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CRITICAL REVIEW

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Does Participating in Physical Activity in Outdoor Natural Environments Have a Greater Effect on Physical and Mental Wellbeing than Physical Activity Indoors? A Systematic Review

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ABSTRACT: Our objective was to compare the effects on mental and physical wellbeing, health related quality of life and long-term adherence to physical activity, of participation in physical activity in natural environments compared with physical activity indoors. We conducted a systematic review using the following data sources: Medline, Embase, Psychinfo, GreenFILE, SportDISCUS, The Cochrane Library, Science Citation Index Expanded, Social Sciences Citation Index, Arts and Humanities Citation Index, Conference Proceedings Citation Index − Science and BIOSIS from inception to June 2010. Internet searches of relevant Web sites, hand searches of relevant journals, and the reference lists of included papers and other review papers identified in the search were also searched for relevant information. Controlled trials (randomized and nonrandomized) were included. To be eligible trials had to compare the effects of outdoor exercise initiatives with those conducted indoors and report on at least one physical or mental wellbeing outcome in adults or children. Screening of articles for inclusion, data extraction, and quality appraisal were performed by one reviewer and checked by a second with discrepancies resolved by discussion with a third if necessary. Due to the heterogeneity of identified studies a narrative synthesis was performed. Eleven trials (833 adults) were included. Most participants (6 trials; 523 adults) were young students. Study entry criteria and methods were sparsely reported. All interventions consisted of a single episode of walking or running indoors with the same activity at a similar level conducted outdoors on a separate occasion. A total of 13 different outcome measures were used to evaluate the effects of exercise on mental wellbeing, and 4 outcome measures were used to assess attitude to exercise. Most trials (n = 9) showed some improvement in mental wellbeing on one or other of the outcome measures. Compared with exercising indoors, exercising in natural environments was associated with greater feelings of revitalization and positive engagement, decreases in tension, confusion, anger, and depression, and increased energy. However, the results suggested that feelings of calmness may be decreased following outdoor exercise. Participants reported greater enjoyment and satisfaction with outdoor activity and declared a greater intent to repeat the activity at a later date. None of the identified studies measured the effects of physical activity on physical wellbeing or the effect of natural environments on exercise adherence. The hypothesis that there are added beneficial effects to be gained from performing physical activity outdoors in natural environments is very appealing and has generated considerable interest. This review has shown some promising effects on self-reported mental wellbeing immediately following exercise in nature which are not seen following the same exercise indoors. However, the interpretation and extrapolation of these findings is hampered by the poor methodological quality of the available evidence and the heterogeneity of outcome measures employed. The review demonstrates the paucity of high quality evidence on which to base recommendations and reveals an undoubted need for further research in this area. Large, well designed, longer term trials in populations who might benefit most from the potential advantages of outdoor exercise are needed to fully elucidate the effects on mental and physical wellbeing. The influence of these effects on the sustainability of physical activity initiatives also awaits investigation.

INTRODUCTION

The vast majority of environmental research focuses on understanding environmental processes and the identification of threats to ecosystems and human health. With mounting concern over climate change, biodiversity loss, and environmental pollution, it is not surprising that the general public often associate the natural environment with unpleasant and overwhelming concerns about the future. However, in recent years interest has grown in the positive benefits that might be gained from natural environments and time spent outdoors. To counteract the fact that we increasingly live in towns and cities (75% of the European population now live in urban environments), efforts are being made to reconnect people with nature. For example, programs such as the Green Gym and the Blue Gym attempt to motivate people to spend more time being active in natural

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Table 1. Master Search Strategy

designed for Ovid MEDLINE(R) 1950 and adapted for other databases	
1	green exercis*.ti,ab.
2	green gym*.ti,ab.
3	ecotherapy.ti,ab.
4	((outdoor* or outside*) and (exercis* or physical activit* or walk* or physical fit*)).ti,ab.
5	(park* and (exercis* or physical activit* or walk* or physical fit*)).ti,ab.
6	((greenspace* or green space*) and (exercis* or physical activit* or walk* or physical fit*)).ti,ab.
7	(natural environment* and (exercis* or physical activit* or walk* or physical fit*)).ti,ab.
8	(nature and (exercis* or physical activit* or walk* or physical fit*)).ti,ab.
9	1 or 2 or 3 or 4 or 5 or 6 or 7 or 8
10	(indoor or inside or laboratory or gym*).ti,ab.
11	9 and 10

environments thereby improving their physical and psychological health.

