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Longitudinal Association between Alcohol Use and Physical Activity in US College Students: Evidence for Directionality

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Abstract

OBJECTIVE—To investigate directionality of the association between alcohol use and physical activity in a college student sample, longitudinally across three time points.

PARTICIPANTS—396 undergraduate students from a large university in the United States (62% women).

METHODS—Self-report data of alcohol use and physical activity were collected at three timepoints with 3-month lags between waves. Random-intercept cross-lagged panel modeling was used to disentangle within- and between-person effects.

RESULTS—Despite no significant between-person effects, there were significant cross-lagged paths from alcohol use to vigorous physical activity at the within-person level. Specifically, when individuals consumed more alcohol than normal at earlier timepoints, they reported more subsequent vigorous physical activity at 3-month follow-ups.

CONCLUSIONS—We provide evidence that alcohol use may positively predict later physical activity in college students over the course of a school year. These findings advance theoretical understanding of how these two health behaviors are linked using sophisticated methods.

Keywords

Health behavior; Emerging adulthood; Drinking; Exercise; Random intercept cross-lagged panel model

Patterns of health behaviors and broader lifestyle can shift dramatically during developmental transitions from adolescence into adulthood, especially when this transition also entails entering post-secondary education.¹ Two particularly salient developmental challenges for emerging adults is maintaining a physically active lifestyle and consuming

alcohol responsibly. This formative stage is marked by a rapid decline in physical activity^{2,3} and a sharp increase in alcohol use.^{4,5} Indeed, only an estimated 47% of college students meet the minimum physical activity recommendations, while 77% of college students report using alcohol even though more than half are underage.⁶ These health behaviors become lifestyle habits that are largely cemented during emerging adulthood and, in particular, during the college years.^{7,8} The current study sought to advance theory regarding how shifts in alcohol use and physical activity are associated in college students over the course of a school year.

Practitioners who promote health or develop prevention strategies are increasingly recognizing the need to understand how health behaviors cluster together or are associated across domains.⁹ Although largescale epidemiological studies have presented evidence that alcohol use increases during college while physical activity decreases,^{3,5} there is a contradictory body of literature indicating that these two behaviors may be *positively* associated.^{10–14} Indeed, a recent systematic review reported that seven out of the eight published studies that examined the association between alcohol use and physical activity in college students found evidence that the two health behaviors were positively related.¹⁰ This association also appears to be stronger in men than women, and may depend on the intensity of the physical activity in question.^{11,12} Because this positive association contradicts the trend of emerging adults generally decreasing physical activity and increasing alcohol use, compared to high school and adolescence, there is a need to study these behaviors a microlevel to better understand how these behaviors relate over time at both the within- and between-person levels.

Researchers have proposed multiple frameworks to explain the positive association between alcohol use and physical activity, and these frameworks tend to describe one behavior as a precursor to the other. Pertaining to social aspects, theorists have speculated that physical activity creates opportunities for students to socialize, which may lead to subsequent opportunities to drink alcohol.¹⁵ This is, in some cases, expected because alcohol is often consumed within or around physical activity settings through the phenomenon of ‘post-game drinks’ or sport fan drinking.¹⁶ In other cases, this association may be generated through more indirect pathways by forming friendships and social connections with other physically-active individuals who also consume alcohol.¹⁷

Other scholars in this domain have described this association by focusing on how individuals see the two behaviors as being offsetting or transactional. On one hand, there is an argument that alcohol use can serve as a reward for physical activity,¹⁸ whereby greater physical activity would essentially justify greater alcohol use. On the other hand, the most popular perspective is that individuals engage in physical activity to compensate for alcohol-related caloric intake.^{14,19} Indeed, recent work has demonstrated that the majority of college women (84%) reported being strongly motivated to engage in greater levels of physical activity to counteract the calories consumed from alcohol as a way of balancing themselves out and maintaining an attractive figure.¹³ Similarly, college men (76%) reported being motivated to engage in physical activity to balance out healthy and unhealthy behaviors with the hope that exercising can negate the adverse health effects of alcohol use.¹³

