Developing Empirical Decision Points to Improve the Timing of Adaptive

mHealth Physical Activity Interventions in Youth

By

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Abstract

Current digital health interventions primarily utilize interventionist-defined rules to guide the timing of intervention delivery. As new temporally dense datasets become available, it is possible to make decisions about intervention delivery and timing empirically. The purpose of this study was to explore the timing of physical activity in youth to inform decision points (e.g., timing of support) for future digital physical activity interventions. This study was comprised of 113 adolescents between the ages of 13-18 (M = 14.64, SD = 1.48) who wore an accelerometer for 20 days. Using a special case of logistic regression, multilevel survival analyses were used to estimate the most likely time of day (via odds ratios and hazard probabilities) when adolescents accumulated their average physical activity. Additionally, odds ratios for the interacting effects of physical activity timing and moderating variables were calculated by entering predictors, such as gender, Body Mass Index (BMI), sports participation, school day, self-efficacy, social support for exercise, and motivation, into the model as main effects and tested for interactions with time of day to determine conditional main effects of these predictors. On average, the likelihood that a participant would accumulate their own average MVPA increased and peaked between the hours of 6pm-8pm before decreasing sharply after 9pm. There were differences in the timing of exercise for boys, adolescents involved in sports, on non-school days, individuals with lower physical activity self-efficacy, and participants with lower autonomous motivation. Hazard and survival probabilities suggest that optimal decision points for digital physical activity programs should occur between 5pm and 8pm. Overall, findings from this study support the idea that the timing of physical activity can be empirically-identified to determine when users are receptive to exercise and potentially used as markers to signal intervention delivery for JITAIs.

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The Importance of Physical Activity in Youth: U.S. Guidelines and Morbidity

Extant literature demonstrates that physical activity is an important health behavior to prevent the onset of non-communicable diseases such as heart disease, diabetes, cancer, and obesity (Lee et al., 2012). Additionally, physical inactivity is an important mortality factor, causing about one in ten deaths within non-communicable diseases in adulthood (Danaei et al., 2009). Conversely, however, physical activity is a modifiable lifestyle factor that can lead to improvements in cardiorespiratory functions, muscular fitness, metabolic health (USDHHS, 2008). Further, physical inactivity is a leading cause of preventable death (Danaei et al., 2009). The current recommendation for physical activity in youth is one hour (60 minutes) of moderate-to-vigorous physical activity (MVPA) each day (USDHHS, 2008); However, less than 25% of youth attain the recommended amounts of MVPA (Katzmarzyk et al., 2016).

Adolescence is a critical developmental period for the formation and maintenance of healthy behaviors, such as physical activity (Telama, 2009). As adolescents gain more autonomy in their lifestyle routines, they become more personally responsible for adhering to the recommended amounts of MVPA. Despite the importance of physical activity for health, it is well documented that rates of daily MVPA decrease from childhood to adolescence about 40 minutes each year between ages nine and fifteen (Nader, Bradley, Hours, McRitchie, & O’Brien, 2008). Additionally, sedentary behaviors increase with age in youth such that adolescents spend about 90 minutes more in sedentary time per day than their pre-adolescent counterparts (Mitchell et al., 2012). Clearly, adolescence is a stage when youth are likely to exhibit declines in physical activity. Therefore, empirical research on the patterns of physical activity in adolescence may have value for future interventions to forestall this decline.

Limitations of Physical Activity Research and Implications for Just-in-time Adaptive Interventions (JITAIs)

There is a growing interest among behavioral scientists to translate efficacious and effective behavioral interventions for improving physical activity and reducing sedentary behavior into digital modalities (Pagoto & Bennett, 2013; Cushing, Fedele, & Riley, 2019). While mobile health (mHealth) interventions for improving health behavior in youth have been shown to be effective, these interventions primarily use technologies to send reminder messages to users (Fedele, Cushing, Fritz, Amaro, & Ortega, 2017). Despite the availability and the capacities of novel digital technologies and biological sensors, current mHealth approaches are quite limited relative to their potential (Cushing et al., 2019; Brannon, Cushing, Crick, & Mitchell, 2016; Riley et al., 2011). For example, most of digital health science has yet to capture the dynamic processes sustaining health behaviors (Cushing et al., 2019; Dunton, 2019; Riley, 2011).

Just-in-time adaptive interventions (JITAIs) are "designed to address the dynamically changing needs of individuals via the provision of the type and amount of support needed, at the right time, and only when needed" (Nahum-Shani et al., 2014, p. 3). JITAIs capitalize on advanced digital technologies and computer automation to not only tailor interventions to users, but also to deliver these interventions only when needed by the user, hence 'just-in-time' (Nahum-Shani et al., 2018). While seemingly aspirational, modern technologies actually have the capacity to produce JITAIs (Brannon et al., 2016). In order to empirically design JITAIs and rigorously evaluate their effectiveness, basic research on what potential users need from a JITAI is necessary.

Critical Windows of Opportunity: States of Vulnerability and Receptivity to Exercise

A critical component of JITAIs is the decision points, or timing of support (Nahum-Shani et al., 2018). JITAIs seek to intervene at critical windows of opportunity for each user to maximize effectiveness and engagement while also minimizing waste or participant burden. A key element of JITAI research and implementation is the need to identify *states of vulnerability* or *states of receptivity* for users (Nahum-Shani, Heckler, & Spruijt-Metz, 2015; Nahum-Shani et al., 2018). A *state of vulnerability* is a dynamic state in which an individual is likely to exhibit health-compromising behaviors whereas a *state of receptivity* is a dynamic state in which an individual is open to performing health-promoting behaviors, is likely to be responsive to health-promoting cues, or is likely to be engaged with intervention options (Nahum-Shani et al., 2015; Nahum-Shani et al., 2018). These states are mediated by situational, contextual, and temporal factors that induce periods of heightened susceptibility to health-promoting behaviors, such as adherence, or health-compromising behaviors, such as drug relapse (Witkiewitz & Marlatt, 2004; Nahum-Shani et al., 2018). Combined with the technological capability to sample user behavior in real-time and in multiple contexts, JITAIs can also identify these individualized states more rapidly than static interventions.

As mentioned previously, there are many factors that may bring about a potential *state of vulnerability* and *receptivity* for health-compromising and health-promoting behaviors. Thus, the process of identifying these states can vary. Bond and colleagues' (2014)'s *B-Mobile* intervention is an example of an mHealth protocol recognizing states of vulnerability for users. In their platform, the research team identified vulnerability for physical inactivity as elongated periods of uninterrupted sedentary activity, and consequently prompted users to engage in "breaks" from their sedentary periods by sending computer-automated real-time reminders to engage in physical activity (Bond et al., 2014). Specifically, their protocol used real-time accelerometry to monitor participants' continuous bouts of sedentary time (conceptualized as 30, 60, and 120 minutes of continuous sedentary activity) and prompted users to engage in physical activity at those moments, illustrating an example of a decision point (e.g., *rationally-derived* periods of uninterrupted sedentary time) for a JITAI (Bond et al., 2014). This study found that more frequent prompting of exercise (i.e., prompting at 30 continuous minutes of sedentary activity compared to 60 and 120 minutes) produced the largest increases in physical activity in users (Bond et al., 2014). This finding can therefore inform decision points for future digital physical activity interventions such as delivering exercise prompts after 30 minutes of uninterrupted sedentary time. The *B-Mobile* study demonstrates how rationally-derived intervention decision points based off critical windows of opportunity can lead to improvements in physical activity (Bond et al., 2014). Given the relative infancy of JITAI development, consistent methods of identifying states of vulnerability or receptivity and corresponding decision points have not been established (Nahum-Shani et al., 2018). As JITAI research advances, it is critical to *empirically* derive and evaluate decision points selected for these interventions to deliver options at observed critical windows of opportunity that can be adjusted based on each user's needs rather than at a set time made a priori by investigators (Riley, 2011).

Correlates of Physical Activity in Youth

Variables with strong empirical associations with physical activity include gender, Body Mass Index (BMI), sports participation, and day of week. Research has established that patterns of objectively-measured physical activity slightly differ between boys and girls, such that boys obtain more levels of MVPA than girls (Trost et al., 2002; Van der Horst, Paw, Twisk, & Van Mechelen, 2007). Adolescents with overweight or obesity spend more time in sedentary behaviors than normal-weight adolescents (Elgar, Roberts, Moore, & Tudor-Smith, 2005). In fact, sedentary time has been shown to predict BMI in longitudinal studies (Elgar et al., 2005). Regardless of the direction of causality, Janssen and coauthors (2005) found that lower physical activity was associated with a higher likelihood of being overweight. Wickel and Eisenmann (2007) found that throughout the day, time spent in organized sports contributed up to 27% of time spent in MVPA in male youth. Additionally, this study concluded that individuals obtain an average of 30 more minutes of MVPA on days when they participate in organized sports than on days when they do not (Wickel & Eisenmann, 2007). Physical activity patterns in youth also substantially vary among days of the week, specifically across weekdays and weekend days (Moore, Beets, Morris, & Kolbe, 2014; Nader et al., 2008; Dossegger et al., 2014). Given these empirically-derived correlates of physical activity, future JITAI research should consider investigating how these variables affect decision points for optimal tailoring of interventions (Riley, 2011). If greater complexity of JITAIs is desirable, then tailoring is needed to avoid habituation (Nahum-Shani et al., 2018).

Beyond empirically-derived correlates of physical activity, a range of psychological theories have identified psychosocial variables that motivate physical activity behavior. Some of the most-established and well-researched theories include Social-Cognitive Theory and Self-Determination Theory (Bandura, 1988; Deci & Ryan, 2000). Within these theories, latent constructs such as self-efficacy, social support, and motivation have been shown to improve health behaviors, such as physical activity. Adolescents who perceive greater self-efficacy for physical activity tend to demonstrate higher levels of physical activity (Lawman, Wilson, Lee

Van Horn, Resnicow, & Kitzman-Ulrich, 2011; Craggs, Corder, van Sluijs, & Griffin, 2011; Van der Horst et al., 2007). In a multinational study, Harrington and coresearchers (2016) found that social support from parents was significantly associated with greater MVPA. Additionally, two systematic reviews also support the positive association between social support and physical activity (Craggs et al., 2011; Van der Horst et al., 2007). Research on Self-Determination Theory (Deci & Ryan, 2000) and adolescent physical activity has established that higher autonomous motivation is associated with higher levels of physical activity while controlled motivation is weakly or negatively related to physical activity (Owens, Smith, Lubans, Ng, & Lonsdale, 2014).

While these empirically- and theoretically-derived factors are undoubtably important for the promotion of physical activity, they may not be easily modifiable, or continuously monitored. In other words, interventions seeking to increase physical activity by manipulating the constructs described above may not produce long-term beneficial changes in activity levels (Cushing, Brannon, Suorsa, & Wilson, 2014). In addition, it would require intense burden from an individual to continuously monitor these factors and therefore implausible to intervene at critical moments. If interventions are to produce substantial changes in activity levels in youth, perhaps special attention to more proximal modifiable factors is necessary (Nahum-Shani et al., 2018). This way, the timing of support can be optimized.

Timing of Physical Activity in Youth

Daily activity in youth is divided across four levels: sleep, sedentary activity, light activity, and MVPA (Tremblay et al., 2016; Pedisic, Dumuid, & Olds, 2017). Time spent in each of these levels is strongly linked, such that reducing or increasing time spent in one of these levels is inversely related to how much time is spent in other levels (Armstrong, Covington, Unick, & Black, 2019; Grgic et al., 2018; Krietsch, Armstrong, McCrae, & Janicke, 2016). As youth choose to pursue sedentary activities (e.g. watching television), available time for and *opportunity* for exercise decreases. That is to say that there are a finite number of minutes in the day, and every passing minute of physical inactivity results in a loss of opportunity for physical activity. Further, previous research has identified latent profiles of youth based on their time spent across activity levels (Mitchell & Steele, 2017; Berlin et al., 2017; Heitzler et al., 2017). Most notably, these studies have consistently identified three profiles (e.g., Active, Moderate, Inactive youth) that are associated with various health outcomes, such as Health-Related Quality of Life (Mitchell & Steele, 2017), indicating that youth with Active profiles have better psychosocial outcomes. These studies demonstrate that patterns of time allocated to physical activity have important implications for a variety of clinical outcomes.

Independent of how activity is distributed across categories of activity, it may prove beneficial to investigate the *timing* of activity in youth. To offset sedentary time and encourage MVPA in users via digital modalities, research must first identify critical windows of opportunity to determine when users allocate time to activity. In other words, in order to develop JITAIs to increase physical activity in youth, primary research identifying when youth allocate time to physical activity is essential. This way, JITAIs can optimize intervention delivery and maximize engagement in physical activity when it is likely to occur for users. Empirical studies investigating the timing of activity levels in youth may reveal temporal patterns in activity levels, providing implications for interventions, such as informing JITAI decision points. With this information, JITAIs could intervene at critical windows of opportunity for users to increase their physical activity. The empirical development and design of JITAIs is contingent on the formation of evidence-based decision points for these interventions to maximize effectiveness and engagement. In other words, by delivering support at the empirically-observed moments, versus at random, interventionist-defined, or user-selected decision-points, levels of physical activity may increase.

Study Aims and Hypotheses

To facilitate an improved knowledge of the timing of physical activity in youth, and therefore inform JITAI decision points, the current study's first aim was to explore the time of day when an adolescent accumulates their average physical activity using a multilevel survival analysis. This aim explores the most likely hour by which an adolescent would have accumulated their average physical activity the greatest, *given that it had not occurred already*. Given that adolescents are unlikely to meet the recommended 60 minutes of MVPA each day, this study examined the likelihood each participant meets their unique MVPA average. This study's first aim was exploratory, with no *a priori* hypothesis postulated.

The current study's second aim was to explore day-level and individual-level factors that moderate the likelihood of accumulating physical activity at the time of day found in the study's first aim. This aim identifies factors that increase or decrease the probability of individuals obtaining their average minutes of physical activity. For this study, day-level and individual-level determinants selected for moderation analyses include empirically-derived variables previously shown to be correlated with physical activity such as gender, BMI, sports participation, and school day (Trost et al., 2002; Van der Horst et al., 2007; Elgar et al., 2005; Wickel & Eisenmann, 2007; Moore et al., 2014). It also examines how theoretically-derived constructs such as self-efficacy, social support for exercise, and motivation influence the timing of exercise (Lawman et al., 2011; Craggs et al., 2011; Van der Horst et al., 2007; Harrington et al., 2016; Owens et al., 2014). The primary focus of Aim 2 is to determine the magnitude of group differences in the odds of meeting their personal MVPA average. Gender and BMI are individual level characteristics that affect how much a person will exercise and therefore influence when they meet their personal MVPA average. It is hypothesized that boys will obtain higher odds ratios of meeting their personal MVPA average compared to girls. This pattern may also apply to youth of average versus higher BMI and so it is hypothesized that youth with average BMI will obtain higher odds ratios of meeting their personal MVPA average compared to youth with overweight BMI or obese BMI. Additionally, participation in organized sports or days in which a person attends school might also permit or constrain opportunities to exercise, thereby affecting timing as well. It is hypothesized that youth who participate in sports will obtain higher odds ratios of meeting their personal MVPA compared to youth who do not participate in sports and that youth will obtain higher odds ratios of meeting their personal MVPA average on days in which they attended school than on days in which they did not.