The Health Survey for England 2008 established that only 40% of men and 28% of women in England meet currently recommended levels of activity of a minimum of 30 min of moderate exercise five times per week.[1] Insufficient physical activity creates additional vulnerabilities to cancers, heart disease, stroke, diabetes, and mental and physical disability and may account for 1.9 million deaths worldwide annually.[2] The health impact of these low levels of activity in England and Wales in terms of coronary heart disease is comparable to that of smoking.[3] To help reduce the burden of chronic disease and morbidity due to an inactive lifestyle, interventions are needed that are effective in increasing physical activity in the general population.[4] Motivating people to spend time participating in one or more of a range of outdoor activities (e.g., gardening, conservation work, bird watching, rockpool rambles, and gentle to vigorous sporting activities in natural environments) represents an important means of ensuring that people become more active. Interventions must be sustainable over the long-term as physical activity levels decline with age. Only 17% of men and 13% of women between the ages of 64 and 75 meet the current recommendations for physical activity.[1] The recent UK Department of Health report, "Be Active Be Healthy" published in 2009, highlights the importance of high-quality green spaces and of the promotion of physical activity within these green spaces.[4] Furthermore, a survey conducted in eight European cities in 2005 concluded that people who live in areas with high levels of greenery are three times more likely to be physically active and 40% less likely to be overweight or obese, though this finding may be due to confounding variables.[5]

Concurrently there has been an increasing awareness of the positive impact of exposure to natural environments on mental wellbeing.[6−11] Experimental research has demonstrated that exposure to views of nature can improve people's health and wellbeing by providing restoration from stress and mental fatigue,[12] and this has led to suggestions that performing physical activity in nature may have additional benefits above and beyond those experienced following a period of physical activity in an indoor environment.[13] As well as tangible effects such as improvements in mental wellbeing,[14,15] initiatives set up to increase physical activity in green spaces (so-called 'green exercise') have been linked with improvements in social networking and feelings of connectivity and companionship, an increased appreciation of nature, improvements in self-esteem, and a means of escape from modern life.[16−18] These benefits could have important implications on the sustainability or longevity of physical activity interventions and also for informing people about the merits of protecting the natural environment and the need to embrace sustainable development. It might be argued that physical activity in health club gyms is a viable alternative to outdoor exercise, but the failure to persevere with indoor exercise initiatives on a long-term basis is well recognized. For example, 40−50% of individuals terminate gym membership within a year of joining.[19] Anecdotal evidence suggests that long-term adherence to exercise initiatives conducted in outdoor natural environments or urban green spaces may be superior to that of indoor exercise interventions.[20]

Several narrative reviews have been published in which the benefits of exercising outside are summarized.[8,11,13,20−22] However, the kinds and magnitude of any additional advantages attributable to being outdoors in nature while participating in physical activity remains unclear. We have therefore adopted well tested procedures from the health science area and performed a systematic review of the available evidence from comparative studies. This provides an objective means of elucidating the value of outdoor green spaces in motivating physical activity and in conferring mental and physical wellbeing.

METHODS

The systematic review was conducted following the general principles published by the NHS Centre for Reviews and Dissemination (CRD).[23] A predefined protocol was developed following consultation with experts in the field and is available from the authors on request.

