Examining Daily Associations of Nature Exposure, Body Appreciation, and Physical Activity Among Adolescents

by

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DISSERTATION ABSTRACT

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Title: Examining Daily Associations of Nature Exposure, Body Appreciation, and Physical Activity Among Adolescents

Substantial evidence supports engaging in moderate-to-vigorous intensity physical activity (MVPA) for myriad health benefits, yet most adolescents are not active enough to maximize the benefits. Especially among girls, adolescence is marked by reductions in MVPA and body appreciation, both linked to poor physical and mental and health outcomes. There are mixed findings on how nature exposure (NE) is related to MVPA and body appreciation. Most of these NE studies were conducted among adults and all have measured NE by self-report or objective proxies (e.g., quantity of vegetation in an area), which are vulnerable to bias and inaccuracy. Objectives of the current study among adolescents were to determine 1) the daily associations among MVPA, body appreciation, and NE using an innovative mobile application that measures objective individual-level indicators of time spent in nature, 2) whether and how gender moderates these associations, and 3) if body appreciation indirectly affects the relationship between NE and MVPA.

In summer 2023, a community sample of Oregon adolescents participated in a prospective 7-day study. Participants wore ActiGraph GT3X+ accelerometers to measure MVPA, enabled the phone application "NatureDose™" to measure NE, and answered the short form 3-item Body Appreciation Scale-2 daily. Adjusting for covariates, multilevel linear regressions and moderation analyses, and indirect pathway analyses were conducted. Participants (N = 209; M = 14.39 y/o ± 1.66; 50.23% cisgender girls; 80.19% White) were highly active (M = 281.9 ± 18.54 MVPA min/day), exposed to nature (M = 95.2 ± 66.6 min/day), and reported moderately high body appreciation (M = 3.99 ± 0.06 per day). Daily NE, not body appreciation, was significantly and positively associated with daily MVPA ($\gamma_{10} = 10.26$, $p < .001$). Gender did not moderate the daily associations. Body appreciation did not indirectly affect the relationship between NE and MVPA. This is the first study among adolescents to use an objective, individual-level measure of NE and confirm the previously identified positive link between NE and MVPA in this age group.

Replication in more diverse adolescent samples is a next step. Findings support interventions that integrate nature and MVPA to promote adolescent health.

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DEDICATION

I dedicate this dissertation to my dad. You have always been my number one fan.
Thank you for your infinite love and support.

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CHAPTER I

INTRODUCTION

Physical inactivity has now been a global issue for decades, with increased industrialization and technological advances reducing opportunities to be active (Woessner et al., 2021). Conversely, there has been a rise in the rates of chronic health conditions related to physical inactivity, such as coronary heart disease, type II diabetes, and certain cancers (Brawner et al., 2016). While historically less prevalent among youth (i.e., 12 – 19 years), chronic health conditions have risen over the last few decades, such as hypertension, type II diabetes, and elevated abnormal blood lipid levels (Anderson & Durstine, 2019).

Physical activity is an essential component of health that influences various aspects of human well-being. In addition to improvements in physical health, including cardiorespiratory and muscular fitness and bone health (Piercy et al., 2018), physical activity is also associated with better academic outcomes (Singh et al., 2012), sleep (Lang et al., 2013), cognitive function (Donnelly et al., 2016), self-esteem (Dale et al., 2019), and mood symptoms (Ahn & Fedewa, 2011; Dale et al., 2019). The US national guidelines recommend youth (ages 6 – 17) spend at least 60 minutes a day in moderate-intensity physical activity and include vigorous-intensity physical activity on at least three days a week (Piercy et al., 2018). Muscle- and bone-strengthening activities should be incorporated as part of the 60 minutes of daily physical activity on at least three days a week (Piercy et al., 2018).

Physical Activity among Youth

Most youth aged 6 – 17 years old (80 %) do not engage in the recommended physical activity (Piercy et al., 2018) and participation tends to decrease as youth get older (Katzmarzyk et al., 2017). For example, objectively measured physical activity using accelerometers have shown that less youth meet the recommended physical activity guidelines with increasing age, 42% for 6-11-year-olds, 8% for 12-15-year-olds, and 7.6% for 16-19-year-olds (Troiano et al., 2008). Additionally, about 17% of youth are not physically active for at least 60 minutes on any single day of the week (Centers for Disease Control and Prevention, 2020). Given these trends of drastic declines in physical activity during adolescence (i.e., beginning about 12 years of age; Troiano et al., 2008), there is urgency to establish effective strategies for increasing physical activity as engagement levels in adolescence tend to predict physical activity levels in adulthood

(Telama et al., 2005). Additionally, just one physical activity session can provide health benefits such as improved sleep and insulin sensitivity, reduced blood pressure, and increased positive state affect on the day of the activity (Liao et al., 2015; Piercy et al., 2018). This is promising and supports the idea that even if youth do not reach the recommended activity guidelines, participating in some physical activity can still produce considerable health benefits.

Gender Disparities in Physical Activity

In addition to general declines in physical activity as youth age throughout adolescence (i.e., 12 – 17 years of age), there are also disparities based on demographic characteristics of adolescents, such as gender. Adolescent girls have 59% lesser odds of achieving the current physical activity guidelines compared to adolescent boys (Belcher et al., 2010). On average, adolescent girls spend 44.4 minutes a day in moderate-to-vigorous intensity physical activity (MVPA) compared to 63.8 minutes a day in MVPA for boys (Belcher et al., 2010). It has been observed that girls experience a greater percent decline per year of MVPA (-5.3%) than boys (-3.5%; Farooq et al., 2020). Numerous investigations have explored the potential factors that reduce girls' participation in physical activity. For example, adolescent girls report significantly greater barriers to participating in physical activity, including body image concerns (e.g., reduced physical activity with greater body dissatisfaction; Finne et al., 2011), social anxiety, more obligations, less free time, lower perceived competence, less support from family and peers, and more safety concerns of neighborhood environment compared to adolescent boys (Duffey et al., 2021; Portela-Pino et al., 2020). While there have been substantial efforts to address physical activity disparities and overall physical activity engagement among adolescents and girls specifically (Kriemler et al., 2011; Pearson et al., 2015), these have not been enough as the gender disparity and low rates of physical activity across genders persist. Thus, there is a need to conduct research into *innovative* mechanisms that may enhance physical activity and physical activity opportunities for adolescents.

Nature Exposure

The biophilia hypothesis explains that human beings have an inherent inclination to be around nature, such as plants and trees (Wilson, 1986). Previous literature has considered nature exposure to include the built and natural environment, such as residential green space, school green space, gardens, and the wilderness (Fyfe-Johnson et al., 2021). An umbrella review across

age groups found green space exposure was associated with various health outcomes and behaviors, including reduced physiologic and perceived stress levels, improved sleep quality, and more frequent physical activity (Yang et al., 2021). There has been a great focus on research for active living, such as how outdoor and community recreation can enhance physical activity. The role that these types of recreation have, where individuals are outside, facilitates "physical activity by choice" and encourages certain behaviors (e.g., walking, bike riding; Henderson & Bialeschki, 2005). Most of the studies exploring the benefits of physical activity in pediatric samples (ages 3 – 19 years) are cross-sectional and focus on younger children (< 12 years old), with limited investigations among adolescents. These studies among younger children identified more time in nature to be associated with positive outcomes, such as greater MVPA during the day and improved cognitive functioning (Fyfe-Johnson et al., 2021).

There are inconsistent findings for the associations between nature exposure and physical activity among adolescents. Objective and perceived access and availability to parks and recreational facilities has (Cohen et al., 2006; Prins et al., 2009) and has not (Prins et al., 2011; Reis et al., 2009) been significantly associated with physical activity. Home gardening (van Lier et al., 2017) has shown to be positively associated with physical activity. Yet, access to a school garden program (Utter et al., 2016) was not associated with physical activity. Distance to urban green space from the home has (Queralt & Molina-García, 2019) and has not (Bringolf-Isler et al., 2014) been associated with MVPA among adolescents. Additionally, greater distance from urban green spaces (e.g., parks and greenways) was associated with lower frequency of physical activity (Akpınar & Cankurt, 2016) and reduced activity in natural environments (Akpınar, 2019). However, greater distance was not associated with changes in leisure-time physical activity throughout adolescence (Magalhães et al., 2017) or with frequency and duration of physical activity during the spring time (Akpinar, 2017). Certain green space characteristics (e.g., grass and trees) were positively associated with frequency, but not duration, of exercise in green settings (Akpınar, 2019), but were not associated with total physical activity (Markevych et al., 2016), boys' MVPA after school, or weekend MVPA for adolescents (Timperio et al., 2008). Green space coverage was positively associated with increased odds for adolescents to engage in MVPA and with adolescent girls' exercise participation (Boone-Heinonen et al., 2010), but was only associated with increased odds of outdoor activity during the winter and not

summer season (Poulain et al., 2020). In a German city, a greater quantity of vegetation in the area was positively associated with adolescent girls' MVPA while it was negatively associated with adolescent boys' MVPA (Markevych et al., 2016). Moreover in another German city, a greater quantity of vegetation in the area was not associated with MVPA among all adolescents (Markevych et al., 2016).

Measurement Concerns

The inconsistent findings regarding the link between nature exposure and physical activity among adolescents may be attributed, in part, to the various ways of measuring these variables and their operational definitions. Studies have most commonly assessed nature exposure using self-report measures of perceived greenery use, perceived parks and sports facilities in environment, and proximity to parks (Gubbels et al., 2016; Prins et al., 2009; Reis et al., 2009; Utter et al., 2016). More recently, studies have utilized objective measures of nature exposure to reduce bias associated with self-report (Lackey & Kaczynski, 2009), but these objective measures have their own inaccuracies. Specifically, they measure nature exposure at a higher aggregate level (e.g., geographical regions of greenspace and vegetation) rather than at the individual level. These measures are a proxy for time spent in nature and speak more to adolescents' opportunity to be in nature. At this point, no studies have objectively assessed nature exposure at the individual level among adolescents. There has been a recent call from reviews for the advanced assessments of nature exposure as well as examining the duration of nature exposure on health outcomes (Jimenez et al., 2021; Yang et al., 2021). Objectively measuring nature exposure at the individual level has the potential to clarify the highly inconsistent literature on the link between nature exposure and physical activity among adolescents as it would address most of the inaccuracies and biases associated with previous measurement strategies.

Similarly, most studies assessing nature exposure and physical activity have used self-report measures for physical activity (Akpinar, 2017; Akpınar, 2019; Boone-Heinonen et al., 2010; Gubbels et al., 2016; Magalhães et al., 2017; Prins et al., 2009; Ries et al., 2009; Utter et al., 2016; van Lier et al., 2017). Fewer studies have used objective measures, like accelerometers, which address self-report bias (Slootmaker et al., 2009). Those that have (Cohen et al., 2006; Prins et al., 2011; Queralt & Molina-Garcia, 2019; Bringolf et al., 2014; Markevych

et al., 2016; Timperio et al., 2008) have provided mixed results for the relationship between nature exposure and physical activity among adolescents. Objective, individual-level data on both nature exposure and physical activity would be ideal to provide valid and reliable data on the associations between these variables among adolescents.

Applying a Theoretical Lens

Mechanistic pathways between the environment, such as nature, and physical activity among adolescents are understudied (Jimenez et al., 2021). Despite theory's ability to guide this research, a recent review of studies among youth highlighted that the use of conceptual models or theories guiding investigations between the environment and physical activity have been scarce (Fyfe-Johnson et al., 2021). Investigating environmental factors, such as time in nature, that can then be leveraged to promote healthy behaviors should be prioritized, particularly as environmental interventions, rather than simply individual-level interventions, can be more effective for health behavior change at the individual and population level (Brown et al., 2019). The Environmental Research framework for weight Gain prevention (EnRG framework; Figure 1) may provide insight regarding if and how nature exposure and physical activity among adolescents are linked (Kremers et al., 2006). While this framework mentions weight in its title, the framework does not include body size as a contributing factor or outcome. Focusing on the promotion of healthy behaviors (e.g., physical activity) rather than weight loss (i.e., a performance goal one has limited control over) is associated with increased self-efficacy and knowledge (Bailey, 2019), which can help facilitate engagement in healthy behaviors. The EnRG framework postulates that health behaviors (misnomered as "energy-balance" behaviors in the framework), such as physical activity and various dietary behaviors, are both directly and indirectly influenced by the environment (Kremers et al., 2006). Additionally, demographic characteristics may moderate the environmental influences on these health behaviors.

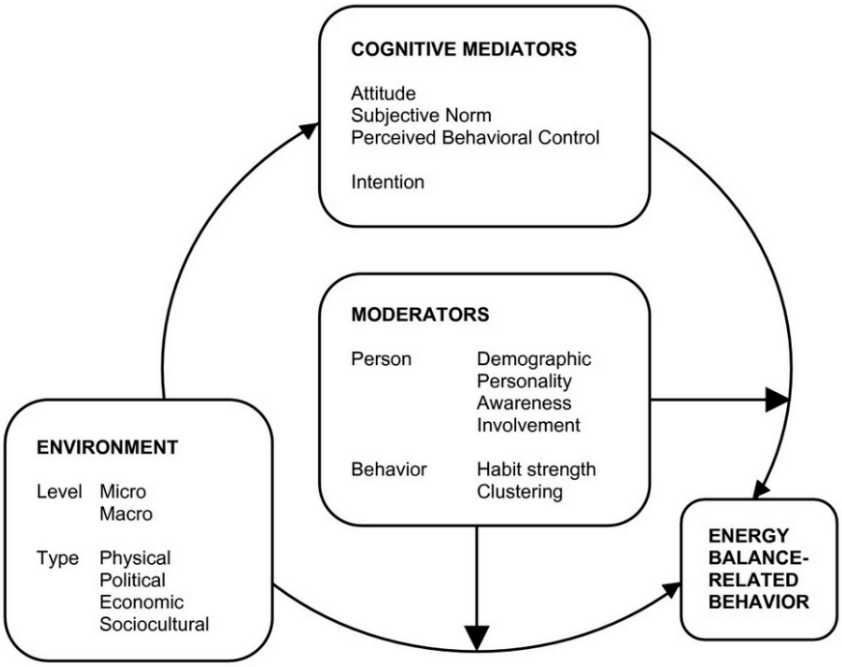


Figure 1. The Environmental Research framework for weight Gain prevention (EnRG)

A dual-process model, the EnRG framework was established through an inductive process, having integrated previous scholarly work of the ANGELO framework (Swinburn et al., 1999) and the Theory of Planned Behavior (Ajzen, 1985). With the use of this framework, the direct effects of environmental factors, like nature exposure, and indirect effects of cognitive factors guide investigations of how these variables interact to explain behavior. While the Theory of Planned Behavior is specific to attitudes, subjective norms, and perceived behavioral control for understanding intention, additional cognitive factors may provide support for physical activity behavior (Lewis et al., 2002). For example, some previous work indicates body appreciation is positively associated with intrinsic motivation for physical activity among college women (Cox et al., 2019).

