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The health impact of nature exposure and green exercise across the life course: a pilot study

Wood CJ[a] & Smyth N[b*]

[a]School of Life Sciences, University of Westminster, 115 New Cavendish Street, London, UK, W1W6UW; c.wood@westminster.ac.uk

[b]School of Social Sciences, University of Westminster, 115 New Cavendish Street, London, UK, W1W6UW; n.smyth@westminster.ac.uk.

*indicates corresponding author

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Abstract:

Background: Both nature exposure and green exercise (GE) provide numerous health benefits. However, there are no studies examining the impact of childhood GE on adult health. Methods: 45 healthy adults (aged 69.8 ± 8.4 years) took part in the study, wearing a Firstbeat heart rate variability (HRV) monitor for 24 hours. Participants also completed questionnaires assessing childhood and adulthood nature exposure and GE, as well as current connectedness to nature (CN), perceived stress and well-being. Pearson's correlations and linear regression were used to examine relationships between variables. Results: Childhood nature exposure and GE significantly predicted adult nature exposure and GE (β .317, $p < 0.05$) as well as CN ($\beta = .831$, $p < 0.01$). After controlling for childhood nature exposure and GE, CN was negatively associated with the percentage of stress over the 24-hour period ($r = -.363$; $p < 0.05$) and positively associated with HRV during sleep ($r = .415$; $p < 0.05$). Conclusions: CN is important for adult health; however childhood nature exposure and GE are essential to developing this connection.

Introduction

The positive impact of physical activity (PA) on health is well documented. Regular PA is an effective primary and secondary prevention strategy for more than 25 chronic diseases including cardiovascular disease and type II diabetes; reducing the risks by approximately 20–30% (eg Wichstrom et al. 2013). PA also reduces the risk of all-cause mortality; with the most active individuals having a 31% reduced risk of premature death compared to the least active individuals (Rhodes et al. 2017). Furthermore, PA behaviours track from childhood into adulthood; with those who are inactive and physically unfit during childhood being more inactive and unfit during adulthood (Malina 2001; Telama et al. 2014). Individuals who are physically active also have a lower prevalence of cognitive impairment in later life; with teenage PA being most strongly associated with a reduction in cognitive impairment during older age (Middleton et al. 2010). Thus, PA is essential to good health throughout the life course.

PA within a natural environment (so-called ‘Green Exercise’; GE) has been demonstrated to provide additive health benefits above PA indoors or in a non-natural environment (Pretty et al. 2005). GE can reduce stress, depression and blood pressure, increase self-esteem and mood, and enhance heart rate variability (HRV); an important marker of cardiovascular health (Acharya et al. 2006; Barton and Pretty 2010; Brown et al. 2013; Wood et al. 2016; Ewert and Chang 2018). The health benefits of spending time in natural environments (termed ‘nature exposure’) have long been known: nature exposure has been demonstrated to increase positive and decrease negative affect, improve life satisfaction and cognitive functioning, reduce stress, enhance both physical health and self-esteem and reduce overall risk of mortality (Mitchell and Popham 2008; Bratman et al. 2012). Furthermore, natural environments are facilitative of PA which promotes further health outcomes (Pearce et al. 2018).

Despite the importance of both nature exposure and GE for health, there is limited evidence regarding their impact on health across the life course (Pearce et al. 2018). One known study examining adults' childhood nature exposure and current nature exposure found positive associations with mental well-being; with the contribution of childhood nature exposure being indirect through its influence on current nature exposure (Pensini et al. 2016). The study also revealed that these relationships were mediated by connectedness to nature, an individual's feelings of connection to the natural world (Mayer and McPherson Frantz 2004); indicating that this might play a key role in the health outcomes derived from nature exposure. However, this study did not consider the influence of nature exposure on markers of physical health, or the potential role of GE in influencing adult health outcomes.