Literature Search and Eligibility Criteria. We devised a search strategy, by analysis of key studies, to capture the concepts of exercise and location (indoors vs outdoors). No suitable MeSH terms were identified. In order to locate all available comparative data on this topic, no methods filter was applied to the search. The master search strategy (Table 1) was adapted and run in the following electronic databases from inception to June 2010: Medline, Embase, and Psychinfo (using the OVID interface), GreenFile and Sport DISCUS (using the Ebsco interface), the Cochrane Library of Systematic Reviews and CENTRAL, Science Citation Index Expanded, Social Sciences Citation Index, Arts and Humanities Citation Index, Conference Proceedings Citation Index − Science and Biosis (via the Web of Science interface). We scrutinized the bibliographies of included studies and of other identified relevant review papers in the search for additional articles. Internet searches were performed of the following Web sites: British Trust for Conservation Volunteers, Collaboration for Environmental Evidence, Countryside Recreation Network,

Environment Agency, Forest Research, Forestry Commission, Green Exercise, Green Space, Groundwork, Living Streets, MIND, National Parks, National Trust, Natural England, Open Space and Walking for Health Initiative. We also hand searched three journals (Psychology of Sport and Exercise, International Journal of Stress Management, and Medicine and Science in Sports and Exercise − from inception to April 2010) identified as being important in the field.

Studies were included if they reported a comparison of the effects of exercise initiatives in the outdoors with exercise initiatives conducted indoors on physical and mental wellbeing in adults or children. Studies in which outdoor images were projected via a virtual reality headset or helmet, while the participant exercised indoors were also included. Studies reported as conference proceedings were included if there was sufficient data to assess the risk of bias. Authors were contacted to supply missing data where necessary. No language restrictions were applied.

Two reviewers (K.B. and R.W.) independently screened titles, abstracts, and full texts and applied the inclusion and exclusion criteria. For potentially relevant references the same procedure was performed for the full text articles (K.B. and J.T.C.). Any discrepancies were resolved through discussion with a third reviewer (K.S.).

Data Collection. Data on participant characteristics, relevant outcomes, and risk of bias were independently extracted by one reviewer (J.T.C. or K.B.) and checked by a second (J.T.C. or K.B.) using a standardized, piloted data extraction form.

Data Synthesis. Due to the paucity of studies eligible for inclusion and the heterogeneity of the study design, population, and outcome measures used in the identified studies, formal statistical meta-analysis of the trials was not felt to be appropriate. An alternative method of summarizing and discussing the results of the included studies (narrative synthesis) was undertaken following the principles described in the Economic and Social Research Council guidelines.[24] Trials were first grouped according to the length of the exercise intervention (short or long-term), the type of exercise intervention (conventional activities or virtual reality), and the outcomes measured (physical and mental wellbeing). Study design was not used as a means of grouping trials.

RESULTS

Study Characteristics. Electronic searches and hand searching of journals identified a total of 2899 potentially relevant articles. Screening of the title and abstract of these resulted in the exclusion of 2865 papers and the full text was retrieved of the remaining 34. Twenty-three papers were excluded following perusal of the full text because the intervention was unsuitable ($n = 3$), there was no comparison between indoors and outdoors ($n = 10$), no relevant outcomes were reported ($n = 4$), the paper was a narrative review, letter, or editorial ($n = 4$) or the citation referred to a conference abstract for which insufficient detail was available ($n = 2$). A total of 11 papers (involving 833 adults) were eligible for inclusion in the review (Figure 1).[15,25−34] We were unable to identify any eligible studies involving children. Five of the trials were described as randomized;[26,28−30,34] five are nonrandomized comparative trials[16,25,27,31,33] and one is a survey;[35] six trials have a crossover design with participants exposed to both indoor and outdoor activity.[16,25,27,30,31,33] Characteristics of the included studies and study participants are shown in Table 2. Sample size ranged from 8 to 269 and included slightly more women (61%) than men. Where provided, the mean age of participants was 25.22 years; six of the included studies were conducted in university students. In most studies ($n = 8$), the level of physical activity undertaken by participants prior to entry into the study is described as recreational; three trials recruited competitive runners.[25,27,31] All interventions were short-term consisting of a single short walk or run in the outdoor environment and a similar single walk or run conducted in an indoor setting on a separate occasion[16,25−31,33,34] or a survey administered on one occasion.[32] In seven studies individuals were instructed to walk indoors and outdoors;[16,26,28−30,33,34] two of these studies also included an indoor walk with virtual reality technology.[26,28] In three studies running was the form of physical activity used.[25,27,31] All the included studies were conducted to assess the influence of location (indoors vs outdoors) on the effects of participating in physical activity; in two of the studies additional hypotheses were simultaneously tested - the influence of attentional focus during exercise[27] and the influence of company during exercise.[29] There is a limited variety of types of outdoor space utilized for physical activity and little descriptive information on the outdoor space provided in most papers. In seven studies the outdoor environment was described as being on a university or college campus[25−29,34,33] one study used the sidewalks and walking paths immediately surrounding the building,[30] one study describes the environment as 'outdoor' no further details are provided,[31] one study was conducted in the forest,[32] and one in a country park.[16]