Body Image and Body Appreciation

Adolescence, about 10 – 19 years of age, is a time when youth experience rapid physical and psychological developments (World Health Organization, n.d.). It is a critical developmental phase that may influence short- and long-term physical and psychological health. Like the declines seen in physical activity, previous literature identifies early adolescence as a phase

associated with increasing value of peer influences and worsening body image, such as being dissatisfied with one's body, and reduced feelings of esteem toward one's appearance (Bucchianeri et al., 2013; Frisén et al., 2015). Among adolescent girls, negative peer influences (e.g., being teased about one's weight, having friends with more negative views of their own appearance) and familial influences (e.g., mothers talking negatively about their own bodies) were associated with more negative body image (Littleton & Ollendick, 2003; Walters et al., 2020). The association between peer influences and negative body image has been similarly observed among men that retrospectively reported on their body image during adolescence (Gattario & Frisén, 2019). Negative body image is linked to poor health outcomes, such as increased inflammation biomarkers (Černelič-Bizjak & Jenko-Pražnikar, 2014), internalizing symptoms like anxiety and depression (Ramos et al., 2019), and development of an eating disorder (Prnjak et al., 2021).

Positive body image (e.g., body appreciation, body acceptance and love, adaptive investment in appearance, interpretation of information in a body-protective way), provides salutogenic effects (Avalos et al., 2005; Tylka & Wood-Barcalow, 2015a, 2015b) including higher psychological well-being (Dotse & Asumeng, 2015; Gillen, 2015) and reduced depression (Gillen, 2015) and disordered eating (Jankauskiene et al., 2020). *Body appreciation*, a component of body image, is defined as holding favorable views toward, accepting, and respecting one's body while rejecting the unrealistic thin-ideal portrayed by media (Avalos et al., 2005). Among adolescents, body appreciation has been positively correlated with psychological well-being, intuitive eating (Lemoine et al., 2018), self-esteem, and adaptive coping with problems and emotions (Jáuregui Lobera & Bolaños Ríos, 2011), and inversely correlated with perceived stress and social withdrawal (Jáuregui Lobera & Bolaños Ríos, 2011). And these associations are robust— increases in body appreciation were associated with greater mental well-being in adolescents one year later (Urke et al., 2021). Adolescent girls with higher body appreciation were also less likely to begin dieting and using alcohol and cigarettes one year later than adolescent girls with lower body appreciation (Andrew et al., 2016).

Gender Differences in Body Appreciation

Similar to the gender disparities seen with physical activity, there are differences observed for body appreciation by gender, such that boys report higher body appreciation than

girls (He et al., 2020). The largest gender differences in body appreciation have been identified among adolescent samples (He et al., 2020). As girls generally experience the onset of puberty at an earlier age than boys, the marked increases in adipose tissue during this time is related to reduced physical self-worth among girls (Lubans & Cliff, 2011). In US culture, sexualized objectification of girls, their bodies, and how they "should look", can further exacerbate the reported gender differences in body appreciation seen within this age group as girls try to fit within cultural norms (American Psychological Association, 2008).

Body Appreciation and Physical Activity

The link between body appreciation and physical activity among adolescents has been documented by only two studies. In one prospective study, adolescent girls with greater body appreciation were more likely to increase their physical activity and sports participation (self-reported) one year later than girls with lower body appreciation (Andrew et al., 2016). In a study (N = 30) that interviewed adolescents with a high level of body satisfaction, a construct similar to body appreciation, almost all adolescents were highly active with a functional view of the body (e.g., being active to improve their body's capabilities) (Frisén & Holmqvist, 2010). The association between body appreciation and physical activity among adolescents, specifically objectively measured MVPA, has not been studied. Body appreciation and physical activity may be related to each other as a more appreciative view of one's body and its abilities (e.g., functional vs appearance) may lead adolescents to want to improve those abilities and take care of their bodies (Frisen & Holmqvist, 2010). A better understanding of these links during pivotal developmental adolescent years could inform novel strategies aimed at increasing adolescents' health and well-being. Literature has called for the investigation of body appreciation as a potential moderator or mediator for well-being (Linardon et al., 2022) and how it may interact with environmental factors, such as nature exposure, to potentially promote physical activity among adolescents is unknown. With some support for the positive associations between nature exposure and physical activity (Fyfe-Johnson et al., 2021), and between body appreciation and physical activity (Andrew et al., 2016), further investigating these links holds promise for informing novel interventions for adolescents' health and well-being. Furthermore, how these relationships may vary by gender also remains a question.

Body Appreciation and Nature Exposure

As previously stated, the EnRG framework supports cognitive factors as having an indirect role between the environment and health behaviors. The Psychophysiological Stress Recovery Theory (Ulrich, 1983) has guided initial work between the natural environment and cognitive factors. It postulates that exposure to natural environments results in a restorative state, both psychological and physiological, by inducing feelings of calm and positive emotions to enhance recovery from negative emotions such as stress. Indeed, a review of interventions that took place outdoors in natural green environments (e.g., urban green spaces and parks, forests, mountains) identified beneficial pre-to-post intervention emotional changes (e.g., stress) among adults (Corazon et al., 2019). Additionally, nature exposure has been positively associated with self-esteem among children (Maller, 2009). Among adults, self-esteem mediated the positive association between nature exposure and body appreciation (Swami et al., 2016).

Nature exposure may shift awareness to eudaemonic views of well-being (e.g., feeling more connected to the larger ecosystem), instead of hedonistic views (e.g., focusing on one's appearance; Swami et al., 2016). Connectedness to nature has also been shown to mediate the positive association between nature exposure and body appreciation (Swami et al., 2016). Further experimental work has reported increases in positive body image indices, such as body appreciation, regardless of whether nature exposure was real or on films and photographs (Swami, Barron, et al., 2018; Swami, Pickering, et al., 2018). Increases in body appreciation after exposure to naturalist environments has been observed in various countries and cultures as well (Swami et al., 2020). Thus, naturalistic environments may play a role in enhancing individuals' psychological well-being (e.g., body appreciation) and, subsequently, support their engagement in healthy behaviors, including physical activity.

The Present Study

Using a prospective study design and guided by theory, this study is the first to investigate the daily direct and indirect associations among nature exposure, body appreciation, and MVPA using objective, continuous individual-level measures of nature exposure and physical activity among adolescents, aged 12 – 17 years old. Adolescence is a period characterized by declines in physical activity and body image, and empirical evidence from this

study can inform future interventions for reversing these declines and improving health and well-being among adolescents. Study research questions and hypotheses follow:

Research Questions and Hypotheses

1. What are the daily associations among nature exposure, body appreciation, and MVPA (Figure 2)?

Based on previous studies among adolescents (Queralt & Molina-García, 2019; van Lier et al., 2017), it was hypothesized that nature exposure would be positively associated with MVPA (hypothesis 1a; H1a) and with body appreciation (H1b; Kremers et al., 2006; Swami et al., 2016; Ulrich, 1983); and it was hypothesized that body appreciation would be positively associated with MVPA (H1c; Andrew et al., 2016). Covariates included were age, gender, race and ethnicity, body mass index (BMI) percentile, receipt of free or reduced-price lunch, physical disability status, seasonal allergies, connectedness to nature, and self-esteem (Belcher et al., 2010; Bucchianeri et al., 2013; Carlon et al., 2013; Fyfe-Johnson et al., 2021; Gubbels et al., 2016; Hanson & Chen, 2007; Swami et al., 2016).

2. Does gender moderate the hypothesized daily associations among nature exposure, body appreciation, and MVPA (Figure 2)?

It was hypothesized that gender would moderate the hypothesized associations between nature exposure and MVPA (H2a; Belcher et al., 2010), nature exposure and body appreciation (H2b; He et al., 2020); and body appreciation and MVPA (H2c; Belcher et al., 2010; He et al., 2020). Specifically, the hypothesized moderated associations would be stronger among adolescent boys than girls (Belcher et al., 2010; He et al., 2020). Unfortunately, the dataset did not have enough adolescents who identified as non-binary or another gender to include additional gender categories in the analyses. Covariates included were age, race and ethnicity, BMI percentile, receipt of free or reduced-price lunch, physical disability status, seasonal allergies, connectedness to nature, and self-esteem (Belcher et al., 2010; Bucchianeri et al., 2013; Carlon et al., 2013; Fyfe-Johnson et al., 2021; Gubbels et al., 2016; Hanson & Chen, 2007; Swami et al., 2016).

3. Does body appreciation indirectly affect the association between nature exposure and MVPA (Figure 2)?

It was hypothesized that body appreciation would indirectly affect the association between nature exposure and MVPA (H3; Kremers et al., 2006), such that higher nature exposure will be associated with greater body appreciation and greater body appreciation then will be associated with greater MVPA. Covariates included were age, gender, race and ethnicity, BMI percentile, receipt of free or reduced-price lunch, physical disability status, seasonal allergies, connectedness to nature, and self-esteem (Belcher et al., 2010; Bucchianeri et al., 2013; Carlon et al., 2013; Fyfe-Johnson et al., 2021; Gubbels et al., 2016; Hanson & Chen, 2007; Swami et al., 2016).

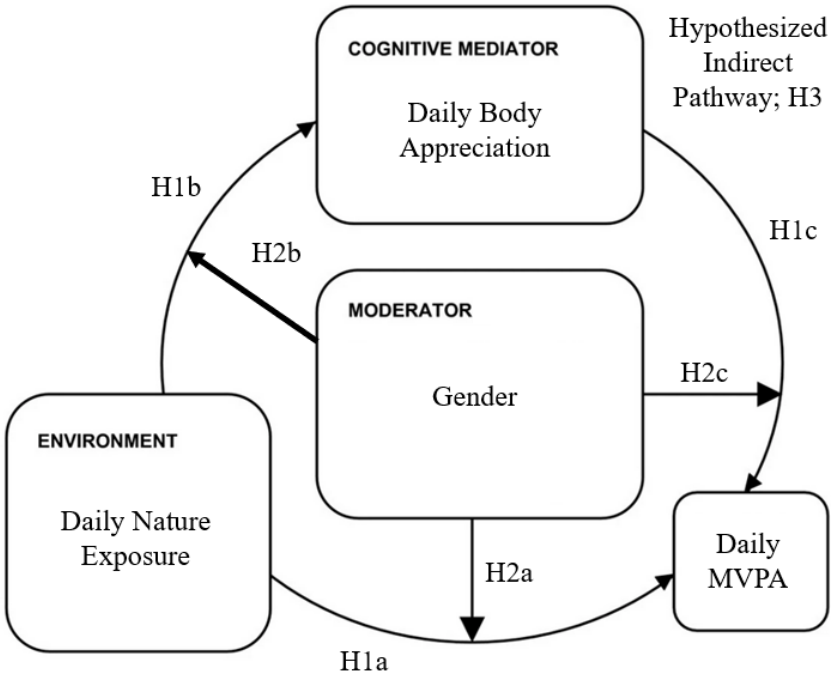


Figure 2. Conceptual Model for Research Questions

CHAPTER II
METHODS

The data presented in this manuscript come from a prospective study among adolescents conducted in the greater geographical area of Eugene/Springfield, Oregon. Data were collected between May and October of 2023. Funding for initial startup of the project was provided by an Innovation Fund from the University of Oregon's Office of the Vice President for Research and Innovation. Funding for the project in 2023 came from the University of Oregon's Sport and Wellness Initiative. The University of Oregon's Institutional Review Board approved all study protocols.

Study Procedure

Recruitment

Various strategies were performed to recruit adolescents for the study. Postcards with brief study details (e.g., study activities, eligibility, contact information of research team) were created and mailed to households within the greater Eugene/Springfield geographic area who had at least one adolescent (between 12 – 17 years old). Recruitment flyers were created and distributed via email, Facebook, and in-person to staff of community-based organizations that serve adolescents. Staff were asked to share the flyer with adolescents (e.g., youth desk at a public library, a summer youth program, a youth sports organization, a pediatrician). Additionally, adolescents were recruited via word of mouth by research staff, parents, and adolescent participants. When adolescents were asked if they wanted to participate in the study, research staff would state that participation would involve filling out surveys, downloading a phone app that tracks nature exposure, and wearing a device on the wrist that tracks movement for a week.

Informed Consent and Assent

Adolescents interested in the study had their parent or guardian (from here referred to as parent) scan a QR code on the study postcard or flyer. Individuals could also reach out with interest via email, phone call, or text message. Scanning the study QR code led parents to an online Qualtrics survey that the research team used to screen for eligibility. Those who emailed, called, or texted with interest were screened by a research staff through that communication channel. Eligible adolescents were 1) between 12 – 17 years old, 2) had a smartphone, and 3)

were able to read and understand English at a 5th grade level. The research team would contact the parent to schedule the study visits after a screening survey was completed.

