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What is the Best Dose of Nature and Green Exercise for Improving Mental Health? A Multi-Study Analysis

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Green exercise is activity in the presence of nature. Evidence shows it leads to positive short and long-term health outcomes. This multistudy analysis assessed the best regime of dose s) of acute exposure to green exercise required to improve self-esteem and mood indicators of mental health). The research used meta-analysis methodology to analyze 10 UK studies involving 1252 participants. Outcomes were identified through a priori subgroup analyses, and dose—responses were assessed for exercise intensity and exposure duration. Other subgroup analyses included gender, age group, starting health status, and type of habitat. The overall effect size for improved self-esteem was d 0.46 CI 0.34—0.59, $p < 0.00001$) and for mood d 0.54 CI 0.38—0.69, $p < 0.00001$). Dose responses for both intensity and duration showed large benefits from short engagements in green exercise, and then diminishing but still positive returns. Every green environment improved both self-esteem and mood; the presence of water generated greater effects. Both men and women had similar improvements in self-esteem after green exercise, though men showed a difference for mood. Age groups: for self-esteem, the greatest change was in the youngest, with diminishing effects with age; for mood, the least change was in the young and old. The mentally ill had one of the greatest self-esteem improvements. This study confirms that the environment provides an important health service.

Introduction

Ecosystems provide important services driven by provisioning, regulation, and support functions (*1, 2*). It is clear they also provide a health service arising from direct activities in contact with nature. Recognition of the potential contribution of natural ecosystems to human population health may contribute to addressing problems associated with inactivity, obesity, mental ill-health, and other chronic diseases. Many of these urgent health challenges are also connected to sedentary and indoor lifestyles (*3, 4*). Physical inactivity results in 1.9 million deaths worldwide annually (*5*), roughly 1 in 25 of all deaths. Preindustrial humans expend some 1000 kcal on activity per day, whereas for modern humans the mean is 300 kcal (*6*). Inactivity increases the likelihood of obesity and reduces life expectancy. Such physical inactivity tracks from childhood, and is a key risk factor in many chronic diseases of later life (*7*). Mental health disorders are now known to affect most people at some point in their lives, with 16 of the general population affected at any given time (*8, 9*). As aging populations will put additional pressure on health services, it is becoming increasingly urgent that all sectors of the population undertake and sustain healthy behaviors as early in life as possible (*10*).

Evidence shows that exposure to natural places can lead to positive mental health outcomes, whether a view of nature from a window, being within natural places, or exercising in these environments (*11–13*). At the population level, there are associations between health and proximity to greenspaces (*14*). Thus, green space is important for mental health and regular engagement is linked with longevity and decreased risk of mental ill-health (*15*). Yet as more than half of the world's population now live in urban settlements, daily environmental contact is becoming rarer (*16*), suggesting the growing importance of access to local greenspace for both quality of life and the sustainability of towns and cities (*17, 18*). It is also well-known that physical activity improves both physical and mental health of all age groups (*19–22*). Thus "green exercise", consisting of activity in green places (in the presence of nature), is predicted to generate positive health outcomes (*23–26*), accrue ecological knowledge (*21, 22, 27, 28*), foster social bonds (*29*), and influence behavioral choices (*11, 24–26, 30, 31*). In economic terms, there should be cost savings if natural places are both protected (*32, 33*) and used as sites for activity, thus generating health benefits.

Achieving good mental health is not just a reflection of the absence of disease or disability. It comprises a balance between self-satisfaction, independence, capability and competency, achieving potential, and coping well with stress and adversity (*34*). Both self-esteem and mood are short- and long-term determinants of mental health: both are commonly assessed in green-exercise research. Self-esteem is an evaluation of a person's sense of worth or value (*35*), and there are strong positive correlations between self-esteem and health (*28, 36*). There are further inverse relationships between self-esteem and mental health (e.g., depression, social anxiety, loneliness, alienation) (*35*). High levels of self-esteem are associated with healthy behaviors, such as healthy eating, participating in physical activities, not smoking, and lower suicide risks (*37*).

Mood is an integral component of daily life and strongly influences feelings of happiness, appreciating the moment, coping with stressful situations, and quality of life (*38, 39*). Mood is linked with physical health and is known to affect the immune system and the onset of certain diseases (*40*). Acute changes in mood are generally maintained for 2—4 h post exercise, though this relatively short duration of enhanced mood has a positive influence on quality of life including more social interaction, improved productivity, and better behavioral choices (*39–41*). Regular exercise contributes to sustained chronic changes in mood. Thus, both self-esteem and mood are regularly used to assess the outcomes of acute-exposures to nature-based interventions.