Further, some of the most strongly associated drivers of physical activity within Social Cognitive Theory (Bandura, 1986) and Self-Determination Theory (Deci & Ryan, 2000) are self-efficacy, social support, and motivation. An individual with greater self-efficacy, social support, or motivation should be able to overcome barriers to obtain physical activity compared to a person who is lower on these traits (Wilson et al., 2008). Therefore, these constructs may influence the accumulation of physical activity and affect the timing of exercise. It is hypothesized that youth with higher levels of these constructs will obtain higher odds ratios of meeting their personal MVPA average compared to youth with lower levels of these constructs.

Lastly, this study's third and final aim is to generate decision points (i.e., when to intervene) to improve the timing of mHealth physical activity interventions given the results from Aims 1 and 2. Sets of decision points were inferenced from hazard and survival probabilities. Decision points were generated for moderators only if the following two conditions were satisfied, 1) if a moderator was found to be significantly different between groups of individuals, and 2) if the differences between these groups were as hypothesized (see Aim 2). These criteria were set forth to identify baseline tailoring variables for physical activity JITAIs so that decision points would only be made for subgroups in which there were meaningful differences in timing of physical activity and to eliminate ineffectual moderators. The purpose of Aim 3 is to introduce empirically-derived decision points for mHealth physical activity interventions.

Methods

Participants

The proposed sample for this study came from an existing dataset comprised of adolescents (*N* = 113) from a Midwestern college-town. Participants were recruited as part of two larger ecological momentary assessment (EMA) studies examining the associations between various psychological constructs and physical activity behaviors. Participants learned about the study through flyers posted around the local community. Interested participants were instructed to contact study personnel via phone call to screen eligibility. Participants enrolled in the study were between the ages of 13-18 (*M* = 14.64, *SD* = 1.48) and lived at home with parent(s). Participants were excluded if the adolescent had any significant physical maladies that would limit physical activity, visual impairments, or an inability to read at a grade level in English. These exclusion criteria were in place to ensure a valid assessment of physical activity behaviors as well as other psychological constructs via EMA methods on a mobile phone app.

The sample included 42 males (37.2%) and 71 females (62.8%). In terms of caregiver demographics, 66.4% (*n* = 75) of parents were married, 22.1% (*n* = 25) were divorced, separated or widowed, and 11.5% (*n* = 13) were never married. Sixty-one percent of mothers (*n* = 69) and 64.3% of fathers (*n* = 72) attained a college education or higher. The majority of the sample (*n* = 69, 61.1%) reported an approximate family income greater than $60,000. The sample was 78.8% (*n* = 89) Caucasian, 8% (*n* = 9) Latino/Latina, 4.4% (*n* = 5) African American, 1.8% (n = 2) Multiracial, .9% (n=1) Native American, and 2.7% (n = 3) Other. Refer to Table 1 for detailed descriptions of participant and caregiver demographics.

Measures and Measurement

Demographics. Adolescents self-reported basic demographic information including their date of birth, age, sex, race, level(s) of parental education, and approximate family income (Refer to Appendix A).

Physical activity. The ActiGraph wGT3X-BT accelerometer (Actigraph LLC, Pensacola, FL) objectively measured participants' MVPA, light, and sedentary behavior (SB) throughout the duration of the 20-day study period. The accelerometers were programmed to sample movements at a rate of 30 Hz on three different axes (up/down, forward/backward, left/right) as in previous studies (Cushing et al., 2017) measuring physical activity in youth.

Once the accelerometer was returned, Actilife software v6.10.2 was used to process the accelerometer data by converting the raw measurements into 60 second epochs that can be utilized to analyze physical activity. Irrelevant activity periods such as sleep periods and non-wear periods were identified using the Sadeh algorithm and the Troiano algorithm respectively and thus removed from the daily activity counts (Sadeh, Sharkey, & Carskadon, 1994; Troiano et al., 2008). The Chandler algorithm was used to identify periods of SB and MVPA (Chandler, Brazendale, Beets, & Mealing, 2015). In order to analyze valid physical activity data, participants needed to have worn the accelerometer for at least ten hours during wake time. Since the Chandler algorithm identifies cut points of physical activity based on five second epochs, research personal modified the algorithm to adjust for the 60 second epoch data. The modified cut points were 0-3660 counts for sedentary behavior, 3661-9804 counts for light activity, and >9805 counts for MVPA. After applying this algorithm, minutes of MVPA and SB per day for each participant were produced. Other commonly-employed algorithms such as Evenson (Evenson, Catellier, Gill, Ondrak, & McMurray, 2008) or Freedson (Freedson, Pober, & Janz, 2005), were not used because the Chandler algorithm is research-validated for processing wrist-worn accelerometry with the ActiGraph GT3X+ equipment (Chandler et al., 2015). However, one limitation of the Chandler method is that the algorithm was developed using samples of school-aged children and the proposed cut points of activity counts may not extend to adolescent samples.

Participant reactivity has long been recognized as a threat to the validity of physical activity measurement (Vincent & Pangrazi, 2002; McClain & Tudor-Locke, 2009). After processing the activity data using the Chandler method, research personal removed the first three days of accelerometer activity data for each participant due to potential activity-based reactivity. Prior research utilizing wearable devices to objectively measure physical activity in youth has demonstrated participant reactivity during the first days of the study (Dossegger et al., 2014).

Body mass index. BMI was calculated using the Center for Disease Control (CDC) growth charts (Kuczmarski et al., 2002). Participants' height in centimeters, weight in kilograms, sex, and age in months at the time of study initiation were used to compute BMI. BMI, BMI *z*-score (BMI*z*), and BMI percentile were calculated using a SAS program for the CDC growth charts found on the CDC website (2016).

Sports participation. During the baseline session, participants were asked if they had any planned physical activity, such as involvement in organized sports, for the next 20-days. The research personnel and the participants together completed a physical activity calendar to record future exercise events (see Appendix B). For example, if participants reported upcoming swimming events, the research staff recorded this event on the calendar. After study completion, participants were dichotomously categorized into two groups: involved in organized sports or uninvolved in organized sports based on their self-reported activity involvement.

School day. It is recommended that physical activity patterns in youth are analyzed separately for weekdays and weekends given significant differences between activity levels on these days of the week (Moore et al., 2014). Moreover, seasonality (e.g., Fall versus Summer) and holidays may affect physical activity levels on non-school days (Tucker & Gilliland, 2007; Fox, Cooper, & McKenna, 2004). Given that the current study samples physical activity across individuals from multiple seasons, research personnel classified daily activity patterns into categorical variables: school day and non-school day to better capture the variability among physical activity patterns for days when youth are in school or not.

Physical activity self-efficacy. The Physical Activity Self-Efficacy Questionnaire (PASE-Q; Motl et al., 2000) measures an individual's perception of their own ability to be physically active and used to assess self-efficacy for exercise in this study (Refer to Appendix C). The PASE-Q is a 8-item measure that asks participants to rate how much they agree on a 5-point Likert scale ranging from 1 (*disagree a lot*) to 3 (*neither agree or disagree*) to 5 (*agree a lot*) on whether or not they can be physically active across scenarios when they would typically have free time. Some example items on the PASE-Q are "*I can be physically active during my free time on most days*" and "*I can be physically active during my free time on most days no matter how busy my day is*". Research personnel summed each participant's responses to the 8-items to compute a total PASE-Q score. To calculate the internal consistency, or the reliability, of the psychosocial constructs measured in this study, the Cronbach's alpha was used. Within this sample of participants, the reliability of the PASE-Q was adequate ($\alpha = .82$).

Social support for exercise. The Social Support for Exercise Survey (SSES; Sallis, Grossman, Pinski, Patterson, & Nader, 1987) measures an individual's level of perceived social support from family and friends to engage in physical activity behaviors (see Appendix D). The

SSES is comprised of 13-items pertaining to support from family and 13-items pertaining to support from friends. Participants are asked to record how often their family and friends have provided support to be physically active on a 5-point Likert scale with the anchors, 1 (*none*), 2 (*rarely*), 3 (*a few times*), 4 (*often*), 5 (*very often*). Examples of the social support measured by the SESS include "*offered to exercise with me*" and "*planned for exercise on recreational outings*". Research personnel summed each participant's responses to the items to compute subscale scores for family social support and friend social support. Both subscales of the SESS were reliable (α = .86 for family social support and α = .93, respectively) for this sample.

Motivation for exercise. To assess motivation for engaging in physical activity, this study employed the Treatment Self-Regulation Questionnaire (TRSQ; Levesque et al., 2007) for physical activity (Refer to Appendix E). The TRSQ is a 15-item measure that computes an individual's autonomous and controlled motivation for engaging in physical activity. Items on the TRSQ comprise various reasons why an individual would exercise, such as "*Because I feel that I want to take responsibility for my own health*" and "*Because I want others to approve of me*". Participants are asked to quantify how true each reason is for them on a 7-point Likert scale ranging from 1 (*not at all true)*, to 4 *(somewhat true),* to 7 *(very true).* Research personnel scored the measure, calculating each participant's mean autonomous and controlled motivation based on their responses to items for each subscale. Summed responses on each of the subscales are averaged to create separate mean scores for each participant. For this sample, the reliability of autonomous and controlled motivation subscales was adequate (α = .88 and .87, respectively).

Procedures

After the local community was canvassed with flyers describing the study, interested participants were instructed to contact the research staff using the lab phone number. Interested participants were initially screened over the phone to ensure that they met eligibility requirements. If they met inclusion criteria, the research team scheduled participants for a baseline laboratory visit, usually within two weeks of screening. Each baseline visit lasted about an hour. At the baseline visit, participants reviewed the study information and the IRB-approved informed consent form with the research staff and gave consent to participate. For participants under the age of 18, their parents provided informed consent, and adolescents provided informed assent. The participants then completed a demographics questionnaire, a planned activity calendar, psychosocial questionnaires, and were oriented to the accelerometer. Participants were instructed to wear the accelerometer on their non-dominant wrist for the entire 20-day study period (Centers for Disease Control and Prevention, 2011). Finally, the research staff measured each participant's height and weight.

During the 20-day study period, participants wore the accelerometer and received EMA surveys via a mobile phone app on lab smartphone to measure dynamic fluctuations in psychosocial constructs. For the purposes of this project, only accelerometer data and baseline measures (gender, BMI, sports participation, physical activity self-efficacy, perceived social support for exercise, motivation) were included. At the end of the 20 days, participants returned for a laboratory exit visit to return the equipment. At the exit visit, once research staff received the returned accelerometer and lab smartphone, research personnel downloaded the data to a secure server. Participants could receive up to $40.00. When all procedures were completed, participants received compensation.

Design and Analysis

Multilevel survival analysis with logistic regression. To address the aims of this study, multilevel survival analyses using logistic regression were conducted to examine by what hour of day when adolescents accumulated their average physical activity. Predictors were entered into the model as main effects and subsequently tested as interactions to determine the conditional main effects of psychological predictors on time of day when adolescents accumulated their average physical activity. Due to the nested structure of the dataset (days within individuals), multilevel analyses are necessary to account for the dependencies in the data.

For the purposes of this project, time of day was analyzed as a discrete-time variable. The dataset was formatted in the univariate or long-data format where the data included multiple rows for each participant, indicating the time of day (entered discretely as the hour of the day), and a dummy-coded variable to illustrate whether the event (average minutes physical activity accumulated, scored 1) was met by that hour or censored (scored 0). Using a special case of logistic regression, a hazard function, or the probability of the event occurring before the time (hour of day, in this case) conditional on no earlier occurrence, was estimated (Hox, 2010).

To estimate the hazard functions, we tested multiple smoothing procedures using polynomial functions of time (Hox, 2010). It is possible that the time of day when adolescents accumulate their average physical time may not function as a linear model. For example, the probability that individuals would have met their average physical activity by a certain hour might not increase at a linear rate. For each survival analysis, polynomials of time were entered into the model as a linear, quadratic, and cubic predictor of the event. Each survival analysis was estimated using maximum likelihood estimation based on Laplace approximation in SAS PROC GLIMMIX. Nested model comparisons using the Chi-square difference of the estimated -2*Log Likelihood (-2LL) ratio tests for each of these models were evaluated to determine the best fitting model for the polynomial effect of time. After fitting the model for time that best represents the data, predictors were entered into the hazard model, as well as interactions between predictors and time of day (e.g., $\log(y = 1) = \beta_0 + \beta_1 Time + \beta_2 Time^n + \beta_3 BMI + \beta_4 BMI \times Time + \beta_5 BMI \times Time^n$). Consistent with previous research estimating survival models for physical activity accumulation, dummy variables with reference categories were entered into the model for categorical predictors (i.e., gender, sports participation, school day; Moore et al., 2014). Each of these hazard models were estimated separately. In the event of a significant interaction of a predictor and time of day, the effect of these interactions was determined by comparing the odds ratio of the estimates by summing all parameter estimates multiplied by their respective variables and then using the inverse link function (i.e., $e^{\log(y=1)}$) to translate estimated logits into odds ratios. To compare the estimates, odds ratios were calculated by inserting meaningful values into the explanatory predictors in the regression equations (e.g., BMI > 85^{th} percentile, ±1 standard deviation from mean of latent constructs). For each analysis, odds ratio estimates representing the likelihood of a participant meeting their average physical activity before discrete hours, compared to a reference point (e.g., 8am), were plotted for visual comparison.

To address Aim 1 and 2, odds ratio estimates were used to determine the most likely hour of average MVPA accumulation and group differences in timing of MVPA obtainment compared to 8am. To investigate whether there were significant differences in the magnitude of the odds ratios for the time of average MVPA accumulation between groups, the 95% confidence intervals around the estimated odds ratios were compared. Odds ratio estimates that do not overlap based on their given confidence bands were considered statistically significant at the $p < .05$ level. For each moderator, statistical differences between groups at every hour of the day were examined. If the odds ratios were statistically significant for a window of time in the direction hypothesized, decision points using hazard and survival probabilities were developed, as stated in Aim 3. The hazard probability, or the instantaneous probability of the event occurring conditional on no earlier occurrence, were created by using the translating estimated logits into probabilities. Additionally, using this information, survival probabilities were also estimated. Survival probabilities represent the cumulative risk that an individual would have not met the event by certain time. To estimate the survival probability at each hour, we multiplied the complement of the hazard probabilities (i.e., 1 – probability) for that hour and all previous hours (Singer & Willet, 2003).

Within the dataset, there are some cases of level 2 psychological predictors (e.g., BMI, physical activity self-efficacy, perceived social support for exercise, motivation) missing for participants. Given the multilevel structure of the data, when estimating the effect of these person-level predictors on time of day, these cases with missing data were dropped from the analysis because estimation procedures require some information on the independent variable for each level of the clustering variable (e.g., missing level 2 variables cannot predict level 1 variables).