Parents were given the opportunity to complete the informed consent form prior to the first study visit. Parents were sent a Qualtrics link to the informed consent document via email or text message. The document was also attached in the email with the study's description. The requirement for written consent was waived. Instead, to acknowledge informed consent, parents would type their name and select a radio button that said, "I consent to have my teen participate in this study". Those who chose to complete the informed consent form at the first study visit did so via an iPad provided by the research team. At the first study visit, a research team member discussed the contents of the forms with the parent and adolescent (from here referred to as participant), allowed them time to read them on their own, and answered any additional questions that arose. Participants provided informed assent to participate in the study by typing their name and selecting a radio button that said, "I agree to participate in this study".

Visit One (Day 0)

An overview of study activities is illustrated in Figure 3. Once consent and assent were obtained, participants completed a one-time survey online through Qualtrics on their own via an iPad provided by the research team (Day 0). Participants were allowed to skip any question they did not want to answer, and a research team member answered any questions they had during the survey (e.g., what a word meant). The survey consisted of 99 questions that assessed different demographic characteristics and psychosocial constructs (e.g., body appreciation, connectedness to nature, self-esteem).

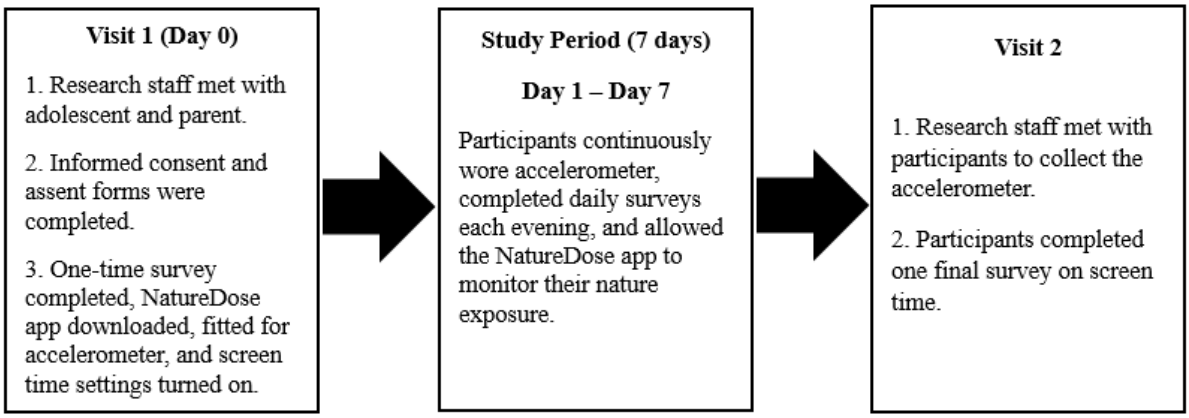


Figure 3. Overview of Study Activities

Participants then installed the free application "NatureDose™" onto their phone. The research team reviewed the installation process with them, helped the participant create an account, and ensured that location permissions were enabled to collect nature exposure continuously throughout the study period. Participants were instructed to keep their phone near them throughout the study period. There were no other required interactions needed with the application for the study. During this visit, participants were also fitted with an accelerometer. They were asked to wear the accelerometer on their non-dominant wrist for 24 hours a day across the seven-day study period, only removing it for any swimming activities. This allowed the device to continuously collect frequency, duration, and intensity of physical activity across the study period. The second study visit was scheduled for eight days later. This allowed data to be collected over seven full days, including weekdays and weekend days, with these seven days (Day 1 – Day 7) consisting of the study period.

Study Period (Day 1 – Day 7)

Participants were instructed to go about their days during the study period as they normally would. Each evening (i.e., between 5pm and 7:30pm) during the study (a total of seven days), a research team member would message participants a personalized link to complete a brief, online survey (about five minutes) through Qualtrics. The daily survey assessed body appreciation during the day. Survey links expired at the end of the day (11:59pm PDT) to ensure participants answered questions on body appreciation for that specific day. Additionally, to ensure participants were wearing the accelerometer and did not have any concerns about it during the study, a text message was sent to participants two days after their first visit to remind them to continuously wear the accelerometer and to contact the research team if they had any questions about it.

Visit Two

At the second study visit, participants returned the accelerometer and a research team member downloaded the data using the ActiLife software. This data set provided information about the percentage of time the participant wore their accelerometer during the study, and compensation varied accordingly. Participants received a $30 Visa gift card for completing the one-time survey, being fitted for an accelerometer, and downloading the free smartphone app. Participants received $20 for completing at least five of the seven daily surveys and another $20

for returning the accelerometer after their seven-day study period. Finally, participants received an additional $30 if they wore the accelerometer at least 70% of their study period.

Measures

Physical Activity

Daily MVPA (i.e., total minutes of moderate- and vigorous-intensity physical activity each day; research questions 1 – 2), was objectively measured using ActiGraph GT3X+ accelerometers. Sensors on these triaxial accelerometers convert acceleration intensity (bodily movement) into counts. Counts are then summed over a specified period (referred to as epochs) and converted to number of minutes per day that the participant spent sedentary and in various levels of physical activity intensity (i.e., light, moderate, and vigorous). Participants continuously wore the accelerometer throughout the study on their non-dominant wrist. ActiGraph GT3X+ accelerometers worn on the wrist (like a watch) offer valid estimates of MVPA based on studies among adolescents (Crouter et al., 2015). Accelerometers were initialized using the ActiLife software with participant self-report of adolescent height and weight, sex, date of birth, and non-dominant wrist. Accelerometry data were collected at 60 second epochs and 100 Hz throughout the study period (Day 1 – Day 7) to obtain seven full days of accelerometry data. At the second study visit, accelerometers were downloaded with ActiLife software version 6. Wear-time was validated using the Choi Wear Time validation algorithm (Choi et al., 2011). This algorithm includes the use of zero-count thresholds for non-wear time intervals, a time window of 90 minutes for consecutive zero and non-zero counts, and a 2-minute allowance interval of non-zero counts during a 30-minute consecutive zero count window for artificial movement (Choi et al., 2011). There are no current cut points to classify physical activity intensity among the 12 – 17 age range exactly, so cut points were taken from previous work by Crouter et al. (2015) among 8 – 15 year-olds. With the raw accelerometry data files for each participant, the ActiGraph files were transformed to five second epochs to use this method. While Crouter et al. (2015) used the dominant wrist for accelerometers, a recent review identified only small differences for cut points calibrated for non-dominant and dominant wrists (Clanchy et al., 2023). To use MVPA for the third research question, the daily MVPA minutes were summed for each participant and divided by the number of days they had any valid data (i.e., sum divided by seven if participants

had data for every study day, sum divided by five if participants had data for five study days only). This created a single MVPA score for each participant.

Nature Exposure

For daily nature exposure (i.e., total minutes of time in nature each day; research questions 1 – 2), the NatureDose™ phone application was used. It was downloaded onto participants' smartphones to objectively assess participant nature exposure, specifically the minutes of nature exposure each day over the seven-day study period (Day 1 – Day 7). NatureDose™ was created by NatureQuant, LLC (NatureQuant, 2023) and assesses time spent indoors, outdoors, and exposure to nature (Browning et al., 2024; NatureQuant, 2023). NatureDose™ runs in the background and uses phone location services to calculate relative exposure to natural elements with a patent-pending algorithm. Within a given one-kilometer radius, NatureQuant analyzes various datasets and process information (e.g., geographic information system, satellite infrared measurements, tree canopies, park data and features) to determine nature exposure. NatureDose™ has previously been found to be a feasible monitoring tool for nature exposure (Vermeesch et al., 2022) and validated against the Normalized Difference Vegetation Index, a quantitative measure of vegetation (Klompmaker et al., 2023). To use nature exposure in the third research question, the daily minutes of nature exposure were summed for each participant and divided by the number of days they had any data (i.e., sum divided by seven if participants had data for every study day, sum divided by five if participants had data for five study days only). This created a single nature exposure score for each participant.

Body Appreciation

For daily body appreciation (i.e., total body appreciation score for each day; research questions 1 – 2), participants completed the short form 3-item Body Appreciation Scale-2 (3-item BAS-2SF) via daily electronic surveys. This abbreviated form was created to reduce participant burden and survey costs, as well as allow researchers to assess body appreciation in more study designs (e.g., longitudinal studies, ecological momentary assessments). The 3-item BAS-2SF consists of the three items, *"I respect my body"*, *"I feel love for my body"*, and *"I appreciate the different and unique characteristics of my body"*. Items are scored on a 5-point Likert scale from 1 (*Never*) to 5 (*Always*), summed, and averaged for a total daily score. This

short form measure is highly correlated with the long form BAS-2 and has shown internal consistency, a unidimensional factor structure, construct validity, and gender invariance (Tylka et al., 2022). Cronbach's alphas were .85 for all participants, .83 for cisgender boys, and .87 for cisgender girls. For body appreciation in the third research question, the daily scores were summed for each participant and divided by the number of days they had data (i.e., sum divided by seven if participants had data for every study day, sum divided by five if participants had data for five study days only). This created a single body appreciation score for each participant.

Covariates

Demographic characteristics that served as covariates include age, gender, race and ethnicity, BMI percentile, receipt of free or reduced-price school lunch (a proxy for socioeconomic status; *"Yes", "No",* and *"Not sure"*), physical disability status ("*Yes, please describe*", "*No*", and "*I prefer not to answer*"), and seasonal allergies ("*Yes, often*", "*Yes, sometimes*", "*No*", and "*Not sure*". A one-time survey was conducted during the first visit to gather demographic information about the participants. Appendix A shows further details on survey questions and responses, including for covariates. The Centers for Disease Control and Prevention (2023) child and teen BMI calculator was used to calculate BMI percentile from self-report height and weight during the accelerometer initialization. Gender served as a hypothesized moderator in the second research question.

The Connectedness to Nature Scale (Mayer & Frantz, 2004) assesses an individual's emotional and experiential response to nature, specifically, how much an individual feels a sense of community, equality, kinship, embeddedness, and belongingness to nature. Participants rated the ten statements on a Likert-type scale with seven options, from *Strongly disagree* (1) to *Strongly agree* (7). For an overall score, negatively worded items were first reversed, items were summed, and then averaged. Higher scores indicate a greater level of connection to nature. The scale has been validated in youth as young as ten years old (Mayer & Frantz, 2004). Cronbach's alphas were .86 for all participants, .82 for cisgender boys, and .86 for cisgender girls.

The Rosenburg Self-Esteem Scale (Rosenberg, 1979) is a 10-item measure that was included in the one-time survey to assess participant self-esteem. Participants rated the ten statements (e.g., "*I feel that I have a number of good qualities"*) on a scale from *Strongly agree* (1) to *Strongly disagree* (4). To obtain an overall score, negatively worded items were first

reversed to then sum all items. Higher scores indicate a greater level of self-esteem. This measure was originally intended for adolescents and its items have demonstrated strong estimated internal consistency ($\alpha = .92$) and validity (Rosenberg, 1979). Cronbach's alphas were .90 for all participants, .87 for cisgender boys, and .90 for cisgender girls.

Statistical Analysis

All analyses were conducted in RStudio Version 4.2.2 (R Core Team, 2013). A significance level at $p < .05$ was used to determine significance for all analyses. Descriptive statistics were performed on key study variables and for demographic variables. Patterns of missing data were investigated using Little's Missing Completely at Random (MCAR) Test (Little, 1988). Multiple imputation was used in each model as it is an appropriate statistical treatment for moderate missing data (< 25% missing; Buhi et al., 2008).