However, health as an environmental service remains hard to value (*42–44*), and these scientific findings do not yet appear to have influenced the planning of urban and rural environments, priorities for public health, social care and youth offender programs, nor recommendations for the emergence of sustainable lifestyles. The evidence to date incorporates different methodologies and variables measured, along with international differences in typologies of greenspaces, length of activity programs, and primary

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TABLE 1. Descriptive Data on the Green Exercise Interventions Included in the Meta-Analysis

project number	no. participants	type of activities	type of environments	cohort
1	256	cycling, gardening, walking, fishing, boating, horse-riding	countryside/farmland, forest and woodland, urban green, waterside	individuals choosing to engage in GE activities
2	153	walking	countryside/farmland, forest and woodland, wild habitats	individuals at NT sites
3	38	farming activities	countryside/farmland	visitors to care farms
4	11	gardening	forest and woodland	students
5	57	walking	countryside/farmland, forest and woodland, waterside, wild habitats	members of local mind association
6	86	walking	forest and woodland	individuals choosing to engage in GE activities
7	447	walking	urban green	individuals at urban flower show
8	59	farming activities	countryside/farmland	visitors to care farms
9	10	walking, water based (sailing)	wild habitats, waterside	young offenders
10	135	gardening	urban green	individuals responsible for allotments

Note: These studies were conducted with (1) Countryside Recreation Network, (2) National Trust, (3) National Care Farming Initiative, (4) University of Essex, (5) Mind, (6) Highwoods Country Park, (7) Royal Horticultural Society, (8) LEAF, (9) Wilderness Foundation, and (10) local allotment societies.

research questions. Uncertainties remain on the ideal duration and intensity of nature-based activities to improve mental health for different cohorts of people. It is also unclear how recommendations should vary according to participant characteristics. The purpose of this research was thus to assess the best regime of dose(s) of acute exposure to green exercise required to improve self-esteem and mood. The term "dose of green exercise" represents the linked relationships between duration of exposure, intensity of activity, and type of greenspace.

Detailed research questions relate to physical activities (duration and intensity), types of green places, and participant characteristics (age, sex, health status): 1. How does exercise duration affect self-esteem and mood?; 2. How does exercise intensity affect self-esteem and mood?; 3. How do different green habitats (e.g., urban green space, countryside, waterside, wilderness, woodlands) affect self-esteem and mood? 4. What are the measurable differences according to selected participant characteristics (e.g., children, adult, elderly; female, male)?

We thus conducted a multistudy analysis of available data using standardized meta-analysis methods to assess the impact of green exercise on self-esteem and mood. This enabled us to determine the most effective regime(s) for a dose of acute green exercise. The recommended dose is based on the combined benefits of both variables and does not assess the separate contributions of nature and physical activity on mental health.

Materials and Methods

Study Selection. Ten studies undertaken by the University of Essex over the past six years were selected for inclusion. The multistudy analysis was limited to these studies because all used identical measurement tools to analyze changes in self-esteem and mood after an acute exposure to green exercise. However, to ensure validity of the overall analysis standardized meta-analysis methods were used.

Self-esteem and mood measures were chosen as they are state measures and can be easily manipulated in the short term. They are also early indicators of long-term disease risk and have implications for health behaviors, motivations, and lifestyle choices. None of the studies used randomized controlled trials or incorporated control groups where participants were exposed to nature without exercising or exercised in nongreen environments. All 1252 participants were self-selecting using an opportunistic sampling methodology and took part only in one study. We had full access to all primary data, including pre- and post- mean values, sample sizes, paired groups *t*-value, effect directions and information on the nature of the intervention, participants and location type (Table 1). This study does not therefore include a large variety of studies from different research groups.

Self Esteem and Mood Measures. The Rosenberg Self-Esteem Scale (RSE) is the most widely used and popular self-esteem measure (*45, 46*). Many researchers regard the scale as the standard against which other measures of self-esteem should be compared. In all of the studies self-esteem was measured immediately pre- and postactivity or intervention using the one-page 10-item RSE scale.

The instrument used to quantify changes in mood was the Profile of Mood States (POMS) standardized short-form (*47*). POMS is the primary instrument for measuring mood in studies of mood states and exercise (*48, 49*). Measurements were taken in all these studies immediately pre- and postactivity or intervention.