All included studies measured the effects of participating in physical activity on measures of mental wellbeing shortly following the activity (the most common mental wellbeing outcome was some measure of an individual's mood or feelings); we were unable to identify any studies which measured effects on physical wellbeing, health related quality of life, the longer term effects of a single episode of physical activity, or the effects of exercise environment on long-term adherence to exercise.

Indicators of study quality are displayed in Table 3. Due to the nature of the study design, the survey[35] is not included in this table. In general the reporting of methodological detail, recruitment procedures, eligibility criteria, and patient characteristics at baseline is sparse. None of the papers provides details of the randomization procedure. None of the studies describes attempts to blind assessment of outcomes nor are there any details of methods used to conceal allocation of interventions.

Short-Term Studies of the Effects of Exercise Environment on Mental Wellbeing. *Walking.* Seven studies[16,26,28−30,33,34] compared the effects of environment on mental wellbeing following a short-term walking intervention. Results of the studies are summarized in Table 4. Six of the studies showed that compared with walking indoors, walking outdoors had a positive effect on some aspect of mood.[16,26,28,30,33,34] For example, measures of revitalization, self-esteem, positive engagement, and subjective vitality were all greater following outdoor walking as were feelings of energy, pleasure, and delight, and there were decreases in feelings of frustration, worry, confusion, depression, tension, and tiredness. Participants reported greater enjoyment following the outdoor walk and expressed a greater intent to repeat the experience. There were trends toward reduced feelings of calmness and tranquillity associated with the outdoor walk compared with the indoor walk in several of the studies[26,28−30] although this was only shown to be statistically significant in the male participants of one study.[28]