Research Question 1 – Multilevel Regressions Analyses

To assess the daily associations among nature exposure, body appreciation, and MVPA, multilevel linear regressions were estimated with the lme4 package (Bates et al., 2015). Level one variables consisted of the time-varying repeated measures of nature exposure, body appreciation, and MVPA, included as random effects. These were nested within individual participants (i.e., level two) which consisted of the time-invariant measures of covariates, included as fixed effects. As the covariates are level two variables, they will represent between-person findings, indicating differences between participants. The time-repeated measures, level one variables, will represent within-person findings, indicating differences at the individual-level, from day to day of the study period. A total of three separate multilevel linear regression models were conducted to assess the adjusted associations (H1a – H1c). To address H1a, nature exposure was the independent variable and MVPA was the dependent variable. Nature exposure was added as a random effect into the model. To address H1b, nature exposure was the independent variable and body appreciation was the dependent variable. Nature exposure was added as a random effect into this model, as well. To address H1c, body appreciation was the independent variable and MVPA was the dependent variable. Body appreciation was added as a random effect into the model. Covariates in the models were age, gender, race and ethnicity, BMI percentile, receipt of free or reduced-price lunch, physical disability status, seasonal

allergies, connectedness to nature, and self-esteem. Assumption tests for linear regression were conducted. Equations for the mixed effects models follow:

$$\textit{Hypothesis 1a: } MVPA_{ij} = \gamma_{00} + \gamma_{01}Age + \gamma_{02}Gender + \gamma_{03}Race + \gamma_{04}BMI + \gamma_{05}FRL + \gamma_{06}Disability + \gamma_{07}Allergies + \gamma_{08}CN + \gamma_{09}SE + \gamma_{10}NE + u_0 + u_1NE + e_{ij}$$

$$\textit{Hypothesis 1b: } BA_{ij} = \gamma_{00} + \gamma_{01}Age + \gamma_{02}Gender + \gamma_{03}Race + \gamma_{04}BMI + \gamma_{05}FRL + \gamma_{06}Disability + \gamma_{07}Allergies + \gamma_{08}CN + \gamma_{09}SE + \gamma_{10}NE + u_0 + u_1NE + e_{ij}$$

$$\textit{Hypothesis 1c: } MVPA_{ij} = \gamma_{00} + \gamma_{01}Age + \gamma_{02}Gender + \gamma_{03}Race + \gamma_{04}BMI + \gamma_{05}FRL + \gamma_{06}Disability + \gamma_{07}Allergies + \gamma_{08}CN + \gamma_{09}SE + \gamma_{10}BA + u_0 + u_1BA + e_{ij}$$

Note: Race refers to race and ethnicity; FRL = free or reduced-price lunch; Disability refers to physical disability status; Allergies refer to seasonal allergies; CN = connectedness to nature; SE = self-esteem; NE = nature exposure; BA = body appreciation

Research Question 2 – Moderation Analyses

To determine if the hypothesized daily associations differed by gender, moderation analyses were conducted (H2a – H2c). Similar to the multilevel regression models, level one variables were the time-varying repeated measures of nature exposure, body appreciation, and MVPA, included as random effects. Nature exposure and body appreciation variables were grand mean centered and entered into their respective models. Time-invariant measures of covariates (e.g., gender) were nested within participants (i.e., level two) and were included as fixed effects in the models. Specifically, to address H2a, nature exposure and an interaction term of grand mean centered nature exposure and gender were entered as predictors with MVPA as the dependent variable. The predictors were the same for H2b, with body appreciation as the dependent variable. To address H2c, body appreciation and an interaction term of grand mean centered body appreciation and gender were entered as predictors with MVPA as the dependent variable. Covariates, and fixed effects, included were age, race and ethnicity, BMI percentile, receipt of free or reduced-price lunch, physical disability status, seasonal allergies, connectedness to nature, and self-esteem. Gender was also maintained as a fixed effect in the models, outside of their respective interaction terms. The equations are as follow:

$$\textit{Hypothesis 2a: } MVPA_{ij} = \gamma_{00} + \gamma_{01}Age + \gamma_{02}Gender + \gamma_{03}Race + \gamma_{04}BMI + \gamma_{05}FRL + \gamma_{06}Disability + \gamma_{07}Allergies + \gamma_{08}CN + \gamma_{09}SE + \gamma_{02}Gender * \gamma_{10}NE(c) + \gamma_{10}NE(c) + u_0 + u_1NE + e_{ij}$$

$$\textit{Hypothesis 2b: } BA_{ij} = \gamma_{00} + \gamma_{01}Age + \gamma_{02}Gender + \gamma_{03}Race + \gamma_{04}BMI + \gamma_{05}FRL + \gamma_{06}Disability + \gamma_{07}Allergies + \gamma_{08}CN + \gamma_{09}SE + \gamma_{02}Gender * \gamma_{10}NE(c) + \gamma_{10}NE(c) + u_0 + u_1NE + e_{ij}$$

$$\textit{Hypothesis 2c: } MVPA_{ij} = \gamma_{00} + \gamma_{01}Age + \gamma_{02}Gender + \gamma_{03}Race + \gamma_{04}BMI + \gamma_{05}FRL + \gamma_{06}Disability + \gamma_{07}Allergies + \gamma_{08}CN + \gamma_{09}SE + \gamma_{02}Gender * \gamma_{10}BA(c) + \gamma_{10}BA(c) + u_0 + u_1BA + e_{ij}$$

Note: Race refers to race and ethnicity; FRL = free or reduced-price lunch; Disability refers to physical disability status; Allergies refer to seasonal allergies; CN = connectedness to nature; SE = self-esteem; NE(c) = nature exposure – centered; BA(c) = body appreciation – centered

Research Question 3 – Indirect Effects Analyses

To test for the indirect effect of body appreciation on the association between nature exposure and MVPA (H3), Baron and Kenny's (1986) criterion for mediation was followed. With partial mediation more common in the social sciences, and body appreciation not expected to fully mediate the association between nature exposure and MVPA, this approach was followed to determine if an indirect effect of body appreciation was present in the association between nature exposure and MVPA (i.e., the requirement is that only the direct effect is less than the total effect; Baron & Kenny, 1986). The Sobel test was used to determine if the direct effect is significantly different than the total effect. Due to the large intraclass correlation (ICC) of body appreciation, indicating that participants' own daily values were highly consistent over the 7-day study period, a cross-sectional analysis was utilized. Thus, nature exposure, body appreciation, and physical activity were averaged for each participant across the study period to create a single value for each variable instead of examining multilevel associations as was done in the first and second research questions. In the model, nature exposure was the independent variable, MVPA the dependent variable, and body appreciation was investigated for indirect effects on the association between these two variables. The covariates included were age, gender, race and

ethnicity, BMI percentile, receipt of free or reduced-price lunch, physical disability status, seasonal allergies, connectedness to nature, and self-esteem. The equations were as follow:

Hypothesis 3:

$$\textit{c path: } MVPA = i_{MVPA} + c(NE) + c_1 Age + c_2 Gender + c_3 Race + c_4 BMI + c_5 FRL + c_6 Disability + c_7 Allergies + c_8 CN + c_9 SE + e$$

$$\textit{a path: } BA = i_{BA} + a(NE) + a_1 Age + a_2 Gender + a_3 Race + a_4 BMI + a_5 FRL + a_6 Disability + a_7 Allergies + a_8 CN + a_9 SE + e$$

$$\textit{b path: } MVPA = i_{MVPA} + c'(NE) + b(BA) + b_1 Age + b_2 Gender + b_3 Race + b_4 BMI + b_5 FRL + b_6 Disability + b_7 Allergies + b_8 CN + b_9 SE + e$$

Note: Race refers to race and ethnicity; FRL = free or reduced-price lunch; Disability refers to physical disability status; Allergies refer to seasonal allergies; CN = connectedness to nature; SE = self-esteem; NE = nature exposure; BA = body appreciation

Statistical Power

A power analysis using Monte Carlo simulations with the simr package (Green & MacLeod, 2016) was conducted in R for the bivariate associations between key study variables. This showed that a sample size of 21 is needed for .8 power and a small effect. For the moderation analysis, the PowerUpR package was used (Bulus et al., 2021). A sample size of 196 is needed for .8 power and a small effect. To test the direct effect of nature exposure on MVPA when adjusting for body appreciation, a sample size of at least 118 is needed for .8 power and a small effect size. This sample size takes into account medium effect sizes for the *a* and *b* paths, based on the previous work of (Fritz & MacKinnon, 2007).

CHAPTER III
RESULTS

Participants

Many participants had learned about the study through word of mouth from friends and teammates on different sports teams (e.g., soccer and track teams). In total, there were 217 participants in this study (M = 14.39 years ± 1.66). Half the participants identified as a cisgender girl (50.23%) and the majority as White (80.19%). A little over half of participants did not qualify for free or reduced-price lunch (54.84%), and most did not have a physical disability (95.85%) and did not experience seasonal allergies (65.44%). Detailed demographic characteristics of participants are provided in Table 1.

Table 1. Demographics Characteristics of Study Participants (N = 217)

Variable	N	Missing	Mean (SD)[a]	Min., Max.
Age (years)	217	0	14.39 (1.66)	12, 17
Body Mass Index Percentile	216	1	51.47 (27.16)	1, 98.9
Connectedness to Nature[b]	217	0	4.7 (0.96)	2.1, 6.9
Self-Esteem[c]	217	0	18.94 (5.05)	6, 30

Variable	N (Valid %)
Gender	
Cisgender boy	91 (41.94)
Cisgender girl	109 (50.23)
Transgender boy	6 (2.76)
Transgender girl	1 (0.46)
Agender, gender non-binary, gender non-conforming, or gender fluid	7 (3.23)
Other gender	3 (1.38)
Race & ethnicity	
White	174 (80.19)
Biracial/bi-ethnic	30 (13.83)

Table 1. (continued)

Variable	N (Valid %)
Multiracial/multi-ethnic	4 (1.84)
Hispanic or Latino/a/x	4 (1.84)
Black or African or African American	2 (0.92)
American Indian or Alaskan Native	1 (0.46)
Asian or Asian American	1 (0.46)
Missing	1 (0.46)
Free or reduced-price lunch	
Yes	58 (26.73)
No	119 (54.84)
Not sure	40 (18.43)
Physical disability status	
Yes	8 (3.69)
No	208 (95.85)
I prefer not to answer	1 (0.46)
Seasonal allergies	
Often	11 (5.07)
Sometimes	50 (23.04)
No	142 (65.44)
Not Sure	14 (6.45)

Note. [a] = standard deviation; [b] = possible values for connectedness to nature range from 1 – 7, with higher scores indicating greater connectedness to nature; [c] = possible values for self-esteem range from 0 – 30, with higher scores indicating greater self-esteem

Zero-order partial correlations indicated a non-significant, negative correlation between nature exposure and body appreciation, $r(1238) = -.02$, $p = .73$, a significant and positive correlation between nature exposure and MVPA, $r(1238) = .10$, $p < .01$, and a significant and positive correlation between body appreciation and MVPA, $r(1238) = .09$, $p < .01$. Participants were removed from the analysis if they did not have any data for nature exposure (n = 4) or

physical activity (n = 4). These participants were significantly different than the analytic sample. They were older (M = 15.13, $p < .01$), identified as White ($p < .001$), qualified for free or reduced-price lunch ($p < .001$), did not have a physical disability ($p < .001$), reported feeling less connectedness to nature (M = 4.25, $p < .001$), had lower self-esteem (M = 15.88, $p < .001$), and lower body appreciation (M = 3.33, $p < .001$) than the rest of the sample. These data were missing due to equipment errors or malfunctions by the NatureDose™ app or the accelerometer. Thus, from a total of 1,463 possible observations, compliance rates were 99.1%, 94.6%, and 90.3% for physical activity, nature exposure, and body appreciation, respectively. Participants spent an average of 281.9 (± 18.54) minutes per day in MVPA and had an average of 95.2 (± 66.6) minutes per day of nature exposure. Additionally, participants reported moderately high body appreciation scores per day of 3.99 (± 0.06) on a scale that ranged from 1 (*Never)* to 5 (*Always*). Detailed multilevel descriptive information for these variables is provided in Table 2.

Table 2. Multilevel Descriptives of Key Study Variables

Variable	**MVPA[a]**	**Nature Exposure**	**Body Appreciation**
No. of cases	1450	1384	1321
No. of missing values	13	79	142
% of missing cases	.89	5.40	9.71
No. of clusters	209	209	209
Average cluster size	6.94	6.62	6.32
SD[b] of cluster size	0.44	1	1.02
Min cluster size	2	2	1
Max cluster size	7	7	7
Mean	281.91	95.21	3.99
Variance Within	4911.92	17898.93	0.06
Variance Between	3874.49	13918.70	0.71
ICC[c]	0.44	0.44	0.92
Design Effect	3.62	3.46	5.89

Note. [a] = moderate-to-vigorous intensity physical activity; [b] = standard deviation; [c] = intraclass correlation

Preliminary Results

Distribution of study variables, aside from nature exposure, were acceptably normal (George & Mallery, 2010). A detailed figure of the daily MVPA distribution is provided as Appendix B. Additionally, participants' average daily MVPA during the study period was normally distributed, illustrated in Appendix C. Nature exposure data was positively skewed at 14 and so transformed by taking the natural logarithm of the values. While nature exposure did not significantly differ by gender, body appreciation and MVPA did. Adolescent cisgender girls reported significantly lower body appreciation scores than adolescent cisgender boys, t = -5.26, df = 1258, $p < .001$. Adolescent cisgender girls engaged in significantly greater MVPA than adolescent cisgender boys, t = 5.40, df = 1188, $p < .001$. ICCs showed that more than half of the variability for MVPA and nature exposure can be attributed at the between-persons level. For body appreciation, most of the variability can be attributed to cluster membership. Thus, participants differed in MVPA and nature exposure amongst each other while the variability in body appreciation values was greatest at the individual level. Little's MCAR test was non-significant, p = .95, indicating that missing data were missing completely at random. Multiple imputation was performed with the mitml package (Grund et al., 2023) to address the multilevel data structure during imputation. To adequately estimate the multiple imputation data, 50,000 burn-in and 5,000 iterations were performed with 100 imputed data sets per multiple imputation recommendations (Grund et al., 2016).

Multilevel Association Results – Research Question 1

For H1a, the multilevel model predicting MVPA (Model 1), a significant within-person association was found such that nature exposure was positively associated with MVPA (γ_{10} = 10.28, $p < .001$). Age was a significant negative between-person predictor of MVPA, (γ_{01} = -7.29, $p < .05$). There were no other significant between-person predictors in the model predicting MVPA. A random slope for nature exposure was observed, indicating that the within-person effect of nature exposure on MVPA varied across adolescents, $p < .01$. The effect size was small to medium (f^2 = .05). For H1b, the multilevel model predicting body appreciation (Model 2),

there were no within-person associations, such that nature exposure was not associated with body appreciation ($\gamma_{10} = 0.004$, $p = .42$). Age ($\gamma_{01} = -0.07$, $p < .01$) was a significant and negative between-person predictor, while free or reduced-price lunch ($\gamma_{05} = 0.12$, $p < .05$) was a significant and positive between-person predictor of body appreciation. Connectedness to nature ($\gamma_{08} = 0.11$, $p < .01$) and self-esteem ($\gamma_{09} = 0.12$, $p < .001$) were significant and positive between-person predictors of body appreciation. For H1c, the multilevel model predicting MVPA with body appreciation as a predictor (Model 3), body appreciation was not a significant within-person, while age ($\gamma_{01} = -6.27$, $p < .05$) was a significant and negative between-person predictor and self-esteem ($\gamma_{09} = 2.51$, $p < .05$) a significant and positive between-person predictor of MVPA. Outliers were not detected nor were multicollinearity assumptions violated. Heteroscedasticity was detected for Models 1 and 3, thus robust standard errors were calculated. Detailed results are depicted in Table 3. Correlation matrices of fixed effects for each model can be found in Appendices D – F .