Statistical Analysis. Standardised meta-analysis methodologies were used to assess changes in self-esteem and mood data pre- and post- green exercise interventions. Summary statistics represented the mean difference between the pre- and postintervention values for both self-esteem and total mood disturbance (TMD) (*46, 47*). The Comprehensive Meta-Analysis Version 2.0 was used for analysis. Data were pooled to calculate an overall intervention effect estimate. This represents the weighted average of the combined individual intervention effects and the inverse-variance method was used to assign weights to each study. Thus, larger studies with smaller standard errors were given more weight than smaller studies with larger standard errors. This reduced the imprecision of the pooled-effect estimate.

It was assumed that the various studies involved in the analysis were measuring different but related intervention effects, and thus the combined intervention effect estimates were calculated using a random-effects model meta-analysis (*50, 51*). A funnel plot of precision and the "trim and fill" output was used to inspect bias, and 95 confidence intervals were calculated on the basis of the standard error of the pooled intervention effect. Statistical significance was set at p 0.05.

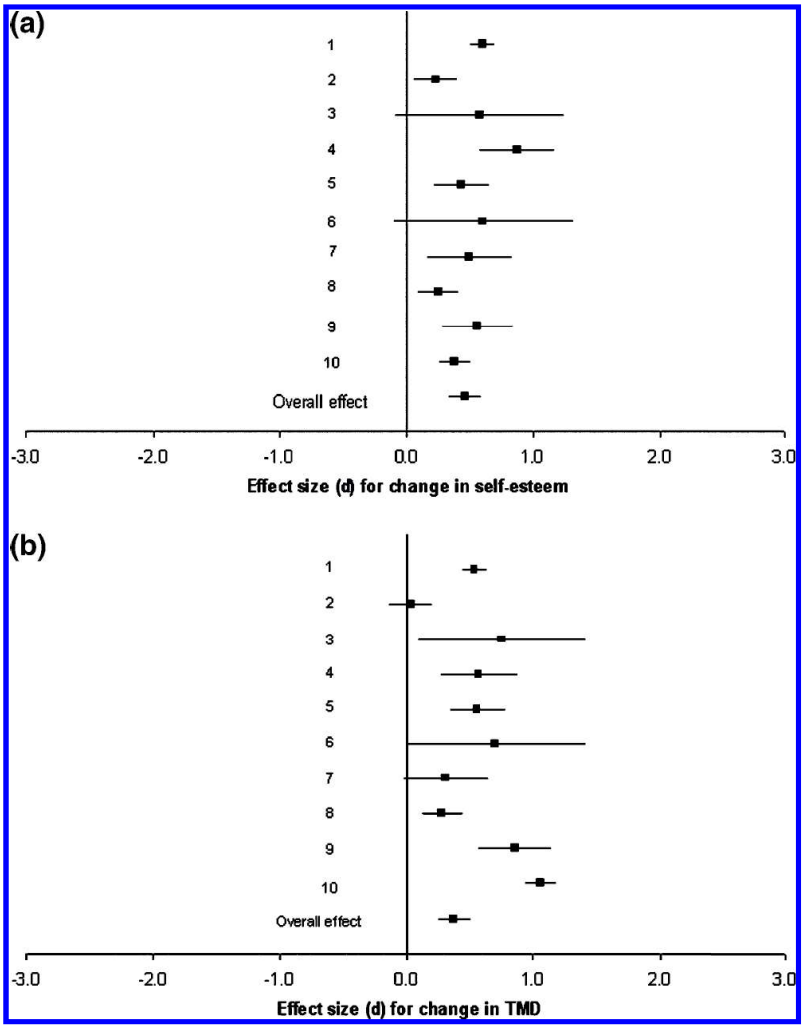

FIGURE 1. a and b. Meta-analysis of studies showing effect sizes and 95 CIs for changes in self-esteem and TMD after participation in green exercise activities (change in self-esteem was calculated as the difference between the pre and postintervention scores).

A statistical test for within-group heterogeneity assessed whether observed differences were due to chance alone. The chi-squared Q statistic was calculated using $Q/(k-1)$, where k is the number of studies in the meta-analysis (*52*). The I^2 statistic was calculated using both Q statistic and degrees of freedom (*53*).