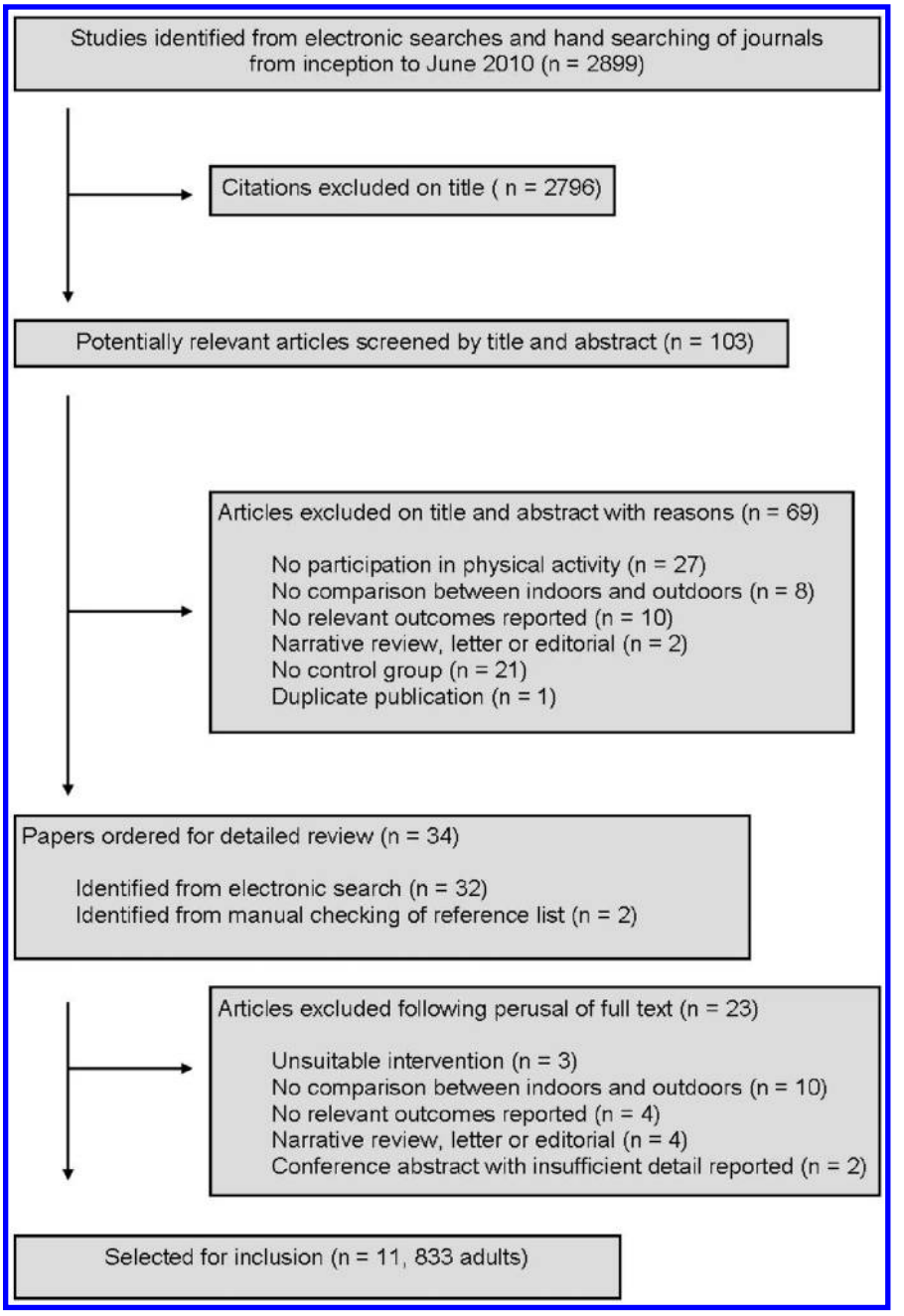

Figure 1. Flowchart.

Nine different outcome scales were used to assess the effect of exercise on mood, and three scales measured the participants' attitude to the exercise. Due to the disparity in the instruments used it was not possible to formally synthesize the results of the trials.

However, in Table 5 we have grouped the measured outcomes into several broad categories with an indication of the direction of the result for each outcome category, which provides a visual summary of the combined results.

Running. Three studies[25,27,31] compared the effects of environment on mental wellbeing following a short running intervention. Results of the studies are summarized in Table 4 and Table 5. In two of these studies there were no effects of running environment on mood or emotion; participants of both studies were described as competitive runners.[25,31] In the study conducted by Harte and colleagues, participants felt less anxious, less depressed, less angry and hostile and less fatigued following the outdoor run. The outdoor run was evaluated most positively.[27]

Survey. Results of the survey[32] showed a greater degree of mental restoration following outdoor activity than indoor activity and a more positive attitude to exercising outdoors. While interesting, due to the methods used in obtaining survey data, these results are subject to bias and confounding and extrapolation is difficult.