Despite directional supposition from researchers in this domain, the literature is primarily limited to cross-sectional studies that have drawn the conclusion that college students who *typically* drink more alcohol also *typically* engage in more physical activity.¹⁰ This cross-sectional evidence-base limits understanding of the directionality of the association. That is, does alcohol use predict physical activity; does physical activity predict alcohol use; or is the association reciprocal? As such, recent calls have been made for longitudinal research to investigate the relationship between alcohol use and physical activity across a longer period of time,¹⁰ and have expressed the need to unpack the directionality of this association.²⁰

A second inherent limitation to the cross-sectional literature is the inability to distinguish processes that shift behaviors within individuals over time from the types of processes that instead exist at the between-person level. To our knowledge, only one study has prospectively sought to understand whether alcohol use and physical activity are associated as part of a within-person process or rather are linked as the result of stable between-person differences.²¹ Within a lifespan sample of participants aged 19 to 89, Conroy and colleagues identified a daily association at the within-person level, such that people engaged in more physical activity than usual on days when they drank more alcohol than usual.²¹ Considering the limitations of the extant literature, an extension of this research is to look at within-person processes extending over longer periods of time to understand shifts in behaviors over months or years. It is also important to examine how these processes apply specifically to college-aged individuals, given the unique social environment within a college setting – especially pertaining to alcohol use and physical activity patterns.⁴ Such knowledge will provide more precise theoretical insight and may provide early evidence for tailored prevention and intervention strategies.

The present work investigated the association between alcohol use and physical activity in a college student sample using a longitudinal three-wave design. This design enabled us to fill important gaps in this literature by examining the directionality of the association across 3-month lagged intervals, and disentangling between- and within-person effects. Previous work on this topic has demonstrated the importance of distinguishing between more intense physical activity that is associated with perspiration and heavy breathing (i.e., vigorous physical activity), from less intense forms of physical activity such as traveling on foot or on bicycle (i.e., moderate physical activity).¹² To better understand the association between alcohol use and nuanced forms of physical activity, we examined associations with vigorous and moderate intensity physical activity separately. Although we hypothesized that alcohol use would be positively associated with both forms of physical activity, the novelty of this research question and contradicting scholarly arguments precluded us from making specific hypotheses pertaining to the directionality of the longitudinal association.

Method

Participants and Procedures

The participants were female ($n = 244$) and male ($n = 152$) college students from a large university in the Mid-Atlantic United States ($M_{\text{age}} = 20.97_{\text{years}}$, $SD = 1.58_{\text{years}}$; 83% Caucasian). At baseline, 2% were first year students, 9% were second year, 20% were third year, 58% were fourth year, and 11% were fifth year or beyond. Participants were recruited

using e-mail addresses obtained through participants' previous enrollment in single-credit health and physical activity courses (e.g., racquetball, ballroom dancing) offered to students in any major. At the university where these data were collected, all students are required to take three credits of health and/or physical activity, though there are alternative options that do not require physical activity. Participation in the research was incentivized by offering entrance in a drawing for a \$50 gift card at each wave. Surveys were administered through e-mail at three timepoints: Baseline, 3-month follow-up, and 6-month follow-up. Six cohorts of participants were enrolled into the study with baseline measurements taking place in: Fall 2014, Spring 2015, Fall 2015, Spring 2016, Fall 2016, and Spring 2017. Across all six cohorts, 2,543 students completed baseline surveys. Although 662 participants completed responses at the third wave, 266 of these were not included in the analyses due to either missing the second wave, or because they did not respond to the alcohol use items.

At each time point, participants were informed that participation was voluntary and that data were confidential. After providing informed consent, participants completed an online survey that encompassed a broad range of health behaviors, which took approximately ten to twelve minutes to complete. Although this survey was completed as part of a larger student health project assessing numerous health behaviors (i.e., fruit and vegetable consumption; active transportation), we utilized items pertaining to alcohol use and physical activity behaviors. Ethical approval was granted by the authors' institutional review board.