To investigate whether the intervention effect varied with differing cohorts, type of green space, exposure duration or exercise intensity, a series of predefined a priori subgroup analyses were conducted. This allowed the exploration of possible sources of heterogeneity by identifying modifiers. Selection was based on causal mechanisms, magnitude of effects and statistical significance (*54*). In accordance with recommendations, all subgroup analyses were justified by existing knowledge of the relationship between green exercise and self-esteem/mood. The subgroup analyses identified were 1. exposure duration: 5 min, 10−60 min, half-day, whole day; 2. exercise intensity: low (3 METs (metabolic equivalent)), moderate (3−6 METs-) and vigorous (>6 METs) (*55*); 3. type of green space: urban green, countryside/farmland, forest/woodland, waterside, and wilderness-type habitats; 4. gender: female or male; 5. age groups: 30 years, 31−50, 51−70, and >70 years of age; 6. starting health status: healthy or with existing mental health problems.

Results

Effect of Green Exercise. The multistudy analysis of differences in self-esteem and mood before and after green exercise are shown in Figures 1a and b. The overall effect size for change in self-esteem was d 0.46 (CI 0.34−0.59, p 0.00001) and significant heterogeneity was found between estimates of self-esteem (Q 29.83, p 0.00001). The overall effect size for change in TMD was d 0.54 (CI 0.38−0.69, p 0.00001) and again there was significant heterogeneity for TMD (Q 45.95, p 0.00001). Effect size was thus higher for mood than self-esteem. These changes represented improvements in both self-esteem and mood. Based on the heterogeneity findings six subgroup analyses were conducted.

Figure 2a and b illustrate dose−responses for duration of exposure: both self-esteem and mood show distinct U shapes. Greatest changes come from 5 min of activity, and thus suggest these psychological measures are immediately increased by green exercise. The changes are lower for 10−60 min and half-day, but rise again for the whole day duration. Figure 3a and b show dose−responses for exercise intensity. For self-esteem, the greatest change is for light activity and then declines with growing intensity. For mood, the response is again greatest for light intensity, declining to the lowest for moderate, and then rises again for vigorous activity.

Figure 4a and b show effect sizes for five categories of habitat or green space. There are no great differences for urban space, countryside and woodland habitats. For both measures, waterside habitats showed the greatest changes. Green places improve self-esteem and mood (mean of d