Table 3. Associations Among Nature Exposure, Body Appreciation, and MVPA

	Model 1	**Model 2**		**Model 3**
	MVPA	**BA**		**MVPA**
Variable	**Estimate (SE)**	**Estimate (SE)**	**Variable**	**Estimate (SE)**
Fixed effects			**Fixed effects**	
NE	10.28*** (1.40)	0.004 (0.005)	BA	-2.79 (6.17)
Age	-7.28* (2.92)	-0.08**(0.03)	Age	-6.27 (2.93)
Gender	7.99 (6.87)	-0.07 (0.06)	Gender	1.14 (7.74)
Race/ethnicity	0.26 (5.29)	0.07 (0.05)	Race/ethnicity	0.09 (5.26)
BMI Percentile	-0.10 (0.18)	0.01 (0.0)	BMI Percentile	-0.09 (0.19)
FRL	11.88 (7.44)	0.12* (0.06)	FRL	11.58 (8.19)
Disability	-19.82 (18.57)	0.33 (0.20)	Disability	-19.39 (21.01)
Allergies	8.54 (8.22)	0.05 (0.06)	Allergies	9.65 (9.12)
Connectedness to nature	2.53 (4.85)	0.11** (0.04)	Connectedness to nature	1.52 (5.17)
Self-esteem	1.94 (0.96)	0.12*** (0.01)	Self-esteem	2.51 (1.21)

Table 3. (continued)

	Model 1	Model 2		Model 3
	MVPA	BA		MVPA
Variable	Estimate (SE)	Estimate (SE)	Variable	Estimate (SE)
Random effects			**Random effects**	
NE slope	91.78** (9.58)	0.00 (0.001)	BA slope	525.4 (22.92)
Residual variance	4438.32 (66.62)	0.06 (0.25)	Residual variance	4561.2 (67.54)
ICC	0.46	-	ICC	0.46
Observations	1369	1252	Observations	1307
Marginal R^2/ Conditional R^2	0.08/0.50	0.87/NA	Marginal R^2/ Conditional R^2	0.04/0.48
-2LL	-7879.8	-418.37	-2LL	-7522.3
AIC	15786	862.74	AIC	15071

Note. The variable of nature exposure is log transformed. Models 1 – 2 depict results of nature exposure predicting moderate-to-vigorous intensity physical activity and body appreciation, respectively. Model 3 depicts body appreciation predicting moderate-to-vigorous intensity physical activity. Singular fit – variances of at least one linear combination of effects are close to zero, did not allow for ICC and conditional R^2 to be obtained in Model 2. MVPA = moderate-to-vigorous intensity physical activity; BA = body appreciation; SE = standard error; NE = nature exposure; BMI = body mass index percentile; FRL = free or reduced-price lunch; Disability = physical disability status; Allergies = seasonal allergies; −2LL = −2 log likelihood; AIC = Akaike information criterion. * $p < .05$, ** $p < .01$, *** $p < .001$.

Moderation Results - Research Question 2

There were no significant moderation effects of gender detected for any of the relationships among nature exposure, body appreciation, or MVPA. Robust standard errors are reported for Models 1 and 3 below due to detection of heteroscedasticity. Detailed results are presented in Table 4. Correlation matrices of fixed effects for each model can be found in Appendices G – I .

Table 4. Associations Among Nature Exposure, Body Appreciation, and MVPA by Gender

	Model 1	Model 2		Model 3
	MVPA	BA		MVPA
Variable	Estimate (SE)	Estimate (SE)	Variable	Estimate (SE)
Fixed effects			**Fixed effects**	
NE	9.25*** (2.08)	-0.001 (0.54)	BA	-7.37 (8.04)
Age	-7.27* (2.91)	-0.08** (0.03)	Age	-6.27* (2.93)
Gender	8.87 (6.76)	-0.06 (0.06)	Gender	1.71 (7.78)
Race/ethnicity	0.19 (5.28)	0.07 (0.05)	Race/ethnicity	0.04 (5.21)
BMI Percentile	-0.09 (0.18)	0.001 (0.001)	BMI Percentile	-0.11 (0.19)
FRL	12.02 (7.40)	0.12 (0.06)	FRL	11.70 (8.21)
Disability	-19.95 (18.56)	0.33* (0.20)	Disability	-21.93 (21.46)
Allergies	8.46 (8.20)	0.05 (0.06)	Allergies	9.54 (9.09)
Connectedness to nature	2.57 (4.82)	0.12** (0.04)	Connectedness to nature	1.88 (5.16)
Self-esteem	1.93 (0.96)	0.12*** (0.01)	Self-esteem	2.43* (1.21)
NE*Gender	1.37 (1.82)	0.01 (0.01)	BA*Gender	5.50 (5.54)
Random effects			**Random effects**	
NE slope	92.16** (9.60)	0.00 (0.001)	BA slope	565.5 (23.78)
Residual variance	4443.26 (66.66)	0.06 (0.25)	Residual variance	4558.5 (67.52)
ICC	0.45	-	ICC	0.46
Observations	1369	1252	Observations	1307
Marginal R^2/ Conditional R^2	0.08/0.50	0.87/NA	Marginal R^2/ Conditional R^2	0.04/0.48
-2LL	-7878	-422.04	-2LL	-7519.2
AIC	15784	872.08	AIC	15066

Note. The variable of nature exposure is log transformed. Models 1 – 2 depict results of nature exposure predicting moderate-to-vigorous intensity physical activity and body appreciation, respectively. Model 3 depicts body appreciation predicting moderate-to-vigorous intensity physical activity. Singular fit – variances of at least one linear

combination of effects are close to zero, did not allow for ICC and conditional R^2 to be obtained in Model 2. MVPA = moderate-to-vigorous intensity physical activity; BA = body appreciation; SE = standard error; NE = nature exposure; BMI = body mass index percentile; FRL = free or reduced-price lunch; Disability = physical disability status; Allergies = seasonal allergies; NE*Gender and BA*Gender represent the interaction terms; −2LL = −2 log likelihood; AIC = Akaike information criterion. * $p < .05$, ** $p < .01$, *** $p < .001$.

Indirect Effects – Research Question 3

For H3, indirect effects were not present. There was no direct effect of nature exposure on MVPA ($p = .11$; Model 1) or nature exposure on body appreciation ($p = .97$; Model 2). Lastly, findings were not significant for the effect of body appreciation on MVPA ($p = .88$) or for the effect of nature exposure on MVPA ($p = .11$), Model 3 when controlling for body appreciation. Robust standard errors were calculated for the second model as heteroscedasticity was detected. Table 5 provides detailed results from the path analyses.

Table 5. Indirect Effects Pathways

	Model 1	**Model 2**	**Model 3**
	MVPA	**Body Appreciation**	**MVPA**
Variable	**Estimate (SE)**	**Estimate (SE)**	**Estimate (SE)**
Nature Exposure	7.07 (4.39)	-0.001 (0.55)	7.07 (4.40)
Body Appreciation	-	-	-1.23 (8.34)
Age	-6.92* (2.99)	-0.08** (0.04)	-7.02* (3.07)
Gender	4.93 (7.07)	-0.06 (0.06)	4.86 (5.91)
Race/ethnicity	0.66 (5.86)	0.08 (0.05)	0.76 (5.91)
Body Mass Index Percentile	-0.11 (0.18)	0.0004 (0.001)	-0.11 (0.18)
Free or reduced-price lunch	10.26 (7.10)	0.12* (0.05)	10.40 (7.18)
Physical disability	-21.00 (23.09)	0.33* (0.14)	-20.59 (23.32)
Seasonal allergies	7.87 (7.48)	0.06 (0.06)	7.94 (7.51)
Connectedness to nature	1.63 (5.01)	0.11* (0.04)	1.76 (5.11)

Table 5. (continued)

Variable	Model 1 MVPA Estimate (SE)	Model 2 Body Appreciation Estimate (SE)	Model 3 MVPA Estimate (SE)
Self-esteem	2.01 (1.03)	0.11*** (0.01)	2.16 (1.41)
Observations	208	208	208
R^2	0.08	0.57	0.08
Adjusted R^2	0.04	0.55	0.03
Residual Standard Error	66.63 (df = 197)	0.57 (df = 197)	66.8 (df = 196)
F Statistic	1.83 (df = 10; 197)	26.31*** (df = 10; 197)	1.66 (df = 11; 196)

Note. The variable of nature exposure is log transformed. The first model depicts results of the effect of nature exposure on moderate-to-vigorous intensity physical activity (MVPA). The second model depicts results of nature exposure on the hypothesized mediator, body appreciation. The final model depicts the effect of nature exposure on MVPA while controlling body appreciation, and the effect of body appreciation on MVPA. * $p < .05$, ** $p < .01$, *** $p < .001$.

CHAPTER IV
DISCUSSION

Adolescence is a period that consists of reduced physical activity and poorer body image (Bucchianeri et al., 2013; Katzmarzyk et al., 2017). Nature exposure has been associated with increased physical activity among adolescents (Fyfe-Johnson et al., 2021) and body appreciation among adults (Swami et al., 2020). The present study was the first to use objective, individual-level measures for nature exposure and MVPA among adolescents. The use of these measures helps to clarify the mixed findings of prior literature on the association between nature exposure and MVPA among adolescents. This study also expands on the limited nature exposure and MVPA research that has included body appreciation and provides novel findings on the putative role of body appreciation in the link between nature exposure and MVPA.

Associations across the Study

The first hypothesis was supported, such that daily nature exposure was positively associated with daily MVPA. This finding corroborates what others have found among adolescents using self-report (van Lier et al., 2017) and objective, proxy measures (Queralt & Molina-García, 2019) among adolescents. In this study sample, for every minute increase an adolescent spent outdoors, there was a ten-minute increase in MVPA. Interventions that aim to promote physical activity among adolescents should prioritize getting youth outside and into natural settings like parks and trails. Outdoor recreation programs are considered evidence-based interventions that promote MVPA, health and well-being, such as self-esteem (Evans et al., 2020). There may be a cyclical relationship between nature exposure and MVPA. For example, as noted earlier, a predictor of MVPA among adolescents is time spent outdoors (Schaefer et al., 2014). This time outdoors could therefore increase the time that adolescents are in nature. Regardless, both nature exposure and MVPA can provide health benefits among adolescents.

The hypothesis that nature exposure was positively associated with body appreciation was not supported in the current study sample, as it had been in previous work that was among adults and measured nature exposure via self-report (Swami et al., 2020; Swami, Pickering, et al., 2018). There are several potential interpretations of this finding. It may be the case that among this sample with higher-than-average nature exposure and body appreciation, and potentially a ceiling effect with body appreciation across the sample, that the two are not

associated. Studies with more diverse adolescents should reassess this association. Another possibility is that nature exposure, when objectively measured, is not important to body appreciation among adolescents wherein other factors are. For example, similar to previous research (Bucchianeri et al., 2013), age was associated with body appreciation in the current study, such that older adolescents were more likely to have lower body appreciation than younger adolescents. Notably, connectedness to nature and self-esteem were also significantly and positively associated with body appreciation, which is in line with prior research among adults that connectedness to nature and self-esteem mediate the association between nature exposure and body appreciation (Swami et al., 2016). Among adolescents, self-esteem has also been positively related to body appreciation (Jáuregui Lobera & Bolaños Ríos, 2011). In this study connectedness to nature and self-esteem were covariates, but they may play a more critical role in understanding body appreciation than nature exposure among adolescents. The Psychophysiological Stress Recovery Theory specifies that those who report feeling more connected to nature, may benefit more from nature exposure and experience the psychological and physiological restorative state, leading to greater body appreciation. As connectedness to nature and self-esteem were only collected at one time point in the current study, further multilevel analysis with these variables could not be performed. A next step in research will be to test the potential mediating role of connectedness to nature and self-esteem in the daily association of objectively measured nature exposure with body appreciation among adolescents.

Finally, the hypothesis that body appreciation was positively associated with MVPA, was not supported. This is the first time the association between body appreciation and objectively measured MVPA has been studied among adolescents. Also novel is the longitudinal association of the association between body appreciation and objectively measured MVPA. The finding indicates that body appreciation may not matter to MVPA engagement among a highly active community-based sample of adolescents. This is inconsistent with what was previously found for body appreciation and physical activity in a prospective study among adolescent girls (Andrew et al., 2016). Also, differences in findings may have occurred because of physical activity measurement differences between the Andrew et al. (2016) study and the current study (e.g., self-report vs objective; total physical activity vs MVPA; one year vs seven days). One review reported adolescents identified body image as both a facilitator and barrier to their participation

in physical activity (Martins et al., 2015). The moderately high body appreciation scores with limited variability across the current study's sample, or the high physical activity levels, may have had a nullifying influence on the link between body appreciation and MVPA in the current study. Future research should examine this association with more diverse samples to test the link between body appreciation and MVPA among adolescents. For example, one's relationship with their body can make certain activities uncomfortable for transgender adolescents, such as increased difficulties in breathing with the use of a chest-binder (Berg & Kokkonen, 2022) but, body appreciation has not been studied among this group.

