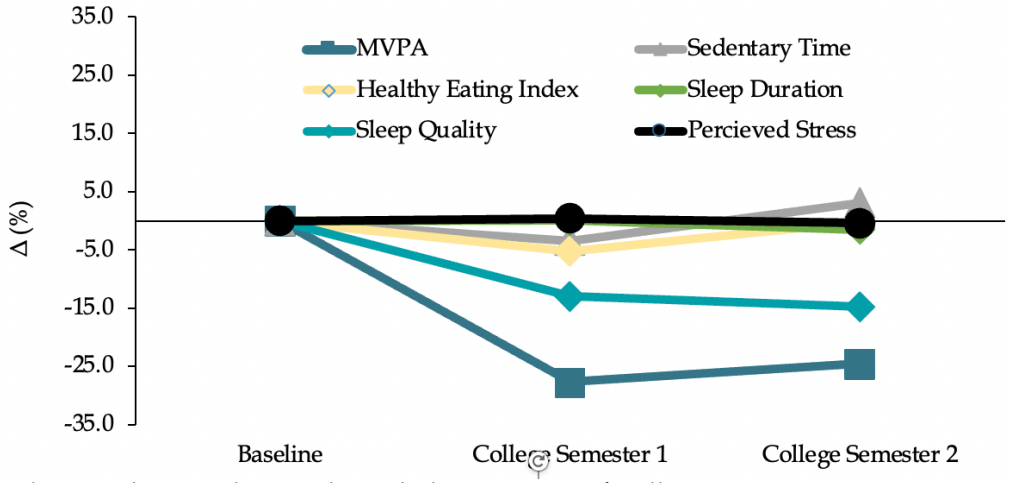

Figure 2. Cumulative Behavior Change Through the First Year of College. AUDIT scores were not included due to large percent change, increasing by 188.8% between baseline and college semester 1 and a further 28.9% by college semester 2. Note. MVPA, moderate-vigorous physical activity; AUDIT, Alcohol Use Disorders Identification Test.

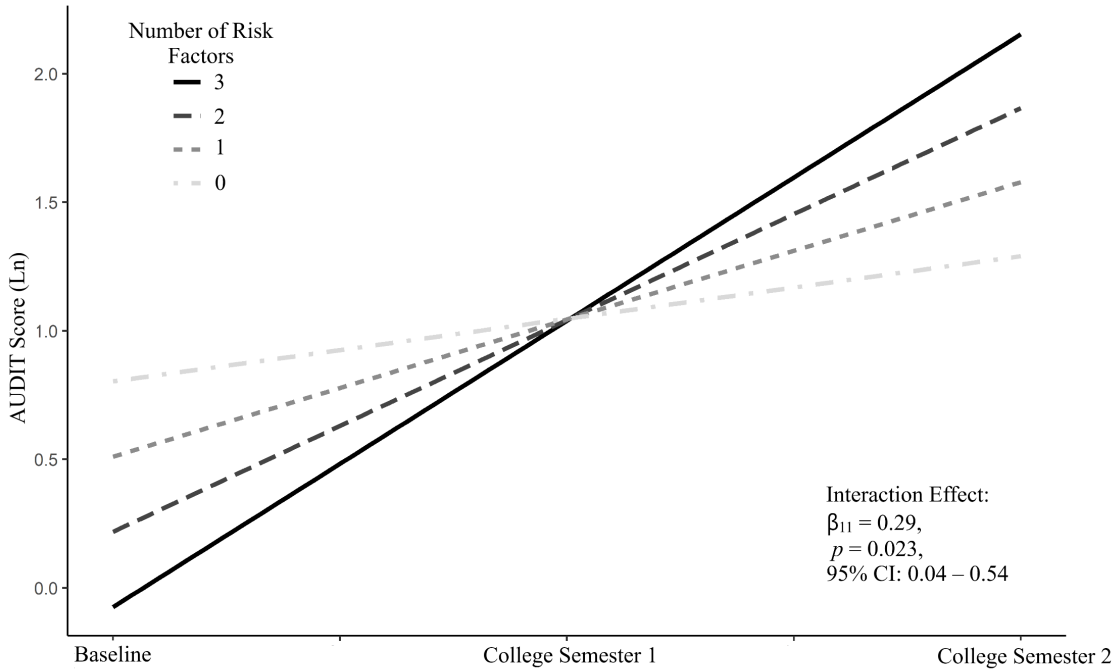

Figure 3. AUDIT Score Trajectory Relative to Baseline Risk Factor Clustering.
Note. AUDIT, Alcohol Use Disorders Identification Test.

