The Temporal Association Between Physical Activity and Fruit and Vegetable Consumption: A Longitudinal Within- and Between-Person Investigation

Oliver W.A. Wilson, Scott Graupensperger, M. Blair Evans, and Melissa Bopp

Background: Entering college is associated with significant lifestyle changes and the potential adoption of a lifelong lifestyle. This study examined the longitudinal relationship between physical activity (PA) and fruit and vegetable consumption (FVC) in the hopes that findings could inform student health promotion. Methods: A total of 369 undergraduate students provided complete responses to demographic, PA, and FVC items via an online survey 3 times over a 6-month period. Random intercept cross-lagged panel modeling examined the association between PA and FVC. Results: Models demonstrated a strong fit for both moderate PA and vigorous PA. In both models, FVC, but not PA, was stable across the 3 waves. Neither model revealed a temporal association between PA and FVC. Unlike the moderate PA model, the vigorous PA model revealed a strong positive association between trait-like vigorous PA and trait-like FVC. Conclusion: The stability of FVC over time reinforces the importance of facilitating the adoption and maintenance of healthy dietary behaviors among college students, whereas the instability of PA over time highlights the importance of promoting students’ PA year round. The absence of a temporal link between PA and FVC indicates that promotion of one behavior should not be assumed to result in improvement of the other.

Keywords: health behavior, exercise, nutrition, adolescent

Pandemics of physical inactivity and obesity are evident among all age groups. College students are of particular interest because of behavior changes that shape the trajectory of their health into adulthood. Specifically, the transition from adolescence to adulthood is associated with a reduction in physical activity (PA) levels and an erosion of healthy eating/dietary behaviors. The number of American college students meeting aerobic PA requirements is declining, with a large proportion of students being both aerobic and muscle-strengthening activity recommendations. Pertaining to students’ diet, recent national data indicate that only 4.2% of American college students are consuming the recommended quantity of fruit and/or vegetables a day, although other studies have reported between 26% and 40% of students met guidelines.

Physical activity and diet impact weight, which is a function of energy intake and expenditure. Perhaps unsurprisingly, considerable increases in weight and the prevalence of overweight and obesity take place during the transition to college. Although the majority of American students are of a healthy weight, an increasing number have overweight (23.3%) and obesity (14.6%). Collectively, the increasingly unhealthy lifestyle habits of young adults are becoming apparent, with future generations’ health looking bleak. Physical inactivity, poor diet, and obesity are associated with numerous negative outcomes, such as increased risk of noncommunicable diseases, mental health disorders, poor quality of life, and increased risk of mortality. Although promising, interventions targeting students’ PA and diet have produced mixed results; thus, it is important to understand the relationship between PA and fruit and vegetable consumption (FVC) to inform decisions as to whether or not the 2 behaviors require specific attention, or targeting 1 behavior can lead to improvement in the other.

The shared trajectories and common outcomes of PA and FVC, such as weight management and general health, mean that it is sensible to consider their cooccurrence. Indeed, unhealthy behaviors do not occur at random and actually tend to cluster together as a result of healthy (or unhealthy) individuals being disposed to behave in a similar manner with respect to various behaviors. However, the nature of the apparent relationship between PA and FVC also remains unclear. Existing research indicates that changes in PA may increase FVC and that there was a tendency for those who were generally more active to also generally consumed more fruit and vegetables, although within-person variability in FVC was unrelated to within-person variability in PA. In light of the presently poorly understood nature of the relationship between PA and FVC, this study aimed to examine the longitudinal relationship between college students’ PA and FVC using innovative statistical techniques that included sex as a covariate. Illumination of the nature of any relationship between PA and FVC has the potential to inform future student health promotion initiatives and policies, in particular whether interventions should target behaviors together or independently.

Methods

Participants and Procedures

This longitudinal study took place at a large, northeastern United States university. Data were collected on a range of health behaviors and basic demographics using an online survey. Undergraduate students enrolled in for-credit PA classes between August 2014 and January 2017 were recruited via direct e-mail. Instructors were requested to encourage participation, although participation was voluntary and had no impact on...
students’ grades. A chance to enter a drawing for a $50 gift card was offered as an incentive for each survey completion. Drawing entries, which required collection of contact information, were collected separately from the survey data to protect participant identity. An informed consent statement was presented to students on opening the survey link. The Pennsylvania State University Institutional Review Board approved this study. Baseline surveys were distributed at the beginning of the semester in which students had enrolled in the PA for-credit class. Follow-up surveys were distributed at the end of the same semester and the subsequent semester for those who responded at baseline. Assessments were conducted at the start of the semester (September or January), end of the semester (December or April), and approximately 4 months after the end of the semester (April and September). All surveys included health behavior measures, whereas demographics were only assessed at baseline.

