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Using Technology to Assess Bidirectionality Between Daily Pain and Physical Activity: The Role of Marginalization During Emerging Adulthood

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Using Technology to Assess Bidirectionality Between Daily Pain and Physical Activity: The Role of Marginalization During Emerging Adulthood

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Biography

The author was born in February 1995 in Cincinnati, Ohio. Helen graduated cum laude from Walnut Hills High School, Cincinnati, Ohio in 2013. She received her Bachelor of Arts in psychology magna cum laude from Mount Holyoke College, South Hadley, Massachusetts in 2017.

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Abstract

Emerging adulthood is often overlooked as a developmental time period critical to shaping future health outcomes. Recurrent pain is a commonly experienced health concern within this age group, particularly headaches and low back pain, and early experiences of recurrent pain are related to subsequent chronic pain and disability. Furthermore, adults from marginalized populations report more frequent and severe recurrent pain. Many studies have demonstrated the therapeutic effect of physical activity on pain relief; however, others have demonstrated that physical activity can also exacerbate pain symptoms. Therefore, the current study aimed to 1) assess a bidirectional relationship between reported pain and engagement in physical activity among an emerging adult sample ($N = 265$) and 2) determine whether sociodemographic factors moderate this relationship. Using longitudinal daily reported pain and ActiGraph monitor data collected over two-weeks, a novel dynamic structural equation modeling approach was employed. Results indicated no significant cross-lagged relationships between pain and physical activity, and no significant moderation effects. These findings suggest that a bidirectional relationship does not exist among a diverse college sample of emerging adults even after considering sociodemographic moderators. Excellent retention and few missing data suggest that using accelerometers and daily diaries are feasible methods to collect data in this population. Sample considerations and future analytical approaches are discussed.

Key words: Emerging Adults; Pain Symptoms; Physical Activity; Marginalized Status; Longitudinal; ActiGraph; Dynamic Structural Equation Modeling

Using Technology to Assess Bidirectionality Between Daily Pain and Physical Activity: The Role of Marginalization During Emerging Adulthood

Emerging adulthood (ages of 18-25 years) is an important developmental context for shaping health outcomes (Arnett, 2000), with new opportunities for autonomy and decision-making in health behaviors (Nelson et al., 2008). Adopting health behaviors has significant implications for the development of chronic conditions during this developmental phase (Irwin, 2010). Recurrent pain is a health concern of particular importance in this developmental context given most emerging adults (65%) report pain-related symptoms (Lester et al., 1994). Low back pain is prevalent among this age group (Gilkey et al., 2010; Heuscher et al., 2010) with 71% reporting low back pain one to five times a week (Reis et al., 1996). Headaches are another common pain symptom reported by emerging adults, with the majority (57% male, 78% female) experiencing their most recent headache in the past month (Linet et al., 1989). Many students (78%) indicated that their headaches affect daily life, such as leading to worse overall academic performance (Bigal et al., 2001). With the prevalence of pain conditions rising (Freburger et al., 2009), it is critical to understand health behaviors that can prevent adverse outcomes. Furthermore, emerging adulthood might be a particularly important developmental context to target health behaviors associated with acute pain relief to prevent a chronic pain trajectory, which is associated with numerous psychosocial and functional limitations and, overall, lower health-related quality of life (Turk et al., 2016).

Physical activity is one health-promoting behavior that has been found to reduce pain symptomatology (Harris & Susman, 2002; Koes et al., 2010). Research has found a therapeutic link between physical activity and pain relief among children and adults with chronic pain (Fanucchi et al., 2009; Hanney et al., 2009; Stephens et al., 2008); for example, thirty minutes of moderate exercise one to three times a week was associated with a 10-12% lower prevalence of chronic pain among adults (Landmark et al., 2011). According to a research study conducted by the American College Health Association (2013), however, most emerging adults are not engaging in enough physical activity. Only 18% of this population are engaging in moderate-intensity physical activity at least 5 days per week and 26% are meeting the standards for vigorous-intensity at least 3 days per week, with a total of 45% meeting either the moderate-intensity or vigorous-intensity 2007 physical activity guidelines (American College Health Association, 2013). Yahia and colleagues (2016) discovered similar results, with only about half of their participants engaging in some form of reported physical activity and a quarter endorsing an "active lifestyle". Racette and colleagues (2008) reported that a quarter of their college student sample did not engage in any exercise, similar to the U.S. adult population (Centers for Disease Control and Prevention 2001).

In the relationship between pain and physical activity, it is important to consider that there may be a threshold or bidirectional relationship. For example, while research has found that physical activity can reduce pain (Fanucchi et al., 2009; Hanney et al., 2009; Stephens et al., 2008), individuals with chronic pain have also reported having a decreased ability to engage in physical activity (Bryant et al., 2007; Dansie et al., 2014), suggesting a bidirectional relationship between pain and physical activity. Essentially, while physical activity can ameliorate pain symptoms, pain can also limit physical functioning. One study with adolescents found evidence for this relationship; Rabbitts and colleagues (2014) compared results from Actigraphy measures and ratings of pain over a ten day period among participants who were healthy and participants with chronic pain and found that higher pain intensity predicted next day lower peak physical activity for both groups and that higher physical activity predicts end of day lower pain only for youth with chronic pain. Given the mixed findings, it is important to better understand this complex relationship among emerging adults experiencing pain symptoms to provide a framework for preventing and managing pain among this often overlooked developmental group.

To fully understand the relationship between pain and physical activity among emerging adults, it is critical to consider how identity factors, such as race and ethnicity, gender, and socioeconomic status (SES) influence health outcomes and behaviors. A growing body of research demonstrates the deleterious relationship between marginalized social status and well-being (Braveman et al., 2011), taking form in health inequities, which are preventable and unjust (Arcaya et al., 2015). Upstream factors, or those at the root of health inequities, such as economic and social resources, educational attainment, living and working conditions, and systematic oppression have been shown to be causally linked to downstream factors, or those most often attributed in explaining health outcomes, like behavior and health care utilization (Braveman et al., 2011). It is necessary to use upstream factors as context for the categorical findings below (i.e., downstream factors). For example, race and ethnicity are often conflated with economic resources and opportunities (Bond, 2016). It is also important to acknowledge that individuals do not fit neatly into these groups and instead, often belong to multiple, dynamic, and intersecting identities (Bond, 2016). Research has shown that pain is inequitably experienced by different sociodemographic groups, with worse pain experiences (frequency and severity; greater risk for pain related disability) among Latinx and Black / African American adults with chronic pain, women, and those with lower SES (Aggarwal et al., 2003; Andersson et al., 1993; Fillingim et al., 2009; Fuentes et al., 2007; Gagnon et al., 2014; Green et al., 2003; Linet et al., 1989; Lipton et al., 2018; Tran, Koven, et al., 2020; Unruh, 1996). Further, Black / African American and Hispanic adults, women, and those with low SES report lower rates of physical activity (Huang et al., 2003; Mathieu et al., 2012; Nguyen-Michel et al., 2006; Vankim & Nelson, 2013; Yahia et al., 2016) than their white, male, and higher SES counterparts.

Taken together, these studies demonstrate how social determinants of health inequitably impact pain and physical activity. Upstream factors, such as chronic minority stress due to prejudice and discrimination, are linked to worse health outcomes (Meyer, 2003) and likely exacerbate experiences of pain among individuals who are marginalized. Individuals with low SES may have fewer resources (limited access to nutrition, and safe and affordable physical activity resources (Braveman et al., 2011)) to facilitate coping with this health concern compared to non-marginalized individuals who do not face additional stress and have resources to cope with any health concerns. Therefore, it is possible that marginalization may moderate and exacerbate the relationships between pain and physical activity. No study to our knowledge has tested the moderation effects of race, ethnicity, gender, and SES on the relationship between pain and physical activity.

Traditional pain and physical activity assessment (self-report, retrospective) often have methodological weaknesses, such as issues with recall and overestimation in the moment. Objective technological measures and daily diary data collection can improve upon these problems to better assess these constructs. Implementing technological advances in methodology is particularly helpful when working with emerging adults, as this population has been uniquely identified for their technology use in many aspects of their lives, such as in both social and personal (Perrin, 2015), as well as college and university contexts (Swanson & Walker, 2015). Use of technological tools is critical when considering accuracy and feasibility of data collection, for example, daily diaries are able to collect moment by moment data on symptomatology compared to retrospective self-reports collected after a study period. Further, objective measures of data, such as Actigraphy monitors, also allow for increased accuracy and feasibility of data collection compared with self-report measures of activity. They have also proven to be a feasible way of data collection and have adapted to easier use; for example, research has shown that adolescents are more likely to wear wrist-worn accelerometers measuring activity versus waist-worn accelerometers due to increased comfortability and decreased social factors (e.g. feeling embarrassed with waist placement) (Scott et al., 2017).

Aims of Current Study

This study aimed to determine whether experiences of pain recorded by daily diary and accelerometer-measured physical activity are bidirectionally related. It was hypothesized that previous day MVPA is expected to predict next day pain, such that higher rates of MVPA will result in lower reported pain, in line with the majority of research demonstrating the therapeutic effect of physical activity in managing pain. Additionally, given past findings that there may be a bidirectional relationship between pain and physical activity among those with and without chronic pain (Rabbitts et al., 2014), the current study also expected that previous day pain will predict next day MVPA, such that higher rates of pain will result in lower observed MVPA. The second aim of the current study examined whether marginalization (race, ethnicity, gender, and socioeconomic status) moderates these bidirectional relationships, due to findings demonstrating the inequitable disparities in experiencing worse pain and lower levels of physical activity, such that marginalization will exacerbate these relationships and demonstrate a stronger link between physical activity and pain.

Method

Participants

Emerging adults (*N*=265), who took part in a larger study aiming to understand health behaviors and daily stressors at a private Midwestern university, were included in the current study. Participants were on average 19.61 years old (*SD* = 1.42), about half identified as white (53.20%), about two-thirds female (69.10%), majority non-Hispanic (76.60%), and reporting a parent income above $50,000 (73.96%). See Table 1 for full sample characteristics.

Table 1. Demographic Characteristics (*N* = 265)

		n	%
Gender			
	Male	76	28.68
	Female	183	69.06
	Other/Gender Non-Conforming/Queer	6	2.26
Race			
	White	141	53.21
	Black / African American	17	6.42
	American Indian / Alaskan Native	1	0.38
	Asian / Asian American	60	22.64
	Native Hawaiian / Pacific Islander	1	0.38
	Other	45	16.98
Ethnicity			
	Hispanic	62	23.40
	Non Hispanic	203	76.60
SES (Parent Income)			
	$0-$24,999	24	9.06
	$25,000-$49,999	41	15.47
	$50,000-$74,999	47	17.74
	$75,000-$99,999	48	18.11
	$100,000-$124,999	39	14.72
	$125,000-$149,999	20	7.55
	$150,000-$174,999	11	4.15
	$175,000-$199,999	10	3.77
	$200,000+	21	7.92

Eligibility requirements for the larger study included the following: age of 18-24 years old at the time of recruitment, current enrollment at the university as an undergraduate student, fluency in English to complete study questionnaires, access to a mobile phone with unlimited text-messaging for daily assessments, and non-varsity athlete status due to differential likelihood of time spent exercising. Participants were recruited from posted flyers around campus, in-person recruitment from student groups and approved classes, and from other participants who were provided a flyer with study contact information.