Interpretation of Moderation Results

The hypotheses on gender as a moderator in the daily associations among nature exposure, body appreciation, and MVPA were not supported, but are novel findings, nonetheless. The literature has extensively documented gender differences in body appreciation (He et al., 2020) and physical activity engagement (Belcher et al., 2010) among adolescents. In the current sample, adolescent cisgender girls engaged in significantly more MVPA (297 min/day) than adolescent cisgender boys (271 min/day), but reported significantly lower body appreciation scores (3.94 compared to 4.19).The null findings of gender as a moderator are promising between cisgender girls and cisgender boys. Namely, the small-to-medium sized, positive association between nature exposure and MVPA was consistent across the two genders demonstrating the robustness of the finding. Alternatively, the unusual characteristics of the study sample (e.g., high levels of MVPA, moderately high body appreciation) may again have limited the variability in experiences across genders and led to the null moderation findings. Future research among a more diverse sample of adolescents (e.g., non-active and less active adolescents) will be useful to corroborate this finding. Additionally, this study was only able to examine gender as a binary variable (i.e., cisgender boys and girls), given the small percentage of transgender and non-binary participants. Future studies can expand on this work and intentionally recruit adolescents that identify as non-cisgender (e.g., transgender, non-binary). There is reason to suspect that these individuals have unique experiences, especially when it comes to their bodies, then cisgender individuals (Moolchaem et al., 2015; Tabaac et al., 2018). Findings can inform interventions to promote body appreciation and physical activity in these groups of individuals who experience even lower body appreciation and physical activity

engagement than their cisgender counterparts (Lightner et al., 2024). Future research should also consider how other demographic characteristics may moderate the association between nature exposure and MVPA. Additional disparities that have been identified among adolescents for physical activity engagement include race and ethnicity (Armstrong et al., 2018), socioeconomic status (Hanson & Chen, 2007), and disability status (Carlon et al., 2013). Findings from research investigating these variables as moderators can support future physical activity interventions by informing if certain groups may benefit most from incorporating in nature exposure.

Interpretation of Indirect Effects Results

The hypothesis that body appreciation would indirectly affect the relationship between objectively measured nature exposure and MVPA was not supported. As a reminder, this finding was from data at one time point, whereas the previously described daily association and moderated daily association findings were multilevel analyses from data over seven time points. In this cross-sectional analysis, the positive association between nature exposure and MVPA was not sustained, and thus, there was no possible indirect effect of body appreciation. The loss of the nature exposure-to-MVPA link appears to have occurred because of the removal of the individual variability over multiple time points in these two variables with the cross-sectional analysis. It seems individual variability over time is important for the relationship between nature exposure and MVPA, which a cross-sectional analysis cannot capture. Future research should be designed to be able to gather individual variability across study variables and allow for multilevel analyses.

The hypothesized indirect effect of body appreciation had been informed by previous literature indicating self-reported nature exposure was significantly and positively associated with body appreciation (Swami et al., 2020; Swami, Pickering, et al., 2018) among adults and of body appreciation predicting self-reported physical activity among adolescent girls (Andrew et al., 2016). Regardless of the changes in findings based on study design, body appreciation may not be important in the link between nature exposure and MVPA, at least not in this sample of highly active, cisgender adolescents. The EnRG framework suggests a host of cognitive factors (e.g., subjective norms) may serve as mediators between environmental factors (e.g., nature) and health behaviors (e.g., physical activity). Given previous support for the positive link between self-efficacy with nature exposure (Fuller et al., 2017; Margalit & Ben-Ari, 2014) and physical

activity (Hamilton et al., 2017; Sheikh et al., 2022) among adolescents, a next step in research is investigating self-efficacy as a mediator for the relationship between nature exposure and MVPA.

Generalizability of the Study Sample

Adolescents in the study were considered highly active, as they spent an average of four and a half hours in MVPA daily. The normal distribution observed when examining by daily MVPA and by participants' average daily MVPA indicate that this study was not comprised of a few participants who engaged in a large amount of MVPA while the rest of the participants did not. In fact, most participants were achieving the physical activity recommended guidelines. This sample is much more active than the general population of adolescents, most of whom achieve less than an hour a day of any kind of physical activity (Nigg et al., 2021; Piercy et al., 2018). The large amount of MVPA for participants in this study could be in part due to the location of the study and methodology for recruitment. The study took place in an area that is internationally known for sports, especially track and field competitions. Previous literature among adolescents has supported the role of physical activity social norms (e.g., from parents and peers; Draper et al., 2015) and built environment supports (McGrath et al., 2015) in increasing physical activity among adolescents and may have led to our highly active study sample. Additionally, study visits took place at a local youth sports organization, which made the study more visible to adolescents who were engaging in physical activity-focused summer camps and youth sports programs and were likely more active than the average adolescent. Also, part of the recruitment strategy was participant word of mouth, which resulted in entire sports teams of adolescents enrolling in the study, which, again, led to an over representation of active adolescents in the study sample. The high amount of MVPA engagement among participants limits the generalizability of study findings to other highly active adolescents. Study procedures should be repeated with a sample of less active and non-active adolescents to better inform physical activity promotion interventions.

Adolescents in this sample spent an average of an hour and a half in nature each day. Of all the sample's study days observed with nature data, about 54% of days included at least half an hour in nature, 38% of days with at least one hour in nature, and 22% with more than two hours in nature. As previous literature has generally not assessed daily quantity of nature

exposure, there is limited information about adolescents' typical daily time in nature. One study among rural-dwelling adolescents that used self-report measures for time in nature found similar average results of an hour and a half in nature each day, but their sample spent more time in nature with 70% having at least half an hour and 40% having more than two hours in nature (Larson et al., 2019). A study that utilized NatureDose™ to measure nature exposure among college students found they spent an average of 25 minutes a day in nature (Vermeesch et al., 2022), about three and a half times less than the average in the current study among a younger age group. The large amount of time in nature may be influenced by the highly active sample in the current study, as outdoor time has also been identified as a predictor of MVPA among adolescents (Schaefer et al., 2014), but such an association is discussed more later. While Vermeesch et al. (2022) did not report MVPA of study participants, their participants did average about eight thousand steps a day, classifying them as 'somewhat active' per step-based estimates (Tudor-Locke & Bassett, 2004). The literature has identified several factors that influence nature exposure and time outdoors, such as seasonality and community setting (i.e., rural/suburban/urban). The current study was conducted during the summer, and warmer seasons have been associated with youth spending more time outdoors (Larouche et al., 2023; Tucker & Gilliland, 2007). The urban/suburban mix of the study setting could have also contributed to the greater time spent in nature in this study sample, as lower urbanization is related to greater frequency and duration of time spent in nature (Cox et al., 2018). Further, while not recorded, many participants in the current study stated to the research team during their first study visit that they had plans of engaging in outdoor activities (e.g., kayaking) and going on camping trips for part of or during all of their time in the study.

The average body appreciation scores in the study sample (3.99 ± 0.06; scale 1 – 5) are slightly higher (i.e., adolescents reported better body appreciation) than previous literature among adolescents (3.39 – 3.64; Andrew et al., 2016; Jankauskiene et al., 2020; Urke et al., 2021). A novel finding was that among each individual in the study, values did not tend to fluctuate, demonstrating that body appreciation was more of a trait characteristic than a state characteristic. To confirm this finding, future research should consider studies that are better equipped to capture potential variability. Ecological momentary assessments, such as has been previously done for body satisfaction and affect, could be utilized (Stevens & Griffiths, 2020).

Furthermore, collecting body appreciation in longitudinal studies across months may better provide information about its potential for variability.

Strengths and Limitations

There are several strengths to this study. First, this is the first study to concurrently measure objective, continuous, and individual-level nature exposure and physical activity among adolescents. The prospective study design allowed for study measures to be taken at multiple time points. Additionally, 89.9% of participants had data for nature exposure, body appreciation, and physical activity on four or more days, resulting in minimal missing data because of high compliance throughout participants week of data collection. The study sample had a near even split for cisgender representativeness and there was a good distribution of participants across age groups. Additionally, seasonal allergies can largely impact individuals' nature exposure and health (Fyfe-Johnson et al., 2021). While previous studies on nature generally do not include them, this study did as a covariate.

This study has several limitations, with the main one being limited generalizability. There may have been selection bias among the sample, as adolescents knew the study included capturing information about nature and physical activity and those with more interest and/or experience in these topics may have been more motivated to participate. To reduce selection bias and reach a more diverse group of adolescents, the study team did send out recruitment postcards to 1,400 households with adolescents in the study age range. The sample was largely comprised of non-Hispanic White, cisgender adolescents who may have had good financial resources as most indicated they did not qualify for free or reduced-price lunch (a proxy for socioeconomic status). Future studies should include greater demographic representation to better understand the links between nature exposure, body appreciation, and MVPA among groups at greater risk of physical activity disparities (Armstrong et al., 2018; Lightner et al., 2024). Additionally, investigating these links among individuals from low socioeconomic backgrounds, who may have reduced access to greenspace, is important as greater access to greenspace has been associated with lower health inequalities in mental well-being (Mitchell et al., 2015) and all-cause mortality and circulatory diseases (Mitchell & Popham, 2008) among adults. Furthermore, this study was conducted in an area rich in forests, rivers, and green valleys. How findings might compare to other areas in the US with a lower density of greenery is needed. Additionally, as it is

a phone application, the study was limited to those with a smartphone. Furthermore, participants must carry their smartphones with them to capture data, which may be inconvenient for individuals who like to unplug and disconnect from technology when they are outdoors. While wrist-worn accelerometers have been validated among adolescents, these devices may overestimate movement, such as counting arm swings as steps. However, wrist-worn accelerometer data has been strongly correlated with hip-worn accelerometer data (Dieu et al., 2017) which are better able to distinguish such movements. While the accelerometers in the current study could not be worn while performing water activities (e.g., swimming), future studies that utilize water-proof devices to track physical activity can fill these gaps.

Conclusion

The current study contributes to the understanding of how nature exposure, body appreciation, and MVPA are associated among adolescents. As the first study to use objective and continuous, individual-level measurements for nature exposure and physical activity, and to do so prospectively, findings clarify some of the previously mixed literature that has utilized self-report and proxy measures. Specifically, findings reinforce daily nature exposure is positively associated with daily MVPA among adolescents, and this finding does not vary by cis-gender girls and boys. Physical activity interventions among this age group should incorporate time outdoors in nature. The findings also suggest that adolescents' body appreciation may not be an important factor when considering the direct or indirect links with objectively measured nature exposure and MVPA. Further work is needed to determine who may benefit most from the inclusion of nature exposure in physical activity interventions.

APPENDIX A

ONE-TIME SURVEY

Investigation of nature exposure, health behaviors, and mental health among adolescents

Thank you for taking the time to complete this survey. Your input is important to us!

1. **Which of the following racial and ethnic group(s) best describe you? Please select all that apply.**
   - o White (e.g., German, Irish, English, Italian, Polish, French)
   - o Spanish
   - o Mexican
   - o Puerto Rican
   - o Cuban
   - o Dominican
   - o Salvadoran
   - o Guatemalan
   - o Colombian
   - o Honduran
   - o Ecuadorians
   - o Peruvians
   - o Other Hispanic or Latinx (please describe)
   - o Black (but not African American; e.g. Haitian, Nigerian)
   - o African American
   - o Chinese
   - o Japanese
   - o Filipino
   - o Korean
   - o South Asian or Indian
   - o Vietnamese
   - o American Indian or Alaska Native
   - o Native Hawaiian
   - o Pacific Islander (e.g., Samoan, Tongan, Figian)
   - o Middle Eastern or North African (Lebanese, Iranian, Egyptian, Moroccan)
   - o Biracial/ethnic, please describe:
   - o Multiracial/ethnic. please describe:
   - o Open answer, please describe:

2. **What is your gender?** *(select one)*
   - o Cisgender boy (meaning you both feel like a boy and you were told that you were a boy when you were born)
   - o Cisgender girl (meaning you both feel like a girl and you were told that you were a girl when you were born)

- Transgender boy (meaning that you feel like a boy and were told that you were a girl when you were born)
- Transgender girl (meaning that you feel like a girl and were told that you were a boy when you were born)
- Agender, gender non-binary, gender non-conforming, or gender fluid (meaning that you don't feel like the boy/girl definitions of gender apply to you)
- Open answer, please explain: _____

3. **What is your current age?** *(select one)*
   - Less than 12 years old
   - 12
   - 13
   - 14
   - 15
   - 16
   - 17
   - 18 years or older

4. **In the Fall, I will attend . . .** *(select one)*
   - Middle School
   - High School
   - Trade School/University/Community College
   - I will not be in school
   - Open answer, please describe: _____

5. **I am currently in...** (select one)
   - Middle School
   - High School
   - Trade School/University/Community College
   - I am not in school
   - Open answer, please describe: _____

6. **Do you qualify for free or reduced priced lunch at school?** *(Select one)*
   - Yes
   - No
   - Not sure

7. **Have you ever been diagnosed with any of the following?** *(Select all that apply)*
   - Anxiety

- o Depression
- o Eating Disorder (e.g., Bulimia Nervosa, Anorexia Nervosa, Binge Eating Disorder)
- o Attention Deficit Hyperactivity Disorder (ADHD)
- o Autism Spectrum Disorder (ASD)
- o None apply to me

8. **Do you have any seasonal allergies that prevent you from spending time outdoors?** *(Select one)*
   - o Yes, Often
   - o Yes, Sometimes
   - o No
   - o Not sure

9. **Do you have a disability that limits or alters the way you move your body?** *(Select one)*
   - o Yes; please describe: _____
   - o No
   - o I prefer not to answer

Next, we want to know more about you and how you feel about your ability to be active.

Please select the option that sounds most like you for each statement.

1. **I can be active in my free time on most days.**

   Disagree a lot Disagree Agree Agree a lot

2. **I can be active in my free time on most days instead of watching TV or playing video games.**

   Disagree a lot Disagree Agree Agree a lot

3. **I can be active or play active games or sports in my free time on most days when it is hot or cold out.**

   Disagree a lot Disagree Agree Agree a lot

ONE-TIME SURVEY

4. **I can be active in my free time on most days when I have to stay home.**

   Disagree a lot Disagree Agree Agree a lot

5. **I have the skills I need to be active in my free time on most days.**

   Disagree a lot Disagree Agree Agree a lot

6. **I can be active in my free time on most days even when I am busy.**

   Disagree a lot Disagree Agree Agree a lot

Below is a collection of statements about your everyday experience.