Measures

Participants self-reported age, sex, race/ethnicity, and other demographic variables. The Global PA Questionnaire (GPAQ), a reliable and valid measure, assessed minutes per week leisure-time aerobic PA. Weekly moderate PA (MPA) and vigorous PA (VPA) were computed using PA frequency and duration, and participants were categorized based on whether they met the American College of Sports Medicine’s PA recommendations (150 min/wk of MPA or 75 min/wk of VPA or an equivalent combination). Fruit and vegetable consumption were assessed using the items from the National College Health Assessment, which have demonstrated reliability and validity, that asked (separately) how many servings of fruits and vegetables participants consume per day on a 7-point scale ranging from 0 to 6 or more servings. A Checklist for Reporting Results of Internet E-Surveys breakdown of the survey performance is displayed in Figure 1.

Statistical Analyses

Independent samples t tests and chi-square tests were used to examine sex differences in study variables at individual time points. A series of paired-samples tests and McNemar tests examined differences in continuous and categorical variables, respectively, within each sex over time.

To examine the association between PA and FVC, a longitudinal structural equation modeling technique called random intercept cross-lagged panel modeling (RI-CLPM) was used. RI-CLPM is a multilevel approach that treats the 3 waves of data as nested within participants and controls for time-invariant trait-like differences—providing improved estimates of directionality in relations between variables. Random intercepts for FVC and MPA (model 1) and VPA (model 2) were specified with factor loadings constrained at 1, which allowed the factor structure to simultaneously capture both the within- and between-person variance. These random intercepts represent the trait-like differences between participants, whereby the path between random intercepts reflected the relation between participants’ typical PA and participants’ typical FVC. These autoregressive paths represent within-person change and reflect participants’ deviations in PA and FVC, respectively, from their own expected values. Moreover, the cross-lagged paths represent the within-person reciprocal associations between variables. Sex was specified as a time-invariant covariate at the between-person level for each model. RI-CLPMs were fit using the “lavaan” package in R. The significance levels for all tests were set at an alpha level of P < .05.

Results

Participant Characteristics

Of the 662 responses eligible for analysis at the third time point, 293 participants did not provide complete demographic data at baseline or complete PA and/or FVC at 1 of the 3 time points. Demographics did not differ significantly between those retained and excluded. Of the remaining participants (N = 369), most were women (62.5%) and non-Hispanic white (82.9%) with an average age of 21.00 (1.59) years.

Sex Differences

Although men reported significantly greater VPA at time 1 compared with women, no other differences in PA were identified.
(ie, VPA at time 2 and 3, MPA at all time points) or the prevalence of participants who met PA recommendations. Women reported significantly greater fruit consumption than men at time 1 and time 3, significantly greater FVC at time 3, and significantly more women reported meeting FVC recommendations at time 1. Vegetable consumption did not differ significantly between genders. Finally, significantly more women reported meeting PA and FVC recommendations at time 1 (Table 1). The only significant longitudinal within-sex difference was men reporting greater VPA at time 1 than both time 2 and time 3. MPA and FVC did not differ significantly within-sexes over time (Table 1).

**Table 1** Between-Sex and Longitudinal Within-Sex Differences in PA and FVC

<table>
<thead>
<tr>
<th>Variable</th>
<th>Time 1</th>
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<tr>
<td></td>
<td>Men</td>
<td>Women</td>
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<td></td>
<td>Mean (SD)</td>
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<td>Mean (SD)</td>
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<td>Mean (SD)</td>
<td>%</td>
<td>Mean (SD)</td>
<td>%</td>
<td>Mean (SD)</td>
<td>%</td>
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<tr>
<td>MPA, min/wk</td>
<td>157.20</td>
<td>87.6</td>
<td>183.80</td>
<td>83.8</td>
<td>173.07</td>
<td>86.9</td>
<td>184.47</td>
<td>86.0</td>
<td>172.96</td>
<td>79.6</td>
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<td></td>
<td>(140.97)</td>
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<td>(171.00)</td>
<td></td>
<td>(144.17)</td>
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<td>(172.90)</td>
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<td>(161.19)</td>
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<tr>
<td>VPA, min/wk</td>
<td>198.80</td>
<td>1.86</td>
<td>216.95</td>
<td>1.96</td>
<td>153.62</td>
<td>1.91</td>
<td>150.32</td>
<td>1.82</td>
<td>149.26</td>
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<td></td>
<td>(202.04)</td>
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<td>(159.34)</td>
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<td>(165.88)</td>
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<td>(164.78)</td>
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<td>(174.27)</td>
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<td>% meeting PA recommendations</td>
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<tr>
<td>Fruit consumption, servings/wk</td>
<td>1.86 (1.14)^d</td>
<td>1.91 (1.03)</td>
<td>1.94 (1.16)</td>
<td>1.82 (0.91)^d</td>
<td>1.97 (1.11)^d</td>
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<tr>
<td>Vegetable consumption, servings/wk</td>
<td>1.85 (1.25)</td>
<td>2.18 (1.24)</td>
<td>2.24 (1.28)</td>
<td>1.94 (1.02)</td>
<td>2.20 (1.17)</td>
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<tr>
<td>FVC, servings/wk</td>
<td>3.72 (2.15)</td>
<td>4.14 (2.04)</td>
<td>4.18 (2.16)</td>
<td>3.77 (1.70)^e</td>
<td>4.18 (1.99)^e</td>
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**Table 2** Means, SDs, and Bivariate Correlations