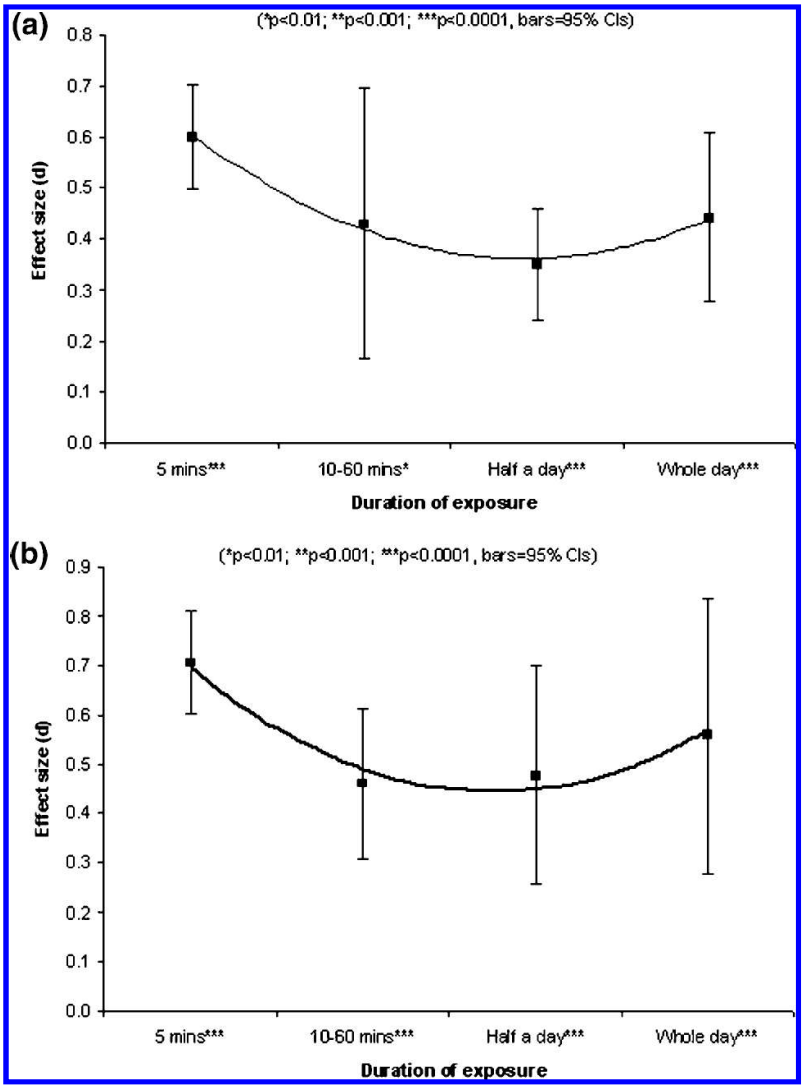

FIGURE 2. a: Dose response data for the effect of exposure duration on self-esteem. b: Dose response data for the effect of exposure duration on TMD.

values 0.44 and 0.56); however, green spaces with water shows a larger difference (increase of 0.29 for self-esteem and 0.19 for mood).

Table 2 shows the results where there are binary groups (male or female; healthy or mentally ill). All subgroup analyses reported significant improvements in self-esteem and mood, with effect sizes ranging from 0.38 (small) to 0.68 (moderate-large). Changes in self-esteem and mood were similar for both men and women. Healthy participants showed a smaller change in self-esteem than those with self-declared mental health problems (d 0.41 compared with d 0.68, p 0.0001), though there was only a small difference for mood (d 0.53 compared with d 0.56). Table 2 shows significant within-group heterogeneity based on starting health status (both mood and self-esteem) and sex (mood only).

Figure 5a and b show the effect sizes over four age groups (30, 31–50, 51–70, and >70 years). The improvement in self-esteem declines with aging (the greatest change is for the youngest age group), whereas mood shows an inverted U-curve with greatest changes in the midage groups.

Discussion

The results show acute short-term exposures to facilitated green exercise improves both self-esteem and mood irrespective of duration, intensity, location, gender, age, and health status. The six subgroup analyses suggest important specific recommendations for the most effective dose of nature and green exercise. 1. Exposure duration: both self-esteem and mood showed greatest changes for the least duration (5 min), both showed smaller positive improvements for 1 h and half-day activities, and both increased for whole-day activities. This suggests that there is an immediate effect obtained from the start of green exercise. Whole-day activities are likely to be qualitatively different activities, involving in some cases camping overnight and in others significant conservation achievements. 2. Exercise intensity: self-esteem improvements declined with growing intensity of activity, and mood improvements were greatest for light and vigorous activity. This suggests that there is a health benefit from any short engagement in green exercise. 3. Type of green space: all green environments improved both self-esteem and mood; the presence of water generated greater improvements. Although participants should be encouraged to undertake outdoor activities in both rural and urban environments, spending time near waterside (e.g., beach or river) or participating in water-based activities may give a greater benefit. 4. Sex: both men and women reported similar improvements in self-esteem after green exercise, though men showed a difference for mood. 5. Age groups: for self-esteem, the greatest change was in the youngest category,