Procedure

Participants completed a baseline assessment that was completed in-person on a tablet or desktop computer, measuring distal stressors and behaviors relating to health promotion and risk. Participants were then followed daily for two weeks. Researchers sent reminder text messages at agreed upon times in the morning to participants to wear the activity monitor, as well as at night to complete daily diary measures of hassles and physical symptoms. Participants were asked to wear a wrist ActiGraph monitor (ActiGraph wGT3X-BT, Pensacola, FL) during the two-week period to measure daily activity. At the end of the two-week period, participants returned to the lab for an in-person follow-up assessment and returned the ActiGraph. In accordance with IRB requirements, all participants received information on the study procedure and provide informed consent prior to participating. The current study was approved by the Institutional Review Boards of DePaul University (IRB#ST042717PSY) and Rosalind Franklin University of Medicine and Science (IRB#CHP17-017). Following the completion of all study tasks, participants were compensated for completing baseline and follow-up measures ($15 gift card, $20 gift card, respectively) and for each daily survey ($5 gift card each, sum paid weekly).

Measures

Pain. Pain was measured as a composite score of self-report pain items from the Physical Health Questionnaire-15 (PHQ-15). The PHQ-15 is a brief, 15-item questionnaire assessing a variety of physical health symptoms. Past research has found high internal consistency ($\alpha = 0.80$)

for the complete PHQ-15 scale among primary care and obstetrics-gynecology samples (Kroenke, Spitzer, & Williams, 2002). The current study includes different pain symptoms in its proposed analysis that are commonly experienced by an undergraduate population. Five items from the PHQ-15 were used for this study and include whether a participant has experienced stomach pain, back pain, pain in arms, legs, or joints, headaches, and chest pain and how much they were bothered by this symptom on a three-point Likert-type scale (0 = "Not bothered at all", 1 = "Bothered a little", or 2 = "Bothered a lot). Average daily composite scores were used from the two-week study period and the possible range of scores is 0 to 10 for the five items included in this study. Previous studies have used the same pain cluster of items to assess pain location (Sherbourne et al., 2009). Measures of internal consistency for the five-item pain subscale at baseline in the current study are poor ($\alpha = 0.55$). The low internal consistency for the current non-chronic pain community sample is not surprising, as it would be unlikely that most participants are experiencing pain at multiple locations. Among a sample of undergraduate emerging adults, Lester and colleages (1994) found participants reported an average of pain symptoms at 2.4 locations out of 9 possible. The Dynamic Structural Equation Model intra-class correlation (ICC) (B. O. Muthén, 2019) for pain was 0.53, which indicates a need to account for nesting within clusters. ICC provides information about the amount of variance in the momentary assessment of a construct associated with the nesting unit (within-individual).

Physical Activity. Participants were asked to wear an ActiGraph monitor continuously for the full two-week study period and until their follow-up appointment was scheduled (approximately 14 days). Participants were instructed to wear the monitor on their non-dominant hand and only remove it when showering or swimming. The ActiGraph objectively measures bodily movement – activity and inactivity and energy expenditure. ActiGraph monitors measure any movement made during the time the device is worn. Raw data from each monitor was computed into length of time (minutes) in moderate to vigorous physical activity (MVPA; a composite of moderate, vigorous, and very vigorous physical activity) per day using ActiLife (v6.13.4) software. Data was transformed according to metabolic rate criteria set by Freedson and colleagues (1998), in which activity counts per minute were defined for sedentary (0 to 99 activity counts), light (100 to 1951), moderate (1952 to 5724), vigorous (5725 to 9498), and very vigorous (>9499) were used. The Dynamic Structural Equation Model ICC (B. O. Muthén, 2019) for physical activity was 0.65, which, similar to pain, indicates a need to account for nesting within clusters. Non-wear time was detected by the ActiGraph sensor. It was excluded from computed physical activity data, as a selected feature of ActiLife (v6.13.4) software. Non-wear time was unable to be verified for sedentary for the current study, see Appendix B for more information.

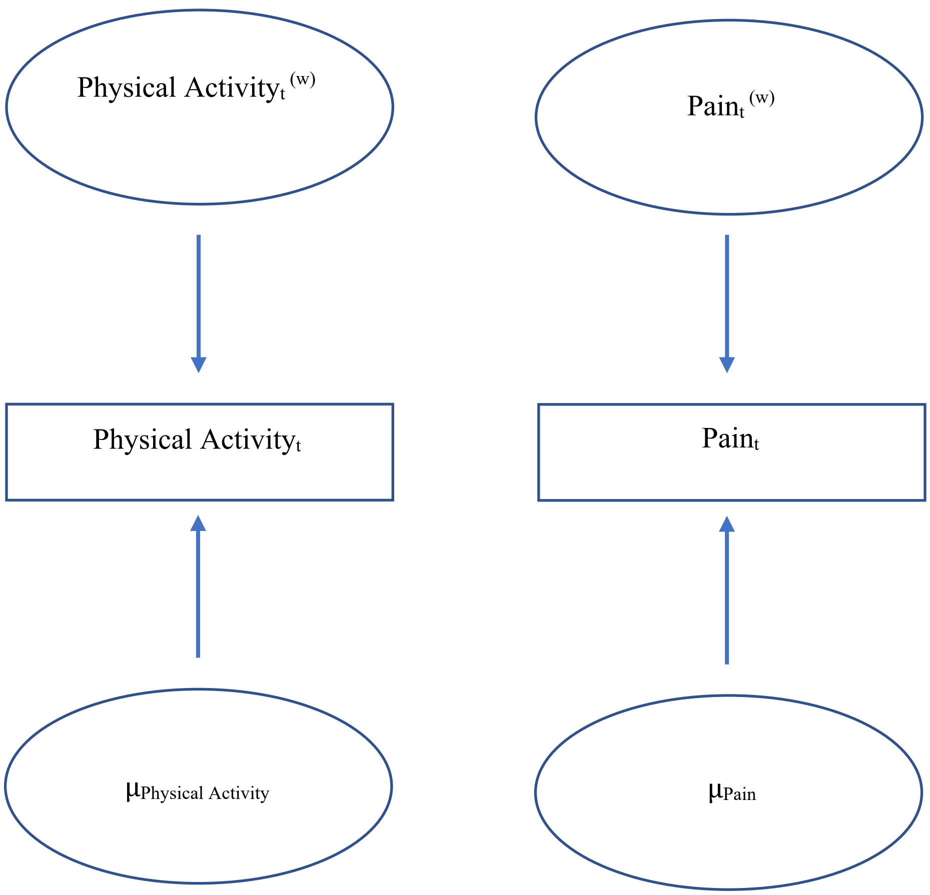
Marginalized Status. Marginalized status was measured by demographic items included in the baseline assessment, specifically, race, ethnicity (Hispanic or non-Hispanic), gender, and SES (parent income) variables. A dummy coding scheme was implemented for analyses in which non-marginalized groups (white, non-Hispanic, male, and mid to high SES ($50,000 and up)) were compared with marginalized groups (person of color, Hispanic, female, and low SES ($49,999 and below)). The current delineation of low SES ($49,999 and below) was selected based on thresholds calculated by the department of Housing and Urban Development (HUD), in which very low income and low income (50% and 80% of the area median family income) in Chicago are $44,550 and $71,300, respectively, for a household of four (Development of Planning and Development, n.d.). Parent income was collected in categorical ranges (e.g. $25,000-$49,999) at baseline and the cutoff for low SES was selected consistent with the economic hardship for a family of four in this metropolitan area. Regarding gender, individuals who identified with the following options "other", "gender non-conforming", or "queer" ($n = 6$) were not included in the current analyses due to the small sample size and possible misrepresentation; however, it is recognized that these individuals experience marginalization (Hendricks & Testa, 2012) and should be represented in future studies.

Statistical Analyses

Dynamic Structural Equation Modeling (DSEM) was used to examine the relationships between total minutes spent in MVPA per day, daily pain composite scores, and marginalized status. DSEM is a type of time series analysis that allows for comparison of intensive longitudinal data within and between individuals at multiple time points (Asparouhov et al., 2018). A first-order vector autoregressive VAR(1) model was used to analyze the concepts of interest. This type of model allows a vector at one time point t to be regressed onto the vector at a previous time point, permitting the analysis of time effects within individuals (Hamaker et al., 2018). The VAR(1) model can also compare mean differences between multiple individuals. The current study examined the cross-lagged regression coefficients between daily MVPA and daily pain composite scores within individuals at time point t and t-1 to assess for strength in predictive ability. Cross-lagged parameters allow for possible determination of causal mechanisms between vectors, representing the effects of one domain of functioning onto the other (Hamaker et al., 2018). DSEM has been used with this sample previously assessing for the relationships among daily hassles and physical health and an in-depth explanation of this innovative statistical approach has been provided there (Tran, Grotkowski, et al., 2020). The current study provides a novel way of looking at the relationship between objective ActiGraph and survey data. An evaluation of these cross-lagged relationships would allow for potential causality at a given time of the effects of previous day pain on next day MVPA and previous day MVPA on next day pain, ultimately providing evidence for a bidirectional relationship. Figures 1, 2, and 3 depict the three features of the VAR(1) model, showing the decomposition of the study data into within- and between-person components (Figure 1), within-person model (Figure 2), and between-person model (Figure 3)

Figure 1

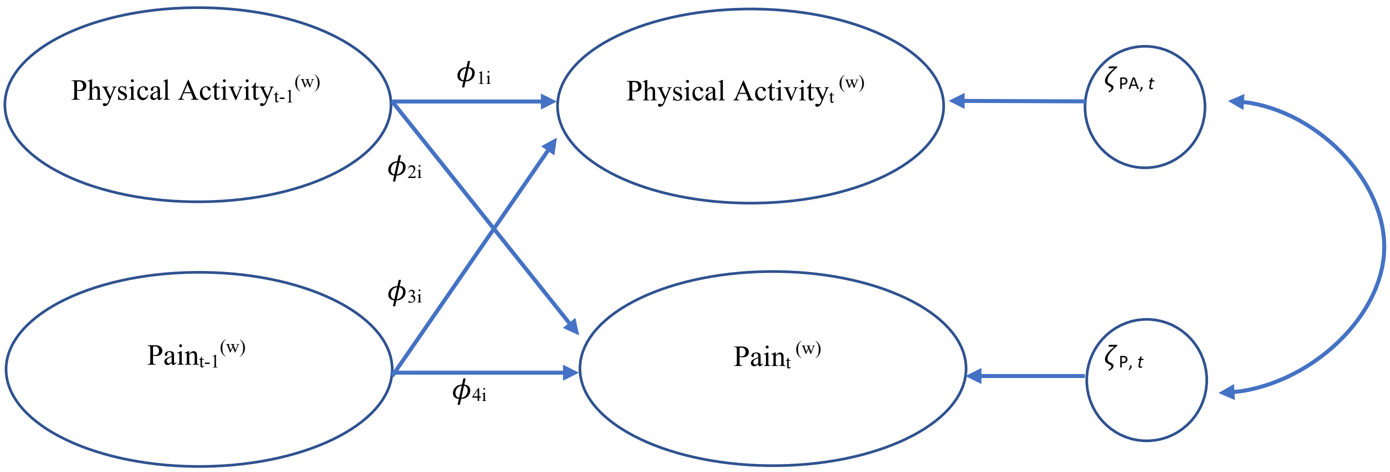
VAR(1) Model: Decomposition



Note. Figure 1 depicts the decomposition of the study data into within- and between-person components. t represents time point, w represents within person, and μ represents within person means.

Figure 2

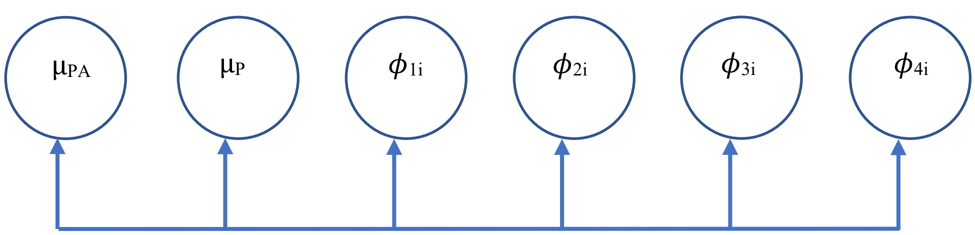
VAR(1) Model: Within-Person



Note. Figure 2 depicts the within-person components of the study model. T represents time point, t-1 represents previous time point, $\boldsymbol{\phi}$ represents autoregressive parameters (how quickly an individual restores to equilibrium) and cross-lagged regression effect (predictive relationships/spill-over), PA represents physical activity, P represents pain, and $\boldsymbol{\zeta}$ represents dynamic errors.