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<td>2. Age</td>
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<td>4. FVC T2</td>
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<td>.00</td>
<td>.47**</td>
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<td>5. FVC T3</td>
<td>.10*</td>
<td>-.03</td>
<td>.45**</td>
<td>.50**</td>
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<td>6. VPA T1</td>
<td>-.14**</td>
<td>-.02</td>
<td>.18**</td>
<td>.08</td>
<td>.09</td>
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<td>7. VPA T2</td>
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<td>.04</td>
<td>.05</td>
<td>.18**</td>
<td>.14**</td>
<td>.52**</td>
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<td>8. VPA T3</td>
<td>.02</td>
<td>.06</td>
<td>.13*</td>
<td>.13*</td>
<td>.14**</td>
<td>.47**</td>
<td>.60**</td>
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<td>9. MPA T1</td>
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<td>.05</td>
<td>-.03</td>
<td>-.05</td>
<td>-.07</td>
<td>.08</td>
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<td>10. MPA T2</td>
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<td>.11*</td>
<td>.01</td>
<td>-.02</td>
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<td>.01</td>
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<td>11. MPA T3</td>
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<td>-.05</td>
<td>.01</td>
<td>.05</td>
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<td>.00</td>
<td>.03</td>
<td>.30**</td>
<td>.36**</td>
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</table>

**Bivariate Correlations**

Bivariate correlations demonstrated significant correlations between baseline and future MPA, VPA, and FVC. A significant correlation was observed between VPA and FVC at each time point, whereas no such relationship was observed between MPA and VPA or FVC (Table 2).

**Random Intercept Cross-Lagged Models**

The data were screened to check for compliance with multivariate assumptions. As VPA and MPA were skewed, log transformations...
were applied to normalize their distributions. Following this transformation, all multivariate assumptions were met.

In addition to the following models, where FVC was treated as a composite variable, associations were examined separately for fruit consumption and vegetable consumption. Pertaining to VPA, the association with fruit consumption mirrored the findings from Figure 2 ($\beta = 0.44$, $P < .01$), whereas the association with vegetable consumption approached significance ($\beta = 0.30$, $P = .05$). With respect to MPA, separate models suggested that neither fruit nor vegetable consumption, independently, were associated with MPA at either the between- or within-person level.

The RI-CLPM displayed in Figure 2 reflects the longitudinal reciprocal association between VPA and FVC. This model demonstrated a strong fit. First, it is important to consider the autoregressive paths that reflect the stability of rank-ordered individual deviations from expected scores. Notably, FVC was somewhat stable across the 3 waves, whereas VPA was not. Pertaining to the between-person level association, results indicated a strong positive association between trait-like VPA and trait-like FVC ($\beta = 0.39$, $P < .01$), indicating that those who typically engage in greater VPA also typically have greater FVC. Finally, the cross-lagged paths reflect the extent that VPA and FVC influence each other over time at the within-person level, indicated that there was no temporal association between VPA and FVC. Taken together, the results shown in Figure 2 suggest that the association between VPA and FVC is primarily a between-person effect rather than a within-person effect.

A second RI-CLPM tested the association between MPA and FVC (Figure 3). The model fit was strong. As with the first model, the autoregressive paths indicated that FVC was stable across time points, but MPA was not. Results indicated that the between-person association between MPA and FVC was not significant. Likewise, there were no significant cross-lagged paths, indicating that participants’ variability in MPA was not associated with variability in FVC.

**Discussion**

In line with previous findings, more vigorously active individuals demonstrated a tendency to have higher FVC, but variation in either behavior at an individual (within-person) level did not necessarily have a temporal influence (influence over time) on the other. Another way of conceptualizing this is that FVC appears to be a more trait-like behavior, in that low and high consumers relative to the population mean at 1 point in time are likely to be low and high consumers at a future point in time, whereas VPA is potentially more prone to fluctuation, in that one with above average VPA will not necessarily have above VPA in future. That being said, the absence of a statistically significant relationship between PA across time points should not be interpreted as an indication that PA is unstable.