Measures

Participant demographic information was only collected at baseline (e.g., age, sex, race, height, and weight), whereas physical activity and alcohol use behaviors were assessed at each time point. The Global Physical Activity Questionnaire (GPAQ) assessed minutes per week that participants engaged in both moderate and vigorous physical activity (separately) by asking participants to recall over the previous 30 days how many days per week they typically engaged in vigorous and moderate intensity sport, fitness, or recreational and leisure activity, and for how many minutes on each day that they were active.^{22,23} Example activities were provided to help participants discern moderate activities (e.g., brisk walking; playing catch; volleyball) from those that entail vigorous intensity activity (e.g., running; ice hockey; football). The GPAQ is one of the most widely employed measures of physical activity and was chosen because of existing evidence for strong reliability and validity.^{22,23} Alcohol use was assessed by an item drawn from the National College Health Assessment,²⁴ where participants indicated how many days they consumed alcohol in the last 30 days. Response options were presented in a 7-point Likert-type scale (treated as continuous) and included: *Zero days* [1], *1–2 days* [2], *3–5 days* [3], *6–9 days* [4], *10–19 days* [5], *20–29 days* [6], and *every day* [7].

Analyses

Participants' data were included in the current study if they completed surveys at each of the three waves. We first calculated descriptive statistics and bivariate correlations, which included auto-correlations across the three timepoints to provide a preliminary overview of constructs' stability across time. As an additional preliminary step, we assessed the extent that participant nesting in the six staggered start-date cohorts affected alcohol use and

physical activity behaviors (i.e., seasonal or annual effects) by calculating intraclass correlation coefficients for each variable. Cohorts were coded categorically. Pertaining to the primary analyses, we specified random intercept cross-lagged panel models (RI-CLPM) to examine the association between physical activity and alcohol use over time.²⁵ Using the 'lavaan' package for R,²⁶ separate models were fit for both vigorous and moderate physical activity. By specifying random intercepts, variance at the within-person level is distinguished from variance at the between-person level. RI-CLPM is a multilevel approach in that it takes into account that measurement occasions are nested within individuals, while controlling for time invariant trait-like individual differences (i.e., between-person effects).²⁵ We parsed out between-person variability in alcohol use and physical activity to provide insight into how these two constructs are linked at the intra-individual level.²⁵ This is an enhancement to traditional cross-lagged modeling that uses aggregated effects to interpret cause and effect at the individual-level, which may result in an error of inference or ecological fallacy.²⁷

To provide a factor structure that captured within- and between-person variance, we included two random intercepts in the models: one for alcohol use, the other for physical activity. These random intercepts represent the stable trait-like differences between participants with regard to alcohol use and physical activity, and are distinguished from the within-person processes. The correlation between the random intercepts reflects how between-person differences in alcohol use are linked with between-person differences in physical activity. Autoregressive paths (i.e., parallel horizontal) reflect the extent that within-person deviations in alcohol use and physical activity can be predicted by deviations from participants' own expected alcohol use and physical activity, respectively. Cross-lagged paths reflect the extent that alcohol use and physical activity are linked reciprocally, and they indicate whether a deviation from participants' own expected alcohol use predicts a deviation from their own expected physical activity three months later (and vice versa). We specified sex and cohort as time-invariant covariates entered at the between-person level to control for sex differences as well as seasonal effects, respectively. Lastly, neither the autoregressive or cross-lagged paths were constrained to equality given that three cohorts began in a Fall semester and three cohorts began in a Spring semester. That is, because a more parsimonious constrained model may risk neglecting meaningful information, we made an a priori decision that it was more appropriate to leave these paths unconstrained, which we note is common among studies using RI-CLPM.^{e.g.,28}

Results

In checking the assumption of multivariate normality, it was revealed that vigorous and moderate physical activity variables were significantly positively skewed. As such, we applied log transformations to normalize the distributions, which yielded acceptable skewness for all variables (i.e., < 1.0). Descriptive statistics and bivariate correlations are presented in Table 1. Strong autocorrelations between the three waves indicated that alcohol use and physical activity were relatively stable across time. Small intraclass correlation coefficients indicated that the staggered start dates for the six cohorts played a minimal, but nevertheless important, role in participants' alcohol use and physical activity behavior – justifying the decision to control for seasonal and/or annual effects within our models.