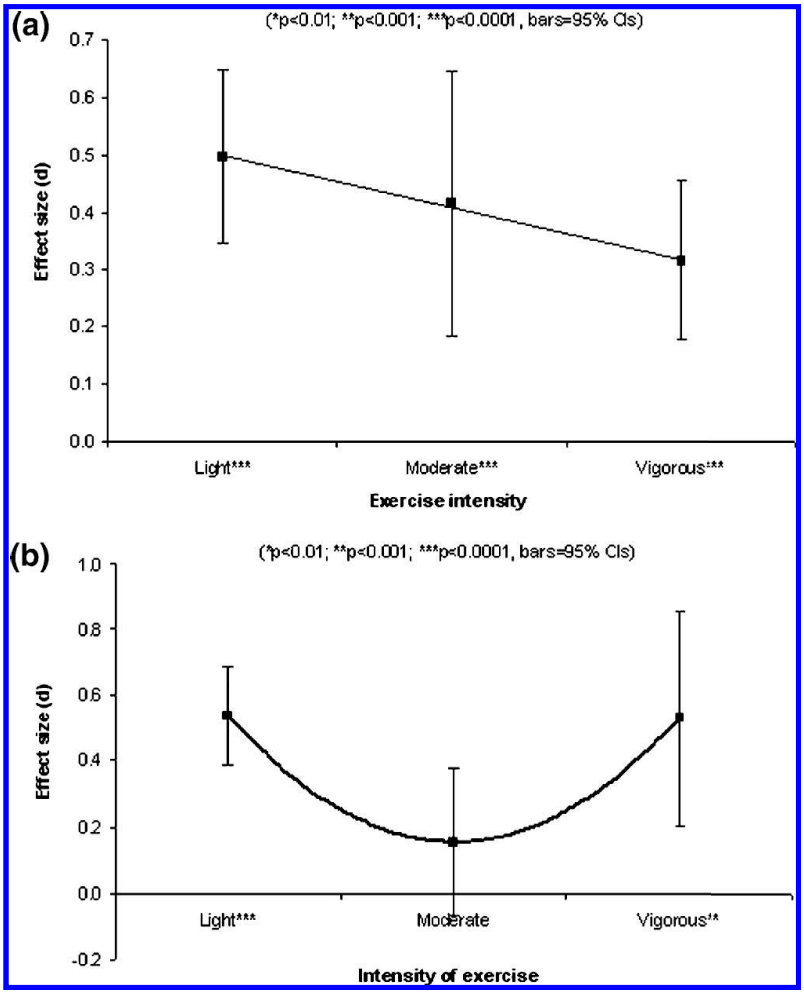

FIGURE 3. a: Dose response data for the effect of exercise intensity on self-esteem. b: Dose response data for the effect of exercise intensity on TMD.

with diminishing effects with age; for mood, the least change was for the young and old. This suggests that younger people will see more self-esteem improvements, and the middle-aged from mood. The over-70 age group experienced the least change, perhaps because those sampled were already experiencing good mental health and further improvements were limited. 6. Starting health status: the mentally ill had one of the greatest changes for self-esteem improvements. This suggests that the mentally ill should be encouraged to undertake green exercise.

Exposure to nature via green exercise can thus be conceived of as a readily available therapy with no obvious side effects (*56*). These findings indicate that dose responses for both intensity and duration showed large benefits from short engagements in green exercise, and then diminishing but still positive returns. The findings also suggest that those who are currently sedentary, nonactive, and/or mentally unwell would accrue health benefits if they were able to undertake regular, short-duration physical activity in accessible (probably nearby) green space. Such doses of nature will contribute to immediate mental health benefits. As with smoking, giving up inactivity and urban-only living results in immediate and positive health outcomes, even from short-duration and light activity such as walking. The findings from this multistudy analysis suggest the need to undertake larger-scale and randomized studies of different cohorts over long time-frames to explore the dose of green exercise further.

All studies included in this multistudy analysis involve exercise in green environments. The combined benefits are thus assessed but the relative contributions of each component are still unknown. Thus, there is also a need for a field-based controlled study to analyze the benefits of each element and assess whether there are any synergistic outcomes. This has been demonstrated in a controlled laboratory environment involving simulated green exercise (*12*), but evidence is limited in the field. Overall mood effect sizes for green exercise in this study are slightly larger (d 0.54) compared with exercise in nongreen environments (d 0.49) reported in other studies (*57*), although future research is still needed to compare different exercising environments.

The findings here are based on short-term exposures to single interventions. There remains a need for longitudinal multicohort studies to track changes over time. Important questions remain on how long the enhanced mood lasts once activity has finished, and whether there are accumulative effects following repeat exposures. The findings comprise studies conducted by one University; thus once other national data becomes available future meta-analyses will be more cross-sectional. The 10 studies were also analyzed over a period of six years, so self-esteem and mood may have been manipulated by extraneous variables which could not be controlled for. However, the outcomes do suggest a new priority for frontline environmental and health professionals—a regime of doses of nature may be prescribed for anyone, but will have a greater effect for the inactive or stressed and mentally ill, or at presurgery (*58*) or for recovery (*59*). Employers, for example, could encourage staff in stressful workplaces to take a short walk at lunchtime in the nearest