Results

Preliminary analyses. On average, participants accumulated 30.91 (SD = 30.94) minutes of MVPA per day, and therefore, did not meet the recommended guidelines. Descriptive statistics of the study sample's activity levels and psychosocial characteristics are presented in Table 2.

Aim 1. After inserting sequential polynomials of time, nested model comparisons indicate that a cubic function of time was the best fitting model (refer to Table 3). On average, the likelihood that a participant would accumulate their own average MVPA increased and peaked between the hours of 6pm-8pm (OR = 13.19-13.02) before decreasing sharply after 9pm (see Table 4 and Figure 1). No participants met their personal MVPA average before 8am or after 11pm. For this reason, tables and figures displaying results for Aims 1-3 reflect the odds ratios, hazard probabilities, and survival probabilities that an individual met their personal MVPA average by that hour, conditional on no earlier occurrence, beginning between the hours before 8am and terminating before 11pm.

Aim 2. Compared to 8am, male adolescents had significantly higher odds of obtaining their average MVPA only between the 8am-12pm window compared to female adolescents (see Table 5 and Figure 2). BMI did not significantly moderate the relationship between time of day and MVPA attainment (see Table 6 and Figure 3). In other words, there were no significant differences in ORs of average MVPA accumulation across time for normal weight (BMI < 85^{th} percentile), overweight (BMI between 85^{th} and 95^{th} percentile), and obese (BMI > 95^{th} percentile) individuals. Additionally, adolescents involved in organized sports had significantly lower odds of attaining their average MVPA between 8am and 10am (see Table 7 and Figure 4). Contrary to our hypothesis, adolescents had significantly higher odds between the 8am and 12pm window, compared to 8am, of meeting their average MVPA on non-school days compared to school days (see Table 8 and Figure 5).

Physical activity self-efficacy significantly moderated the relationship between time of day and MVPA attainment but in the unexpected direction (see Table 9 and Figure 6). Individuals with low physical activity self-efficacy (≤ -1 SD below the mean) had higher ORs of obtaining their MVPA average between 8am and 10am compared to individuals with high physical activity self-efficacy (≥ +1 SD above the mean). There were no significant differences in ORs across time between individuals with low and average physical activity self-efficacy as well as between individuals with average and high physical activity self-efficacy. Contrary to our hypotheses, neither family nor friend social support moderated the relationship between time of day and MVPA attainment (see Tables 10-11 and Figures 7-8).

Participants with low autonomous motivation had significantly higher odds of accumulating their MVPA average between the hours of 8am and 10am compared to individuals with high autonomous motivation (see Table 12 and Figure 9). There were no significant differences in ORs across time between individuals with low and average autonomous motivation as well as between individuals with average and high autonomous motivation. Lastly, there were no significant differences in ORs of MVPA accumulation across time for individuals with low, average, and high controlled motivation for exercise (see Table 13 and Figure 10).

Aim 3. On average, hazard probabilities indicated that adolescents were most likely to instantaneously meet their average MVPA between the hours of 5pm-8pm[1] (See Table 14 and

[1] Odds ratio estimates and hazard probabilities indicate slightly different times due to their mathematical computation. The most likely times offered by the OR estimates and hazard probabilities generally overlap and are conceptually congruent.

Figure 11). Adolescents may be receptive to exercise between this window of time. Survival probabilities demonstrate that after 8pm, adolescents had a 73% chance of not meeting their own MVPA average (See Table 14 and Figure 12). The sharp decline (-12%) in survival probabilities between the hours of 5pm to 8pm indicate that adolescents' risk for not meeting for personal MVPA average drastically reduced during this time compared to the windows of time before and after this period. Intervention decision points should therefore be prioritized during this time period (e.g., 5pm-8pm).

Based off the criteria set in place for generating decision points for moderators, sex was the only moderator which upheld both criteria. Although males were significantly more likely to meet their average MVPA during the 8am-12pm time, there are essentially no differences in the hazard and survival probabilities of MVPA accumulation during this window (see Table 15 and Figures 13-14). Nonetheless, sex differences in the OR estimates at these times indicate that timing of activity may differ across sex. Overall, male adolescents may be more receptive to exercise during the morning hours compared to females.

Discussion

The *just-in-time* of JITAIs refers to the delivery of digital intervention content during critical windows of opportunity for each user when they are likely to make either health-promoting or health-compromising choices (Smyth & Heron, 2016; Nahum-Shani et al., 2015; Nahum-Shani et al., 2018). The purpose of this study was to explore the timing of exercise for adolescents, identify correlates of physical activity that moderate the timing of exercise, and generate decision points for digital physical activity interventions. Odds ratios indicate that youth are most likely to obtain their person mean physical activity averages between the hours of 6pm to 8pm compared to the 8am time. Sex, participation in sports, non-school day, physical activity self-efficacy, and autonomous motivation significantly moderated the time of physical activity accumulation. Hazard and survival probabilities, or the instantaneous probability that an individual met their MVPA average, suggest that optimal decision points for digital physical activity programs should occur between 5pm and 8pm. These results also suggest that decision points for digital interventions can be tailored by sex such that males should receive additional decision points during the 8am-12pm window given their increased receptivity to exercise in the morning compared to females. Overall, findings from this study support the idea that the timing of physical activity can be empirically-identified to determine when users are receptive to exercise and potentially used as markers to signal intervention delivery for JITAIs addressing physical activity.

The pattern of odds ratios, hazard probabilities, and survival probabilities indicating overall user receptivity to exercise in the late afternoon and early evening coincides with adolescents' daily schedule. Generally, adolescents' ability to exercise is constrained by their school attendance for a large portion of the day until about 3pm, designating early-to-mid afternoon as the earliest convenience for adolescents to meaningfully accrue MVPA (Brook, Atkin, Corder, Brage, & van Sluijs, 2016). Furthermore, the decline in odds ratios as well as hazard probabilities after 8pm can be explained by adolescents' needs to attend to other important routines such as eating dinner, completing homework, and preparing for the next day (Gyurcsik, Spink, Bray, Chad, & Kwan, 2006). Therefore, adolescents might not engage with mHealth intervention options outside of this window of time (e.g., 3-8pm) and digital support to encourage exercise during these times could be wasteful. Persistent inopportune support is likely to lead to intervention failure and decreased user engagement, a continual challenge in mHealth literature (Nahum-Shani et al., 2018; Scherer, Ben-Zeev, Li, Kane, & 2017). Our findings suggest that just-in-time support during this window, and only this window, especially between 5-8pm, could be most helpful for adolescents and lead to positive engagement with digital support for exercise.

Consistent with previous research demonstrating that boys obtain more MVPA than girls, these findings show that males have significantly higher odds of obtaining their personal MVPA average in the morning compared to females and, further, may be more inclined to exercise in the morning compared to females (Cooper et al, 2015; Sallis, Prochaska, & Taylor, 2000). These findings highlight that receptivity to digital support may vary by sex and suggest that male adolescents may benefit from exercise prompts in the morning *and* in the afternoon, whereas female adolescents might only benefit from exercise prompts later in the day (e.g., 5-8pm). In other words, while it could be wasteful to prompt female adolescents to exercise in the morning, supplementary digital support for exercise in the morning (e.g., 8am-12pm) could be helpful for male adolescents. Although sending digital support for exercise in the morning to males could be conceived as wasteful given that they are in school, research demonstrates that males obtain more exercise than females in-school that out-of-school, including when leisurely on school grounds and also when at recess and gym class (Klinker et al., 2014). Therefore, digital support for male teenagers during this may prove beneficial.

Counter to our hypothesis, there were no significant differences in the timing of average MVPA across groups of different weight statuses. While previous research has indicated that youth with overweight and obesity exercise less, this study did not find substantial differences in MVPA levels across weight statuses (Table 6; Trost, Kerr, Ward, & Pate, 2001; Elgar et al., 2005). The absence of person mean MVPA differences across groups of varying weight statues probably contributed to the lack of timing differences across these groups. In this case, BMI may not affect the actual timing of exercise and serve as unimportant tailoring criteria for determining when to deliver digital intervention content. Surprisingly, non-sports participators had significantly higher odds of obtaining their person mean MVPA in the morning compared to sports-participators. Consistent with previous research, sports participators in this study displayed higher person mean MVPA (Table 7; Sallis et al., 2000). Therefore, it should take longer for sports-participators to accumulate their averages compared to non-sports participators. This relation between higher MVPA averages and later time of exercise may explain why these results were counter to the hypothesis.

There were higher odds of MVPA attainment in the morning on non-school days compared to school days, which may be indicative of the lack of constraints that prevent exercise on school days, especially considering that there were similar levels of person mean MVPA across school versus non-school days (Table 8). In other words, there may be more opportunity for adolescents to exercise in the morning on these non-school days, which might modify the ideal timing of support on those days (Moore et al., 2007).

Both physical activity self-efficacy and autonomous motivation for exercise modified timing of exercise but opposite to the hypothesized direction, such that individuals with lower physical activity self-efficacy and lower autonomous motivation had higher odds of MVPA attainment in the morning. However, like sports participation, those with lower physical activity self-efficacy and autonomous motivation displayed lower MVPA relative to this sample such that it would take them less time to accumulate their average exercise and lead to significant differences in timing of MVPA in the morning (Tables 9 & 12 respectively). These patterns of results suggest that digital interventions to promote gains in physical activity should consider how much the user is exercising beyond just group membership given that it will take users longer to surpass their average exercise amounts. That is to say users with higher amounts of MVPA attainment may be more receptive to digital intervention options later in the day.

Beyond the fact that the consistent distribution of activity between subgroups lead to non-significant differences in the timing of activity for physical activity self-efficacy and autonomous motivation, there are other reasons why no timing differences were found for these subgroups. Physical activity self-efficacy and autonomous motivation may be ineffectual moderators of decision points for individuals who accumulate exercise only in certain contexts (e.g., sports practice). For instance, physical activity self-efficacy, or other psychosocial constructs, would not alter the timing of activity for the person who exercises only at sports practices, or only in gym class, or only in green spaces. In these cases, the adaptation of decision points based on physical-activity self-efficacy or autonomous motivation would be wasteful for these individuals.

Based on the current study, decision points for JITAIs promoting exercise should occur between the 5pm to 8pm time frame, and additionally between 8am to 12pm for male teenagers, as indicated by odds ratios, hazard probabilities, and survival probabilities. This period appears to overlap when adolescents are receptive to exercise and could serve as an optimal starting place for novice exercisers to accrue MVPA. Additionally, on days when youth have met their average MVPA by this window, this period could serve as an opportunity to make exercise gains. It should be added that survival probabilities indicated that youth are still 73% unlikely to obtain their person mean MVPA after 8pm. There were more days when adolescents did not meet their average than days they did, suggesting a positive skew in the data. In conjunction with previous research documenting that adolescents are unlikely to meet the recommended 60 minutes of MVPA per day, these results add that adolescents' daily MVPA attainment varies around their personal MVPA average as well (Nader et al., 2008; Chung, Skinner, Steiner, & Perrin, 2012). This finding indicates that more consistently meeting one's own MVPA average would constitute a meaningful shift in MVPA attainment and a consequent increase in average MVPA. Since each user's average MVPA is known and achievable, given it's their average, future physical activity JITAIs might consider using each user's average MVPA as a worthwhile reference value to obtain. This approach may be more useful than utilizing the 60 minutes recommendation as an intervention target because it seeks to promote exercise within the user's current ability level. Further, the utilization of a user's average as a proximal target for intervention could arrest the decline in MVPA typically seen in the adolescence by sustaining one's ability to meet their average.

Limitations. To determine when users were receptive to exercise, this study investigated the time of day when adolescents met their person mean MVPA. Some users probably do not accrue MVPA in extensive, continuous bouts of time, rather they likely obtain MVPA over intermittent spans of time throughout the day (Brook et al., 2016). For instance, a person may gain some MVPA walking to school in the morning, in gym class, and after school at sports practice. Therefore, users may be receptive to exercise prompts at multiple times throughout the day and this study's conceptualization of receptivity does not capture this pattern.

Each of the moderators investigated in the study was analyzed independent of the others. In reality, these variables are not mutually exclusive and interact, such that there could have been unlimited interactions between these variables that moderated the most likely time of exercise. For example, the effect of sex*school day or sports participation*physical activity self-efficacy on the most likely time of exercise were not investigated, given the three-way interaction effects and complexity of these models. Future research should consider a more nuanced examination of how these moderators in tandem influence the timing of exercise to better optimize decision points for physical activity JITAIs across multiple contexts. Additionally, another limitation of the study was that it did not seek to determine which moderator of timing would be the most useful for adjusting decision points. Therefore, future research should investigate the experimental effects of tailoring decision points via different situational and contextual factors on improvements in physical activity.

This study included participants recruited from different seasons of the year (e.g., Fall, Summer, etc.) which convolutes the timing of exercise on non-school days. In this study, weekend days during the school year and weekdays during the summer were both classified as non-school days, given that the lack of school during these periods likely creates a comparable day structure and similarly affect the timing of activity. This study did not include interactions between weekday and seasonal physical activity, due to the complexity of the multilevel structure to estimate these models. Additionally, work hours or other contexts that would constrain an adolescent's ability to engage in MVPA were not assessed in the study. Future research should consider how these contexts would suppress one's ability to exercise and ultimately affect their decision points.

Given that the timing of average MVPA accumulation appears to be dependent on the amount of MVPA, it is important to employ measures that are sensitive to differences in activity levels when investigating how physical activity-related variables influence timing. In other words, these measures of social support and controlled motivation for exercise may have lacked convergent validity with MVPA for this study's sample, such that having more social support or controlled motivation for exercise was not predictive of more or less MVPA. Without this sensitivity to differences in MVPA, the value of these instruments as moderators for investigating timing differences is impractical. Additionally, it is possible that other variables might moderate timing of exercise including one's built environment characteristics (e.g., neighborhood walkability, access to recreational activities; Ding, Sallis, Kerr, Lee, & Rosenberg, 2011; Sallis et al., 2018; Cushing, Monzon, Ortega, Bejarano, & Carlson, 2019). For example, youth who actively transport (e.g., biking, walking, etc.) themselves to and from school might be receptive to more vigorous exercise during these windows. Ultimately, this study demonstrates that it is possible to investigate how important correlates of physical activity moderate the timing of exercise; Future research should explore how additional variables influence timing.