Please indicate how frequently or infrequently you currently have each experience.

Please answer according to what really reflects your experience rather than what you think your experience should be.

1. **I could be experiencing some emotion and not be conscious of it until some time later.**

   Almost Always Very Frequently Somewhat Frequently Somewhat Infrequently
   Very Infrequently Almost Never

2. **I break or spill things because of carelessness, not paying attention, or thinking of something else.**

   Almost Always Very Frequently Somewhat Frequently Somewhat Infrequently
   Very Infrequently Almost Never

3. **I find it difficult to stay focused on what's happening in the present.**

   Almost Always Very Frequently Somewhat Frequently Somewhat Infrequently
   Very Infrequently Almost Never

4. **I tend to walk quickly to get where I'm going without paying attention to what I experience along the way.**

ONE-TIME SURVEY

Almost Always Very Frequently Somewhat Frequently Somewhat Infrequently

Very Infrequently Almost Never

5. **I tend not to notice feelings of physical tension or discomfort until they really grab my attention.**

Almost Always Very Frequently Somewhat Frequently Somewhat Infrequently

Very Infrequently Almost Never

6. **I forget a person's name almost as soon as I've been told it for the first time.**

Almost Always Very Frequently Somewhat Frequently Somewhat Infrequently

Very Infrequently Almost Never

7. **It seems I am "running on automatic" without much awareness of what I'm doing.**

Almost Always Very Frequently Somewhat Frequently Somewhat Infrequently

Very Infrequently Almost Never

8. **I rush through activities without being really attentive to them.**

Almost Always Very Frequently Somewhat Frequently Somewhat Infrequently

Very Infrequently Almost Never

9. **I get so focused on the goal I want to achieve that I lose touch with what I am doing right now to get there.**

Almost Always Very Frequently Somewhat Frequently Somewhat Infrequently

Very Infrequently Almost Never

10. **I do jobs or tasks automatically, without being aware of what I'm doing.**

Almost Always Very Frequently Somewhat Frequently Somewhat Infrequently

Very Infrequently Almost Never

11. **I find myself listening to someone with one ear, doing something else at the same time.**

Almost Always Very Frequently Somewhat Frequently Somewhat Infrequently

Very Infrequently Almost Never

12. **I find myself preoccupied with the future or the past.**

ONE-TIME SURVEY

Almost Always Very Frequently Somewhat Frequently Somewhat Infrequently
Very Infrequently Almost Never

13. I find myself doing things without paying attention.

Almost Always Very Frequently Somewhat Frequently Somewhat Infrequently
Very Infrequently Almost Never

14. I snack without being aware that I'm eating.

Almost Always Very Frequently Somewhat Frequently Somewhat Infrequently
Very Infrequently Almost Never

We are also interested in learning about your resilience behaviors. Please respond to each item by marking <u>one box per row.</u>

1. I tend to bounce back quickly after hard times.

Strongly Disagree Disagree Neutral Agree Strongly Agree

2. I have a hard time making it through stressful events.

Strongly Disagree Disagree Neutral Agree Strongly Agree

3. It does not take me long to recover from a stressful event.

Strongly Disagree Disagree Neutral Agree Strongly Agree

4. It is hard for me to snap back when something bad happens.

Strongly Disagree Disagree Neutral Agree Strongly Agree

5. I usually come through difficult times with little trouble.

Strongly Disagree Disagree Neutral Agree Strongly Agree

6. I tend to take a long time to get over set-backs in my life.

Strongly Disagree Disagree Neutral Agree Strongly Agree

You are halfway done with the survey! Keep up the good work!

ONE-TIME SURVEY

Please indicate whether the question is true about you never, seldom, sometimes, often, or always.

1. **I respect my body.**

   Never Seldom Sometimes Often Always

2. **I feel good about my body.**

   Never Seldom Sometimes Often Always

3. **I feel that my body has at least some good qualities.**

   Never Seldom Sometimes Often Always

4. **I take a positive attitude towards my body.**

   Never Seldom Sometimes Often Always

5. **I am attentive to my body's needs.**

   Never Seldom Sometimes Often Always

6. **I feel love for my body.**

   Never Seldom Sometimes Often Always

7. **I appreciate the different and unique characteristics of my body.**

   Never Seldom Sometimes Often Always

8. **My behavior reveals my positive attitude toward my body; for example, I hold my head high and smile.**

   Never Seldom Sometimes Often Always

9. **I am comfortable in my body.**

   Never Seldom Sometimes Often Always

ONE-TIME SURVEY

10. I feel like I am beautiful even if I am different from media images of attractive people (e.g., models, actresses/actors).

Never Seldom Sometimes Often Always

We are interested in how you feel about the following statements. Read each statement carefully. Indicate how you feel about each statement.

1. There is a special person who is around when I am in need.

Very Strongly Disagree Strongly Disagree Mildly Disagree Neutral Mildly Agree Strongly Agree Very Strongly Agree

2. There is a special person with whom I can share my joys and sorrows.

Very Strongly Disagree Strongly Disagree Mildly Disagree Neutral Mildly Agree Strongly Agree Very Strongly Agree

3. My family really tries to help me.

Very Strongly Disagree Strongly Disagree Mildly Disagree Neutral Mildly Agree Strongly Agree Very Strongly Agree

4. I get the emotional help and support I need from my family.

Very Strongly Disagree Strongly Disagree Mildly Disagree Neutral Mildly Agree Strongly Agree Very Strongly Agree

5. I have a special person who is a real source of comfort to me.

Very Strongly Disagree Strongly Disagree Mildly Disagree Neutral Mildly Agree Strongly Agree Very Strongly Agree

ONE-TIME SURVEY

6. My friends really try to help me.

Very Strongly Disagree Strongly Disagree Mildly Disagree Neutral Mildly Agree
Strongly Agree Very Strongly Agree

7. I can count on my friends when things go wrong.

Very Strongly Disagree Strongly Disagree Mildly Disagree Neutral Mildly Agree
Strongly Agree Very Strongly Agree

8. I can talk about my problems with my family.

Very Strongly Disagree Strongly Disagree Mildly Disagree Neutral Mildly Agree
Strongly Agree Very Strongly Agree

9. I have friends with whom I can share my joys and sorrows.

Very Strongly Disagree Strongly Disagree Mildly Disagree Neutral Mildly Agree
Strongly Agree Very Strongly Agree

10. There is a special person in my life who cares about my feelings.

Very Strongly Disagree Strongly Disagree Mildly Disagree Neutral Mildly Agree
Strongly Agree Very Strongly Agree

11. My family is willing to help me make decisions.

Very Strongly Disagree Strongly Disagree Mildly Disagree Neutral Mildly Agree
Strongly Agree Very Strongly Agree

ONE-TIME SURVEY

12. I can talk about my problems with my friends.

Very Strongly Disagree Strongly Disagree Mildly Disagree Neutral Mildly Agree
Strongly Agree Very Strongly Agree

The next set of questions is to learn more about the activities you do when you are on social network/social media sites.

Please select the option that sounds most like you for each statement.

1. **Using social media is my daily habit.**

   Strongly Disagree Disagree Undecided Agree Strongly Agree

2. **I browse social media whenever I have time.**

   Strongly Disagree Disagree Undecided Agree Strongly Agree

3. **Even if it's late, I'll take a look at social media before sleep.**

   Strongly Disagree Disagree Undecided Agree Strongly Agree

4. **I often use social media to relax in habit.**

   Strongly Disagree Disagree Undecided Agree Strongly Agree

5. **I get fulfilled from the attention and comments of others on social media.**

   Strongly Disagree Disagree Undecided Agree Strongly Agree

6. **The support and encouragement of others on social media is very important to me.**

   Strongly Disagree Disagree Undecided Agree Strongly Agree

7. **Using social media, I am satisfied with the relationship between myself and my friends.**

   Strongly Disagree Disagree Undecided Agree Strongly Agree

8. **Compared to the real world, social media makes me feel more comfortable.**

   Strongly Disagree Disagree Undecided Agree Strongly Agree

9. **I feel bored when I can't use social media.**

ONE-TIME SURVEY

Strongly Disagree Disagree Undecided Agree Strongly Agree

10. Compared to the real world, I am happier when I socialize on social media.

Strongly Disagree Disagree Undecided Agree Strongly Agree

11. I feel anxious when I can't use social media.

Strongly Disagree Disagree Undecided Agree Strongly Agree

Almost finished!

Indicate how you generally feel about each statement below.

1. I often feel a strong connection to nature.

1 2 3 4 5 6 7

Strongly Disagree — Neither agree nor disagree — Strongly Agree

2. I think of nature as a family that I belong to.

1 2 3 4 5 6 7

Strongly Disagree — Neither agree nor disagree — Strongly Agree

3. I see myself as a part of the greater circle of life.

1 2 3 4 5 6 7

Strongly Disagree — Neither agree nor disagree — Strongly Agree

4. Humans are more important than plants and animals.*

1 2 3 4 5 6 7

ONE-TIME SURVEY

Strongly Disagree		Neither agree nor disagree				Strongly Agree

5. I feel related to animals and plants.

1	2	3	4	5	6	7
Strongly Disagree			Neither agree nor disagree			Strongly Agree

6. I feel I belong to Earth and that the Earth belongs to me.

1	2	3	4	5	6	7
Strongly Disagree			Neither agree nor disagree			Strongly Agree

7. I feel that all living things in this world are connected, and I am a part of that.

1	2	3	4	5	6	7
Strongly Disagree			Neither agree nor disagree			Strongly Agree

8. There is something that every living thing shares.

1	2	3	4	5	6	7
Strongly Disagree			Neither agree nor disagree			Strongly Agree

9. Like the tree in the forest, I feel I belong in nature.

1	2	3	4	5	6	7
Strongly Disagree			Neither agree nor disagree			Strongly Agree

ONE-TIME SURVEY

10. I don't feel part of nature.*

1	2	3	4	5	6	7
Strongly Disagree			Neither agree nor disagree			Strongly Agree

Please record the appropriate answer for each item, depending on whether you strongly agree, agree, disagree, or strongly disagree with it.

1. On the whole, I am satisfied with myself.

Strongly Agree Agree Disagree Strongly Disagree

2. At times I think I am no good at all.

Strongly Agree Agree Disagree Strongly Disagree

3. I feel that I have a number of good qualities.

Strongly Agree Agree Disagree Strongly Disagree

4. I am able to do things as well as most other people.

Strongly Agree Agree Disagree Strongly Disagree

5. I feel 1do not have much to be proud of.

Strongly Agree Agree Disagree Strongly Disagree

6. I certainly feel useless at times.

ONE-TIME SURVEY

Strongly Agree Agree Disagree Strongly Disagree

7. I feel that I'm a person of worth.

Strongly Agree Agree Disagree Strongly Disagree

8. I wish I could have more respect for myself.

Strongly Agree Agree Disagree Strongly Disagree

9. All in all, I am inclined to think that I am a failure.

Strongly Agree Agree Disagree Strongly Disagree

10. I take a positive attitude toward myself.

Strongly Agree Agree Disagree Strongly Disagree

Indicate how you generally feel about each statement below.