Figure 3

VAR(1) Model: Between-Person



Note. Figure 3 depicts the between-person components of the study model. PA represents physical activity, P represents pain, μ represents within person means, and $\boldsymbol{\phi}$ represents autoregressive parameters.

As seen in Figure 2, the within-person model demonstrates the autoregressive relationships of the vectors of interest: MVPA ($PA_t^{(w)}$) and pain ($P_t^{(w)}$) being autoregressed onto themselves on the previous day ($PA_{t-1}^{(w)}$) and ($P_{t-1}^{(w)}$), respectively (paths ϕ_{1i} and ϕ_{4i}); in addition to the cross-lagged relationships of MVPA ($PA_t^{(w)}$) on previous day pain ($P_{t-1}^{(w)}$) (path ϕ_{3i}) and pain ($P_t^{(w)}$) on previous day MVPA ($PA_{t-1}^{(w)}$) (path ϕ_{2i}). These auto-regressive and cross-lagged parameters in the within-subjects model then become possible predicted variables in the between-person models (Hamaker et al., 2018). As seen in Figure 3, the between-person model includes between-person means for both MVPA (μ_{PA}) and pain(μ_P), as well as random intercept variances. The two autoregressive terms (ϕ_{1i} and ϕ_{4i}) and cross-lagged parameters (ϕ_{3i} and ϕ_{2i}), also have fixed effects but their random effects are set to 0 (McNeish & Hamaker, 2019). Figure 4 includes the equations underlying both the within- and between-person models. As seen in Figure 5, marginalized status variables (race, ethnicity, gender, and SES) were entered into four separate models in addition to the main MVPA and pain model, to assess for moderation of the cross-lagged regression coefficients, specifically whether the presence of the moderator significantly changed the slope and path parameters.

Figure 4

VAR(1) Model: Within-Person Equation

$$y_{it} = \alpha_1 + \phi_i y_{it-1} + \varepsilon_{it}$$

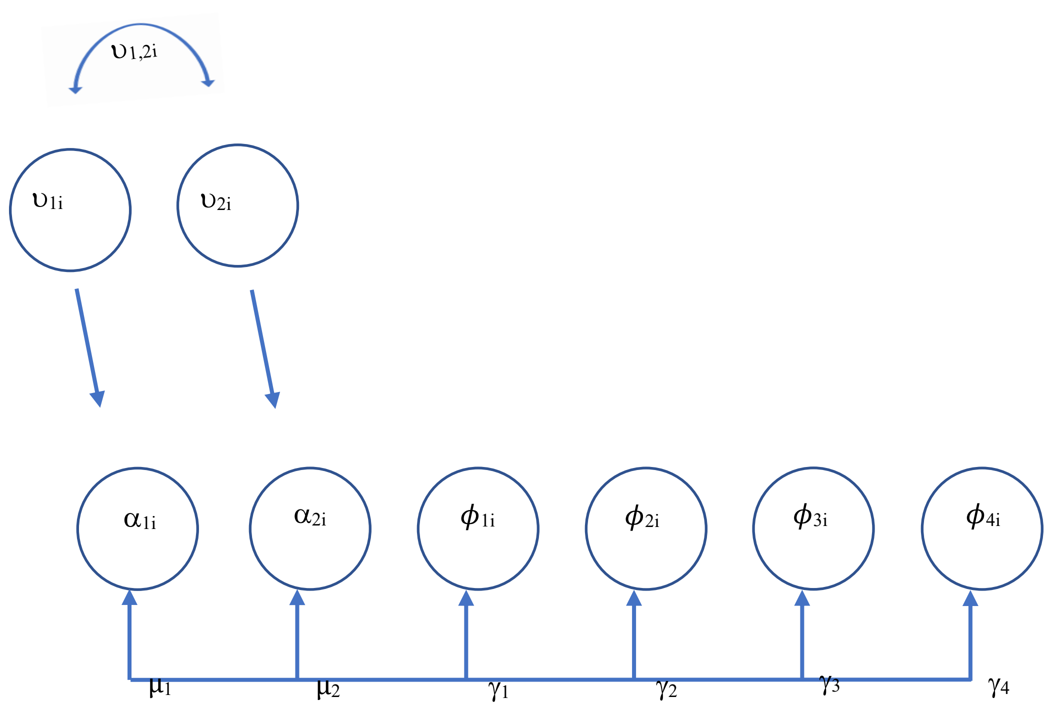
$$\begin{bmatrix} Physical\ Activity_{it}^{(w)} \\ Pain_{it}^{(w)} \end{bmatrix} = \begin{bmatrix} \alpha_{1i} \\ \alpha_{2i} \end{bmatrix} + \begin{bmatrix} \phi_{1i} & \phi_{2i} \\ \phi_{3i} & \phi_{4i} \end{bmatrix} \begin{bmatrix} Physical\ Activity_{it-1}^{(w)} \\ Pain_{it-1}^{(w)} \end{bmatrix} + \begin{bmatrix} \varepsilon_{Physical\ Activity,it} \\ \varepsilon_{Pain,it} \end{bmatrix}$$

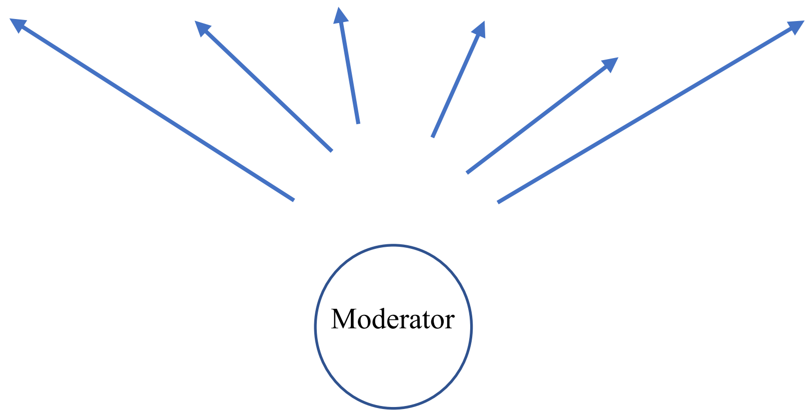
VAR(1) Model: Between-Person Equation

$$\begin{bmatrix} \alpha_{1i} \\ \alpha_{2i} \\ \phi_{1i} \\ \phi_{2i} \\ \phi_{3i} \\ \phi_{4i} \end{bmatrix} = \begin{bmatrix} \mu_1 \\ \mu_2 \\ \gamma_1 \\ \gamma_2 \\ \gamma_3 \\ \gamma_4 \end{bmatrix} + \begin{bmatrix} \upsilon_{1i} \\ \upsilon_{2i} \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix}$$

Figure 5

VAR(1) Model: Moderation of the Between-Person Model (Within-Person Means, Autoregressive Parameters, and Cross-Lagged Parameters)





Note. Figure 4 depicts the moderation of the between components of the study model. α represents person-specific intercepts for physical activity (α_{1i}) and pain (α_{2i}); fixed effects (μ_1, μ_2); $\upsilon_{1,2i}$ represents random effects related to physical activity and pain; $\phi_{1\text{-}4i}$ represents autoregressive parameters and cross-lagged regression effects; $\gamma_{1\text{-}4}$ represents fixed effects of autoregressive and cross-lagged regression parameters.

Missing Data. Participants with at least 71% complete data (10 out of 14 days) were included in analyses (n = 251). Specifically, participants missing 5 or more days of either ActiGraph or pain survey data were excluded from analyses, resulting in an analytic sample size of 251. Chi-square tests were conducted to assess whether there were significant differences by dummy coded sociodemographic groups in likelihood of meeting the 71% complete data threshold. Results indicated a significant relationship with SES and missing daily pain survey data, in which those with lower SES had more missing data than expected (χ^2 (1, N = 261) = 6.24, p = 0.01), however, Cramer's V effect size (0.16) demonstrates that this association is weak. Independent-Samples t-tests were conducted to assess whether there were significant differences in primary outcomes (average daily pain and average daily MVPA of the complete study period) for participants who met the 71% complete data threshold. These results demonstrated that those who were who did not meet the threshold (M = 137.23, SD = 79.95) for complete ActiGraph data had significantly lower rates of average MVPA ($t(261) = 3.00$, $p = 0.003$) compared to those that met the threshold ($M = 215.70$, $SD = 62.88$). Cohen's d (1.09) indicates that this is a large effect.

Results

Descriptive Data

Pain. Among the analytic sample ($n = 251$), average total daily pain was 1.16 ($SD = 1.03$) out of a possible high score of 10. Average daily headaches were rated the highest ($M = 0.32$, $SD = 0.34$), followed by average daily back pain ($M = 0.29$, $SD = 0.38$), average daily arms, legs, joint pain ($M = 0.25$, $SD = 0.34$), stomach daily pain ($M = .24$, $SD = .28$), and chest daily pain ($M = 0.06$, $SD = .12$). These scores indicate that participants were within the range of "Not bothered at all" (0) to "Bothered a little" (1) by a given symptom per day. Independent-Samples t-tests were run to assess for differences among sociodemographic groups on average reported daily pain. Participants who identified as white had significantly higher reports of average daily pain compared to participants of color ($t(249) = 2.98$, $p = 0.003$). The effect size ($d = 0.38$) indicates this is a small to medium effect. Additionally, those who identified as female had significantly higher daily pain ratings per day compared to male participants ($t(244) = -2.07$, $p = 0.04$). The effect size ($d = 0.30$) indicates this is also a small to medium effect. See Table 2 for pain averages across sociodemographic groups.

Table 2. Descriptive Results Pain & MVPA by Dummy-Coded Groups

		Average Total Daily Pain	Average MVPA
		M (SD)	*M (SD)*
Race			
	White	1.33 (1.08)*	217.69 (64.86)
	Person of Color	.95 (.92)	213.96 (56.77)
Ethnicity			
	Hispanic	1.17 (.97)	221.85 (52.02)

	Non Hispanic	1.15 (1.04)	214.16 (63.72)
Gender			
	Male	.95 (.90)*	213.41 (63.64)
	Female	1.25 (1.08)	217.53 (60.05)
SES (Parent Income)			
	$0-$49,999	1.19 (.99)	209.32 (59.43)
	$50,000+	1.14 (1.04)	218.67 (62.02)

Significance *p < 0.05

Physical Activity. The average minutes spent in MVPA per day among the analytic sample was 215.96 (*SD* = 61.16). This average exceeds the physical activity national guidelines for adults (U.S. Department of Health and Human services, 2018), suggesting the current analytic sample is highly active. See Table 2 for MVPA averages across sociodemographic groups. Independent-Samples t-tests were run to assess for differences among sociodemographic groups. No significant differences were found among groups on average time spent in MVPA per day. See Appendix B for more information regarding sedentary behavior.

Model Estimates

Five VAR(1) multilevel models were estimated in Mplus version 8 (L. K. Muthén & Muthén, 2017). Models were run using Bayesian estimation and Markov chain Monte Carlo chains algorithms with seeds generated randomly. Non-informative priors were used as there are not previous DSEM analyses relating to the current study. Due to non-significant findings of cross-lagged regression parameters across all five models, models were conceptualized as stable according to potential scale reduction criterion (PSR). When PSR values were close to 1.001, indicating the total variance across the two of the MCMC was rendered similar to the variance of the within-chains (Hamaker et al., 2018), no additional iterations were added. For the main MVPA and pain model, 20,000 iterations were run with a thin of 100 (same procedures were used for the sedentary and pain model, see Appendix B). For three of the moderation models testing the effect of race, ethnicity, and SES, 10,000 iterations were run with a thin of 100. For the gender moderation model, 30,000 iterations with a thin of 100 were needed to produce a PSR value of 1.001. For the SES moderation model, MVPA was defined by a constant (100) to reduce the variance between one and ten to attempt to remove a warning indicating difficulty computing the standardized estimates for clusters. This warning was present for all moderation models; however, defining by a constant did not remove the warning for SES.