DISCUSSION

Currently, there is renewed interest in the value of the natural environment. This is exemplified by, for example, the TEEB

Table 2. Characteristics of Included Studies

study, year	study design	country, setting	*n*	patient characteristics	interventions	study duration (weeks)	outcomes
				Short-Term Studies — Walking (*n* = 7)			
Focht, 2009 [30]	randomized, open, counterbalanced crossover	USA, university	35	female, physically active mean age 22.14 years	1 walk in outdoor setting (10 min) 2 walk on a treadmill in a laboratory (10 min)	two single visits 48 h apart	a exercise induced feeling inventory b feeling scale c felt arousal scale d enjoyment e intention f rating of perceived exertion
Ryan, 2009 [34]	randomized, open, parallel group	USA, university	80	male (18%) and female students mean age 20 years	1 walk in outdoor setting (15 min) 2 walk in indoor setting (15 min)	single visit	a subjective vitality scale
Plante, 2007 [29]	randomized, open, parallel group	USA, university	88	female students mean age 19.31 years	1 walk in outdoor setting alone (20 min) 2 walk in outdoor setting with a friend (20 min) 3 walk on treadmill in fitness facility alone (20 min) 4 walk on treadmill in fitness facility with a friend (20 min)	single visit	a activation—deactivation adjective checklist b physical activity enjoyment scale
Teas, 2007 [33]	nonrandomized, open, crossover	USA, university	19	female, recreational exercise mean age 58 years	1 walk in outdoor setting (60 min) 2 walk on treadmill in gym (60 min)	two single visits approx one week apart	a positive affect scale b negative affect scale
Peacock, 2007 [16]	nonrandomized, open, crossover	UK, local associations MIND	20	male (35%) and female mean age not provided (range 31 to 70 yrs)	1 walk in Belhus Woods, Essex (30 min) 2 walk in indoor shopping center (30 min)	two single visits one week apart	a rosenberg self-esteem scale b profile of mood states c enjoyment
Plante, 2006 [28]	randomized, open, parallel group	USA, university	112	male (42%) and female students mean age not provided	1 walk in outdoor setting (20 min) 2 walk on treadmill in indoor setting with virtual reality of outdoor walk (20 min) 3 seated with virtual reality of outdoor walk (20 min)	three single visits on separate days	a activation — deactivation adjective checklist b physical activity enjoyment scale
Plante, 2003 [26]	randomized, open, parallel group	USA, university	154	male (34%) and female students mean age not provided	1 walk in outdoor setting (20 min) 2 walk on treadmill in indoor setting with virtual reality of the outdoor walk (20 min) 3 walk on treadmill in indoor setting (20 min) 4 seated with virtual reality outdoor walk (20 min)	four single visits on separate days	a activation — deactivation adjective checklist

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Table 2. Continued

study, year	study design	country, setting	*n*	patient characteristics	interventions	study duration (weeks)	outcomes
				Short-Term Studies − Running (*n* = 3)			
Kerr, 2006 [25]	nonrandomized, open, crossover	university	44	male students, recreational and competitive runners mean age 21.7 years	1 run in outdoor setting (5 km) 2 run on treadmill in laboratory (5 km)	two single visits one week apart	a tension and effort stress inventory
Harte,1995 [27]	nonrandomized, open, counterbalanced, crossover	Australia, university	10	male amateur triathletes or marathon runners mean age 27.1 years	1 run in indoor setting with outdoor noises (45 min) 2 run in indoor setting with heartbeat/breathing noises (45 min) 3 run in outdoor setting (45 min) 4 reading in laboratory (45 min)	four single visits on separate days	a profile of mood states b attention checklist c recent life events questionnaire d urine adrenaline e urine noradrenaline f urine cortisol g blood pressure h evaluation of activity
McMurray, 1988 [31]	nonrandomized, open, crossover	USA, university	8	male runners mean age not provided (range 21−41 years)	1 run in outdoor setting (10 mile) 2 run on treadmill in indoor setting (10 mile)	two single visits on separate days	a oxygen uptake b heart rate c plasma beta-endorphin concentrations d general affect scale
				Other Study Designs (*n* = 1)			
Hug, 2008 [32]	survey	Switzerland, forest and fitness centers	269	male (55%) and female, engaging in exercise mean age not reported	1 exercising outdoors in the forest 2 exercising indoors	single visit	a questionnaire designed to assess the restorative effect of physical activity b air quality