Table 3. Linear Mixed Models Depicting Behavioral Characteristics During the Transition to College

	Behavior Change Descriptives			Intercept					Slope				
	Baseline (n = 21)	College Semester 1 (n = 20)	College Semester 2 (n = 19)	β_{00}	SE	LLCI	ULCI	*P*-value	β_{10}	SE	LLCI	ULCI	*P*-value
MVPA* (mins/day)	98.00 ± 72.60	70.90 ± 51.10	73.90 ± 59.40	4.24	0.20	3.85	4.62	< 0.001	-0.15	0.11	-0.37	0.07	0.185
Sedentary Time (hours/day)	6.06 ± 3.19	5.85 ± 2.54	6.24 ± 2.13	5.95	0.66	4.66	7.25	< 0.001	0.05	0.34	-0.62	0.71	0.890
HEI Score	61.00 ± 10.10	57.80 ± 9.49	60.90 ± 10.60	60.00	2.13	55.82	64.18	< 0.001	-0.04	1.04	-2.07	2.00	0.971
Sleep Duration (hours)	7.29 ± 1.04	7.29 ± 1.14	7.17 ± 1.09	7.30	0.20	6.91	7.69	< 0.001	-0.04	0.18	-0.04	0.30	0.801
PSQI Score*	5.00 ± 2.49	5.65 ± 2.91	5.74 ± 3.11	1.73	0.09	1.54	1.91	< 0.001	0.05	0.05	-0.05	0.02	0.318
Perceived Stress Score	16.40 ± 7.10	16.50 ± 7.00	16.37 ± 6.58	16.44	1.53	13.44	19.44	< 0.001	0.06	0.97	-1.84	1.96	0.951
AUDIT Score*	1.33 ± 2.11	3.85 ± 4.22	4.37 ± 3.68	0.63	0.16	0.31	0.95	< 0.001	0.39	0.09	0.22	0.57	< 0.001

Note. Values are written as mean ± SD, unless otherwise noted. AUDIT, Alcohol Use Disorders Identification Test; MVPA, moderate-vigorous physical activity; PSQI, Pittsburgh Sleep Quality Index; HEI, healthy eating index. LLCI = Lower Limit of 95% Confidence Interval. ULCI = Upper Limit of 95% Confidence Interval. B_{00} = The coefficient for the intercept represents the average value at baseline. B_{10} = The coefficient for the slope represents the trajectory of behavioral change across the first year of college. *AUDIT, MVPA, and PSQI scores were log transformed prior to inclusion in linear mixed models

DISCUSSION

This study aimed to describe lifestyle-related behavior change trajectories during the transition from high school to college. Additionally, we aimed to identify whether baseline MetS risk predicted the degree of behavior change, as well as to assess the feasibility of conducting a comprehensive assessment of behavioral and cardiometabolic risk trajectories in young adults as they transition from high school to college. Our findings indicate that 47.6% of students had at least one MetS risk factor at baseline and experienced notable transition-related lifestyle behavior change. Among the most prominent were significant and drastic increases in AUDIT score as well as apparent decreases in MVPA, relative to baseline. Importantly, participants with a greater number of risk factors at baseline experienced a steeper alcohol-related behavior change trajectory across the first two semesters of college. In general, the study design and methods were well accepted, with excellent participant retention, minimal missing data, and few adverse events. Taken together, these findings highlight the importance of primordial prevention strategies during the high school and early college years, as MetS risk factors are already beginning to accrue. Furthermore, there is a need to assess concurrent, longitudinal change in MetS risk factors to identify the link between behavior change trajectories and risk factor development. Such data will inform the design of behavioral interventions by identifying population-specific behaviors that may be important preventative targets, given their role in the development of MetS risk. Our data suggest that a large-scale, prospective longitudinal trial that concurrently assesses behavioral and cardiometabolic outcomes across the transition from high school to college would be a feasible means to achieve this long-term goal.