In the literature, there is little research specifically examining GE. One potential reason for this is the limited number of tools available to assess frequency of GE participation. Whilst there are tools to assess PA and nature exposure separately, to date researchers examining the links between GE and health have used PA questionnaires coupled with mapping systems or GPS trackers to isolate the exercise location (Loveday et al. 2015). Such measures make for time-consuming and complex analysis. The recently developed current and retrospective nature exposure and GE scales (Wood et al., under review) allow for the assessment of habitual nature exposure and GE participation and therefore provide an opportunity to examine these relationships.

The aims of this study were therefore:

1. To explore the relationships between childhood nature exposure and GE, adult nature exposure and GE and connectedness to nature
2. To examine the influence of childhood and adulthood nature exposure and GE and connectedness to nature on adult heart rate variability, well-being and stress.

Materials and Methods

Participants

A total of 45 healthy participants took part in the study, with a mean age of 69.8 ± 8.4 years. Participants were recruited through emails to university staff and study advertisements via the University of the Third Age; an international movement of retired and semi-retired people. Participants were required to be free from psychiatric illness and aged 50 years or above to enable examination of the impact of nature exposure and GE across the life course in healthy older individuals. All participants provided individual consent prior to taking part in the study; with institutional ethical approval provided by the University Ethics Committee.

Procedure

On entry to the study, all participants were invited to attend a one-to-one induction session at the University. Prior to attending this session, they completed an online questionnaire. The questionnaire asked participants to provide demographic information including age, sex, and socio-economic status (SES). Subjective SES was self-assessed with the 1–10 ‘ladder’ measure; participants rated where they stood in society in terms of education, occupation and wealth; the top of the ladder represents a higher social standing (Goodman et al. 2001). The online questionnaire also included questions about the participants’ well-being, stress, engagement with nature and GE (both current and during childhood) and their connectedness to nature (see psychosocial measures section).

On arrival at the university campus participants were provided with a set of instructions for the subsequent two study days, which were conducted from the participants’ home environments. On the two study-days participants, were asked to wear a Firstbeat bodyguard HRV monitor continuously to allow selection of a continuous 24 hour HRV measurement. Participants were provided with instructions on how to wear the monitors, and were also provided with a diary to log their daily activities and sleeping and awakening times. Participants were given the opportunity to ask questions and clarify anything they were unsure of. During this induction, height and weight were also measured by the researcher to allow the calculation of body mass index (BMI); which was calculated by dividing weight in kilograms by height in meters squared.

Online Questionnaire

The online questionnaire included the Warwick Edinburgh Mental wellbeing scale (Tennant et al. 2007), the perceived stress scale (Cohen et al. 1983), the childhood and adult nature exposure and GE scales (Wood et al. 2018) and the connectedness to nature scale (Mayer and McPherson Frantz 2004).

Warwick Edinburgh Mental Wellbeing Scale (WEMWBS)

The WEMWBS is a 14-item positively worded scale which monitors wellbeing in the general population (Tennant et al. 2007). The scale has five response categories from one (none of the time) to five (all of the time) which are summed to give a score from 14-70; with a higher score representing a better wellbeing. The scale has a Cronbach alpha score of 0.90 (Tennant et al. 2007) and in the current sample had an alpha of 0.90, indicating very good reliability. The scale was used to ask participants to rate their wellbeing over the last month.

Perceived Stress Scale (PSS)

Stress was assessed using the 10-item PSS (Cohen et al. 1983). The scale measures an individual's appraisal of the degree to which situations in his or her life are stressful. All items were rated on a five point scale from zero (never) to four (very often). Four items were reverse scored and an overall score between 0-40 was computed, with higher scores reflecting greater stress. The PSS has previously been demonstrated to have a Cronbach alpha ranging from .78-.91 (Lee 2012). In the current sample the alpha was .83, indicating very good reliability.