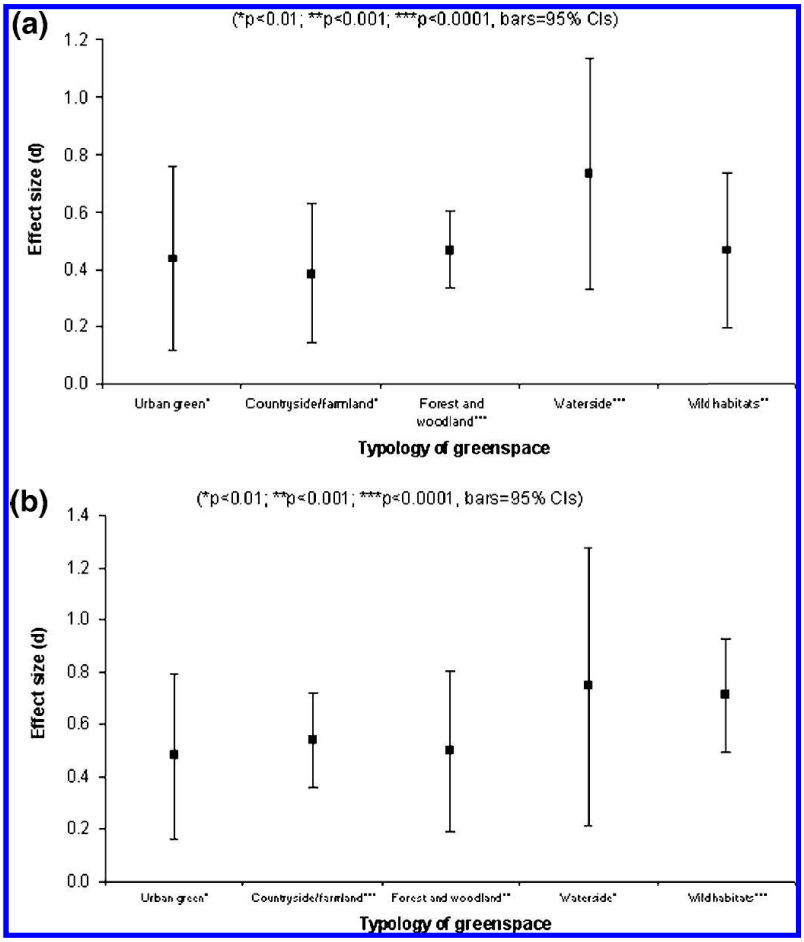

FIGURE 4. a: The effect of typology of green space on self-esteem. b: The effect of typology of green space on TMD.

TABLE 2. Summary of Effect Sizes for Two Sub-Groups Where These Are Divided into Only Two Categories Gender and Health Status)

							heterogeneity	
sub-group	measure	category	value	95 CI	P	N	Q	P
sex	self-esteem	female	0.38	0.23 – 0.54	0.0001	363	14.52	0.07
		male	0.42	0.32 – 0.53	0.0001	377	7.82	0.45
		combined	0.41	0.33 – 0.50	0.0001	740	23.40	0.14
	mood	female	0.49	0.33 – 0.64	0.0001	408	15.00	0.06
		male	0.55	0.25 – 0.85	0.0001	387	42.48	0.0001
		combined	0.50	0.36 – 0.64	0.0001	795	58.45	0.0001
starting health status	self-esteem	healthy	0.41	0.28 – 0.55	0.0001	1076	22.13	0.001
		mental ill-health	0.68	0.42 – 0.94	0.0001	105	2.73	0.26
		combined	0.46	0.40 – 0.52	0.0001	1181	29.83	0.0001
	mood	healthy	0.53	0.34 – 0.71	0.0001	1146	40.52	0.0001
		mental ill-health	0.56	0.19 – 0.93	0.003	99	4.99	0.08
		combined	0.53	0.37 – 0.70	0.0001	1245	45.95	0.0001

park to improve mental health, which may in turn affect productivity (*60*).A particular focus should be on children: regular outdoor play brings immediate health benefits, and may instill healthy behaviors early in life (*61*). Childhood social and economic conditions also predict adult health status (*62*), and outdoor free-play is vital for development and cognitive skills (*63, 64*). Given the therapeutic affects of green exercise (*65*), youth offender teams should engage certain groups of young people more in outdoor programs. Health inequalities could be reduced if attention were also given to the importance of urban design for both private dwellings and public institutions such as schools, care homes and hospitals (*14*).