Comparison to Relevant Literature: In the present study, 47.6% of the sample had at least one MetS risk factor while only 5% had defined MetS. The finding that approximately half of college students had one or more MetS risk factor agrees with previous studies using similar MetS criteria and sample demographics. A study conducted by Keown, Smith, and Harris in the southeastern United States found that out of 21 college students, 43% had at least one MetS risk factor (24). In contrast, Morrell et al. reported higher rates in their sample of 360 college students at three different universities, with 62% of males and 52% of females possessing at least one MetS risk factor (26). Taken together, these data support the present finding that individual MetS risk factors are prevalent in college students and suggest that rates approach and, in some samples, exceed 50%. Importantly, our data indicate that though individual risk factor prevalence was common, risk factor clustering was not. Numerous studies have documented similar observations in which the prevalence of individual risk factors greatly exceeded the rate of defined MetS (i.e. risk factor clustering) in a college population (16, 22, 24, 47). Since MetS risk factors have not yet begun to cluster in college-aged individuals, the college years may serve as a key time period for the implementation of primordial prevention strategies that aim to prevent additional risk factor development.

With respect to behavior change, there was a significant increase in AUDIT score as well as an apparent decrease in MVPA during the transition from high school to college. These findings are consistent with prior research investigating the lifestyle-related changes that occur during the transition to college. Deforche et al. followed 291 Belgian students transitioning to college

and reported significant increases in alcohol consumption, with males increasing an average of 110% (d = 0.68, p < 0.001) and females increasing an average of 50% (d = 0.45, p < 0.001). Deforche et al. also noted that sport participation decreased significantly in males by 42.7% (d = 0.47, p < 0.001) and in females by 40.0% (d = 0.37, p < 0.001) (12). Similarly, Sher and Rutledge reported a substantial mean increase in alcohol consumption (p < .001) between high school and the first semester of college in in their sample of 3720 students (39). Furthermore, Wengreen and Moncur documented that in a sample of 159 students, those who gained 5% or more of their baseline bodyweight during the transition to college engaged in less physical activity relative to high school (44). These studies collectively support the present finding that alcohol consumption and physical activity may be key behaviors that are susceptible to adverse change during the college transition. Additionally, though previous literature may suggest that negative behavior change is associated with increases in MetS risk by way of weight gain (44), comprehensive and objective measures of transition-related behavior change as well as longitudinal MetS risk assessments are needed to more clearly characterize the relationship between behavior change and subsequent risk factor development.

In addition to AUDIT score and MVPA, other potentially influential lifestyle behaviors have been reported in college populations. Deforche et al. noted changes in dietary habits during the transition to college, including a significant decrease in fruit and vegetable intake. Though no dietary changes were noted in the current study, diet quality may be an in important factor affecting weight as increases in fruit and vegetable intake were associated with decreases in BMI in college females (12). Moreover, Wengreen and Moncur found that those who experienced the greatest weight gain during the transition to college reported longer average sleep durations, indicating that sleep may be another key behavior influencing MetS risk in college students (44). Though the present study found that increases in AUDIT score and decreases in MVPA were the most prominent lifestyle behavior changes occurring during the college transition, previous literature suggests that several lifestyle behaviors may be impeacted leading to possible increases in MetS risk.

To our knowledge, this is the first study to examine the relationship between baseline MetS risk factor clustering and subsequent lifestyle behavior change during the college transition. In our sample, we found that 47.6% had a least one MetS risk factor and that the number of risk factors present at baseline predicted the trajectory of alcohol-related behavior change during the college transition. Specifically, participants with higher numbers of MetS risk factors presented with a steeper negative behavior change trajectory. While no other studies have investigated the effect of risk factor clustering on subsequent lifestyle-related behavior change, research in adult populations has explored this relationship in the opposite direction, reporting that drinking behavior may affect the development of MetS risk factors (2, 15). Specifically, in a study of 3833 adults from Korea aged 40-69 years old, heavy drinkers consuming more than 30 grams of alcohol per day were significantly more likely to develop MetS than lighter or non-drinkers (2). Similarly, a different study reported that excess alcohol consumption was associated with the development of several MetS risk factors in adults aged 20-84 years old, including elevated fasting blood glucose and triglycerides, abdominal obesity, and hypertension (15). While the association between excess alcohol consumption and MetS risk has been well documented in

older populations, the present study suggests a need to both consider the directionality of this relationship and further investigate its significance in college populations. Confirming that greater baseline MetS risk is associated with steeper alcohol-related behavior change trajectories during the college transition and that steeper trajectories are also associated with increased lifetime MetS risk would emphasize the importance of primordial prevention strategies during the late-adolescent or early college years to halt a negative cascade of MetS risk development.