The main model investigating the relationships among daily reported pain and MVPA (DIC = 48990.26, pD = 709.11) did not reveal significant cross-lagged relationships. The subsequent moderation models testing the effects of race (moderation of previous day MVPA on pain estimate = -0.03, p = 0.29; moderation of previous day pain on MVPA estimate = -0.08, p = 0.38; DIC = 48997.24, pD = 1001.26), ethnicity (moderation of previous day MVPA on pain estimate = 0.01, p = 0.45; previous day pain on MVPA = 0.14, p = 0.28; DIC = 48999.97, pD = 1002.24), gender (moderation of previous day MVPA on pain estimate = 0.03, p = 0.31; moderation of previous day pain on MVPA estimate = -0.20, p = 0.21; DIC =48026.40, pD = 984.21), and SES (moderation of previous day MVPA on pain estimate = 0.08, p = 0.32; moderation of previous day pain on MVPA estimate = 0.001, p = 0.50; DIC = 17707.90, pD = 808.91) on the cross-lagged relationships also did not render significant findings. All models demonstrated significant autoregressive relationships of the variables of interest (previous day pain predicting next day pain and previous day MVPA predicting next day MVPA); however, these findings are not surprising, as they demonstrate consistency among individuals and their symptoms and activity. See Tables 3-7 for full results. See Appendix B for information regarding sedentary activity model.

Table 3. MVPA Activity and Pain VAR (1) Model Standardized Results

Level	Estimate	Standard Deviation	P-Value (One-Tailed)	95% Credibility Interval
Within				
Outcome: Pain				
Predictor: $Pain_{t-1}$	0.27	0.02	<0.001*	0.23, 0.32
Predictor: $MVPA_{t-1}$	0.02	0.02	0.15	-0.02, 0.06
Outcome: MVPA				
Predictor: $MVPA_{t-1}$	0.14	0.02	<0.001*	0.10, 0.18
Predictor: $Pain_{t-1}$	-0.01	0.02	0.26	-0.05, 0.03
Covariance	-0.00	0.02	0.45	-0.04, 0.04
Residual Variances				
MVPA	0.98	0.01	<0.001*	0.97, 0.99
Pain	0.92	0.01	<0.001*	0.90, 0.95
Between				
Means				
MVPA	3.86	0.22	<0.001*	3.45, 4.31
Pain	1.26	0.10	<0.001*	1.08, 1.47
Variances				
MVPA	1.00	0.00	<0.001	1.00, 1.00
Pain	1.00	0.00	<0.001	1.00, 1.00

* Significant

Table 4. Race Moderation VAR (1) Model Standardized Results

Level	Estimate	Standard Deviation	P-Value (One-Tailed)	95% Credibility Interval
Within				
Outcome: Pain				
Predictor: $Pain_{t-1}$ [PA1]	0.29	0.03	<0.001*	0.24, 0.35
Predictor: $MVPA_{t-1}$ [PA4]	0.01	0.02	0.22	-0.02, 0.05

Outcome: MVPA				
Predictor: $MVPA_{t-1}$ [PA2]	0.14	0.02	<0.001*	1.0, 1.9
Predictor: $Pain_{t-1}$ [PA3]	-0.02	0.02	0.25	-0.06, 0.03
Covariance	-0.01	0.02	0.39	-0.05, 0.03
Residual Variances				
MVPA	0.94	0.01	<0.001*	0.91, 0.97
Pain	0.70	0.02	<0.001*	0.66, 0.74
Between				
Outcome: PA1 Predictor: Race	-0.03	0.09	0.39	-0.20, 0.14
Outcome: PA4 Predictor: Race	-0.03	0.06	0.29	-0.14, 0.08
Outcome: PA2 Predictor: Race	0.20	0.11	0.03	-0.00, 0.43
Outcome: PA3 Predictor: Race	-0.08	0.32	0.38	-0.78, 0.62
Means				
MVPA	3.91	0.23	<0.001*	3.48, 4.41
Pain	1.32	0.13	<0.001*	1.10, 1.60
Intercepts				
PA1	1.27	0.22	<0.001*	0.87, 1.75
PA4	0.09	0.12	0.23	-0.15, 0.31
PA2	0.58	0.26	0.004*	0.17, 1.16
PA3	-0.13	0.79	0.41	-1.91, 1.16
Variances				
MVPA	1.00	0.00	<0.001	1.00, 1.00
Pain	1.00	0.00	<0.001	1.00, 1.00
Residual Variances				
PA1	1.00	0.01	<0.001*	0.96, 1.00
PA4	1.00	0.01	<0.001*	0.98, 1.00

PA2	0.96	0.05	<0.001*	0.81, 1.00
PA3	0.96	0.18	<0.001*	0.31, 1.00

* Significant

Table 5. Ethnicity Moderation VAR (1) Model Standardized Results

Level	**Estimate**	**Standard Deviation**	**P-Value (One-Tailed)**	**95% Credibility Interval**
Within				
Outcome: Pain				
Predictor: $Pain_{t-1}$ [PA1]	0.29	0.03	<0.001*	0.24, 0.35
Predictor: $MVPA_{t-1}$ [PA4]	0.01	0.02	0.21	-0.02, 0.05
Outcome: MVPA				
Predictor: $MVPA_{t-1}$ [PA2]	0.14	0.02	<0.001*	0.10, 0.19
Predictor: $Pain_{t-1}$ [PA3]	-0.02	0.02	0.25	-0.07, 0.03
Covariance	-0.01	0.02	0.39	-0.05, 0.04
Residual Variances				
MVPA	0.94	0.01	<0.001*	0.91, 0.97
Pain	0.70	0.02	<0.001*	0.66, 0.74
Between				
Outcome: PA1 Predictor: Ethnicity	-0.07	0.09	0.22	-0.24, 0.10
Outcome: PA4 Predictor: Ethnicity	0.01	0.05	0.45	-0.10, 0.11
Outcome: PA2 Predictor: Ethnicity	-0.06	0.10	0.28	-0.27, 0.14
Outcome: PA3 Predictor: Ethnicity	0.14	0.30	0.28	-0.46, 0.82
Means				
MVPA	3.90	0.23	<0.001*	3.48, 4.39
Pain	1.32	0.13	<0.001*	1.10, 1.60
Intercepts				

PA1	1.29	0.20	<0.001*	0.95, 1.75
PA4	0.03	0.09	0.37	-0.15, 0.21
PA2	0.92	0.25	<0.001*	0.55, 1.52
PA3	-0.35	0.68	0.21	-2.00, 0.63
Variances				
MVPA	1.00	0.00	<0.001	1.00, 1.00
Pain	1.00	0.00	<0.001	1.00, 1.00
Residual Variances				
PA1	0.99	0.02	<0.001*	0.94, 1.00
PA4	1.00	0.00	<0.001*	0.99, 1.00
PA2	0.99	0.02	<0.001*	0.93, 1.00
PA3	0.96	0.18	<0.001*	0.30, 1.00

* Significant

Table 6. Gender Moderation VAR (1) Model Standardized Results

Level	Estimate	Standard Deviation	P-Value (One-Tailed)	95% Credibility Interval
Within				
Outcome: Pain				
Predictor: $Pain_{t-1}$ [PA1]	0.29	0.03	0.000*	0.24, 0.34
Predictor: $MVPA_{t-1}$ [PA4]	0.01	0.02	0.28	-0.03, 0.04
Outcome: MVPA				
Predictor: $MVPA_{t-1}$ [PA2]	0.14	0.02	0.000*	0.10, 0.18
Predictor: $Pain_{t-1}$ [PA3]	-0.02	0.03	0.24	-0.07, 0.03
Covariance	-0.01	0.02	0.36	-0.05, 0.03
Residual Variances				
MVPA	0.94	0.01	<0.001*	0.91, 0.97
Pain	0.70	0.02	<0.001*	0.66, 0.74

Between				
Outcome: PA1 Predictor: Gender	0.04	0.09	0.34	-0.13, 0.21
Outcome: PA4 Predictor: Gender	0.03	0.06	0.31	-0.08, 0.14
Outcome: PA2 Predictor: Gender	0.07	0.11	0.25	-0.13, 0.29
Outcome: PA3 Predictor: Gender	-0.20	0.30	0.21	-0.84, 0.40
Means				
MVPA	3.91	0.24	<0.001*	3.48, 4.40
Pain	1.32	0.13	<0.001*	1.09, 1.59
Intercepts				
PA1	1.78	0.19	<0.001*	0.84, 1.59
PA4	0.00	0.09	0.49	-0.18, 0.18
PA2	0.80	0.23	<0.001*	0.43, 1.33
PA3	-0.08	0.67	0.42	-1.59, 0.91
Variances				
MVPA	1.00	0.00	<0.001	1.00, 1.00
Pain	1.00	0.00	<0.001	1.00, 1.00
Residual Variances				
PA1	1.00	0.01	<0.001*	0.96, 1.00
PA4	1.00	0.01	<0.001*	0.98, 1.00
PA2	0.99	0.02	<0.001*	0.92, 1.00
PA3	0.94	0.19	<0.001*	0.28, 1.00

* Significant

Table 7. SES Moderation VAR (1) Model Standardized Results

Level	Estimate	Standard Deviation	P-Value (One-Tailed)	95% Credibility Interval
Within				
Outcome: Pain				

Predictor: $Pain_{t-1}$ [PA1]	0.29	0.03	<0.001*	0.24, 0.34
Predictor: $MVPA_{t-1}$ [PA4]	0.03	0.02	0.07	-0.01, 0.07
Outcome: MVPA				
Predictor: $MVPA_{t-1}$ [PA2]	0.14	0.02	<0.001*	0.10, 0.19
Predictor: $Pain_{t-1}$ [PA3]	-0.02	0.02	0.22	-0.06, 0.03
Covariance	-0.01	0.02	0.36	-0.04, 0.03
Residual Variances				
MVPA	0.95	0.01	<0.001*	0.92, 0.97
Pain	0.85	0.02	<0.001*	0.81, 0.89
Between				
Outcome: PA1 Predictor: SES	0.05	0.09	0.27	-0.12, 0.22
Outcome: PA4 Predictor: SES	0.08	0.21	0.32	-0.30, 0.56
Outcome: PA2 Predictor: SES	-0.16	0.11	0.06	-0.40, 0.05
Outcome: PA3 Predictor: SES	0.001	0.29	0.50	-0.59, 0.59
Means				
MVPA	3.93	0.24	<0.001*	3.49, 4.44
Pain	1.30	0.11	<0.001*	1.09, 1.54
Intercepts				
PA1	1.22	0.21	<0.001*	0.87, 1.70
PA4	0.28	0.40	0.15	-0.27, 1.33
PA2	1.03	0.27	<0.001*	0.63, 1.67
PA3	-0.26	0.46	0.25	-1.27, 0.56
Variances				
MVPA	1.00	<0.001	<0.001	1.00, 1.00
Pain	1.00	<0.001	<0.001	1.00, 1.00
Residual Variances				

PA1	1.00	0.01	<0.001*	0.95, 1.00
PA4	0.98	0.10	<0.001*	0.66, 1.00
PA2	0.97	0.05	<0.001*	0.84, 1.00
PA3	0.97	0.14	<0.001*	0.48, 1.00

* Significant

Discussion

The current study sought to understand the directionality of relationships among daily reported pain and actigraphy-measured physical activity across a 14-day longitudinal study period. DSEM analyses were implemented to examine the predictive ability of previous day MVPA on next day reported pain, in addition to previous day reported pain on next day MVPA. No significant cross-lagged relationships were found, suggesting that neither single directionality nor bidirectionality was present among these health indicators for this study sample. These findings are inconsistent with research that has provided evidence for the deleterious effects of pain on physical activity (Bryant et al., 2007; Dansie et al., 2014), therapeutic effects of physical activity on pain (Harris & Susman, 2002; Koes et al., 2010), as well as the bidirectional effects of these constructs (Rabbitts et al., 2014).