Consideration of the nature of the two health behaviors offers a way to reconcile the differences revealed by this study. Humans, by necessity, must consume food to survive, and as such can form habits when it comes to consuming certain foods. By contrast, PA, although beneficial, is not a necessity beyond household, occupational, and transport-related PA, and in the case of leisure

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**Figure 2** — Random intercept cross-lagged panel model of the association between FVC and VPA. The model contains 2 random intercepts (FVC between and VPA between) that reflect between-person differences. Autoregressive paths between variables across time points reflect within-person processes. Cross-lagged paths between variables reflect the temporal association between FVC and moderate VPA. Sex was added to the model as a time-invariant covariate at the between-person level. Solid lines indicate significant paths and dashed lines indicate nonsignificant paths. Coefficients are standardized ($\beta$). N = 369, $R^2 = 11.39$ ($P = .04$), root mean square error of approximation (RMSEA) = .059, confirmatory fit index (CFI) = .998, and standardized root mean residual (SRMR) = .015. FVC indicates fruit and vegetable consumption; VPA, vigorous physical activity. *$P < .05$. **$P < .01$.

**Figure 3** — Random intercept cross-lagged panel model of the association between FVC and MPA. The model contains 2 random intercepts (FVC between and MPA between) that reflect between-person differences. Autoregressive paths between variables across time points reflect within-person processes. Cross-lagged paths between variables reflect the temporal association between FVC and moderate MPA. Sex was added to the model as a time-invariant covariate at the between-person level. Solid lines indicate significant paths, and dashed lines indicate nonsignificant paths. Coefficients are standardized ($\beta$). N = 369, $R^2 = 2.83$ ($P = .73$), RMSEA = .000, CFI = 1.00, and SRMR = .014. FVC indicates fruit and vegetable consumption; MPA, moderate physical activity. *$P < .05$. **$P < .01$. 

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time PA, in particular, requires a level of intent and fore planning to integrate into everyday life. In addition, PA behaviors are more susceptible to environmental influences, such as the weather\textsuperscript{49} or availability of resources to be active.\textsuperscript{50} In short, humans need to eat and tend to eat similar things, but humans do not need to do PA. One can easily chose to not exercise on a day-to-day basis for a short or prolonged period of time, but while one can decide not to eat for a day or two, one cannot simply decide not to eat for a prolonged period.

That changes in one health behavior will not necessarily influence the other suggests that interventions intended to exclusively improve either diet or PA should not be expected to result in a positive change in the other behavior over time. Moreover, findings offer a potential explanation as to why those with high levels of PA remain overweight, in that the absence of a relationship between PA and FVC indicate that one could be extremely influential period during which a healthy and active lifestyle that may continue throughout one’s life could be adopted.\textsuperscript{51} findings highlight the importance of universities implementing policies and programs (eg, greater breadth and quality of affordable fruit and vegetable options, and offering kosher and halal food, at campus dining outlets, or making campus recreational facilities available to all students) that facilitate the development and maintenance of healthy dietary behaviors and sufficient PA levels all year round to benefit students’ physical and mental health.

**Limitations and Future Research Recommendations**

Despite the strengths of this study, it still has several limitations. Findings are not generalizable to less active populations, as participants were considerably more active than the average student population, which is likely attributable to recruiting students enrolled in PA for-credit classes, in addition to self-selection and/or respondent tendency bias.\textsuperscript{32} On a related note, student-athlete status was not assessed nor were other characteristics such as eating behaviors symptoms of eating disorders, which may influence FVC. Future researchers should consider conducting similar research in more representative populations and framing research to limit respondent tendency bias. Future studies could also improve the measurement of both PA and dietary behaviors, which are both susceptible to social desirability bias when measured via self-report.\textsuperscript{53,54} Objective PA measures could be employed, while the consumption of other food groups (eg, meat, dairy, fiber, etc) could also be assessed. Examining the relationship between PA and dietary behaviors during important life transitions, such as the transition from secondary school to higher education, also represents an opportunity to understand how changes in health behaviors influence one another, which could inform future interventions development.

**Conclusion**

To the authors’ knowledge, this is the first study to examine the relationship between different PA intensities and FVC over time. Despite the tendency for those with greater VPA demonstrating a tendency to have greater FVC, no temporal link was found between changes in VPA and FVC. Moreover, MPA was not associated with FVC, indicating that PA intensity is important when considering the relationship between PA and FVC. Findings suggest that, typically, natural fluctuations in PA or FVC will not necessarily influence the other behavior, and that interventions targeting multiple behaviors may be necessary to achieve improvements in both dietary characteristics and PA. That being said, it remains unclear whether the influence of changes in 1 behavior influence the other immediately or whether there is a delayed effect. For example, it is possible an improvement in dietary quality may follow an increase in PA or vice versa. The temporal delay between any such change may vary between persons depending on various extraneous factors, such as whether or not, or how long ago, one previously adopted a healthy lifestyle.

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