Future directions. Developing decision points for JITAIs by investigating the timing of exercise is a direct answer to calls in the research literature to model and incorporate microtemporal dynamics of health determinants, or the study of behavioral phenomenon in small timescales, within health behavior science (Dunton, 2018; Cushing et al., 2017; Nahum-Shani et al., 2018). Expansion of health behavior research to the microtimescale may elucidate the "temporal specificity" of health behaviors such as physical activity (Dunton et al., 2018; Nahum-

Shani et al., 2018). Additionally, because the microtemporal study of physical activity can be continuously-monitored and passively-detected, JITAIs can therefore optimize and adapt interventions for each individual user more readily than in-person and static eHealth/mHealth interventions. Most importantly, with these temporally-dense datasets, researchers can statistically uncover the unique temporal patterns for each participant given the immense quantity of observations (Cushing et al., 2019; Hamaker, 2012). It is conceivable that activity patterns may be highly idiosyncratic depending on the temporal, contextual, and psychosocial processes involved. However, with this idiographic data, automated JITAIs can be tailored to match the temporal specificity of each individual user's microtemporal physical activity patterns. Future research exploring the timing of exercise, and decision points generally, should therefore consider employing idiographic methods, such as precision medicine approaches, to enhance decision points for each user (Collins & Varmus, 2015; Cnossen et al., n.d.). Furthermore, given the dynamic nature of states of receptivity for exercise, it is likely that the decision points generated for each user would require adjustment as individuals progress through interventions. Future JITAIs will need to empirically re-assess individuals' timing of exercise to update these personalized decision points and continue providing timely support.

Ultimately, the notion that improved timing of support for digital physical activity interventions will lead to improvements in physical activity requires experimental testing. The current study demonstrates that there are ways to identify the temporal specificity of physical activity and that timing of exercise may differ among groups of people. Given this information, it can then be empirically tested whether sending digital intervention options at empirically-identified critical moments leads to more exercise compared to random, user-chosen, or interventionist-defined times. For example, a user's physical activity could be monitored for a duration of time and then analyzed to determine when he or she is likely to exercise. This data could then be integrated into an *N*-of-1 randomized clinical trial to test how empirical and idiographic decision points affect physical activity (Cushing, Walters, & Hoffman, 2014). More importantly, experimental research can determine which moderating variable would be most useful for adapting decision points to improve activity. Furthermore, these timing adjustments can also be personalized such that future JITAIs could adapt the timing of support from idiographic moderators that provided the most benefit for the individual user in mind.

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Table 1.

Adolescent and Caregiver Demographic Characteristics

	N	*M*	*SD*	%
Age				
Adolescent Age	113	14.64	1.48	
Adolescent Gender				
Male	42			37.2
Female	71			62.8
Race/Ethnicity				
Caucasian	89			77.8
Latino/Latina	9			8.0
African American	5			4.4
Asian	4			3.5
Native American	1			.9
Multiracial	2			1.8
Other	3			2.7
Parent's Marital Status				
Married	75			66.4
Divorced	19			16.8
Never married	13			11.5
Separated	5			4.4
Widowed	1			.9
Mother Education				
High school graduate	23			20.4
College graduate	46			40.7
Master's degree	30			26.5
PhD, JD, MD	8			7.1
Other	6			5.3
Father Education				
High school graduate	31			27.4
College graduate	41			36.3
Master's degree	17			15.0
PhD, JD, MD	9			7.96
Other	15			13.3
Approximate Family Income				
<$10,000	2			1.8
$11,000-$20,000	5			4.4
$21,000-$30,000	9			8.0
$31,000-$40,000	4			3.5
$41,000-$50,000	3			2.7
$51,000-$60,000	19			16.8
>$60,000	69			61.1
Missing	2			1.8

Table 2.

Descriptive Statistics of the Study Sample

Variable	*M*	*SD*
MVPA	30.91 mins	30.95 mins
Sedentary Activity	698.53 mins	178.88 mins
Light Physical Activity	245.39 mins	89.00 mins
BMI percentile	63.72	27.63
Physical Activity Self-Efficacy	27.28	6.14
Family Social Support for Exercise	22.87	7.93
Friend Social Support for Exercise	22.62	10.8
Autonomous Motivation for Exercise	5.06	1.23
Controlled Motivation for Exercise	3.07	1.39

Note. Physical Activity Self-Efficacy scores range from 1-40, with higher scores indicating higher efficacy. Family and Friend Social Support for Exercise scores range between 1-65, with higher scores indicating greater social support. Autonomous and controlled motivation scores range from 1-7, with higher scores indicating greater motivation.

Table 3.

Fit Indices for Polynomial Sequence of Models

Model	-2*log likelihood	-2*log likelihood $_{diff}$
1. Linear Polynomial of Time	6467.40	
2. Quadratic Polynomial of Time	6385.03	
Difference between Model 2 and Model 1		82.37*
3. Cubic Polynomial of Time	6375.27	
Difference between Model 3 and Model 2		9.76*
4. Quartic Polynomial of Time	6374.22	
Difference between Model 4 and Model 3		1.05

Note. $*p < .05$

Table 4.

Odds Ratio Estimates of Obtaining Average MVPA Before Hour of Day

Hour	Frequency	OR Estimates [95% CI]
Before 8 AM (reference)	0	
Before 9 AM	5	1.24 [1.31-1.36]
Before 10 AM	21	1.60 [1.34-1.91]
Before 11 AM	18	2.13 [1.67-2.72]
Before 12 PM	24	2.87 [2.12-3.7]
Before 1 PM	22	3.90 [2.73-5.56]
Before 2 PM	24	5.24 [3.53-7.77]
Before 3 PM	50	6.90 [4.51-10.55]
Before 4 PM	55	8.79 [5.63-13.72]
Before 5 PM	85	10.70 [6.78-16.89]
Before 6 PM	89	12.30 [7.77-19.45]
Before 7 PM	82	13.19 [8.38-20.73]
Before 8 PM	91	13.02 [8.38-20.22]
Before 9 PM	79	11.70 [7.66-17.84]
Before 10 PM	43	9.45 [6.3-14.12]
Before 11 PM	32	6.77 [4.6-9.94]

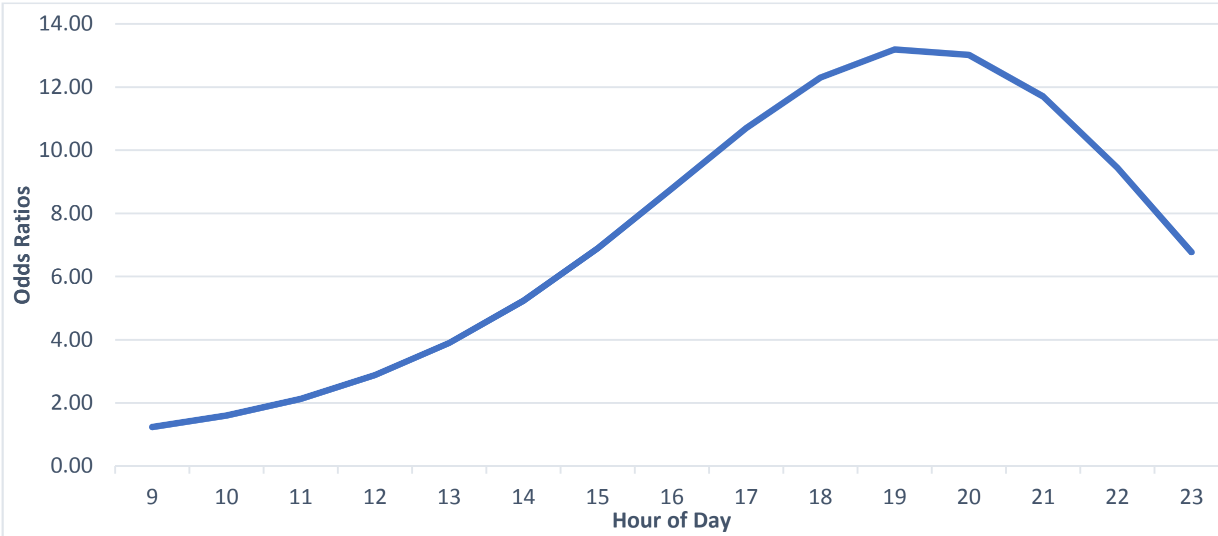

Figure 1. Odds ratios of obtaining average MVPA before each hour of day

Table 5.

Moderating Effect of Sex on Odds Ratio Estimates of Time of Average MVPA Accumulation

Hour	OR Estimates [95% CI]	
	Males (*n* = 42)	Females (*n* = 71)
Before 8 AM (reference)		
Before 9 AM	1.52 [1.29-1.79]*	1.12 [1-1.25]
Before 10 AM	2.30 [1.8-3.34]*	1.33 [1.08-1.64]
Before 11 AM	3.43 [2.42-5.78]*	1.66 [1.24-2.23]
Before 12 PM	5.02 [3.21-9.54]*	2.16 [1.49-3.11]
Before 1 PM	7.15 [4.2-14.95]	2.86 [1.85-4.38]
Before 2 PM	9.83 [4.87-16.66]	3.81 [2.35-6.11]
Before 3 PM	12.94 [6.07-27.23]	5.04 [3-8.36]
Before 4 PM	16.20 [7.31-35.35]	6.52 [3.76-11.04]
Before 5 PM	19.12 [8.43-42.52]	8.11 [4.61-13.88]
Before 6 PM	21.13 [9.26-47.12]	9.58 [5.41-16.38]
Before 7 PM	21.69 [9.57-47.79]	10.58 [6-19.91]
Before 8 PM	20.52 [9.24-44.12]	10.77 [6.18-17]
Before 9 PM	17.76 [8.23-36.87]	9.96 [5.81-16.15]
Before 10 PM	13.96 [6.7-27.81]	8.24 [4.89-13.01]
Before 11 PM	9.88 [4.9-18.91]	6.02 [3.62-9.27]

Note. Person mean MVPA for Males = 31.48 minutes and for Females = 30.66 minutes. * = significant differences in ORs between groups at the $p < .05$ level.

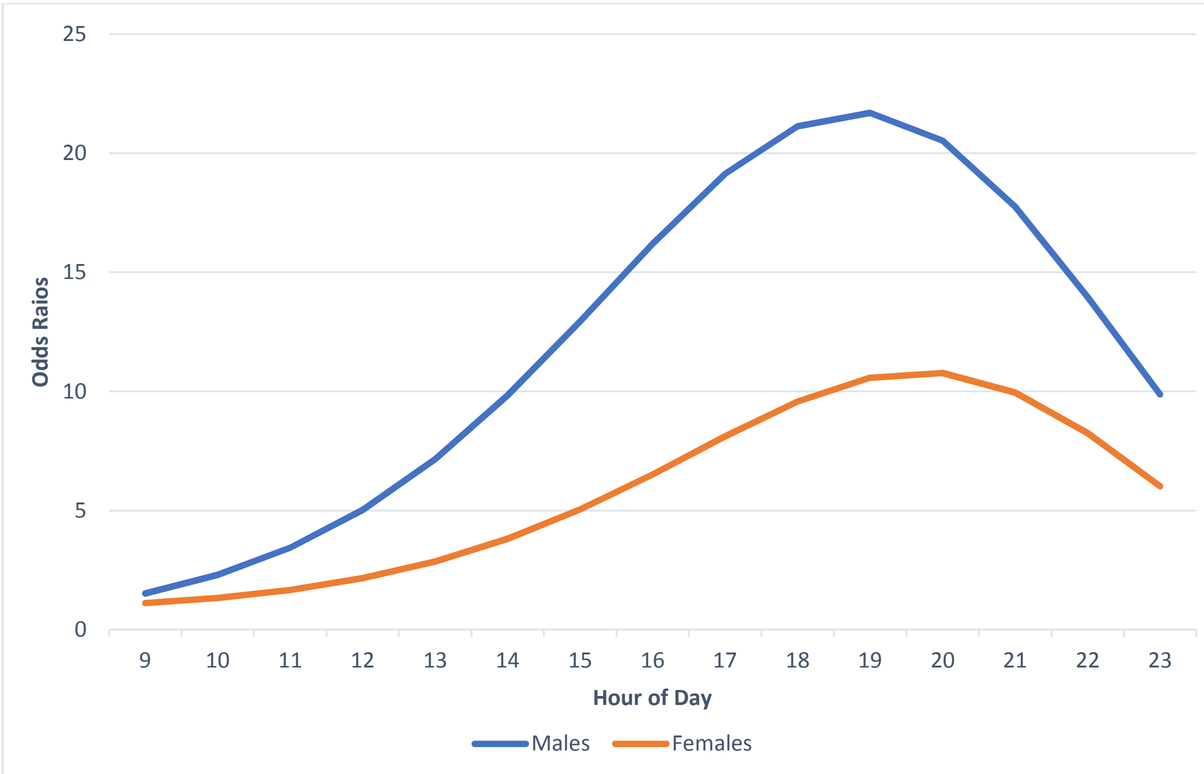

Figure 2. Sex differences in odds ratios of obtaining average MVPA before each hour of day.

Table 6.

Moderating Effect of Body Mass Index (BMI) on Odds Ratio Estimates of Time of Average MVPA Accumulation

Hour	OR Estimates [95% CI]		
	Normal Weight Status (n = 81)	Overweight Status (n = 13)	Obese Status (n = 19)
Before 8 AM (reference)			
Before 9 AM	1.28 [1.16-1.39]	1.25 [1.14-1.36]	1.24 [1.24-1.36]
Before 10 AM	1.68 [1.4-1.97]	1.61 [1.36-1.9]	1.59 [1.34-1.89]
Before 11 AM	2.26 [1.76-2.83]	2.14 [1.68-2.7]	2.10 [1.64-2.68]
Before 12 PM	3.07 [2.25-4.07]	2.86 [2.12-3.83]	2.8 [2.06-3.8]
Before 1 PM	4.16 [2.91-5.81]	3.83 [2.7-5.4]	3.74 [2.61-5.33]
Before 2 PM	5.57 [3.76-8.12]	5.06 [3.42-7.44]	4.93 [3.3-7.35]
Before 3 PM	7.29 [4.79-10.99]	6.54 [4.29-9.92]	6.34 [4.09-9.8]
Before 4 PM	9.22 [5.95-14.24]	8.15 [5.23-12.67]	7.87 [4.95-12.5]
Before 5 PM	11.14 [7.17-17.48]	9.68 [6.13-15.29]	9.30 [5.73-15.09]
Before 6 PM	12.73 [8.11-20.11]	10.83 [6.82-17.27]	10.35 [6.3-17.03]
Before 7 PM	13.58 [8.7-21.44]	11.29 [7.11-18.04]	10.71 [6.48-17.79]
Before 8 PM	13.40 [8.66-20.99]	10.82 [6.85-17.25]	10.18 [6.14-17.01]
Before 9 PM	12.09 [7.91-18.67]	9.43 [6.01-14.95]	8.79 [5.29-14.74]
Before 10 PM	9.86 [6.53-14.96]	7.39 [4.74-11.64]	6.80 [4.09-11.47]
Before 11 PM	7.19 [4.79-10.72]	5.13 [3.31-8.07]	4.66 [2.79-7.94]

Note. Person mean MVPA for Normal Weight Status = 31.23 minutes and for Overweight Status = 27.33 minutes and for Obese Status = 32.32.