These relationships may not have been present in the study sample due to our measures of pain and our sample's average reported pain. Average reported pain per day in the sample was very low with low variability (M = 1.16, SD = 1.03). The current study used a composite score of total pain (stomach pain, back pain, pain in arms, legs, or joints, headaches, and chest pain) from the PHQ-15; however, when examining reported pain across pain symptoms, it is evident that headaches and back pain were endorsed the most for "bothering" participants. These pain symptoms are most commonly endorsed by this age group (Bigal et al., 2001; Curry & Green, 2007; Heuscher et al., 2010; Linet et al., 1989; Reis et al., 1996). Future analyses may want to consider focusing on these pain symptoms exclusively and measuring multiple indicators, such as frequency, severity, and functional impairment on daily life, as they may be the most meaningful. A composite score including a count of pain locations like the one used in this study may not provide the best measure of sensitivity in pain symptoms for this population and may better serve clinical populations with specified pain locations. In fact, measures of internal consistency demonstrated poor validity among this sample, providing further evidence that most emerging adults in college likely are not experiencing multiple pain symptoms, but rather perhaps a few localized areas of pain, such as headache and back pain.

Descriptive analyses demonstrated this sample engages in a high amount of MVPA in reference to national guidelines for adults ($M = 215.96$, $SD = 61.16$), which recommend 150-300 minutes of moderate-intensity or 75-150 minutes of vigorous intensity per week (U.S. Department of Health and Human services, 2018). These findings suggest, despite varsity athletes being excluded from participation, our sample is unique with higher amounts of activity observed. Many studies have found the opposite (Huang et al., 2003; Racette et al., 2008; Yahia et al., 2016), concluding that many emerging adults are not engaging in recommended activity, with one report suggesting this population is meeting less than half the recommended (2007) guidelines (American College Health Association, 2013). Some research among adolescents and emerging adults has demonstrated that wrist-worn accelerometers capture higher rates of activity compared to waist-worn accelerometers (Loprinzi & Smith, 2017; Scott et al., 2017), which may have contributed to the high average.

Marginalized status was examined as a potential moderator in the relationships among pain and physical activity. Specifically, four moderation variables were entered into separate models testing the effects of gender, race, ethnicity, and SES separately on the cross-lagged relationships of physical activity and pain. The current study did not find any evidence for moderation of identity characteristics. Though no study to our knowledge has specifically looked at the moderating effects of identity among the relationships between pain and physical activity, there is evidence from other studies that marginalized groups are at an inequitable risk of worse pain experiences (Aggarwal et al., 2003; Andersson et al., 1993; Fillingim et al., 2009; Gagnon et al., 2014; Green et al., 2003; Hastie et al., 2005; Linet et al., 1989; Lipton et al., 2018; Tran, Koven, et al., 2020) and lower rates of physical activity (Huang et al., 2003; Mathieu et al., 2012; Nguyen-Michel et al., 2006; Vankim & Nelson, 2013; Yahia et al., 2016).

Descriptively, we found significant mean differences in pain ratings by gender, with female identifying participants reporting higher average total pain than male participants– these findings are consistent with existing research (Fillingim et al., 2009; Linet et al., 1989; Lipton et al., 2018). In addition, there were significant differences in average total pain by race, with participants who identified as white with higher rates compared to individuals who identified as a person of color, though similar to gender, this effect was small to medium. This finding conflicts with some research finding the opposite phenomenon (Gagnon et al., 2014; Green et al., 2003; Hastie et al., 2005). Perhaps this finding suggests that reports of pain are experienced differently than the impact of pain; other research has found that white adolescents also report more pain than those of color (Tran, Koven, et al., 2020). Findings from experimentally induced pain studies examining conditioned pain modulation, an identified risk factor of chronic pain, demonstrated that when engaging in similar levels of physical activity as their white peers, African American / Black and Latinx young adults exhibited the same conditioned pain responses (Umeda et al., 2017; Umeda & Escobedo, 2019). These studies conjecture that if groups are similar in physical activity, they may share a similar risk to pain implying that physical activity may positively regulate pain processing among these groups (Umeda et al., 2017; Umeda & Escobedo, 2019). Though this does not explain why we found higher averages of reported pain among white participants, perhaps physical activity is a protective factor against pain experiences (particularly because we had overall high averages of MVPA), weakening any moderation effect. More research needs to be done regarding the role of physical activity in moderating pain experiences.

Our study found no differences in rates of MVPA among sociodemographic groups, suggesting that individuals were engaging in similar levels of activity. This finding was surprising in light of research demonstrating disparate levels of activity across sociodemographic groups (Huang et al., 2003; Mathieu et al., 2012; Nguyen-Michel et al., 2006; Vankim & Nelson, 2013; Yahia et al., 2016). Some potential factors may have contributed to allowing for similar strength of the relationship between pain and physical activity among sociodemographic groups. For example, perhaps the centralization of physical activity resources and its access to all students (i.e. fitness center with various methods of engaging in MVPA, such as facilities with equipment and related programming) offset any differences among groups. Additionally, lack of moderation may have been due to campus location in a metropolitan area, in which participants walk across campus to various academic buildings and facilities, and commute by walking and biking, in addition to trains, busses, and cars. Lastly, although our sample was relatively diverse compared to other studies in this population, greater representation of participants of color – specifically having equal numbers of participation among different racial and ethnic groups, allowing differences to be assessed between each group— may provide even more power to examine a moderation effect.

Limitations & Future Directions

Though dummy coding sociodemographic variables lends itself to the current analyses, using dummy coded identity variables is a reductionist way of viewing these relationships and potentially masks differences among subgroups (e.g. differences among Black / African American, American Indian / Alaskan Native, Asian or Asian American, Native Hawaiian / Pacific Islander, and those in the "other" category likely indicating multiracial status, as well as nuances among gender identifications (however the current sample endorsed a small (*n* = 6) sample of non-binary individuals who were excluded from gender moderation analyses)). One aim of the current study attempted to explore whether these identity characteristics moderated daily health experiences. These identity characteristics should be studied in a more intersectional way, providing more accurate findings on the nuances of different identity characteristics of gender, race, ethnicity, and SES. In particular, it is essential to contextualize differences among groups with components of intersectionality (Bond, 2016).

Another limitation includes missing data and associations with sample characteristics and outcome measures. Using a threshold of including participants who had at least 10 out of 14 days of complete data, analyses revealed that participants who were of lower SES had more data missing than expected (though this association was weak). In addition, those that were missing MVPA data had lower average MVPA observed. Taken together, perhaps individuals with lower SES were less likely to be included in analyses and decreased likelihood of finding moderation among pain and physical activity. Lastly, the current study only used daily cut offs of physical activity for inclusion in analyses (e.g., we included participants with at least 71% of days, or 10 out of 14 days). Some studies include an hourly threshold, with ranges of 7-10 hours of activity per day to meet inclusion criteria (Dansie et al., 2014; Ellingson et al., 2012; Peterson et al., 2018; Rabbitts et al., 2014; Umeda et al., 2017; Wilson & Palermo, 2012), though they do not provide a rationale for these cut offs. To account for this, our MVPA calculations excluded non-wear time that was detected by the ActiGraph sensor and removed from computed physical activity data, as a selected feature of ActiLife (v6.13.4) software.

Strengths & Conclusion

A strength of the present study includes the use of objective accelerometer-measured physical activity over a two-week period, with daily diary reports of pain symptoms. These methods are an improvement over recall measures and suggest that future studies using other objective biometric measures are feasible as well. Regarding data, this study had excellent retention and little missing data, only 14 out of 265 participants were excluded from analyses due to not meeting the minimum daily data requirement. Given emerging adults' comfort wearing wrist activity monitors and response to text messaging for daily diary completion, this study demonstrates a feasible method of examining these and related empirical questions with advanced statistical methods. Additionally, this is the first study of our knowledge using DSEM, a cutting-edge analytical approach, to explore the relationships among daily reported pain and actigraphy. DSEM has shown to be more sensitive to multiple data points per person. Future DSEM analyses investigating these concepts may want to consider using more than 14 points of data per person for each variable, such as using more moment-by-moment physical activity (e.g. minute-by-minute) and an objective indicator of pain experiences (e.g. heart rate or blood pressure). Lastly, our sample was relatively diverse across several characteristics and allowed for tests of moderation of race, ethnicity, and SES when other studies may not have the power to do so.

In conclusion, the current study did not find evidence for significant predictive relationships among daily reported pain and observed physical activity. Despite these null findings, this study provided evidence for successful digital advancements in data collection of emerging adult samples with ActiGraph monitor wear and text reminders for daily survey completion. In addition, this relatively diverse study sample provided initial insight into the moderation of the relationships among pain and physical activity. Future research should aim to further include diverse samples of emerging adults and increased data points per person to investigate health concerns among this population.

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Appendix A: Original Thesis Proposal

Assessing for Bidirectionality Between Daily Pain and Physical Activity and the Role of Marginalized Status During Emerging Adulthood

Proposal for a Thesis

Presented to the Department of Psychology

DePaul University

By

Helen Bedree

August 21, 2020

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Abstract

Emerging adulthood is often overlooked as a developmental time period critical to shaping future health outcomes. Past research has shown that not only do health concerns tend to peak during this developmental time period, but also health behaviors adopted have significant implications for developing chronic health conditions. Recurrent pain is a commonly experienced health concern within this age group, with headaches and low back pain being frequently reported. Many studies have demonstrated the effect of physical activity on pain relief; however, others have demonstrated that for some individuals, physical activity can exacerbate pain symptoms. Within the context of experiencing systematic oppression, marginalized emerging adults have reported more frequent and severe recurrent pain. To compound these health inequities, research has shown that individuals are less likely to engage in physical activity that could alleviate pain symptomatology during this developmental context, with marginalized emerging adults even less likely. Therefore, the current study aims to 1) assess a bidirectional relationship between reported pain and engagement in physical activity among an emerging adult sample ($N = 265$) and 2) determine whether demographic factors moderate this relationship. Using longitudinal daily reported pain and actigraphy data over the span of a two-week study period, a dynamic structural equation modeling approach will be employed to determine whether a bidirectional relationship exists among these constructs. Second, the influence of social identity factors on the relationship between recurrent pain and physical activity will be examined. Findings will provide more insight into the directionality between pain and physical activity, providing more guidance on both the therapeutic uses of physical activity as pain relief and possible caution of engagement in exacerbating pain symptoms. Lastly, it will fill gaps in the literature on the moderating effects of marginalized status on these relationships.

Assessing for Bidirectionality Between Daily Pain and Physical Activity and the Role of Marginalized Status During Emerging Adulthood

Young adulthood, otherwise known as emerging adulthood, is an important developmental context for shaping health outcomes that takes place between the ages of 18-25 years old (Arnett, 2000). Individuals face new experiences with autonomy and decision-making, especially in what health behaviors to engage in (Nelson et al., 2008). Research on this population has shown that the prevalence of health concerns tends to peak during this developmental time period. For example, Park and colleages (2006) reviewed studies with nationally representative samples investigating mortality, morbidity, health behaviors, and health care use to create a "health profile" of emerging adults. The authors' findings highlighted that health concerns like substance use (tobacco use, illicit drug use, binge drinking, and heavy alcohol use), sexually-transmitted diseases, unintentional injury (around 70% caused by a motor vehicle accident), and homicide peak during emerging adulthood (Park et al., 2006). Adopting health behaviors during young adulthood has significant implications for the development of chronic conditions and well-being because individuals are just beginning to learn how to take care of their own health (Irwin, 2010). Results from national data analyses revealed that that weight gain, physical inactivity, and poor dietary intake are especially common among this age-group, putting emerging adults at an increased risk for developing future chronic conditions (Nelson et al., 2008). Coupled with increasing rates of chronic conditions among the global population (Murray et al., 2012), emerging adulthood is a critical developmental time period to better understand health behavior.