Adult (current) Nature Exposure and Green Exercise Scale

The adult nature exposure and GE scale is a new five item scale which assesses overall exposure to nature and GE during adulthood; including exposure to nature in everyday life, exposure outside everyday environments and the participation in PA when in these environments (Wood et al. 2018). Each question on the scale was scored on a 5-point likert scale (1 = *high/a great deal*, 5 = *low/not much*), with higher scores reflecting greater exposure and participation in GE. The scale has recently been demonstrated to have an alpha of 0.84 and is negatively correlated with measures of depression, anxiety, stress; and positively correlated with wellbeing, self-esteem and feelings of connectedness to nature (Wood et al. 2018). In the current sample had an alpha of .89; indicating very good reliability.

Childhood (retrospective) Nature Exposure and Green Exercise Scale

The childhood nature exposure and GE scale is a retrospective version of the adult nature exposure and GE scale which assesses participants' experiences of nature and GE during childhood; where childhood was defined as between the ages of 5-10 years (Wood et al. 2018). The questions on this scale match those on the adult nature exposure and GE scale but simply reflect childhood activities. Each question on the scale was scored on a 5-point likert scale (1 = *high/a great deal*, 5 = *low/not much*), with higher scores reflecting greater exposure. The scale has recently been demonstrated to have an alpha of 0.89, with overall scores negatively correlated with measures of depression, anxiety, stress; and positively correlated with wellbeing, self-esteem and feelings of connectedness to nature (Wood et al. 2018). In the current sample had an alpha of .87, indicating very good reliability

Connectedness to Nature Scale

The connectedness to nature scale is a measure of an individuals' trait levels of feeling emotionally connected to the natural world (Mayer and McPherson Frantz 2004). The scale consists of 14 items with response categories from one (strongly disagree) to five (strongly agree). Three items are reversed score, with the overall score ranging from 14-70. A higher score represents a greater connection to nature. The scale has previously been demonstrated to have a Cronbach alpha of 0.84 (Mayer and McPherson Frantz 2004). In the current sample the alpha was 0.70 indicating good reliability.

Heart Rate Variability Monitoring

Throughout the study participants wore a FirstBeat Bodyguard HRV monitor which obtains beat to beat R-R interval recordings in real time (FirstBeat Technologies Ltd, Jyvaskyla, Finland). Participants fitted the monitor before they went to bed on the day of the induction and were asked to wear the monitor continuously for all of the following day and overnight until they awoke on the following day. The monitors were fitted via two electrodes placed directly onto the skin; once attached they monitored continuously until detachment. The only time participants removed the monitors was during showering or swimming activities. After removal participants used new electrodes to fit the monitors. Pictures of how and where to reattach the monitors were provided in the guidelines document for those participants who needed a reminder. Participants were asked to record the time of attaching the monitor, any time periods for which the monitor was removed and the time that they ended the monitoring, along with any issues encountered.

On return of the monitor, data were downloaded using the FirstBeat Lifestyle Assessment Software, which includes a powerful artefact detection and corrects for irregular ectopic heartbeats and signal noise. For each participant a period of approximately 24 hours (mean: 24.01±0.66hours) was selected for analysis; this was from awakening on the day after induction to awakening on the second day of the study. Second by second indices reflecting the activities of the parasympathetic and sympathetic nervous system were calculated using the Fourier Transform method. The data were then categorised into different physiological states including stress, recovery and physical activity (Firstbeat Technologies Ltd, 2014). The programme detects stress when sympathetic nervous system activity dominates and recovery when parasympathetic nervous system activity dominates. This information was used to create a number of indices, as detailed in table 1. These indices are typically used to reflect the activities of the nervous system.

Statistical Analysis

Pearson's correlations were conducted to examine the relationship between childhood nature exposure and GE, adult nature exposure and GE and connectedness to nature. Multiple linear regression models were conducted to examine the contribution of childhood and adulthood nature exposure and GE to connectedness to nature; and childhood nature exposure and GE and connectedness to nature to adult nature exposure and GE. Pearson's correlations were also conducted to examine the relationships between connectedness to nature, childhood and adulthood nature exposure and GE and the psychosocial and HRV measures. Given the unique contribution of childhood nature exposure and GE to both adult nature exposure and GE and connectedness to nature, partial correlations were conducted to explore these relationships after controlling for the childhood exposure variable.