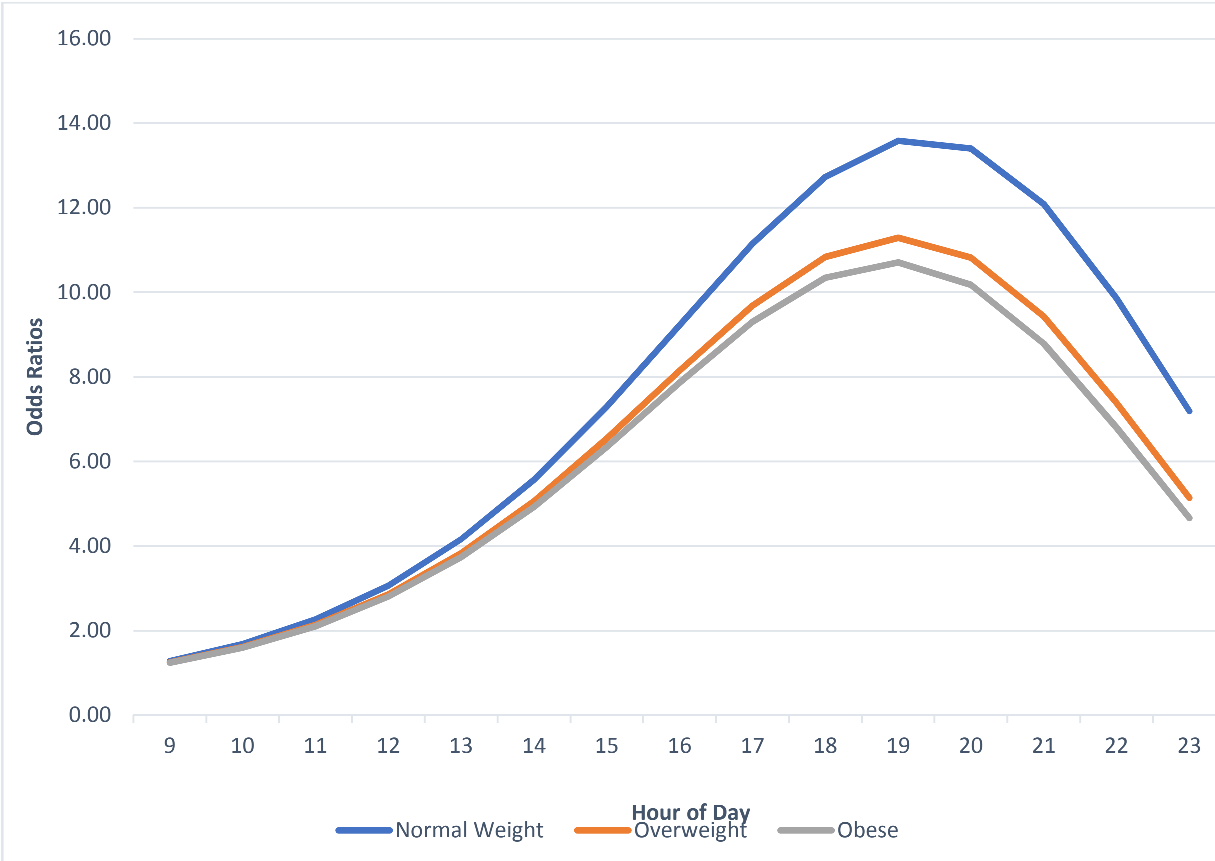

Figure 3. BMI differences in odds ratios of obtaining average MVPA before each hour of day.

Table 7.

Moderating Effect of Involvement in Organized Sports (Sports Part.) on Odds Ratio Estimates of Time of Average MVPA Accumulation

Hour	OR Estimates [95% CI]	
	No Sports Part. (*n* = 68)	Sports Part. (*n* = 45)
Before 8 AM (reference)		
Before 9 AM	1.41 [1.26-1.58]*	0.95 [0.81-1.12]
Before 10 AM	1.95 [1.62-2.48]*	1.05 [0.78-1.43]
Before 11 AM	2.65 [1.96-3.57]	1.32 [0.86-2.02]
Before 12 PM	3.51 [2.42-5.1]	1.83 [1.16-3.41]
Before 1 PM	4.54 [2.94-7]	2.68 [1.44-4.96]
Before 2 PM	5.71 [3.53-9.25]	4.06 [2.2-8.9]
Before 3 PM	6.96 [4.15-11.7]	6.14 [2.9-12.81]
Before 4 PM	8.22 [4.78-14.15]	9.01 [4.41-21.43]
Before 5 PM	9.36 [5.37-16.33]	12.44 [5.24-27.36]
Before 6 PM	10.26 [5.88-17.95]	15.65 [7.34-37.64]
Before 7 PM	10.79 [6.23-18.75]	17.40 [7.7-37.94]
Before 8 PM	10.88 [6.38-18.6]	16.57 [7.92-38.37]
Before 9 PM	10.47 [6.28-17.52]	13.11 [6.05-27.03]
Before 10 PM	9.60 [5.91-15.68]	8.35 [4.28-18.27]
Before 11 PM	8.36 [5.47-13.96]	4.16 [2.02-7.98]

Note. Person mean MVPA for non-sports participators = 24.45 minutes and for sports participators = 40.81 minutes. * = significant differences in ORs between groups at the $p < .05$ level.

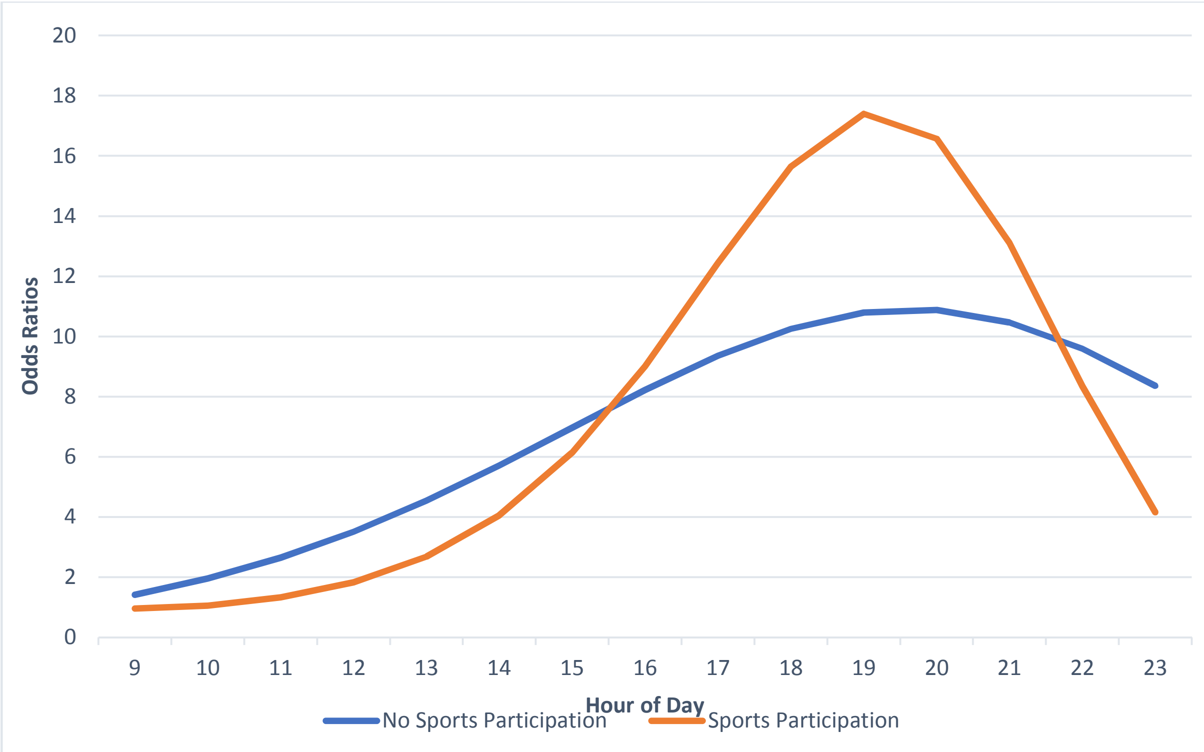

Figure 4. Involvement in organized sports differences in odds ratios of obtaining average MVPA before each hour of day.

Table 8.

Moderating Effect of School Day on Odds Ratio Estimates of Time of Average MVPA Accumulation

Hour	OR Estimates [95% CI]	
	Non-School Day (1036 days)	School Day (862 days)
Before 8 AM (reference)		
Before 9 AM	1.55 [1.63-1.77]*	0.99 [0.87-1.12]
Before 10 AM	2.34 [1.82-3]*	1.1 [0.86-1.4]
Before 11 AM	3.41 [2.4-4.83]*	1.34 [0.95-1.88]
Before 12 PM	4.79 [3.08-7.39]*	1.76 [1.15-2.68]
Before 1 PM	6.48 [3.87-10.73]	2.43 [1.47-3.95]
Before 2 PM	8.43 [4.73-14.75]	3.44 [1.97-5.89]
Before 3 PM	10.50 [5.63-19.17]	4.88 [2.67-8.67]
Before 4 PM	12.52 [6.5-23.48]	6.77 [3.59-12.31]
Before 5 PM	14.25 [7.25-27.09]	9.00 [4.67-16.51]
Before 6 PM	15.44 [7.8-29.37]	11.16 [5.75-20.43]
Before 7 PM	15.91 [8.06-29.9]	12.65 [6.53-22.82]
Before 8 PM	15.54 [7.99-28.56]	12.78 [6.66-22.52]
Before 9 PM	14.37 [7.54-25.59]	11.26 [5.95-19.25]
Before 10 PM	12.54 [6.76-21.54]	8.44 [5.53-13.99]
Before 11 PM	10.32 [5.7-17.08]	5.27 [2.85-8.5]

Note. Mean MVPA on non-school days = 28.49 minutes and on school days = 33.82. * = significant differences in ORs between groups at the p <.05 level.

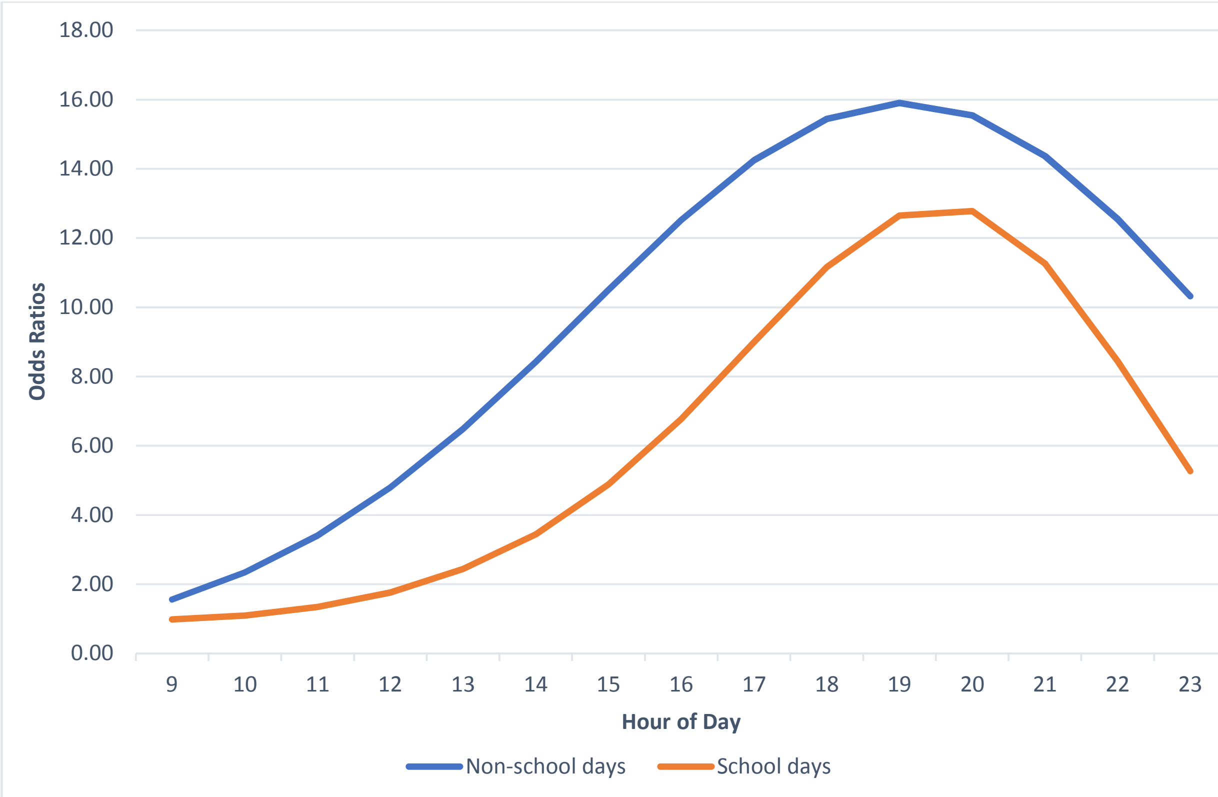

Figure 5. School day differences in odds ratios of obtaining average MVPA before each hour of day.

Table 9.

Moderating Effect of Physical Activity Self Efficacy (PASE) on Odds Ratio Estimates of Time of Average MVPA Accumulation

Hour	OR Estimates [95% CI]		
	Low PASE (n = 21)	Average PASE (n = 71)	High PASE (n = 21)
Before 8 AM (reference)			
Before 9 AM	1.42 [1.29-1.56][a]	1.21 [1.13-1.36]	1.05 [0.99-1.2]
Before 10 AM	1.98 [1.65-2.36][a]	1.61 [1.35-1.92]	1.31 [1.09-1.58]
Before 11 AM	2.69 [2.09-3.45]	2.15 [1.68-2.75]	1.72 [1.33-2.23]
Before 12 PM	3.56 [2.6-4.87]	2.91 [2.14-3.97]	2.39 [1.73-3.31]
Before 1 PM	4.60 [3.19-6.64]	3.98 [2.78-5.7]	3.45 [2.35-5.06]
Before 2 PM	5.77 [3.83-8.7]	5.39 [3.61-8.03]	5.04 [3.28-7.75]
Before 3 PM	7.00 [4.49-10.92]	7.14 [4.64-10.97]	7.27 [4.56-11.61]
Before 4 PM	8.24 [5.15-13.16]	9.14 [5.82-14.34]	10.13 [6.17-16.65]
Before 5 PM	9.37 [5.76-15.23]	11.18 [7.04-17.73]	13.31 [7.93-22.34]
Before 6 PM	10.27 [6.26-16.84]	12.86 [8.08-20.46]	16.09 [9.46-27.36]
Before 7 PM	10.84 [6.59-17.81]	13.78 [8.7-21.8]	17.51 [10.22-30.01]
Before 8 PM	10.98 [6.71-17.99]	13.55 [8.67-21.19]	16.73 [9.73-28.74]
Before 9 PM	10.67 [6.59-17.37]	12.09 [7.87-18.58]	13.70 [7.98-23.54]
Before 10 PM	9.92 [6.14-16.04]	9.73 [6.46-14.66]	9.40 [5.48-16.14]
Before 11 PM	8.81 [5.471-14.2]	6.81 [4.61-10.09]	5.32 [3.1-9.16]

Note. Person mean MVPA for low PASE = 23.77 minutes and for average PASE = 28.92 minutes and for high PASE = 45.07. [a] = significant differences in ORs between low and high groups at the p <.05 level.