The model testing the association between alcohol use and vigorous physical activity (Figure 1), revealed strong fit to the data: $\chi^2(10) = 19.47$ ($p = .04$), RMSEA = 0.05, CFI = 0.99, and SRMR = 0.03. The between-person association between alcohol use and vigorous physical activity was not statistically significant. Next, inspecting the autoregressive paths, within-person deviations in alcohol use were positively predicted by deviations from participants' own expected scores on alcohol use at earlier timepoints. Autoregressive paths were not significant for vigorous physical activity. Most relevant to the aims of this research, recall that we expected significant cross-lagged paths between the two behaviors. In the current model, cross-lagged paths indicated that deviations from participants' expected scores in alcohol use positively predicted deviations from participants' expected scores on vigorous physical activity at 3-month lagged timepoints. This means that alcohol use positively predicted vigorous physical activity at later timepoints, but vigorous physical activity did not significantly predict alcohol use.

The second model tested the association between alcohol use and moderate physical activity. This model, presented in Figure 2, also revealed strong fit to the data: $\chi^2(10) = 13.89$ ($p = .18$), RMSEA = .03, CFI = .99, and SRMR = 0.02. The between-person level association between alcohol use and moderate physical activity was not significant. The autoregressive paths again indicated that within-person deviations in alcohol use were positively predicted by deviations from participants' own expected scores on alcohol use at earlier timepoints, and the autoregressive paths were not significant for moderate physical activity. Lastly, the cross-lagged paths indicated that alcohol use did not significantly predict moderate physical activity, nor did moderate physical activity predict alcohol use.

Comment

Increased alcohol use and decreased physical activity are among the top health concerns for college students^{3,5}. Typically, college students' health behaviors cluster in expected ways, whereby healthful behaviors cluster together and health-risk behaviors cluster together²⁹; however, there is a large body of literature demonstrating that this is not the case for physical activity and alcohol use.³⁰ The current study was designed to investigate the longitudinal association between alcohol use and physical activity in college students using three waves of data across a six-month period. The findings indicated that alcohol use and physical activity are not significantly associated at the between-person level but, at the within-person level, reports of alcohol use were positively associated with future (i.e., 3-month lagged) reports of vigorous (but not moderate) physical activity. Furthermore, the cross-lagged design revealed that the association was not reciprocal in that physical activity did not predict alcohol use as other studies have suggested.¹⁰ These findings generate three primary messages for developing theory on these behaviors, as they: (a) Demonstrate that the directionality of this effect may stem from alcohol use, (b) provide evidence that this effect may exist primarily at the within-person level, and (c) demonstrate that alcohol use may relate to vigorous, but not moderate, physical activity.

The long-term directionality of this association holds important theoretical value. While the current results only apply to our understanding of a 3-month-lagged timescale, the finding that alcohol use predicted later physical activity, but physical activity did not predict alcohol

use, may provide early support for the compensatory supposition. That is, individuals show a linear increase in physical activity following a period of time that they engaged in relatively more alcohol use. However, it remains unclear whether this is an intentional process or an artifact of a more complex mechanism. Nevertheless, Dinger and colleagues used qualitative methods to reveal that, in the majority of binge-drinking college students, the up-regulation in physical activity is indeed an attempt to ‘balance out’ the negative health effects of alcohol use.¹³ Weighing the present positive longitudinal association, it can be surmised that college students may compensate for alcohol use by increasing physical activity, but perhaps this compensation does not occur until weeks or months later. The crucial next step is to investigate the mechanism underlying this association to better understand why, and under what circumstances, college students increase physical activity following periods of greater alcohol use, or decrease physical activity following periods of less alcohol use.

The innovative methodology used in the current study also enabled us to find evidence that the association between alcohol use and physical activity may occur at the within-person level rather than at the between-person level. In other words, it is not that those who tend to drink more also tend to exercise more, but rather *when* an individual drinks more, relative to their own typical level, they are likely to engage in more vigorous physical activity than usual at 3-month follow-up. This finding in itself may help move the field forward by encouraging researchers to apply similar longitudinal designs to investigate how health behaviors relate over time, and whether behaviors are related as part of within- or between-person effects. In addition to further unpacking how and when alcohol use and physical activity are related,²⁰ it is also prudent that researchers in this domain begin to move towards providing a clear understanding of *why* they are related and *for whom*.