1. Not matter how much I weigh, I can do just as much as everyone else.

I disagree I somewhat disagree I somewhat agree I agree

2. I am less attractive than other people because of my weight.

I disagree I somewhat disagree I somewhat agree I agree

3. I feel anxious about my weight because of what people might think of me.

I disagree I somewhat disagree I somewhat agree I agree

ONE-TIME SURVEY

4. I wish I could change my weight a whole lot.

I disagree I somewhat disagree I somewhat agree I agree

5. Whenever I think a lot about my weight, I feel depressed.

I disagree I somewhat disagree I somewhat agree I agree

6. I hate myself because of my weight.

I disagree I somewhat disagree I somewhat agree I agree

7. My weight strongly influences what I think of myself as a person.

I disagree I somewhat disagree I somewhat agree I agree

8. Because of my weight, I don't deserve having a lot of friends and fun.

I disagree I somewhat disagree I somewhat agree I agree

9. I am OK being the weight I am.

I disagree I somewhat disagree I somewhat agree I agree

10. Because of my weight, I don't feel like true self.

I disagree I somewhat disagree I somewhat agree I agree

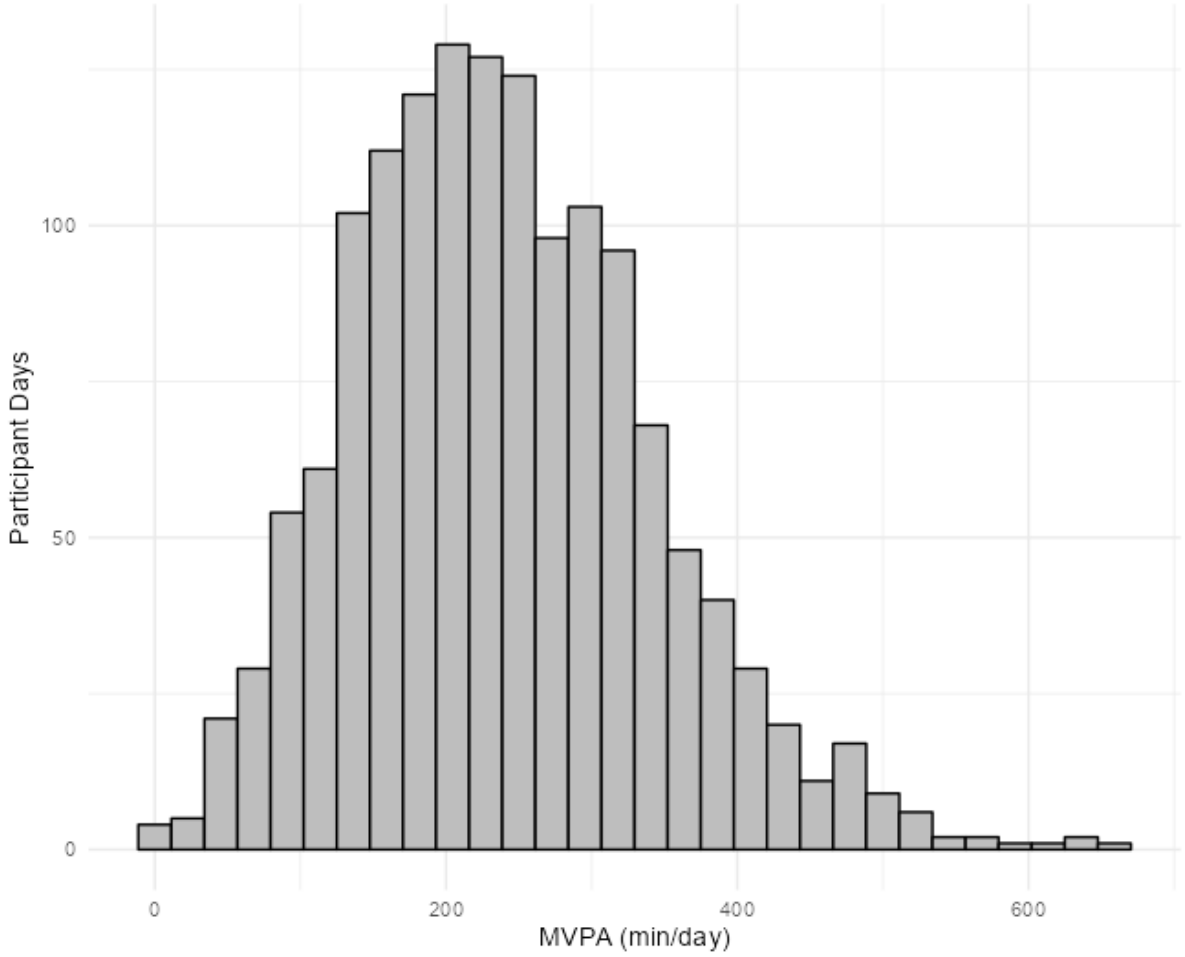
11. Because of my weight, I don't understand why attractive peers would want to play with me.

I disagree I somewhat disagree I somewhat agree I agree

Thank you for taking the time to fill out the survey. Your time and responses are important!

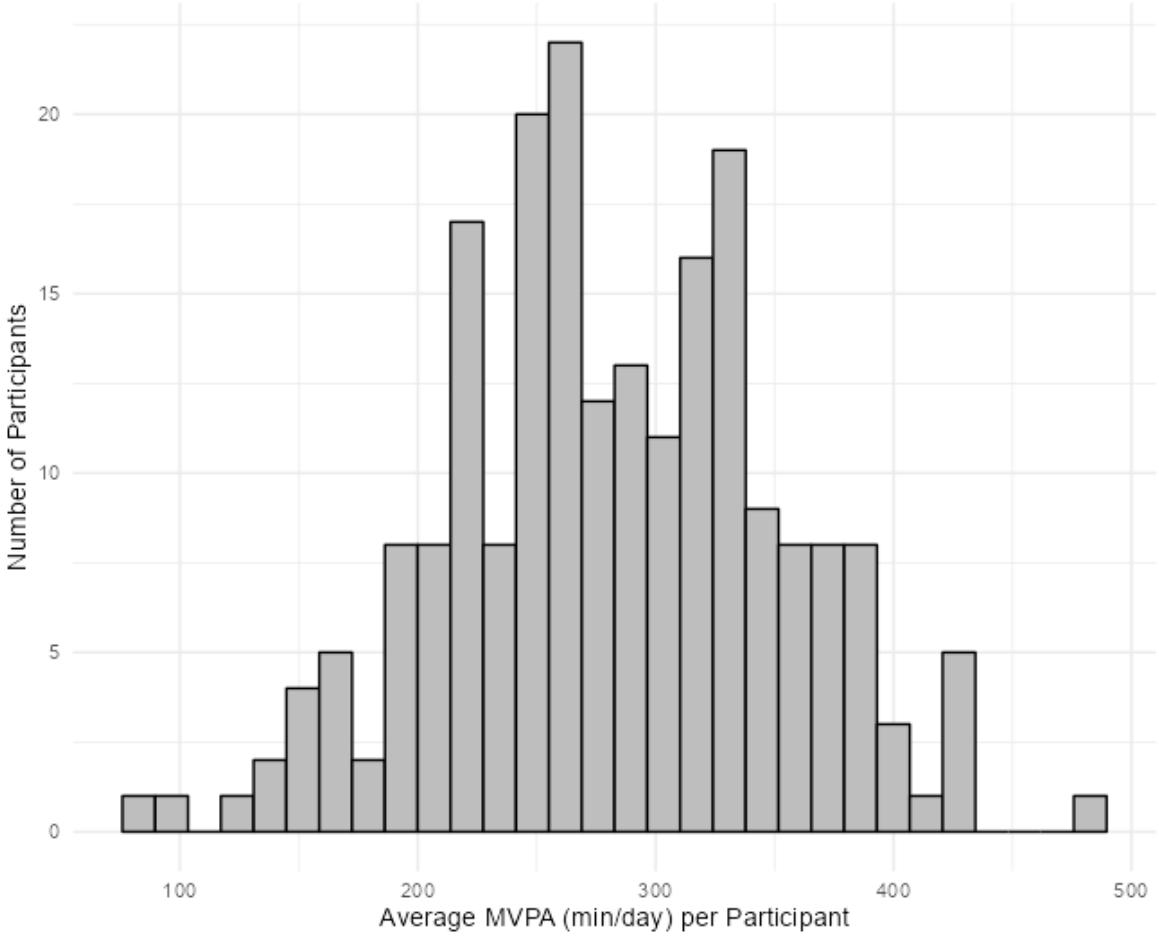
APPENDIX B

DISTRIBUTION OF PARTICIPANTS' DAILY MVPA



APPENDIX C

DISTRIBUTION OF PARTICIPANTS' AVERAGE DAILY MVPA



APPENDIX D

Correlations of Fixed Effects for Association of Nature Exposure and MVPA

	1	2	3	4	5	6	7	8	9
1. Nature Exposure	-								
2. Age	-.05	-							
3. Gender	.09	.03	-						
4. Race/ethnicity	.05	.02	.13	-					
5. BMI Percentile	.04	-.01	.06	-.09	-				
6. FRL	-.01	-.16	.03	-.05	.17	-			
7. Disability	.03	.08	.13	.09	-.02	-.04	-		
8. Seasonal allergies	-.01	.07	.07	.16	-.02	-.07	-.07	-	
9. Connectedness to nature	-.02	-.12	.20	-.03	-.02	-.02	-.03	.08	-
10. Self-esteem	.01	.20	.29	.05	.15	.07	-.05	.01	-.11

Note. Table provides information about the fixed effects for the model examining the daily association between nature exposure and MVPA when adjusting for covariates. It demonstrates how fixed effects estimates may be associated if this model was replicated many times over using a new random sample each time. Nature exposure has been log transformed. MVPA = moderate-to-vigorous intensity physical activity; BMI Percentile = body mass index percentile; FRL = free or reduced-price lunch; Disability = physical disability status

APPENDIX E

Correlations of Fixed Effects for Association of Nature Exposure and Body Appreciation

	1	2	3	4	5	6	7	8	9
1. Nature Exposure	-								
2. Age	-.02	-							
3. Gender	.04	.03	-						
4. Race/ethnicity	.02	.02	.12	-					
5. BMI Percentile	.02	-.28	.06	-.09	-				
6. FRL	-.003	-.15	.04	-.04	.16	-			
7. Disability	.02	.07	.12	.08	-.02	-.03	-		
8. Seasonal allergies	-.01	.06	.06	.14	-.02	-.06	-.09	-	
9. Connectedness to nature	-.01	-.12	-.20	-.03	-.02	-.04	-.04	.07	-
10. Self-esteem	.01	.19	.28	.06	.15	.07	-.04	.01	-.11

Note. Table provides information about the fixed effects for the model examining the daily association between nature exposure and body appreciation when adjusting for covariates. It demonstrates how fixed effects estimates may be associated if this model was replicated many times over using a new random sample each time. Nature exposure has been log transformed. BMI Percentile = body mass index percentile; FRL = free or reduced-price lunch; Disability = physical disability status

APPENDIX F

Correlations of Fixed Effects for Association of Body Appreciation and MVPA

	1	2	3	4	5	6	7	8	9
1. Body Appreciation	-								
2. Age	.15	-							
3. Gender	.04	.03	-						
4. Race/ethnicity	-.08	.002	.11	-					
5. BMI Percentile	.04	-.26	.06	-.11	-				
6. FRL	-.11	-.16	.03	-.03	.17	-			
7. Disability	-.08	.05	.10	.09	-.02	-.01	-		
8. Seasonal allergies	-.04	.07	.05	.14	-.03	-.04	-.09	-	
9. Connectedness to nature	-.14	-.15	-.21	-.02	-.03	-.02	-.01	.06	-
10. Self-esteem	-.55	.07	.21	.09	.11	.14	.02	.04	-.01

Note. Table provides information about the fixed effects for the model examining the daily association between body appreciation and MVPA when adjusting for covariates. It demonstrates how fixed effects estimates may be associated if this model was replicated many times over using a new random sample each time. MVPA = moderate-to-vigorous intensity physical activity; BMI Percentile = body mass index percentile; FRL = free or reduced-price lunch; Disability = physical disability status

APPENDIX G

Correlations of Fixed Effects for Association of Nature Exposure and MVPA by Gender

	1	2	3	4	5	6	7	8	9	10
1. Nature Exposure	-									
2. Age	-.04	-								
3. Gender	-.08	.03	-							
4. Race/ethnicity	.05	.02	.13	-						
5. BMI Percentile	.001	-.01	.06	-.09	-					
6. FRL	-.03	-.16	.03	-.05	.17	-				
7. Disability	.03	.08	.13	.09	-.02	-.04	-			
8. Seasonal allergies	.003	.07	.07	.16	-.02	-.07	-.07	-		
9. Connectedness to nature	-.02	-.12	.20	-.03	-.02	-.02	-.03	.08	-	
10. Self-esteem	.01	.20	.29	.05	.15	.07	-.05	.01	-.11	-
11. NE*Gender	-.72	-.001	0.19	-.02	.03	.03	-.01	-.02	.01	-.01

Note. Table provides information about the fixed effects for the model examining the moderation of gender in the daily association between nature exposure and MVPA when adjusting for covariates. It demonstrates how fixed effects estimates may be associated if this model was replicated many times over using a new random sample each time. Nature exposure has been log transformed. MVPA = moderate-to-vigorous intensity physical activity; BMI Percentile = body mass index percentile; FRL = free or reduced-price lunch; Disability = physical disability status; NE*Gender = interaction term of nature exposure and gender

APPENDIX H

Correlations of Fixed Effects for Association of Nature Exposure and Body Appreciation by Gender

	1	2	3	4	5	6	7	8	9	10
1. Nature Exposure	-									
2. Age	-.02	-								
3. Gender	-.02	.03	-							
4. Race/ethnicity	.02	.02	.12	-						
5. BMI Percentile	.004	-.28	.06	-.09	-					
6. FRL	-.01	-.15	.04	-.04	.16	-				
7. Disability	.02	.07	.12	.08	-.02	-.03	-			
8. Seasonal allergies	.001	.06	.06	.14	-.02	-.06	-.09	-		
9. Connectedness to nature	-.02	-.12	-.19	-.03	-.02	-.04	-.04	.08	-	
10. Self-esteem	.01	.20	.28	.06	.15	.07	-.04	.01	-.11	-
11. NE*Gender	-.75	.001	0.06	-.004	.01	.01	-.01	-.01	.01	-.01

Note. Table provides information about the fixed effects for the model examining the moderation of gender in the daily association between nature exposure and body appreciation when adjusting for covariates. It demonstrates how fixed effects estimates may be associated if this model was replicated many times over using a new random sample each time. Nature exposure has been log transformed. BMI Percentile = body mass index percentile; FRL = free or reduced-price lunch; Disability = physical disability status; NE*Gender = interaction term of nature exposure and gender

APPENDIX I

Correlations of Fixed Effects for Association of Body Appreciation and MVPA by Gender

	1	2	3	4	5	6	7	8	9	10
1. Body Appreciation	-									
2. Age	.11	-								
3. Gender	-.02	.04	-							
4. Race/ethnicity	-.06	.003	.11	-						
5. BMI Percentile	.07	-.27	.06	-.11	-					
6. FRL	-.11	-.16	.03	-.03	.16	-				
7. Disability	.01	.04	.09	.09	-.01	-.01	-			
8. Seasonal allergies	-.02	.06	.05	.14	-.03	-.04	-.09	-		
9. Connectedness to nature	-.15	-.15	-.20	-.02	-.04	-.02	-.02	.05	-	
10. Self-esteem	-.39	.06	.20	.09	.11	.13	.02	.04	-.02	-
11. BA*Gender	-.63	.02	0.09	.00	-.07	.03	-.11	-.02	.07	-.06

Note. Table provides information about the fixed effects for the model examining the moderation of gender in the daily association between body appreciation and MVPA when adjusting for covariates. It demonstrates how fixed effects estimates may be associated if this model was replicated many times over using a new random sample each time. MVPA = moderate-to-vigorous intensity physical activity; BMI Percentile = body mass index percentile; FRL = free or reduced-price lunch; Disability = physical disability status; BA*Gender = interaction term of body appreciation and gender

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