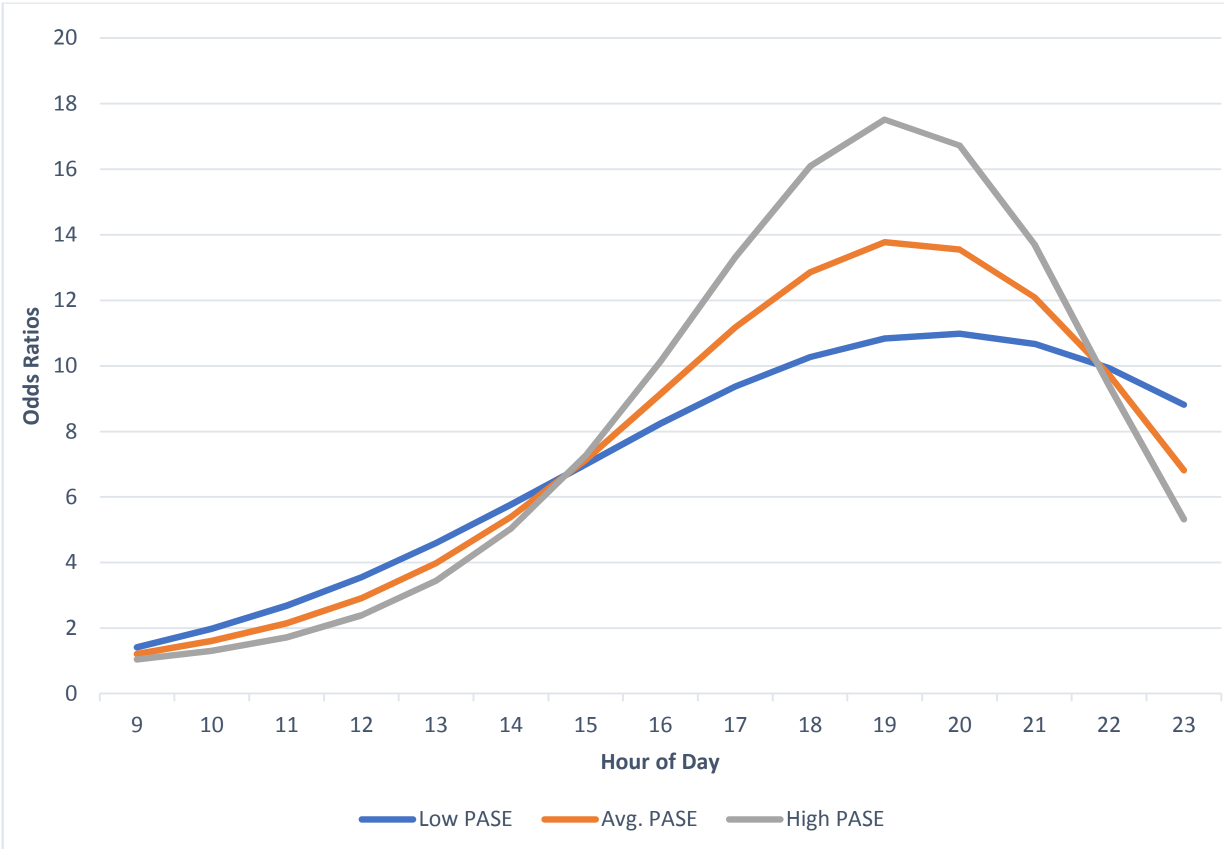

Figure 6. Physical activity self-efficacy differences in odds ratios of obtaining average MVPA before each hour of day.

Table 10.

Moderating Effect of Family Social Support on Odds Ratio Estimates of Time of Average MVPA Accumulation

Hour	OR Estimates [95% CI]		
	Low Family Social Support (*n* = 24)	Average Family Social Support (*n* = 68)	High Family Social Support (*n* = 21)
Before 8 AM (reference)			
Before 9 AM	1.53 [1.12-2.17]	1.27 [1.16-1.42]	1.06 [0.85-1.35]
Before 10 AM	2.29 [1.3-4.17]	1.66 [1.4-2.06]	1.20 [0.8-1.87]
Before 11 AM	3.34 [1.52-7.75]	2.20 [1.75-3]	1.45 [0.82-2.89]
Before 12 PM	4.70 [1.78-13.47]	3.11 [3-4.35]	1.98 [0.9-4.32]
Before 1 PM	6.40 [2.11-21.84]	4.22 [2.87-6.21]	2.62 [1.05-6.55]
Before 2 PM	9.07 [2.5-32.92]	5.64 [3.68-8.63]	3.50 [1.25-9.77]
Before 3 PM	12.41 [2.9-53.09]	7.35 [4.67-11.59]	4.62 [1.6-13.4]
Before 4 PM	14.43 [3.5-59.39]	9.26 [5.78-14.85]	5.94 [1.84-19.23]
Before 5 PM	17.05 [4.11-70.68]	11.14 [6.9-17.98]	7.28 [2.17-24.47]
Before 6 PM	19.20 [4.77-77.31]	12.66 [7.87-20.39]	8.35 [2.45-28.5]
Before 7 PM	20.56 [5.45-77.55]	13.46 [8.47-21.45]	8.80 [2.6-29.82]
Before 8 PM	20.87 [6.11-71.22]	13.23 [8.43-20.76]	8.39 [2.55-27.55]
Before 9 PM	20.00 [6.68-59.85]	11.54 [7.48-17.8]	7.08 [2.27-22.09]
Before 10 PM	18.05 [7.06-46.14]	9.68 [6.34-14.79]	5.19 [1.78-15.13]
Before 11 PM	15.29 [7.1-32.94]	7.06 [4.62-10.79]	3.26 [1.22-8.71]

Note. Person mean MVPA for low family social support = 28.77 minutes and for average family social support = 31.88 minutes and for high family social support = 30.53.

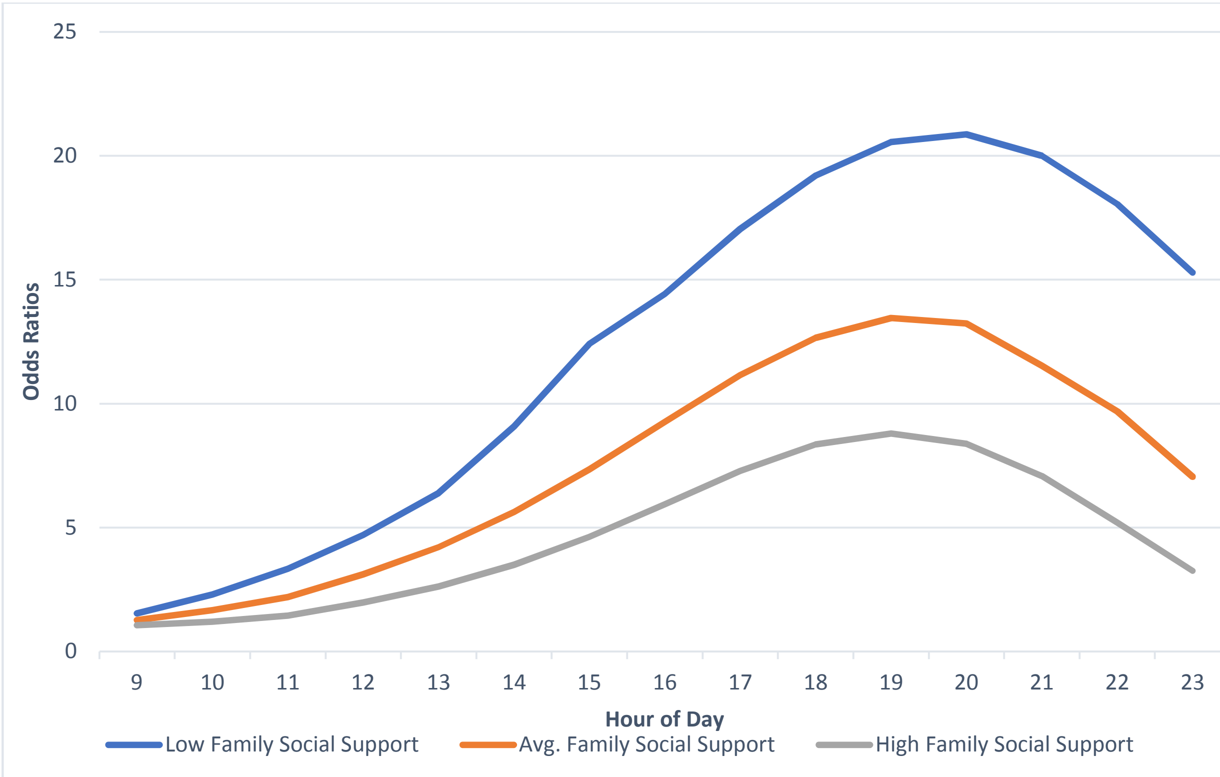

Figure 7. Family social support differences in odds ratios of obtaining average MVPA before each hour of day.

Table 11.

Moderating Effect of Friend Social Support on Odds Ratio Estimates of Time of Average MVPA Accumulation

Hour	OR Estimates [95% CI]		
	Low Friend Social Support (n = 28)	Average Friend Social Support (n = 68)	High Friend Social Support (n = 17)
Before 8 AM (reference)			
Before 9 AM	1.29 [1.01-1.63]	1.27 [1.15-1.4]	1.25 [0.95-1.62]
Before 10 AM	1.71 [1.09-2.63]	1.69 [1.67-1.97]	1.68 [0.97-2.71]
Before 11 AM	2.30 [1.19-4.19]	2.21 [1.71-2.86]	2.15 [1.04-4.41]
Before 12 PM	2.97 [1.37-6.4]	2.93 [2.13-4.05]	2.98 [1.19-7.43]
Before 1 PM	3.90 [1.6-9.49]	3.99 [2.73-5.82]	4.01 [1.38-11.62]
Before 2 PM	5.05 [1.87-13.61]	5.22 [3.43-7.96]	5.55 [1.66-18.57]
Before 3 PM	6.39 [2.22-18.37]	6.86 [4.34-10.85]	7.23 [1.97-25.5]
Before 4 PM	7.81 [2.62-23.26]	8.47 [5.23-13.74]	9.44 [2.35-37.91]
Before 5 PM	9.11 [3.07-27.06]	10.28 [6.21-17]	11.50 [2.72-48.59]
Before 6 PM	10.27 [3.5-30.2]	11.48 [6.88-19.17]	13.46 [2.98-60.82]
Before 7 PM	10.78 [3.88-29.96]	12.29 [7.31-20.66]	13.91 [3.22-60.13]
Before 8 PM	10.73 [4.11-28.03]	11.88 [7.08-19.94]	13.45 [3.2-56.57]
Before 9 PM	9.79 [4.15-23.13]	10.75 [6.4-18.06]	11.45 [2.94-44.63]
Before 10 PM	8.33 [3.9-17.78]	8.60 [5.14-14.41]	8.83 [2.44-31.98]
Before 11 PM	6.39 [3.36-12.14]	6.30 [3.73-10.62]	5.96 [1.81-19.67]

Note. Person mean MVPA for low friend social support = 33.87 minutes and for average friend social support = 29.67 minutes and for high friend social support = 31.39.

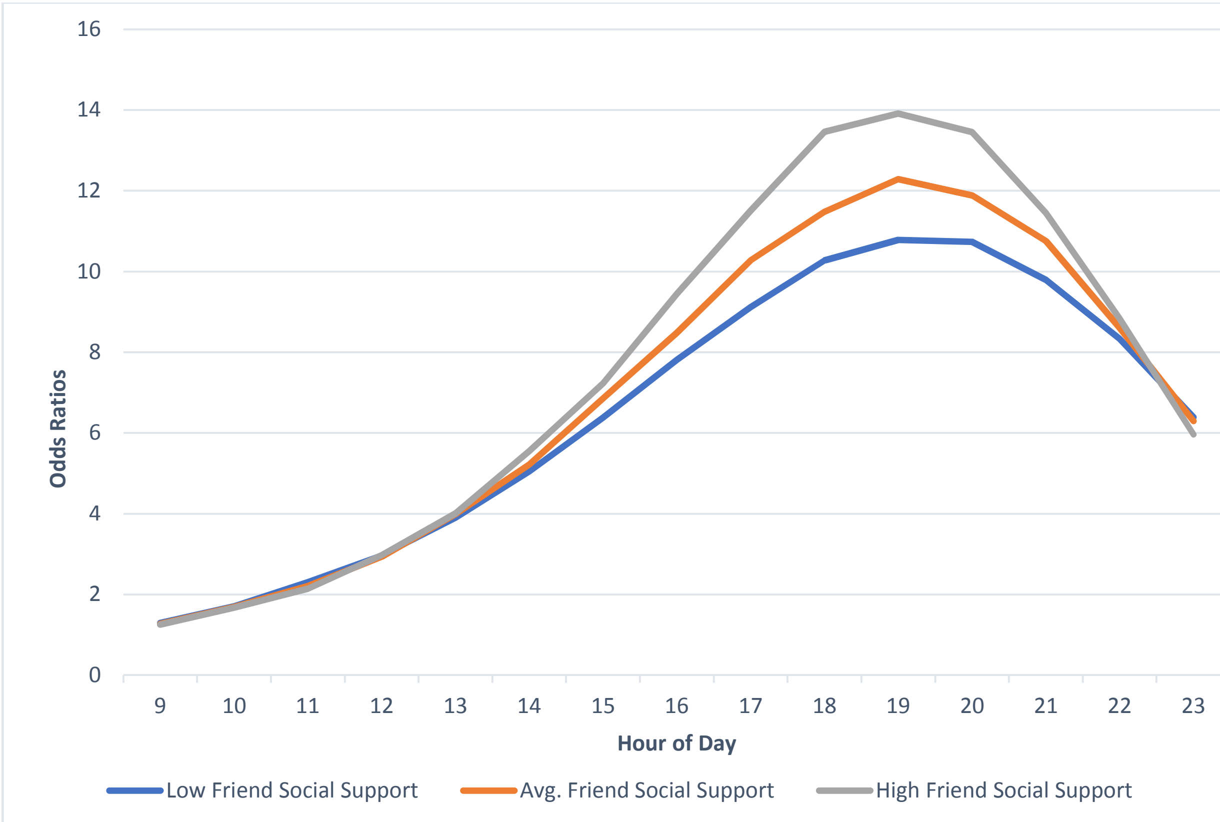

Figure 8. Friend social support differences in odds ratios of obtaining average MVPA before each hour of day.

Table 12.