A key distinction made in the current study is between moderate and vigorous physical activity. Whereas many of the previous cross-sectional studies found positive associations between alcohol use and both types of physical activity,¹⁰ the current results indicate that alcohol use may only be longitudinally predictive of vigorous physical activity and not moderate physical activity. From a theoretical perspective, it is important to consider the types of physical activities that students engage in, especially as they may pertain to compensation for previous alcohol use. Whereas moderate physical activity is often engaged in for the sake of travel (e.g., light bicycling) or non-intense recreation (e.g., passing a frisbee), vigorous physical activities are more intense forms of exercise (i.e., requires greater energy expenditure) that are likely to be engaged-in for the sake of improving physical health.³¹ If the motivation to be physically active is indeed to compensate for alcohol use, it is reasonable that students would engage in more intense forms of physical activity.

It is also prudent to consider the timescale for the current measurement waves (i.e., 3-month lags). The processes and mechanism underlying the longitudinal association across months may be quite different from those processes at a more proximal level (e.g., day-to-day association).²¹ Student drinking is also largely impacted by the season (e.g., football season)¹⁶ and other large alcohol-related events (e.g., Greek-Life initiation weeks, St. Patrick’s Day).³² Despite controlling for cohorts, the variations seen from these potential spikes in alcohol use were not currently able to be captured, but are nevertheless an

important consideration. Ultimately, the current study provided a deeper investigation of this association across 3-month lags, but does not necessarily generalize to other timescales.

As these findings did not reveal the mechanism behind the link between these behaviors, practical implications for stakeholders to promote college student health are linked to the key theoretical explanations for this association. First, practical implications extend from the expectation that students employ exercise instrumentally through weight-related motives to counterbalance the negative health effects of increased alcohol use.¹³ If students indeed operate under the presumption that exercise behavior can cancel-out or balance alcohol use, one practical approach to target alcohol use is to highlight other serious risks such as injury or liver disease.^{5,33} Campus alcohol prevention messaging could indicate that the health risks of alcohol use cannot be ‘undone,’ despite the potential misperception that they can. Similarly, if students’ exercise is limited to weight-related motives to counterbalance calories gained through alcohol use, campus programming may seek to highlight the more proximal benefits of exercise as a means of promoting positive affect, managing stress, or connecting with peers.³⁴ Broadly, the current findings demonstrate the need for college health stakeholders to develop ways of bundling health promotion strategies that promote an overall healthy lifestyle and correct the misperception that healthy and unhealthy behavior can ‘balance’ out. Specifically, exercising later does not make alcohol any less damaging to one’s health. Indeed, future work can build on early promising work that pairs alcohol prevention efforts directly with physical activity interventions.^{i.e. 35} Considering this association over several months, alcohol use and physical activity may coincide because they are shaped by similar forces in college students’ lives. For example, seasonal demands such as exam sessions may simultaneously reduce students’ time for physical activity and impede opportunities to engage in alcohol use. That is, the events that lead students to consume more alcohol may also be linked to physical activities. From a practical perspective, it is prudent to consider ways of focusing on the temporal periods where it is most essential to promote increased exercise and reduced alcohol consumption.

Limitations

Despite strengths, this study involved limitations that must be considered. First, although we used statistical techniques to control for the effect of sex, our study sample size was insufficient to investigate sex effects separately (e.g., multiple group analyses). Future work should investigate whether the association between alcohol use and physical activity is different for male and female college students.¹² Relatedly, although representative of the university, the sample was largely white, non-Hispanic, from one region of the country that may not generalize to more diverse populations in other regions. The present sample was also relatively active compared to other samples with similar-aged students.^{e.g. 34} The sample was primarily fourth-year students with insufficient heterogeneity to test whether year in school may moderate the association between physical activity and alcohol use, which would be a valuable direction for future work. Considerations should also be made for participant characteristics such as student athlete status, who may be teetotal and highly physically active during the sport season, but perhaps engage in alcohol use and less physical activity during the off season. The last sampling-related limitation is that the sample comprised only college students, so the findings may not generalize to the ‘forgotten

half⁷ of emerging adults who do not attend college. It is also prudent for future work to consider additional mechanisms that may influence these associations, such as changes to diet and sleep health.