Results

Participants

Demographic data for participants are presented in Table 2. The majority of participants were female and of a white background. Participants' ages ranged from 54 to 89 years, with ratings of SES ranging from 5 to 9. Scores obtained on the nature exposure, GE, connectedness to nature, psychosocial and HRV variables are also presented in Table 2. Participant scores were in the bottom 30% of the scoring range for the perceived stress scale indicating low levels of perceived stress. They scored within the top 30% of the scoring range for the other psychosocial measures; indicating high nature exposure and GE participation, connectedness to nature and psychological well-being. Across the 24-hour period, the mean score for the percentage of stress reactions was below average; whilst the amount of recovery was deemed to be average (see Table 2); indicating good health in this sample.

Nature Exposure, Green Exercise and Health Status

Table 3 presents the correlations between childhood and adulthood nature exposure and GE and connectedness to nature. There were significant positive correlations between all variables; childhood and adulthood nature exposure and GE were related to each other as well as connectedness to nature. Multiple regression was conducted to examine the extent to which these variables predicted each other. The first multiple regression revealed a significant combined effect of childhood and adulthood nature exposure and GE on connectedness to nature ($F_{(2,41)} = 7.68$; $p < 0.01$); with the model accounting for 27.2% of the variance in connectedness to nature scores. Only childhood nature exposure and GE made a unique significant contribution to connectedness to nature (see Table 3, model 1). A second multiple regression revealed a significant combined effect of childhood nature exposure and GE and connectedness to nature on adult nature exposure and GE ($F_{(2,41)} = 9.20$; $p < 0.001$), accounting for 27.6% of the variance in scores. Only childhood nature exposure and GE made a unique significant contribution to adult nature exposure and GE (see Table 3, model 2).

Next, we examined the relationships between childhood and adulthood nature exposure, GE, connectedness to nature and health variables (psychosocials and HRV variables), these are displayed in Table 4. Connectedness to nature was the only variable to be significantly correlated with any of the health variables, with a moderate negative correlation with the percentage of stress reactions ($p < 0.01$). Partial correlations were examined to control for childhood nature exposure and GE, given its unique contribution to both connectedness to nature and adulthood nature exposure and GE. After controlling for childhood nature exposure and GE, the relationship between connectedness to nature and percentage of stress reactions over 24 hr period remained ($r = -.42$; $p < 0.01$), and there was a significant positive relationship between connectedness to nature and HRV during sleep ($r = .47$; $p < 0.01$). These results indicate that being connected to nature is associated with fewer stress reactions (ie lower heart rate and higher HRV) and greater HRV during sleep. There were no significant correlations between stress, well-being and the HRV variables and adult nature exposure and GE after controlling for childhood nature exposure and GE.

Discussion

The aims of this study were (i) to explore the relationships between childhood nature exposure and GE, adult nature exposure and GE and connectedness to nature and; (ii) to examine the influence of childhood and adulthood nature exposure and GE and connectedness to nature on adult heart rate variability, well-being and stress. The study findings firstly revealed that childhood nature exposure and GE uniquely predicted both adult nature exposure and GE and connectedness to nature. Greater exposure and participation during childhood was associated with greater exposure, participation and connectedness to nature during adulthood. These findings are in line with previous studies which have identified the importance of childhood nature exposure in fostering habits for nature exposure in later life (Bixler et al. 2002; Pensini et al. 2016). Additionally, they support the notion that like PA, nature exposure and GE behaviours might track across the life course (Malina 2001; Pretty et al. 2009; Hirvensalo and Lintunen 2011; Telama et al. 2014; Pensini et al. 2016). Pretty et al. (2009) suggest a funnel of life pathways which shape our lives. On the ‘healthy’ pathway people live longer with a better quality of life due to behaviours such as increased PA and engagement with nature, whilst those on the ‘unhealthy pathway’ are sedentary and lack access to natural environments. The evidence of these pathways, combined with the increasing body of evidence demonstrating the health benefits derived from as little as five minutes of GE (Barton and Pretty 2010; Wood et al. 2016); emphasise the importance of providing children with access to natural environments.