Moderating Effect of Autonomous Motivation on Odds Ratio Estimates of Time of Average MVPA Accumulation

Hour	OR Estimates [95% CI]		
	Low Autonomous Motivation (n = 15)	Average Autonomous Motivation (n = 80)	High Autonomous Motivation (n = 18)
Before 8 AM (reference)			
Before 9 AM	1.46 [1.27-1.68][a]	1.24 [1.14-1.37]	1.06 [0.94-1.21]
Before 10 AM	2.11 [1.63-2.77][a]	1.61 [1.36-1.93]	1.23 [0.98-1.58]
Before 11 AM	3.03 [2.07-4.4]	2.14 [1.7-2.77]	1.51 [1.1-2.16]
Before 12 PM	4.27 [2.71-6.93]	2.89 [2.16-4]	1.95 [1.31-3.05]
Before 1 PM	6.01 [3.48-10.38]	3.90 [2.8-5.72]	2.58 [1.63-4.37]
Before 2 PM	8.09 [4.4-14.863]	5.22 [3.63-8.03]	3.46 [2.08-6.24]
Before 3 PM	10.51 [5.46-20.23]	7.13 [4.65-10.93]	4.58 [2.67-8.74]
Before 4 PM	13.08 [6.58-26.01]	9.90 [5.81-14.23]	6.32 [3.39-11.78]
Before 5 PM	15.52 [7.68-31.39]	11.08 [7-17.53]	7.30 [4.17-15]
Before 6 PM	17.43 [8.59-35.37]	12.74 [8.04-20.20]	9.31 [4.87-17.75]
Before 7 PM	18.40 [9.15-36.99]	13.65 [8.66-21.51]	10.12 [5.34-19.19]
Before 8 PM	18.15 [9.21-35.75]	13.46 [8.65-20.95]	9.98 [5.35-18.63]
Before 9 PM	16.61 [8.69-31.78]	12.06 [7.89-14.45]	8.76 [4.8-15.99]
Before 10 PM	14.02 [7.59-25.91]	9.71 [6.48-14.56]	5.59 [3.77-11.92]
Before 11 PM	10.85 [6.09-19.34]	6.93 [4.71-10.21]	3.59 [2.55-7.7]

Note. Person mean MVPA for low autonomous motivation = 21.57 minutes and for average autonomous motivation = 30.23 minutes and for high autonomous motivation = 42.09. [a] = significant differences in ORs between low and high groups at the p <.05 level.

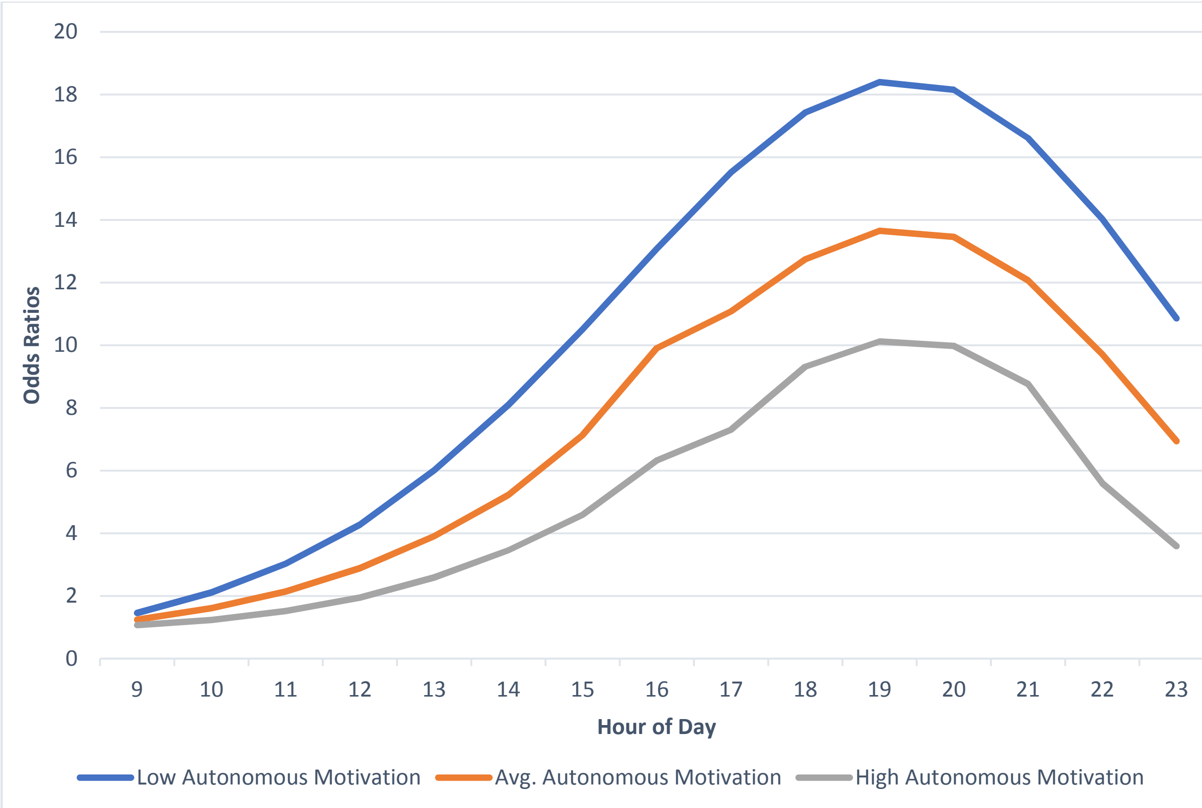

Figure 9. Autonomous motivation differences in odds ratios of obtaining average MVPA before each hour of day.

Table 13.

Moderating Effect of Controlled Motivation on Odds Ratio Estimates of Time of Average MVPA Accumulation

Hour	OR Estimates [95% CI]		
	Low Controlled Motivation (n = 23)	Average Controlled Motivation (n = 67)	High Controlled Motivation (n = 23)
Before 8 AM (reference)			
Before 9 AM	1.35 [1.19-1.54]	1.20 [1.13-1.35]	1.06 [0.96-1.25]
Before 10 AM	1.84 [1.52-2.47]	1.51 [1.28-1.81]	1.24 [1.02-1.68]
Before 11 AM	2.51 [1.9-3.77]	1.97 [1.55-2.51]	1.55 [1.18-2.37]
Before 12 PM	3.39 [2.38-5.61]	2.64 [2.1-3.87]	2.05 [1.44-3.44]
Before 1 PM	4.52 [2.98-8.08]	3.55 [2.72-5.23]	2.8 [1.84-5.082]
Before 2 PM	5.90 [3.69-11.18]	4.77 [3.51-7.74]	3.86 [2.41-7.46]
Before 3 PM	7.50 [4.49-14.81]	6.30 [4.5-10.52]	5.30 [3.16-10.68]
Before 4 PM	9.20 [4.99-17.34]	8.07 [5.63-13.71]	7.08 [4.08-14.64]
Before 5 PM	10.81 [6.16-22.2]	9.88 [6.79-19.91]	9.03 [5.1-18.9]
Before 6 PM	13.05 [6.86-24.85]	11.44 [7.79-19.5]	10.80 [5.56-20.69]
Before 7 PM	13.78 [7.3-26.03]	12.33 [8.4-20.79]	12.14 [6.3-23.39]
Before 8 PM	12.75 [6.97-23.84]	12.23 [8.39-20.26]	12.42 [6.48-23.46]
Before 9 PM	11.82 [7.02-22.99]	11.01 [7.65-17.85]	10.25 [5.613-19.26]
Before 10 PM	10.14 [6.23-19.26]	8.87 [6.27-14.07]	7.76 [4.49-14.49]
Before 11 PM	8.00 [5.1-14.93]	6.32 [4.55-9.86]	4.98 [2.93-9.03]

Note. Person mean MVPA for low controlled motivation = 32.33 minutes and for average controlled motivation = 27.22 minutes and for high controlled motivation = 40.52.

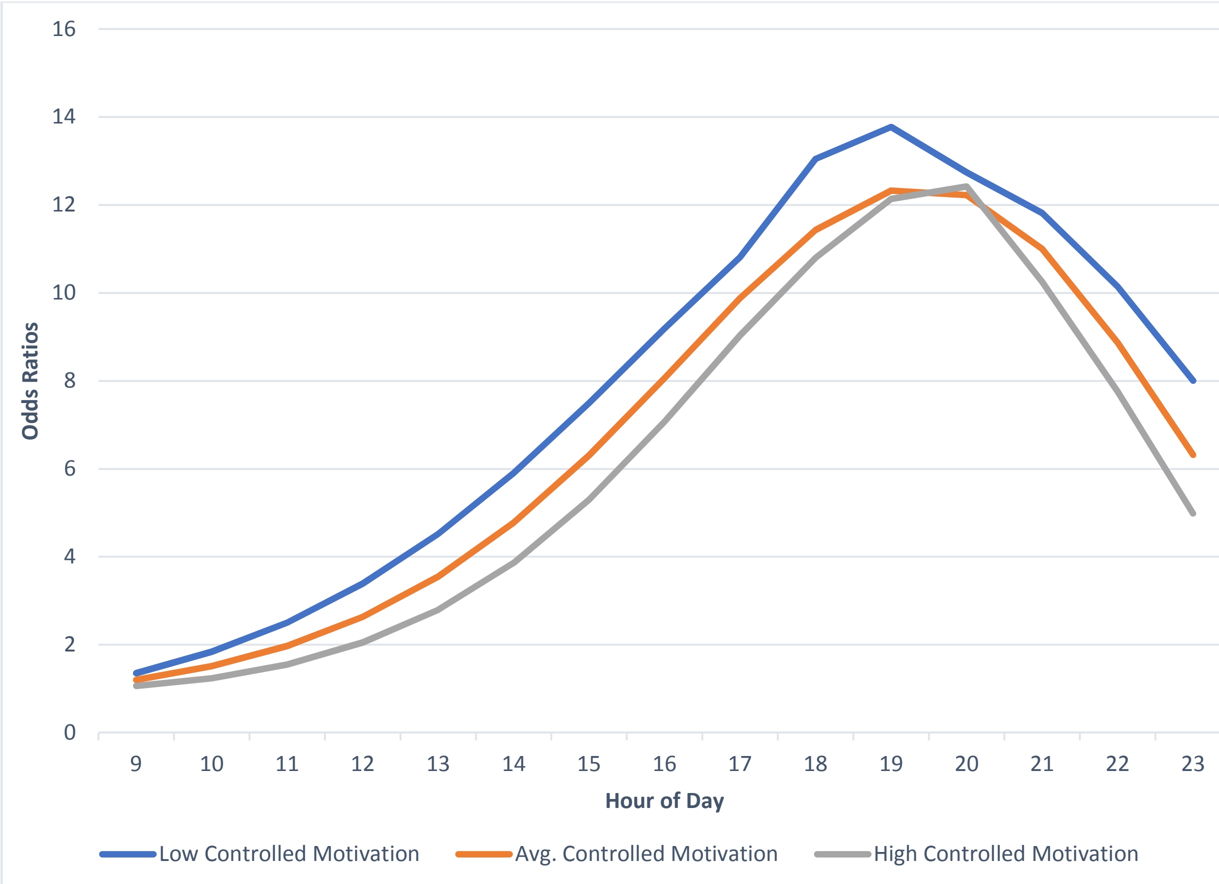

Figure 10. Controlled motivation differences in odds ratios of obtaining average MVPA before each hour of day.

Table 14.

Hazard and Survival Probabilities of Time of Average MVPA Accumulation

Hour	Hazard Prob.	Survival Prob.
Before 8 AM	0.00	1.00
Before 9 AM	0.01	1.00
Before 10 AM	0.01	0.99
Before 11 AM	0.01	0.98
Before 12 PM	0.01	0.97
Before 1 PM	0.02	0.96
Before 2 PM	0.03	0.94
Before 3 PM	0.03	0.91
Before 4 PM	0.04	0.88
Before 5 PM	0.05	0.85
Before 6 PM	0.05	0.81
Before 7 PM	0.05	0.77
Before 8 PM	0.04	0.73
Before 9 PM	0.04	0.70
Before 10 PM	0.03	0.68
Before 11 PM	0.00	0.66

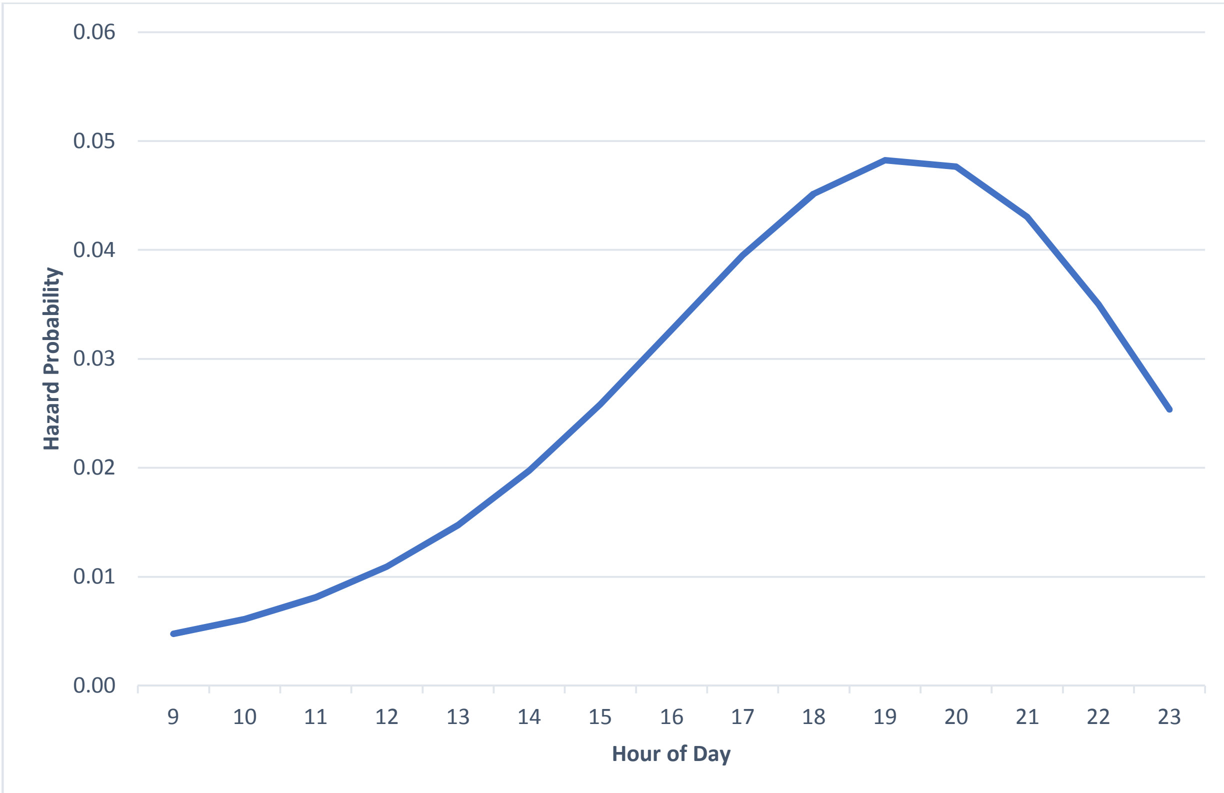

Figure 11. Hazard probabilities of obtaining average MVPA before each hour of day.