The limitations raised by this observational and self-report design preclude us from making causal inferences or conclusions. Although self-reports of alcohol use have demonstrated strong validity,³⁶ college students tend to overestimate their physical activity.³⁷ Participants were also asked to recall these variables across the past month, which could yield inaccurate estimates and constrained the opportunity to consider drinking intensity (instead of only frequency). Although we presently focused on frequency of alcohol use, future work would also consider intensity as well. If feasible, future work should utilize objective markers of alcohol use and physical activity such as wearable monitors.^{20,38}

Conclusion

The current study provided a deeper investigation into the association between alcohol use and physical activity in US college students by using a longitudinal design. Notably, we found evidence for the directionality of this association in that, across 3-month lagged time waves, alcohol use positively predicted vigorous physical activity, but physical activity did not predict alcohol use. Moreover, we demonstrated the value in using this innovative methodology (i.e., RI-CLPM) that enabled us to find evidence that this association exists primarily at the within-person level, as opposed to between-persons. Future work should continue to investigate the association between alcohol use and physical activity within this high-risk population of college students using objective measurement tools such as accelerometers and transdermal alcohol sensors, as well across a range of timescales.

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References

1. Simons-Morton B, Haynie D, O'Brien F, Lipsky L, Bible J, Liu D. Variability in measures of health and health behavior among emerging adults 1 year after high school according to college status. *J Am Coll Health*. 2017;65:58–66. [PubMed: 27661849]
2. Irwin JD. Prevalence of university students' sufficient physical activity: A systematic review. *Percept Mot Skills*. 2004;98:927–943. [PubMed: 15209309]
3. Deforche B, Van Dyck D, Deliens T, De Bourdeaudhuij I. Changes in weight, physical activity, sedentary behaviour and dietary intake during the transition to higher education: A prospective study. *Int J Behav Nutr Phys Act*. 2015;12:1–10. [PubMed: 25592201]
4. Johnston LD, O'Malley PM, Bachman JG, Schulenberg JE, Miech RA. Monitoring the Future National Results on Drug Use, 1975–2014: Volume 2, College Students & Adults Ages 19–55. Institute for Social Research, The University of Michigan; Ann Arbor 2016.
5. Hingson R, Zha W, Smyth DP. Magnitude and trends in heavy episodic drinking, alcohol-impaired driving, and alcohol-related mortality and overdose hospitalizations among emerging adults of college ages 18–24 in the United States. *J Stud Alcohol Drugs*. 2017;78:540–548. [PubMed: 28728636]
6. American College Health Association. Executive Summary Report. http://www.acha-ncha.org/reports_ACHA-NCHAIIc.html Published 2017