Although good self-esteem and mood are known to be protective against future long-term health threats, these mental health measures should also be assessed in conjunction with a range of further health markers, such as blood pressure, cholesterol, stress hormones (e.g., cortisol), and inflammatory markers (e.g., C-RP). This research has not assessed the benefits of undertaking activities with other people (the benefits of social capital), nor the benefits of connections with animals (*28, 66*). It also does not assess how short-term changes to self-esteem and mood could lead to long-term changes in knowledge and behavior, such as the possible conservation benefits arising from more people engaging in outdoor activity, and therefore coming to know

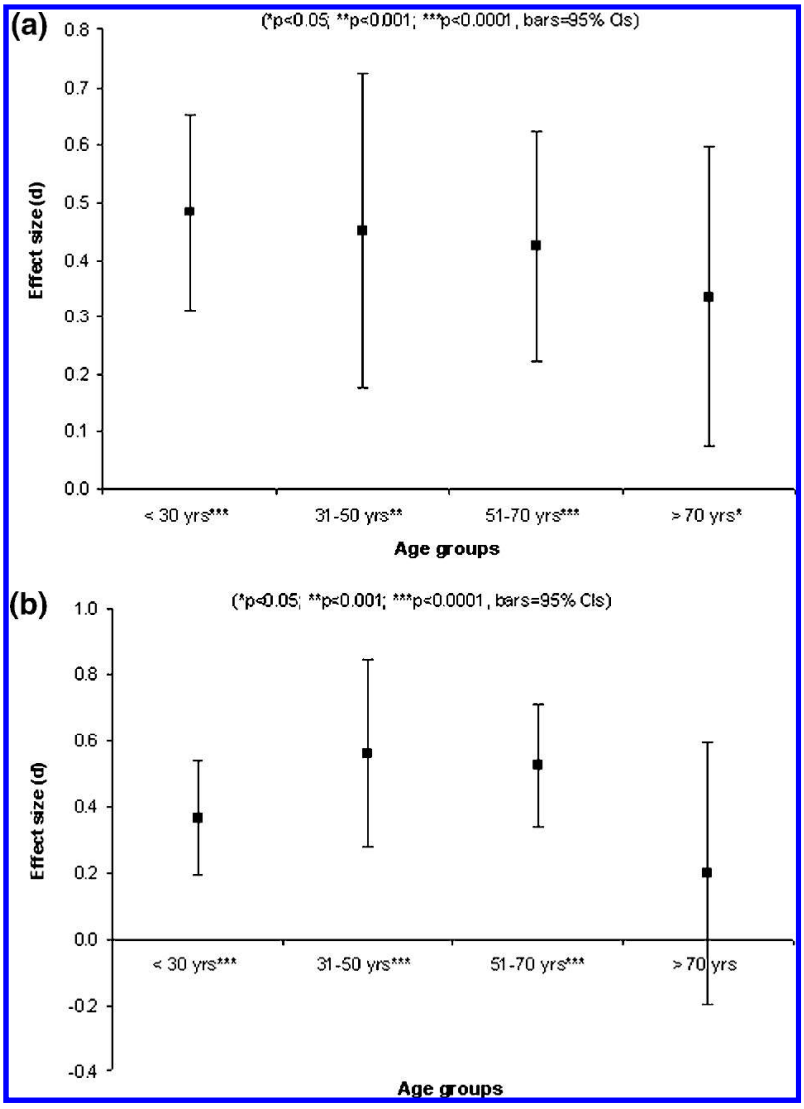

FIGURE 5. a: The effect of age on self-esteem. b: The effect of age on TMD.

more about natural habitats, and whether such engagements with nature could lead to changes in food consumption behavior. Contact with nature might thus promote more pro-environmental behavior and attitudes.

This study using meta-analysis methods suggests that attention should be given to developing the use of green exercise as a therapeutic intervention (green care), that planners and architects should improve access to green space (green design), and that children should be given opportunities to learn in outdoor settings (green education). Some of the substantial mental health challenges facing society (*9, 60*) and physical challenges arising from modern diets and sedentary lifestyles (*8, 67, 68*) could be addressed by increased forms of activity in green places.

A challenge for policy makers is that policy recommendations on physical activity are easily stated but rarely adopted widely. The economic benefits are hard to calculate, though could be substantial (*42, 67*). Policy frameworks that suggest active living (*69, 70*) point to the need for changes to physical, social and natural environments, and are more likely to be effective if physical activity becomes an inevitable part of life rather than a matter of daily choice (*71*). Simple prescriptions are unlikely to be adopted by whole populations unless supported by shifts in urban design, transport policy, support for social care, parenting, and patients' expectations of their doctors. Accessing natural places for their health as well as environmental services may aid these transitions.

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Supporting Information Available

A brief summary of the instruments used to measure self-esteem (Rosenberg Self-Esteem Scale) and mood (Profile of Mood States). This material is available free of charge via the Internet at http://pubs.acs.org.

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