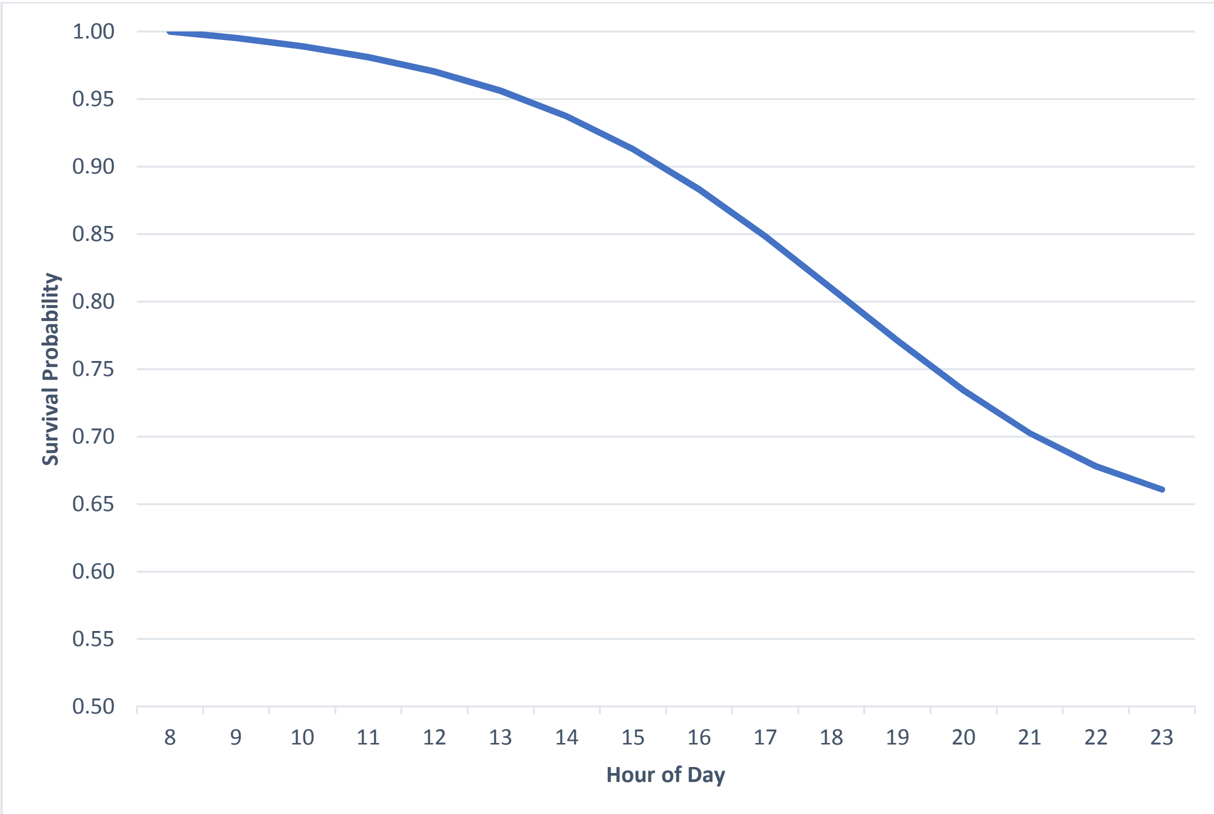

Figure 12. Survival probabilities of obtaining average MVPA before each hour of day

Table 15.

Moderating Effect of Sex on Hazard and Survival Probabilities of Time of Average MVPA Accumulation

Hour	Hazard Probabilities		Survival Probabilities	
	Males	Females	Males	Females
Before 8 AM	0.00	0.00	1.00	1.00
Before 9 AM	0.00	0.01	1.00	0.99
Before 10AM	0.01	0.01	0.99	0.99
Before 11AM	0.01	0.01	0.98	0.98
Before 12 PM	0.01	0.01	0.97	0.97
Before 1 PM	0.02	0.01	0.96	0.96
Before 2 PM	0.02	0.02	0.94	0.94
Before 3 PM	0.03	0.02	0.91	0.91
Before 4 PM	0.04	0.03	0.88	0.89
Before 5 PM	0.04	0.04	0.84	0.85
Before 6 PM	0.05	0.05	0.80	0.81
Before 7 PM	0.05	0.05	0.76	0.77
Before 8 PM	0.04	0.05	0.73	0.73
Before 9 PM	0.04	0.05	0.70	0.70
Before 10 PM	0.03	0.04	0.68	0.67
Before 11 PM	0.02	0.03	0.66	0.65

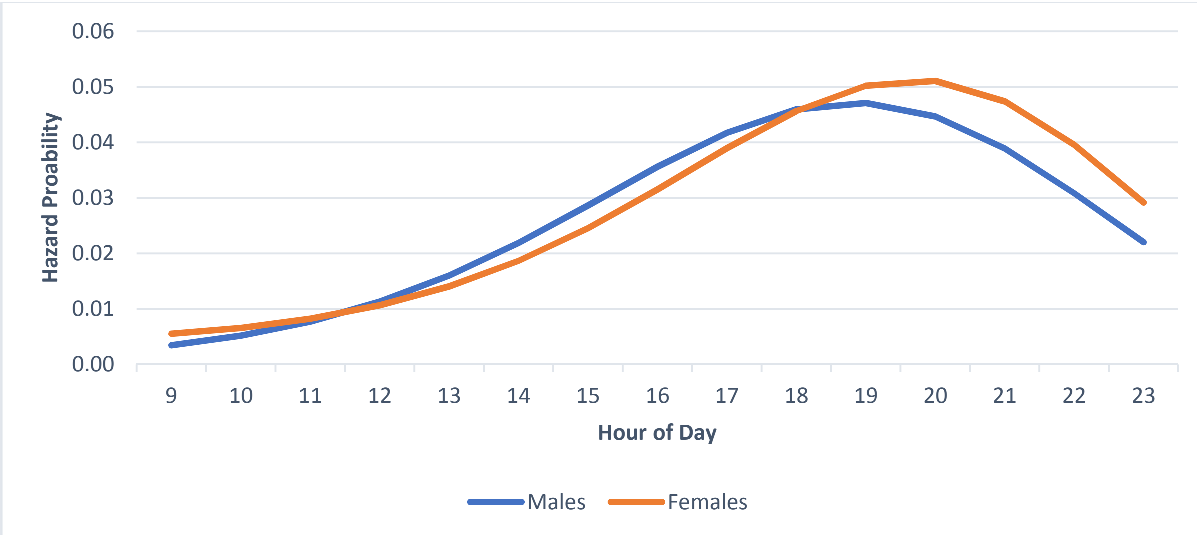

Figure 13. Sex Differences in hazard probabilities of obtaining average MVPA before each hour of day.

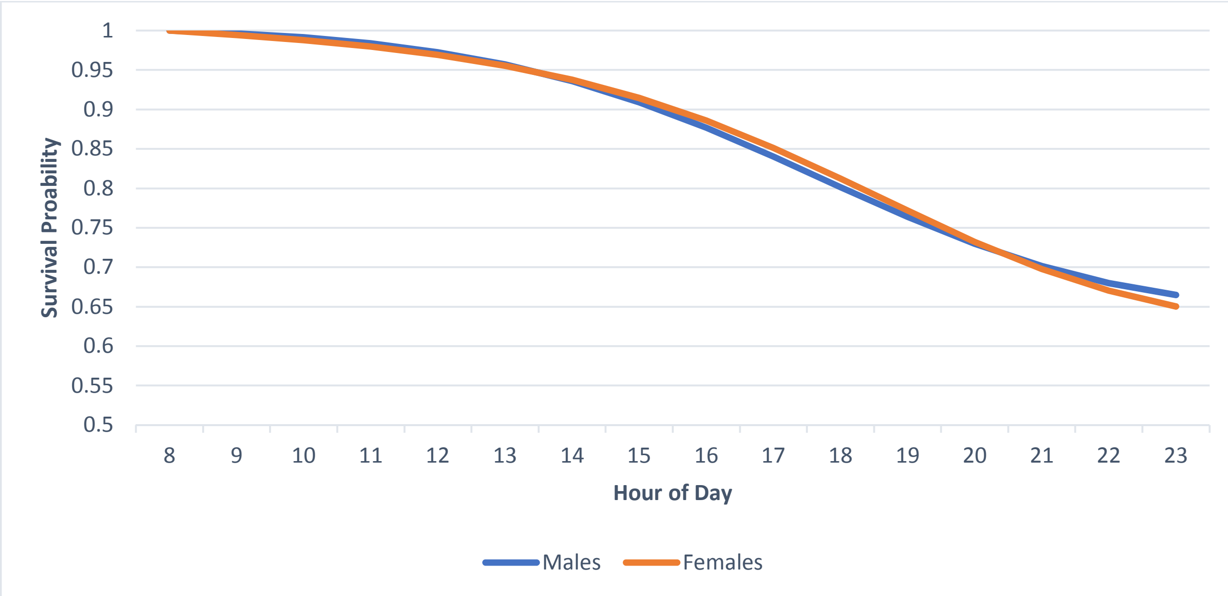

Figure 14. Sex differences in survival probabilities of obtaining average MVPA before each hour of day.

Appendix A
Demographics

DEMOGRAPHIC INFORMATION

Sex: F M **Age**: _____________ **Date of Birth**: _____________________

Address: _____________________

Phone Number: _____________________

Phone Number of Close Family Member: _____________________

Race/Ethnicity: _____ Caucasian _____ Latino/Latina
_____ African American _____ Chicano/Chicana
_____ Asian _____ Middle Eastern
_____ Pacific Islander _______ American Indian
_____ Other (Please specify: ________________________)

Place of Birth: ____________________ **Primary Language** __________________________

Mother's Age: ______________ **Father's Age**: ______________

Mother's Education: _____ high school graduate
_____ college graduate
_____ masters degree
_____ PhD, JD, MD
_____ other
(please specify: _________________)

Father's Education: _____ high school graduate
_____ college graduate
_____ masters degree
_____ PhD, JD, MD
_____ other
(please specify: _________________)

Mother's Occupation: ____

Father's Occupation: ____

Approximate *family* income: _____ < $10,000 _____ $10, 000-$20,000 _____ $21,000-$30,000
_____ $31,000-$40,000 _____ $41,000-$50,000 _____ $51,000-$60,000 _____ > $61,000

Parent's Marital Status: _____ married _____ separated _____ divorced
_____ mother passed away ____ father passed away _____ never married

Appendix B
20-Day Physical Activity Calendar

Participant #:
Date:

Physical Activity Calendar						
Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
Activity 1: Time:	Activity 1: Time:	Activity 1: Time:	Activity 1: Time:	Activity 1: Time:	Activity 1: Time:	Activity 1: Time:
Activity 2: Time:	Activity 2: Time:	Activity 2: Time:	Activity 2: Time:	Activity 2: Time:	Activity 2: Time:	Activity 2: Time:
Activity 3: Time:	Activity 3: Time:	Activity 3: Time:	Activity 3: Time:	Activity 3: Time:	Activity 3: Time:	Activity 3: Time:
Sunday	**Monday**	**Tuesday**	**Wednesday**	**Thursday**	**Friday**	**Saturday**
Activity 1: Time:	Activity 1: Time:	Activity 1: Time:	Activity 1: Time:	Activity 1: Time:	Activity 1: Time:	Activity 1: Time:
Activity 2: Time:	Activity 2: Time:	Activity 2: Time:	Activity 2: Time:	Activity 2: Time:	Activity 2: Time:	Activity 2: Time:
Activity 3: Time:	Activity 3: Time:	Activity 3: Time:	Activity 3: Time:	Activity 3: Time:	Activity 3: Time:	Activity 3: Time:

Appendix C
Physical Activity Self-Efficacy Questionnaire (PASE-Q)

Please answer all questions using the following 5-point scale:

1	2	3	4	5
Disagree a lot				Agree a lot

1. I can be physically active during my free time on most days.
2. I can ask my parent or other adult to do physically active things with me.
3. I can by physically active during my free time on most days even if I could watch TV or play video games instead.
4. I can be physically active during my free time on most days even if it is very hot or cold outside.
5. I can ask my best friend to be physically active with me during my free time on most days.
6. I can by physically active during my free time on most days even if I have to stay at home.
7. I have the coordination I need to be physically active during my free time on most days.
8. I can be physically active during my free time on most days no matter how busy my day is.

Appendix D
Social Support for Exercise (SESS)

Below is a list of things people might do or say to someone who is trying to exercise regularly. If you are not trying to exercise, then some of the questions may not apply to you, but please read and give an answer to every question. Please rate each question twice. Rate how often your friends, acquaintances, or coworkers have said or did what is described during the day today. Please rate how many times this happened to you today:

Today one of my friends, acquaintances, or coworkers:

Not at all   Once   Twice   Three times   Four or more times

1. Today one of my friends exercised with me.
2. Today one of my friends offered to exercise with me.
3. Today one of my friends gave me helpful reminders to exercise ("are you going to exercise tonight?").
4. Today one of my friends gave me encouragement to stick with my exercise program.
5. Today one of my friends changed their schedule so we could exercise together.
6. Today one of my friends discussed exercise with me.
7. Today one of my friends complained about the time I spend exercising.
8. Today one of my friends criticized me or made fun of me for exercising.
9. Today one of my friends gave me rewards for exercising (bought me something or gave me something I like).
10. Today one of my friends planned for exercise on recreational outings.
11. Today one of my friends helped plan activities around my exercise.
12. Today one of my friends asked me for ideas on how they can get more exercise.
13. Today one of my friends talked about how much they like to exercise.

14. Today one of my family members exercised with me.
15. Today one of my family members offered to exercise with me.
16. Today one of my family members gave me helpful reminders to exercise ("are you going to exercise tonight?").
17. Today one of my family members gave me encouragement to stick with my exercise program.
18. Today one of my family members changed their schedule so we could exercise together.
19. Today one of my family members discussed exercise with me.
20. Today one of my family members complained about the time I spend exercising.
21. Today one of my family members criticized me or made fun of me for exercising.
22. Today one of my family members gave me rewards for exercising (bought me something or gave me something I like).
23. Today one of my family members planned for exercise on recreational outings.
24. Today one of my family members helped plan activities around my exercise.
25. Today one of my family members asked me for ideas on how they can get more exercise.
26. Today one of my family members talked about how much they like to exercise.

Appendix E
Treatment Self-Regulation Questionnaire for Exercise (TRSQ)

The following question relates to the reasons why you would either start to exercise regularly or continue to do so. Different people have different reasons for doing that, and we want to know how true each of the following reasons is for you. All 15 response are to the one question. Please indicate the extent to which each reason is true for you, using the following 7-point scale:

1	2	3	4	5	6	7
Not at all true			Somewhat true			Very true

The reason I would exercise regularly is:

1. Because I feel that I want to take responsibility for my own health.
2. Because I would feel guilty or ashamed of myself if I did not exercise regularly.
3. Because I personally believe it is the best thing for my health.
4. Because others would be upset with me if I did not.
5. I really don't think about it.
6. Because I have carefully thought about it and believe it is very important for many aspects of my life.
7. Because I would feel bad about myself if I did not exercise regularly.
8. Because it is an important choice I really want to make.
9. Because I feel pressure from others to do so.
10. Because it is easier to do what I am told than think about it.
11. Because it is consistent with my life goals.
12. Because I want others to approve of me.
13. Because it is very important for being as healthy as possible.
14. Because I want others to see I can do it.
15. I don't really know why.