Recurrent pain is a health concern of particular importance in this developmental context given that 65% of young adults report pain-related symptoms (Lester et al., 1994). Low back pain, for example, has been shown to be a prevalent symptom for this age group, specifically for college students, with studies reporting prevalence rates of 38% and 29.2% in the past year (Gilkey et al., 2010; Heuscher et al., 2010). One study found that among their college sample, 71% of students reported having lower back pain one to five times a week (Reis et al., 1996). Headaches are another common pain symptom reported by emerging adults, with 56.8% of young men and 78.3% of young women experiencing their most recent headache within the past month (Linet et al., 1989). Curry & Green (2007) found that half their sample (50.9%) experienced headaches at least once per month and the majority of those students (76.9%) indicated that their headaches affected daily activities. Experiences of recurrent pain during this developmental context are linked to an increased risk of developing chronic pain conditions in the future. For example, Walker and colleagues (1998) found that adolescents and emerging adults with recurrent abdominal pain (RAP) were more likely to meet criteria for irritable bowel syndrome and report higher functional disability 5 years later compared to their peers without RAP.

Chronic pain, in particular, is associated with numerous psychosocial, as well as functional limitations and lower health-related quality of life (Turk et al., 2016). For example, mood and affect, coping abilities, beliefs and expectations of pain, sleep impairments, physical mobility, and impact on daily activities have all been cited as consequences of chronic pain on daily life (Turk et al., 2016). For emerging adults in college or university, pain can negatively affect functioning, such as grades and course engagement. College students with headache pain, however, reported worse overall academic performance (Bigal et al., 2001). With the prevalence of pain conditions rising (Freburger et al., 2009) and negative implications for well-being, it is critical to understand what pain symptoms are occurring among this population and possible health behaviors that can prevent adverse outcomes. Furthermore, emerging adulthood might be a particularly important developmental context to target health behaviors associated with acute pain relief to prevent a chronic trajectory.

Pain and Physical Activity

Physical activity is one health-promoting behavior that has been found to reduce pain symptomatology (Harris & Susman, 2002; Koes et al., 2010). In addition to reducing risk for many other chronic conditions, such as cardiovascular disease, diabetes mellitus, cancer, and osteoporosis (Warburton et al., 2006), research has found a therapeutic link between physical activity and pain relief among children and adults with chronic pain (Fanucchi et al., 2009; Hanney et al., 2009; Stephens et al., 2008). Among adults, one study found that thirty minutes or more of moderate exercise one to three times a week was associated with a 10-12 percent lower prevalence of chronic pain (Landmark et al., 2011). Therefore, it is critical to better understand this relationship in order to increase preventative efforts in pain reduction.

There are mixed findings on whether the intensity or frequency of physical activity plays a more critical role in pain relief. In a systematic review and meta-analysis aiming to determine the type of exercise that was most effective in pain reduction for those with knee osteoarthritis, Juhl and colleages (2014) concluded that exercise intensity or duration does not change individual pain perception, but the frequency of exercise (three times per week among their sample of studies) was a more important factor in pain relief. Though evidence of the mechanisms that enable this therapeutic relationship is inconclusive, some researchers argue that beta-endorphins are underlying it and that exercise intensity does matter. Bender and collegues (2007) found that across studies of those with chronic pain and those without, beta-endorphins were released as a result of physical activity that enabled pain relief, particularly when individuals reached their anaerobic threshold at high exercise intensity. Nijs and colleages (2012) present evidence in their review that this relationship is more easily established for healthy individuals. Chronic pain conditions are associated with dysregulated pain responses, thus individuals with chronic pain warrant tailored physical activity in order to reduce the likelihood of painful flare-ups post exercise. Nevertheless, physical activity is an important health behavior for pain reduction for healthy and chronic pain populations, particularly for emerging adults experiencing more acute pain symptoms.

The U.S. Department of Health and Human Services (2018) recently updated physical activity guidelines for adults to include ranges of recommended activity per week, suggesting spreading activity throughout the week, and including muscle-strengthening exercises. Specifically, the new guidelines include 150 minutes to 300 minutes of moderate-intensity or 75 minutes to 150 minutes of vigorous-intensity aerobic physical activity per week, or a combination of moderate- and vigorous-aerobic activity (U.S. Department of Health and Human services, 2018). According to a research study conducted by the American College Health Association (2013) surveying college students across the country, most emerging adults are not engaging in enough physical activity – especially female identifying students. This is problematic, because low levels of physical activity are associated with increased risk of developing heart disease and stroke, cancer, depression, and dementia outside of the compounding effects of body mass index and diet (Institute of Medicine & National Research Council, 2013). Using 2007 guidelines that suggest engaging in moderate-intensity cardio or aerobic exercise of at least 30 minutes 5 days per week or vigorous-intensity cardio or aerobic exercise for at least 20 minutes 3 days per week (Haskell et al., 2007), the report by the American College Health Association (2013) concluded that only 18.4 percent are engaging in moderate-intensity physical activity at least 5 days per week and 26.4 percent are meeting the standards for vigorous-intensity at least 3 days per week, with a total of 44.6 meeting either the moderate-intensity or vigorous-intensity 2007 guidelines. In other words, most young adults are not meeting physical activity guidelines.

Other studies with college students have found similar results (Huang et al., 2003; Racette et al., 2008; Yahia et al., 2016). For example, Yahia and colleagues (2016) discovered that about half of participants reported engaging in some form of physical activity, one third exercised more than four hours per week, and only 26 percent endorsed an “active lifestyle”. Racette and colleagues (2008) examined changes in physical activity from a student’s first year to their last year in college. Their results suggest that in their first year, a little more than half (59%) were able to engage in regular exercise, meeting guidelines, but about a third (29%) did not exercise regularly – not meeting guidelines. These patterns held fairly stable by a students’ last year and are similar to what has been found among the general adult population in the U.S. (Centers for Disease Control and Prevention 2001), with a quarter of the student population not engaging in exercise (25%) and not meeting the recommended guidelines of physical activity (Racette et al., 2008). Some research, though, has found age to be a factor among college students in their physical activity behavior. Despite the majority of the sample was not meeting recommended guidelines, Huang and colleagues (2003) reported that college students younger than 20 years old were more likely to report engaging in aerobic exercise and those younger than 19 years old were more likely to report strength training as compared to older students.

In the relationship between pain and physical activity, it’s important to consider that there may be a threshold or bidirectional relationship. For example, while research has found that physical activity can reduce pain (Fanucchi et al., 2009; Hanney et al., 2009; Stephens et al., 2008), individuals with chronic pain have also reported having a decreased ability to engage in physical activity (Bryant et al., 2007; Dansie et al., 2014), suggesting a bidirectional relationship between pain and physical activity. Essentially, while physical activity can ameliorate pain symptoms, pain can also limit physical functioning. One study with adolescents found evidence for this relationship; Rabbitts and colleagues (2014) compared results from actigraphy measures and ratings of pain over a ten day period among participants who were healthy and participants with chronic pain and found that higher pain intensity predicted next day lower peak physical activity for both groups and that higher physical activity predicts end of day lower pain only for youth with chronic pain. Given the mixed findings, it is important to better understand this complex relationship, especially among emerging adults experiencing pain symptoms in order to prevent chronicity of symptoms and to provide a framework for managing pain among this often overlooked developmental group.

Pain and Sedentary Behavior

As discussed in the chronic pain literature, physical activity – typically exercise – is studied for its positive effect on health status. Physical *inactivity*, also referred to as sedentary behavior, is also important to consider in this relationship as a risk factor for poor health outcomes. Physical inactivity is associated with an increased risk of developing chronic conditions, such as coronary heart disease, type 2 diabetes, and certain cancers (Lee et al., 2012; Warburton et al., 2006). Among those with chronic pain conditions, such as Fibromyalgia, sedentary behavior has been found to be negatively associated with responses in the central nervous system that help manage pain – that is, more sedentary behavior resulted in decreased responses of the central nervous system regulating pain (Ellingson et al., 2012). In a systematic review assessing the relationship between screen-based sedentary behavior and health status with adolescent populations, musculoskeletal pain was found to be associated with increases in sedentary behavior (Costigan et al., 2013).

Despite these findings linking pain to sedentary behavior, other research has concluded the opposite. For example, another systematic review concluded that the evidence for sedentary behavior as a risk factor for pain is weak due to one out of 15 studies reporting a positive relationship between sedentary behavior and low back pain (Chen et al., 2009). Chen and colleages (2009) note that this single study demonstrating evidence was among the eight studies with high methodology quality. It is possible that with inclusion of more high-quality studies there would be more evidence for the link between pain and sedentary behavior. Further, It is important to further examine the relationship between sedentary and pain among emerging adults, however, as both physical activity and inactivity patterns are likely to persist into adulthood (Keating et al., 2005) and adopting sedentary behaviors has been found to be common among college students, with some studies reporting almost half their sample as inactive (Keating et al., 2005).

Social Factors Leading to Differential Experiences with Pain and Physical Activity

To fully understand the relationship between pain and physical activity among emerging adults, it is critical to consider how identity factors, such as race and ethnicity, gender, and socioeconomic status (SES) influence health outcomes and behaviors. A growing body of research demonstrates the deleterious relationship between marginalized social status and well-being (Braveman et al., 2011) that lead to health inequities, which are preventable and unjust (Arcaya et al., 2015). Upstream factors, or those at the root of health disparities, such as economic and social resources and opportunities, educational attainment, living and working conditions, and systematic oppression have been shown to be causally linked to downstream factors, or those most often attributed in explaining health outcomes, such as behavior and health care utilization (Braveman et al., 2011). Therefore, it is necessary to keep these upstream factors in mind to contextualize the categorical findings below (i.e., downstream factors). For example, race and ethnicity are often conflated with economic resources and opportunities (Bond, 2016). It is also important to acknowledge that individuals do not fit neatly into these groups and instead, often belong to multiple, dynamic, and intersecting identities (Bond, 2016).

Race and Ethnicity. Research has shown that pain is inequitably experienced by different sociodemographic groups (Gagnon et al., 2014; Green et al., 2003; Hastie et al., 2005). Regarding race and ethnicity, when compared to their white counterparts, higher level of pain severity has been shown to be more prevalent among Latinx and African American / Black adults with chronic pain (Gagnon et al., 2014; Green et al., 2003). Some research has found differences in pain experience among emerging adults. Hastie and colleagues (2005) found that among their college student sample that reported pain in the past six months (about half), frequency or severity of pain did not vary by individuals of different racial or ethnic group, but pain location did. Chest and stomach pain was reported more among African American / Black emerging adults than white or Latinx students and leg and foot pain was reported more among Latinx participants than any other group (Hastie et al., 2005).

Some research has found that rates of physical activity differ among sociodemographic groups. In longitudinal study assessing cardiovascular disease, Mathieu and colleagues (2012) found that after accounting for socioeconomic status, age, sex, and BMI, among their sample of around 3,000 adults, African American / Black and Hispanic adults were less likely to engage in physical activity than white participants. Taken together, these studies demonstrate how due to inequitable, social determinants of health, pain and physical activity are both impacted by race and ethnicity. Therefore, it is possible that these factors may individually moderate the relationships between pain and physical activity. No research to our knowledge has tested the moderation effects of race and ethnicity on the relationship between pain and physical activity.