This study also allowed us to confirm the feasibility of our research design for the comprehensive assessment of lifestyle behavior change and MetS risk across the college transition. To assess transition-related behavior change, previous studies collected baseline data of pre-college lifestyle behaviors using retrospective recall that occurred after participants had already moved onto their college campuses (6, 44). This approach maximizes the potential for recall bias as participants were asked to remember pre-college behaviors from as far back as six months. The current study implemented a prospective approach that aimed to minimize recall bias by assessing behaviors when participants were still residing in their home environments, then following up during the first and second semester of college. Each behavioral assessment asked participants to report average behaviors over the past 7-30 days, depending on the outcome, with the shorter timeframe of behavioral recall helping to minimize bias associated from retrospective recall. Though longitudinal studies are typically limited by poor participant retention (11), our attrition rate of 9.5% (n = 2) was lower than that reported in previous college transition research (44). Moreover, 95% of the sample complied with all aspects of the study methodology, with only one participant failing to complete questionnaires during college semester 2. Our high retention and compliance rates also affirm the feasibility of assessing lifestyle behaviors prospectively during the college transition rather than relying on retrospective data. Furthermore, the minimal occurrence of adverse events and lack of concern expressed by participants about the burden of such a wide range of assessments provide confidence that a large-scale, prospective longitudinal study would be well accepted. With respect to future studies, prospective lifestyle behavior data will be imperative for identifying the relationship between behavior change trajectories and subsequent MetS risk development in college students.

Limitations and Strengths: Though this study has many strengths, it is important to acknowledge potential limitations such as the limited sample size which may have impacted our ability to detect changes in all behavioral outcomes. With this in mind, we chose to utilize linear mixed models to analyze behavior change trajectories, a statistical approach that provides greater power to assess such associations by allowing for the inclusion of participants with missing data at one or more time points. Such models also account for the non-independence inherent to multiple-observation designs when assessed using traditional methods such as repeated measures analysis of variance (48). This allowed us to detect actual or marginally significant changes in several behaviors, showing similar trajectories to those reported by others (12, 39), and giving us confidence that our findings are valid and meaningful. Furthermore, although we used validated questionnaires to assess lifestyle behaviors, we recognize that subjective data collection may lead to bias-related over- or under-reporting of lifestyle-related variables. For example, participants may have been more likely to remember extreme behaviors, such as

episodes of binge drinking or excessive exercise, that are not representative of their day-to-day lifestyle. To address issues surrounding self-report, future studies should seek to assess lifestyle behaviors via objective measures wherever possible, including the use of accelerometry to determine MVPA, sleep duration, and sleep quality. Moreover, we acknowledge that the onset of the COVID-19 pandemic may have affected lifestyle behaviors and the ways in which they were remembered and reported during the spring semester. Though we set out to do so, COVID-19 prevented the longitudinal assessment of MetS risk and objective behavioral change, as participants were not able to complete wearable-based assessments or return to the lab for follow-up cardiometabolic measures at the end of their first year of college. Finally, this study did not exclude participants based upon their status as a student athlete, military reserve officers' training corps, or other social choices that may have influenced their lifestyle-related behaviors. This is an important consideration for future studies as the required physical activity associated with these roles may alter behavioral trajectories during the college transition. Despite these limitations, this study was the first to assess both baseline MetS risk and a comprehensive array of lifestyle-related behaviors across the transition from high school to college. While previous studies have documented the prevalence of MetS and its individual risk factors on college campuses (16, 22–24, 26), few have done so in conjunction with lifestyle-related behavior change (25, 27, 47), and none have included a comprehensive evaluation of lifestyle behaviors.

Conclusions and Future Directions: Collectively, our data suggest that young adults may develop MetS risk factors before beginning college and that those with a greater number of risk factors before matriculating may experience more pronounced increases in adverse alcohol-related behaviors during their first two semesters, relative to their peers with lower MetS risk. In addition to alcohol consumption and MVPA, other lifestyle behaviors may also negatively change during the college transition and may serve as key targets for behavioral intervention efforts on college campuses. Future studies should focus on the longitudinal assessment of a comprehensive range of lifestyle behaviors and cardiometabolic risk factors during the college transition. To better understand how lifestyle behaviors change in relation to specific contexts within the first year of college (e.g. orientation, transitioning between semesters, final exams), investigators may choose to administer lifestyle-related assessments more frequently throughout each semester. Additionally, there is a need to assess the role of sex differences in both lifestyle behavior changes and MetS risk factor prevalence. Collectively, understanding how changing lifestyle behaviors affect the prevalence and emergence of MetS risk factors and identifying if sex differences moderate this relationship will help identify specific behavioral targets for the primordial prevention of MetS risk advancement in college students.

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