The study also revealed that connectedness to nature is significantly related to the percentage of stress reactions over a 24 hour period and HRV during sleep after controlling for the impact of childhood nature exposure and GE. Those with lower connectedness to nature scores had significantly more stress reactions and a lower HRV during sleep; both of which indicate poorer health (Stein et al. 2005; Acharya et al. 2006; Geisler et al. 2010. These findings suggest that connectedness to nature might play an essential role in predicting physiological health outcomes during adulthood, but for a connection to nature to be developed, nature exposure and GE participation during childhood is essential. In the current society, whereby young people spend less time interacting with nature than previous generations these findings are of particular concern. Less than 10% of young people have regular contact with nature compared to the 50% who did so 30–40 years ago (Bird 2007), and fewer than one quarter of children currently use their 'local patch of nature'. Furthermore, the radius in which children roam from their homes has decreased by 90% since the 1970s. All of this has resulted in widespread disconnection of our children from nature. Given the importance of connection to nature for health throughout life (Bratman et al. 2012; Pensini et al. 2016), the threats facing our natural environments and the fact that young people are our conservationists and environmentalists of the future (Maas et al. 2006; Maller et al. 2006), it is essential that we engage and connect our children with nature to ensure that natural environments are preserved for future generations.

There was no effect of either childhood nature exposure and GE, adult nature exposure and GE or connectedness to nature on the measured psychological variables. Previous research by Pensini et al. (2016) revealed positive relationships between childhood and adulthood nature exposure and well-being, in adults aged 19–40; with the contribution of childhood nature exposure being indirect through its influence on current nature exposure (ie being exposed to nature during childhood encourages connections with nature). The study also identified connectedness to nature as a key mediator in these relationships. Whilst these findings are somewhat supported by the current physiological data, we did not find any influence on psychological health outcomes in older adults aged between 54 and 89 years. There are some distinct differences between the two studies that potentially explain the differences in findings. Pensini et al. (2016) used participants aged 19–40 years, a much younger group than in the current study, potentially middle-aged adults are more akin to reporting stress and well-being. In the current study, the physiological measures of stress (HRV variables) did not correlate with the psychosocial measures (stress and well-being), indicating disparity between these measures. The authors also defined childhood as up to 18 years of age and only assessed nature exposure as opposed to nature exposure and GE, as per the current study. Furthermore, the assessment of nature exposure was performed by a questionnaire examining exposure to 13 different environments typically found in Australia whilst in the current study we assessed nature exposure in the UK, mostly in those living in an urban environment, which is likely to have significantly contrasting natural environments (eg mountains, rainforests). Additionally, the health status of participants in the study by Pensini et al. (2016) is unclear, perhaps also explaining contrasting findings.

There are some limitations to the current study that warrant consideration. The majority of participants were of good health and reported high levels of childhood and adulthood nature exposure and GE and connectedness to nature; limiting the ability of the study to fully explore the relationships between these variables. The sample were predominately drawn from an urban environment; thus nature exposure and GE may be limited to urban nature (ie green area or nature in built-up environments). The mean well-being score in the current study was 55.64 out of a maximum of 70; whilst the average score on the PSS was 11.61 on a 40 point scale, with a score of 0 indicating the least possible level of stress. The mean scores for the HRV were also demonstrated to reflect average 'healthy' individuals, whilst the mean scores for the nature, GE and connectedness to nature scales were all within the top 75% of possible scores. The mean age of participants in the current study was also high, with 87% of participants being over 60 years. It is possible that the relationships between nature exposure and GE and health outcomes might vary across generations due to differences in opportunities for nature exposure and GE participation. Future research should therefore seek to include participants with varied health, nature exposure and GE participation and from a range of age groups. It would also be beneficial for the 24-hour snapshot used to examine physiological health status to be extended, as this period might not have been representative of the typical activities and experiences of participants. Future research should also seek to incorporate additional physiological health measures to ensure a more comprehensive assessment of physical health status.