Gender. Gender has been considered a social determinant of health and has contributed to differential experiences of pain. Higher rates of pain are often reported by women (Fillingim et al., 2009; Linet et al., 1989; Lipton et al., 2018). Researches have posited that the gender difference in pain begins in adolescence, as LeResche and colleagues (2005) found that rates of chronic pain conditions – back pain, headache, and temporomandibular disorder – increase through puberty for adolescent girls, whereas they either decrease or remained unchanged for adolescent boys. In an epidemiology study conducted by Linet and colleagues (1989), young women were more likely to have headaches more frequently, severely, and longer in duration than men. In fact, a review of pain studies found that across conditions, women are more likely to report pain at a more frequent and severe rate, and longer in duration – putting them at greater risk for pain-related disability (Unruh, 1996) and clinical pain conditions, such as neuropathic and musculoskeletal pain (Fillingim et al., 2009).

To compound the issue, physical activity may not serve the same role in mitigating pain, as women typically report less engagement in physical activity (Mathieu et al., 2012). Further, among emerging adults, women have reported lower levels of physical activity (Huang et al., 2003; Nguyen-Michel et al., 2006; Vankim & Nelson, 2013; Yahia et al., 2016). Young men, for example, are more likely to engage in aerobic exercise more days per week than women (Huang et al., 2003). Previous research has found that females experience more pain and are less physically active, but no research to date has looked at how gender mediates the pain and physical activity relationship.

Socioeconomic Status. Lastly, it is also critical to take socioeconomic status (SES) into account when assessing the relationship between pain and physical activity. Lower educational attainment and income level have been shown to be related to worse health outcomes, likely due to a lack of economic resources like nutrition, housing, neighborhood characteristics, and an increase in stress without resources to cope (Braveman et al., 2011). Notably, lower SES has been associated with higher rates of pain (Aggarwal et al., 2003; Andersson et al., 1993; Tran, Koven, et al., 2020). As discussed previously, components of SES are often overlooked in their contribution to racial disparities in health. Comparing the experience of older African American / Black and white adults, Fuentes and colleages (2007) found that race and SES are both critical factors in chronic pain. Specifically, the researchers found that higher SES was associated with a decrease in pain outcomes for both groups, confirming other studies on SES and pain, however, increased affective pain and low SES was associated with African American / Black demographic variables (Fuentes et al., 2007).

Lower SES may not only be a risk factor for pain, but also for less engagement in physical activity to help reduce pain symptoms. In fact, income and educational attainment have been found to be positively related to physical activity; meaning, as income and education levels rise an individual might have, so do rates of physical activity (Mathieu et al., 2012). SES has been linked with neighborhood characteristics, such as having a safe place to exercise (Braveman et al., 2011). For example, Estabrooks and colleagues (2003) examined the availability of such places (i.e. parks, sports facilities, fitness clubs, community centers, and trails) in low, medium, and high SES neighborhoods. They found that not only did low and medium SES neighborhoods have less resources for physical activity, but also those that are free (Estabrooks et al., 2003). Though SES is linked with other social determinants of health in a manner that may not lend itself to looking at these constructs separately, it is important to also consider how this construct changes the relationships between pain and physical activity among emerging adults. Given past research indicating that individuals with low SES experience increased pain and lower rates of physical activity, it is possible that this construct also moderates the pain and physical activity relationship. Similar to the constructs previously reviewed, no research to our knowledge has tested this moderation effect on the relationship between pain and physical activity.

Aims of Current Study

The current study seeks to better understand the relationships among pain, physical activity and inactivity, and how marginalized status inequitably changes these relationships among a diverse, emerging adult sample. The aims are twofold. First, the study will determine whether experiences of pain and engagement in physical activity are related to each other in a bidirectional manner. Within this first aim, two hypotheses are posited to examine this bidirectional relationship. It is hypothesized that previous pain symptoms will predict next day physical activity levels, such that higher rates of pain will predict lower rates of physical activity and higher rates of physical inactivity. It is also hypothesized that previous day physical activity levels will predict next day pain symptoms, such that higher rates of physical activity will predict lower rates of pain and that higher rates of physical inactivity will predict higher rates of pain. The second aim of the current study will examine whether marginalized status – race and ethnicity, gender, and socioeconomic status – moderates these bidirectional relationships. It is hypothesized that marginalized status will strengthen the associations between previous day pain and next day physical activity, as well as previous day physical activity and next day pain.

Method

Participants

Emerging adults, who took part in a larger study aiming to understand health behaviors and daily stressors at a private Midwestern university, will be included in the current study. Eligibility requirements for the larger study included being between the ages of 18-24 years old at the time of recruitment, current enrollment at the university as an undergraduate student, fluency in English to complete study questionnaires, access to a mobile phone with unlimited text-messaging for daily assessments, and non-varsity athlete status due to differential likelihood of time spent exercising. Participants were recruited from posted flyers around campus, in-person recruitment from student groups and approved classes, and from other participants who were given a flyer with study contact information. Recruitment yielded a diverse sample of 265 emerging adults. In accordance with IRB requirements, all participants received information on the study procedure and provide informed consent prior to participating. Following the completion of all study tasks, participants were compensated for completing baseline and follow-up measures ($15 gift card, $20 gift card, respectively) and for each daily survey ($5 gift card paid weekly).

Procedure

The current study will assess physical functioning and pain symptoms over the span of two weeks in order to better understand relationships between identity, pain, and physical activity. Participants completed a baseline assessment that was completed in person on a tablet or desktop computer, measuring distal stressors and behaviors relating to health promotion and risk. Participants were then followed daily for two weeks. Researchers sent reminder text messages at agreed upon times in the morning to participants to wear the activity monitor, as well as at night to complete daily measures of daily hassles and physical symptoms. Participants were asked to wear an ActiGraph monitor (ActiGraph wGT3X-BT, Pensacola, FL) during the two-week period to measure daily activity. At the end of the two-week period, participants returned to the lab for an in-person follow-up assessment and returned the ActiGraph.

Measures

Pain. Pain will be measured as a composite score of self-report pain items from the Physical Health Questionnaire-15 (PHQ-15). The PHQ-15 is a brief, 15-item questionnaire assessing a variety of physical health symptoms. Since the study sample is not strictly a chronic pain sample (though there may be some participants who experience chronic pain), the current study includes different pain symptoms in its proposed analysis that are commonly experienced by an undergraduate population. Five items from the PHQ-15 will be used for this study and include whether a participant has experienced stomach pain, back pain, pain in arms, legs, or joints, headaches, and chest pain and how much they were bothered by this symptom on a three-point Likert-type scale ("Not bothered at all", "Bothered a little", or "Bothered a lot). Daily composite scores will be used from the two-week study period and the possible range of scores is 0 to 10 for the five items included in this study. In addition to calculating Cronbach's alpha to assess reliability of the pain items, interitem correlations will be calculated to assess that the unidimensional scale is appropriate. Previous studies have used the same pain cluster of items to assess pain location (Sherbourne et al., 2009). Past research has found high internal consistency ($\alpha = .80$) for the PHQ-15 among primary care and obstetrics-gynecology samples (Kroenke, Spitzer, & Williams, 2002).

Physical Activity. Participants were asked to wear an ActiGraph monitor continuously for the full two-week study period and until their follow-up appointment was scheduled (approximately 15 days). Participants were asked to wear the monitor on their non-dominant hand and only asked to remove it when showering or swimming. The ActiGraph objectively measures bodily movement – activity and inactivity and energy expenditure. ActiGraph monitors measure any movement made during the time the device is worn. Raw data outputted from ActiGraph monitor will be in metabolic rates (METs) according to the time of movement. Cut points for sedentary (0 to 99 METs), light (100 to 1951), moderate (5725 to 9498), and vigorous (5727 to 9408) will be used according to the criteria set by Freedson and colleagues (1998). Data will be checked for missing values to ensure that the participant wore the ActiGraph for the full study period. Daily averages of an individual's sedentary, light, moderate, and vigorous activity will be calculated from the two-week span of the study during all daytime wake-periods. Non-wear time will be assessed for and excluded from analyses.

Marginalized Status. Marginalized status will be measured by demographic items included in the baseline assessment, specifically, from gender, race and ethnicity, and SES (parent income) variables. A dummy coding scheme will be used with non-marginalized groups (male, white, Non-Hispanic, and mid to high SES ($50,000 and up) as the referent group. Marginalized groups will be coded as female or non-white or Hispanic or low to mid SES ($0 - $49.000).

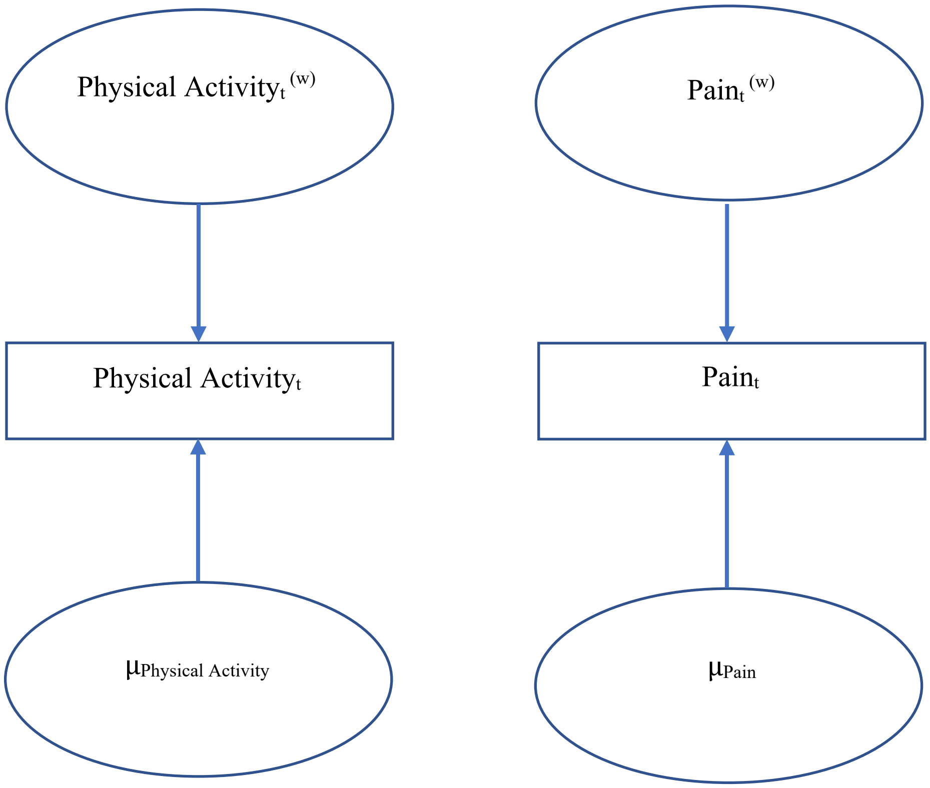
Proposed Data Analyses

Dynamic Structural Equation Modeling (DSEM) will be used to examine the relationships between average daily physical activity, daily pain composite scores, and marginalized status. DSEM is a type of time series analysis that allows for comparison of intensive longitudinal data within and between individuals at multiple time points (Asparouhov et al., 2018). A first-order vector autoregressive (VAR(1)) model will be used to analyze the concepts of interest. This type of model allows a vector at one time point *t* to be regressed onto the vector at a previous time point, permitting the analysis of time effects within individuals (Hamaker et al., 2018). The VAR(1) model can also compare mean differences between multiple individuals. The current study will be examining the cross-lagged regression coefficients between average daily physical activity and daily pain composite scores within individuals at time point t and t-1 to assess for strength in predictive ability. Marginalized status variables (gender, race, ethnicity, and SES) will also be entered into the model to assess for how they change the strength of the cross-lagged regression coefficients. Figures 1, 2, and 3 depict the three features of the VAR(1) model, showing the decomposition of the study data into within- and between-person components (Figure 1), within-person model (Figure 2), and between-person model (Figure 3).