7. Arria AM, Caldeira KM, Allen HK, Vincent KB, Bugbee BA, O'Grady KE. Drinking like an adult? Trajectories of alcohol use patterns before and after college graduation. *Alcohol Clin Exp Res*. 2016;40:583–590. [PubMed: 26893253]
8. Plotnikoff RC, Costigan SA, Williams RL, et al. Effectiveness of interventions targeting physical activity, nutrition and healthy weight for university and college students: a systematic review and meta-analysis. *Int J Behav Nutr Phys Act*. 2015;12:45. [PubMed: 25890337]
9. Spring B, Moller AC, Coons MJ. Multiple health behaviours: Overview and implications. *J Public Health (Bangkok)*. 2012;34:3–10.
10. Dodge T, Clarke P, Dwan R. The relationship between physical activity and alcohol use among adults in the United States. *Am J Health Promot*. 2017;31:97–108. [PubMed: 27630108]
11. Barry AE, Piazza-Gardner AK. Drunkorexia: Understanding the co-occurrence of alcohol consumption and eating/exercise weight management behaviors. *J Am Coll Health*. 2012;60:236–243. [PubMed: 22420701]
12. Buscemi J, Martens MP, Murphy JG, Yurasek AM, Smith AE. Moderators of the relationship between physical activity and alcohol consumption in college students. *J Am Coll Health*. 2011;59:503–509. [PubMed: 21660805]
13. Dinger MK, Brittain DR, O'Mara HM, et al. The relationship between physical activity and binge drinking among college students: A qualitative investigation. *Am J Health Educ*. 2018;49:33–39.
14. Abrantes AM, Scalco MD, O'Donnell S, Minami H, Read JP. Drinking and exercise behaviors among college students: between and within-person associations. *J Behav Med*. 2017;40:964–977. [PubMed: 28593427]
15. French MT, Popovici I, Maclean JC. Do alcohol consumers exercise more? Findings from a national survey. *Am J Health Promot*. 2009;24:2–10. [PubMed: 19750956]
16. Palmer C *Rethinking Drinking and Sport: New Approaches to Sport and Alcohol*. London, U.K.: Routledge; 2015.
17. Barnett NP, Ott MQ, Rogers ML, Loxley M, Linkletter C, Clark MA. Peer associations for substance use and exercise in a college student social network. *Health Psychol*. 2014;33:1134–1142. [PubMed: 24364375]
18. Nelson MC, Lust K, Story M, Ehlinger E. Alcohol use, eating patterns, and weight behaviors in a university population. *Am J Health Behav*. 2009;33:227–237. [PubMed: 19063644]
19. Bryant JB, Darkes J, Rahal C. College students' compensatory eating and behaviors in response to alcohol consumption. *J Am Coll Health*. 2012;60:350–356. [PubMed: 22686357]
20. Conroy DE, Pincus AL, Ram N, Al'Absi M. Thirsting to understand the temporal dynamics of physical activity and alcohol use. *Br J Sports Med*. 2017:
21. Conroy DE, Ram N, Pincus AL, et al. Daily physical activity and alcohol use across the adult lifespan. *Health Psychol*. 2015;34:653–660. [PubMed: 25222084]
22. Bull FC, Maslin TS, Armstrong T. Global Physical Activity Questionnaire (GPAQ): Nine country reliability and validity study. *J Phys Act Health*. 2009;6:790–804. [PubMed: 20101923]
23. Herrmann SD, Heumann KJ, Der Ananian CA, Ainsworth BE. Validity and reliability of the global physical activity questionnaire (GPAQ). *Meas Phys Educ Exerc Sci*. 2013;17:221–235.
24. American College Health Association. About ACHA-NCHA: Survey 2017. 2017:Retrieved from: <http://www.acha-org/survey.ht>.
25. Hamaker EL, Kuiper RM, Grasman RPPP. A critique of the cross-lagged panel model. *Psychol Methods*. 2015;20:102–116. [PubMed: 25822208]
26. Rosseel Y lavaan: An R package for structural equation modeling. *J Stat Softw*. 2012;48:1–36.
27. Curran PJ, Bauer DJ. The disaggregation of within-person and between-person effects in longitudinal models of change. *Annu Rev Psychol*. 2011;62:583–619. [PubMed: 19575624]
28. te Poel F, Baumgartner SE, Hartmann T, Tanis M. The curious case of cyberchondria: A longitudinal study on the reciprocal relationship between health anxiety and online health information seeking. *J Anxiety Disord*. 2016;43:32–40. [PubMed: 27497667]
29. Colby S, Zhou W, Sowers M, et al. College students' health behavior clusters: Differences by sex. *Am J Health Behav*. 2017;41:378–389. [PubMed: 28601097]

30. Leasure JL, Neighbors C, Henderson CE, Young CM. Exercise and alcohol consumption: What we know, what we need to know, and why it is important. *Front Psychiatry*. 2015;6:1–13. [PubMed: 25653621]
31. Garber CE, Blissmer B, Deschenes MR, et al. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: Guidance for prescribing exercise. *Med Sci Sports Exerc*. 2011;43:1334–1359. [PubMed: 21694556]
32. Neighbors C, Walters ST, Lee CM, et al. Event-specific prevention: Addressing college student drinking during known windows of risk. *Addict Behav*. 2007;32:2667–2680. [PubMed: 17616260]
33. Tapper EB, Parikh ND. Mortality due to cirrhosis and liver cancer in the United States, 1999–2016: Observational study. *BMJ*. 2018;362:k2817. [PubMed: 30021785]
34. Joseph RP, Royse KE, Benitez TJ, Pekmezi DW. Physical activity and quality of life among university students: exploring self-efficacy, self-esteem, and affect as potential mediators. *Qual Life Res*. 2014;23:659–667. [PubMed: 23928820]
35. Werch C, Moore M, DiClemente CC, Owen DM, Jobli E, Bledsoe R. A sport-based intervention for preventing alcohol use and promoting physical activity among adolescents. *J Sch Health*. 2003;73:246–253.
36. Del Boca FK, Darkes J. The validity of self-reports of alcohol consumption: State of the science and challenges for research. *Addiction*. 2003;98:1–12.
37. Slootmaker SM, Schuit AJ, Chinapaw MJM, Seidell JC, van Mechelen W. Disagreement in physical activity assessed by accelerometer and self-report in subgroups of age, gender, education and weight status. *Int J Behav Nutr Phys Act*. 2009;6:17. [PubMed: 19320985]
38. Leffingwell TR, Cooney NJ, Murphy JG, et al. Continuous objective monitoring of alcohol use: Twenty-first century measurement using transdermal sensors. *Alcohol Clin Exp Res*. 2013;37:16–22. [PubMed: 22823467]