Overall, the findings of this study indicate that childhood nature exposure and GE participation is an important predictor of both connectedness to nature and adult nature exposure and GE; and that connectedness to nature is important for physical health during adulthood. These findings emphasise the importance of childhood nature exposure and GE for ensuring both participation and connection across the life course. Strategies focused on promotion of nature exposure and GE during childhood and in connecting the current generation of young people to natural environments are therefore essential to ensuring the health of future generations.

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Tables

Table 1: Stress and recovery variables derived from the analysis of Firstbeat HRV monitors.

Index	Description
Amount of stress (%)	Amount of stress reactions across the measurement period, reflected by an elevated activation level of the body. The average for a 24-hour period is 50%
Amount of recovery (%)	Amount of recovery across the measurement period, reflected by a calming down of the body. The average recovery during a 24-hour period is 26%
Amount of recovery during sleep (%)	The amount of recovering during sleep periods.
Quality of recovery during sleep (ms)	The average heart rate variability during the sleep period.

Table 2: Demographic statistics for psychosocial and HRV variables.

Demographic Details		M±SD	Min-Max
Age (years)		69.8±8.4	54-89
Sex (%)	Male (n=8)	17.8	
	Female (n=37)	82.2	
Ethnicity (%)	White background(n=43)	95.6	
	Black background (n=1)	2.2	
	Asian background (n=1)	2.2	
BMI (kg.m²)		25.5±4.6	18-37
Socio economic status (1-10)		7.1±1.1	5-9
Childhood nature exposure and GE		19.7±4.3	7-25
Adult nature exposure and GE		22.5±3.0	14-25
Connectedness to Nature		53.2±8.5	36-69
% Stress reactions		48.64±15.36	2-72
% recovery day and night		23.31±10.23	4-49
% recovery sleep		54.69±25.71	1-92
HRV during sleep (ms)		28.84±16.64	9-99
Wellbeing score		55.64±7.50	34-68
Stress score		11.61±6.21	1-25

Table 3.Multiple Regression analyses; predicting CN, childhood and adulthood nature exposure & GE, and health.

Model 1: prediction of connectedness to nature	**β**	**P-value**
Childhood nature exposure and GE	.831	.008
Adulthood nature exposure and GE	.483	.275
Model 2: prediction of Adulthood nature exposure and GE		
Connectedness to nature	.317	.005
Childhood nature exposure and GE	.062	.275

Table 4: Correlations between measured variables

	Childhood nature exposure and GE	**Adult nature exposure and GE**	**Connectedness to nature**	**% stress reactions**	**% recovery (day and night)**	**% recovery sleep**	**HRV during sleep**	**Wellbeing**	**Stress**
Childhood nature exposure and GE	-	**.55**	**.54**	-.08	-.04	-.19	-.17	-.17	.12
Adult nature exposure and GE		-	**.40**	.02	.12	.05	.12	.03	-0.12

Connectedness to nature	-	**-.40**	.07	.02	.29	-.09	.12
% stress reactions		-	**-.39**	**-.31**	**-.36**	.18	-.05
% recovery (day and night)			-	**.79**	.00	.11	-.08
% recovery sleep				**-**	.16	.06	-.10
HRV during sleep					-	.06	-.17
Wellbeing						-	**-.60**
Stress							-

Bold= significant correlation (P<0.05)