Previous day physical activity is expected to predict next day pain, in line with the majority of research demonstrating the therapeutic effect of physical activity in managing pain (Fanucchi et al., 2009; Hanney et al., 2009; Harris & Susman, 2002; Koes et al., 2010; Stephens et al., 2008). Additionally, given past findings that there may be a bidirectional relationship between pain and physical activity among those with and without chronic pain (Rabbitts et al., 2014), the current study also expects that previous day pain will predict next day physical activity. Marginalized status is expected to strengthen these associations, due to findings demonstrating the inequitable disparities in experiencing more severe and intense pain (Aggarwal et al., 2003; Green et al., 2003; Lipton et al., 2018) and in engaging in lower levels of physical activity (Estabrooks et al., 2003; Mathieu et al., 2012; Nguyen-Michel et al., 2006).

Figure 1

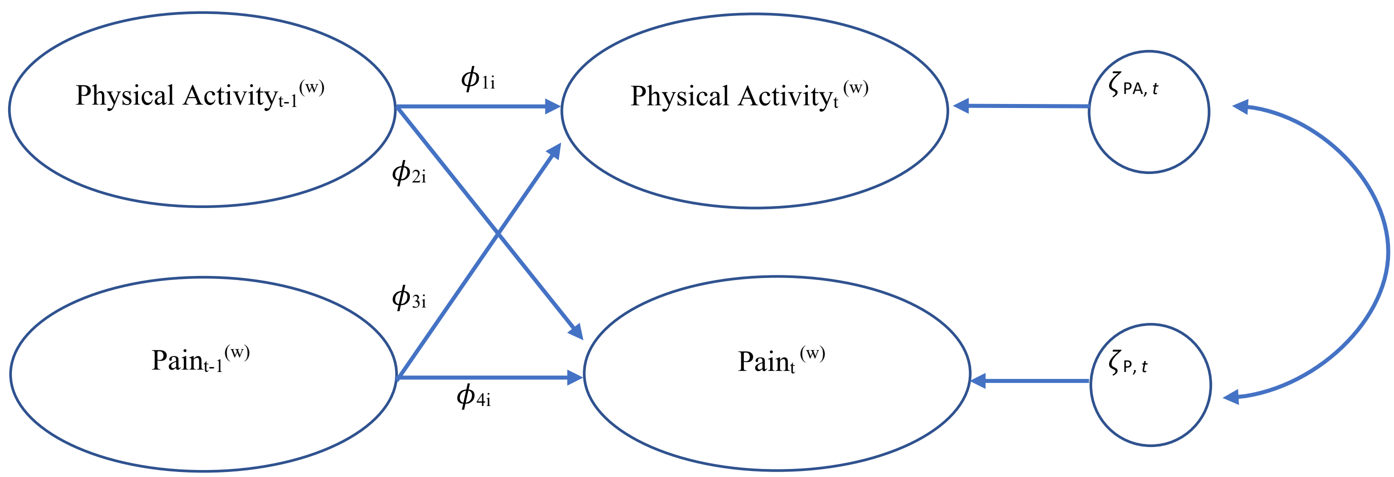
VAR(1) Model: Decomposition



Note. Figure 1 depicts the decomposition of the study data into within- and between-person components. t = Time point, w = Within person, and μ = Within person means.

Figure 2

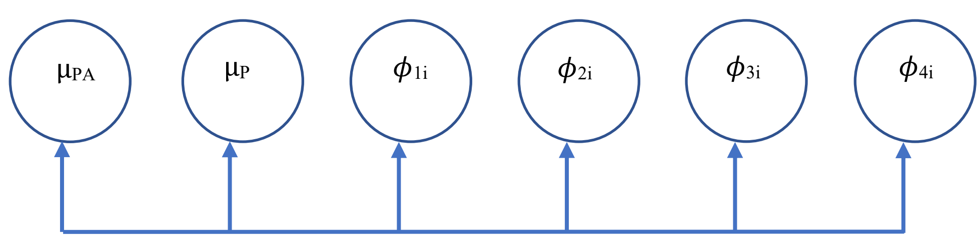
VAR(1) Model: Within-Person



Note. Figure 2 depicts the within-person components of the study model. t = Time point, t-1 = Previous time point, $\boldsymbol{\phi}$ = Autoregressive parameters (how quickly an individual restores to equilibrium) and cross-lagged regression effect (predictive relationships/spill-over), PA = Physical activity, P = Pain, and $\boldsymbol{\zeta}$ = Dynamic errors.

Figure 3

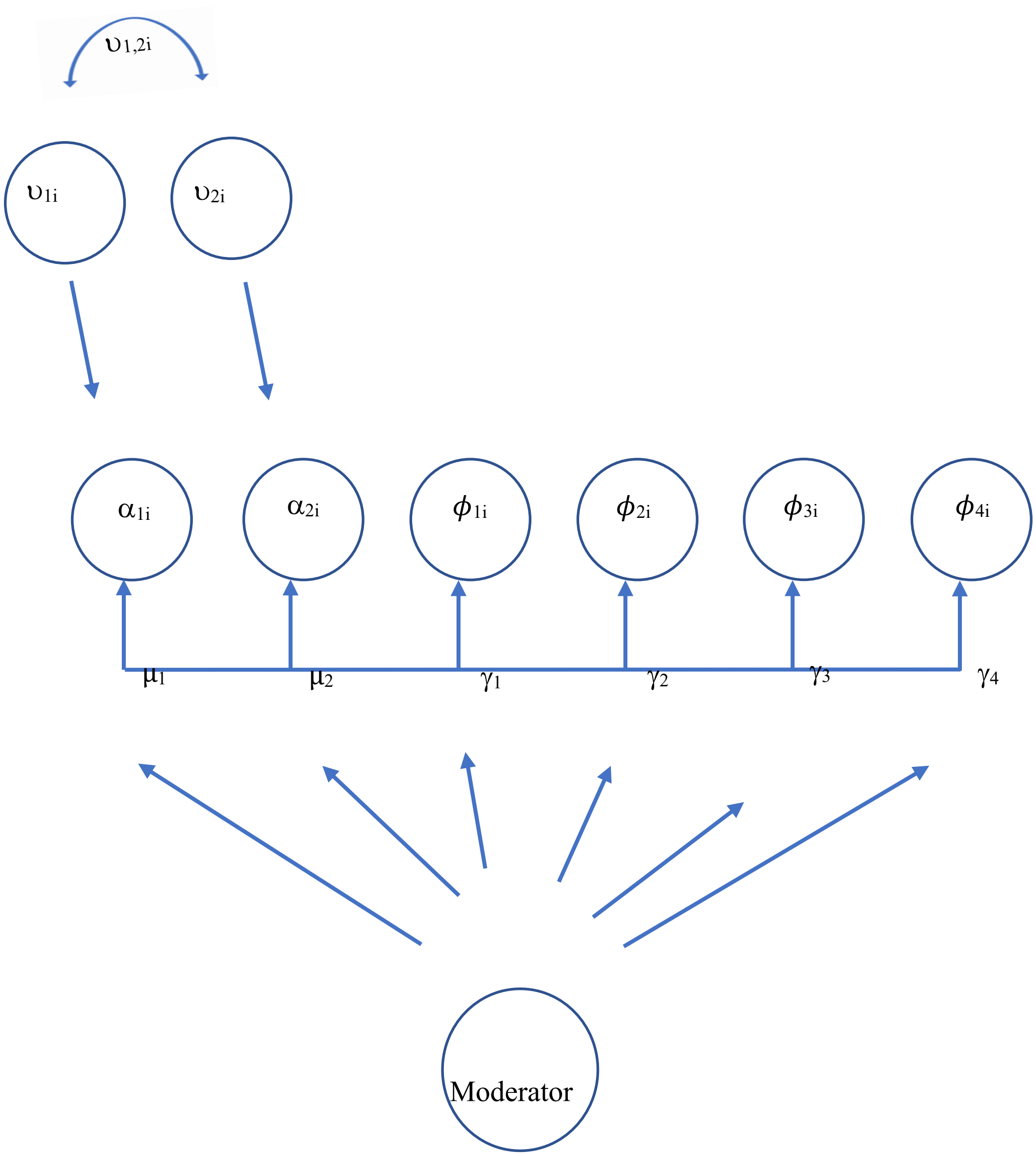
VAR(1) Model: Between-Person



Note. Figure 3 depicts the between-person components of the study model. PA = Physical activity, P = Pain, μ = Within person means, and $\boldsymbol{\phi}$ = Autoregressive parameters.

Figure 4

VAR(1) Model: Moderation of the Between-Person Model (Within-Person Means, Autoregressive Parameters, and Cross-Lagged Parameters)



Note. Figure 4 depicts the moderation of the between components of the study model. $\boldsymbol{\alpha}$ = person-specific intercepts for physical activity ($\boldsymbol{\alpha_{1i}}$) and pain ($\boldsymbol{\alpha_{2i}}$); fixed effects ($\boldsymbol{\mu_1}$, $\boldsymbol{\mu_2}$); $\boldsymbol{\upsilon_{1,2i}}$ = random effects related to physical activity and pain; $\boldsymbol{\phi_{1\text{-}4i}}$ = autoregressive parameters and cross-lagged regression effects; $\boldsymbol{\gamma_{1\text{-}4}}$ = fixed effects of autoregressive and cross-lagged regression parameters.

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Appendix B: Sedentary Analyses

The original thesis proposal included examining sedentary activity in relation to pain reports in addition to MVPA. Sedentary analyses, however, were excluded from the current study due to being unable to distinguish wear time from non-wear time from the imported data. It appears the software, ActiLife (v6.13.4), requires setting a minimum and maximum count level of epochs to distinguish non-wear time from wear time. It is unclear what procedures were taken at the time of data importing. In order to proceed as cautiously as possible to ensure data quality, only analyses relating to MVPA will be submitted for publication; however, the analyses pertaining to sedentary time were conducted and are included below.

The Dynamic Structural Equation Model ICC (B. O. Muthén, 2019) for pain was 0.71, which, similar to MVPA, indicates a need to account for nesting within clusters. Participants spent on average, 272.19 minutes (*SD* = 66.70) in sedentary activity during the study period. For the sedentary and pain model, 20,000 iterations were run with a thin of 100. The model investigating the relationships among daily reported pain and sedentary activity (DIC = 50523.99, pD = 689.77) did not reveal significant cross-lagged relationships. See the table below for full results. No moderation models were run with sedentary analyses.

Table. Sedentary Activity and Pain Multilevel Vector Model Standardized Results

Level	Estimate	Standard Deviation	P-Value (One-Tailed)	95% Credibility Interval
Within				
Outcome: Pain				
Predictor: Pain$_{t-1}$	0.27	0.02	<0.001*	0.23, 0.32
Predictor: Sedentary$_{t-1}$	0.02	0.02	0.16	-0.02, 0.06
Outcome: Sedentary				

Predictor: $Sedentary_{t-1}$	0.08	0.02	<0.001*	0.04, 0.12
Predictor: $Pain_{t-1}$	0.02	0.02	0.17	-0.02, 0.06
Covariance	0.05	0.02	0.004*	0.01, 0.09
Residual Variances				
Sedentary	0.99	0.003	<0.001*	0.98, 1.00
Pain	0.92	0.01	<0.001*	0.90, 0.95
Between				
Means				
Sedentary	4.50	0.27	<0.001*	4.00, 5.04
Pain	1.26	0.10	<0.001*	1.07, 1.46
Variances				
Sedentary	1.00	<0.001	<0.001	1.00, 1.00
Pain	1.00	<0.001	<0.001	1.00, 1.00

* Significant