Fig 1.

Random intercept cross lagged panel model of the association between alcohol use and vigorous physical activity (PA) across three waves, with 3-month lag times. The model contains two random intercepts (Alcohol Use *Between* and Vigorous PA *Between*) that reflect between-person differences. Within-person processes are reflected by autoregressive paths between variables across timepoints. Cross-paths between variables reflect the reciprocal relationship between alcohol use and vigorous PA. Sex is added to the model as a time-invariant covariate at the between-person level. Solid lines indicate significant paths and dashed lines indicate non-significant paths. Coefficients are standardized (β). $N = 396$. $\chi^2 = 19.48$ ($p = .035$), RMSEA = .051, CFI = .987, SRMR = .028. * $p < .05$, ** $p < .01$.

Fig 2.

Random intercept cross lagged panel model of the association between alcohol use and moderate physical activity (PA) across three waves, with 3-month lag times. The model contains two random intercepts (Alcohol Use *Between* and Moderate PA *Between*) that reflect between-person differences. Within-person processes are reflected by autoregressive paths between variables across timepoints. Cross-paths between variables reflect the reciprocal relationship between alcohol use and moderate PA. Sex is added to the model as a time-invariant covariate at the between-person level. Solid lines indicate significant paths and dashed lines indicate non-significant paths. Coefficients are standardized (β). $N = 396$. $\chi^2 = 13.88$ ($p = .179$), RMSEA = .032, CFI = .994, SRMR = .023. * $p < .05$, ** $p < .01$.

Table 1.

Descriptive statistics and bivariate correlations

Variable	1	2	3	4	5	6	7	8	9	10	11
1. Sex (m = 1, f = 2)	-										
2. Age	-.11 [*]	-									
3. Alcohol Use T1	-.09	.10 [*]	-								
4. Alcohol Use T2	-.09	.08	.58 ^{**}	-							
5. Alcohol Use T3	-.08	.03	.53 ^{**}	.78 ^{**}	-						
6. Vigorous PA T1	-.14 ^{**}	-.02	.03	-.02	-.05	-					
7. Vigorous PA T2	-.01	.04	.09	.04	.05	.52 ^{**}	-				
8. Vigorous PA T3	.02	.06	.07	.07	.03	.47 ^{**}	.60 ^{**}	-			
9. Moderate PA T1	.09	.06	.02	-.03	-.03	.19 ^{**}	.17 ^{**}	.11 [*]	-		
10. Moderate PA T2	.04	0	-.02	-.02	-.04	.17 ^{**}	.30 ^{**}	.12 [*]	.15 ^{**}	-	
11. Moderate PA T3	.03	-.010	.03	.02	-.02	.23 ^{**}	.27 ^{**}	.33 ^{**}	.12 [*]	.39 ^{**}	-
<i>M</i>	-	20.97	4.19	4.29	4.08	168.95	160.34	158.22	114.79	175.61	171.23
<i>SD</i>	-	1.59	1.65	1.61	1.58	174.48	166.22	172.27	100.86	163.02	168.77
<i>Cohort ICC</i>	-	-	.02	.00	.02	.00	.02	.04	.02	.00	.05

Note. PA = physical activity. T1 = Time point 1 (baseline), T2 = Time point 2 (3-months after baseline), T3 = Time point 3 (6-months after baseline).

* Indicates $p < .05$;

** Indicates $p < .01$. *M* and *SD* are used to represent mean and standard deviation, respectively.