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Table 3. Indicators of Quality of Included Studies

quality indicator	randomized controlled trials					nonrandomized controlled trials				
	Focht, 2009 [30]	Ryan, 2009 [34]	Plante, 2007 [29]	Plante, 2006 [28]	Plante, 2003 [26]	Teas, 2007 [33]	Kerr, 2006 [25]	Peaock, 2007 [16]	Harte, 1995 [27]	McMurray, 1988 [31]
Is a power calculation reported?	yes	no	no	no	no	no	no	no	no	no
Are the inclusion criteria explicit?	partial	no	partial	partial	no	yes	partial	no	partial	no
Is the randomization procedure adequate?	unclear	unclear	unclear	unclear	unclear	N/A	N/A	N/A	N/A	N/A
Is the allocation concealment adequate?	unclear	unclear	unclear	unclear	unclear	unclear	unclear	unclear	unclear	unclear
Were the outcome assessors blinded?	no	unclear	no	no	no	no	no	no	no	no
Were the groups similar at baseline?	N/A	unclear	unclear	unclear	partial	N/A	N/A	N/A	N/A	N/A
Are all participants accounted for?	yes	yes	unclear	yes	unclear	yes	yes	yes	yes	yes
Is there a clear description of intervention?	yes	yes	partial	yes	yes	partial	yes	yes	yes	yes
Are outcome measures valid and objective?	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Are all outcomes reported?	yes	yes	yes	yes	yes	yes	no	unclear	no	yes
Is the method of analysis appropriate?	yes	yes	yes	yes	yes	yes	yes	N/A	yes	partial
Are the conclusions supported by the results?	yes	yes	yes	yes	yes	partial	yes	yes	yes	yes
Are the results generalizable?	partial	partial	partial	partial	partial	partial	partial	partial	partial	partial

project (The Economic Evaluation of Biodiversity) and by the dramatic increase in studies looking at the relationships between biodiversity, the natural environment, and human health. In the present study we have examined whether natural environments can add value to human health and wellbeing by promoting physical exercise outdoors.

We found some evidence that physical activity in an outdoor natural environment may bring additional positive effects on measures of mental wellbeing that are not seen when participating in similar physical activity indoors. All of the studies we examined reported the effects on mental wellbeing immediately following cessation of a single episode of exercise. The duration of these effects is unclear, as are the expected characteristics and magnitude of effects following repeated exposure to outdoor activity, and the impact on adherence to long-term exercise initiatives. Whether improvements in mood are accompanied by changes in physical wellbeing is also unknown.

This systematic review focuses on comparative studies of the effects of participating in indoor and outdoor activity on physical and mental wellbeing. We searched a wide range of data sources (electronic databases, relevant Web sites, and hand searching of appropriate journals) and identified studies published in a disparate collection of publications. It was notable that the design of available studies was often inadequate. Interpretation and extrapolation of the findings was difficult for several reasons:

1) The studies included were small with no evidence of a sample size calculation to support the number of included participants. It is therefore unclear whether the absence of effect seen in some studies was an artifact of the small number of participants in the trial or a true indication that there is no effect of exercise environment on the outcomes measured. Eligibility criteria for the studies were sparsely reported, as were the baseline characteristics of included individuals. This lack of detail prohibits any meaningful comment on the between-study comparability of participants at baseline and limits the extrapolation of the results to a wider population. It is not clear whether the results obtained in the trials would be obtained in trials of older, sedentary individuals or those with chronic health conditions.
2) All the interventions used single episodes of activity; it is not clear whether similar effects would be seen during repeated physical activity sessions. The impact of changing weather conditions was not explored and may be important over a longer time period, particularly in a country such as the UK. There was also a lack of variation in both the type of green space used and in the type of exercise performed. It would be interesting to discover whether the results obtained during single episodes of walking in a campus environment could also be obtained after, for example, repeated episodes of activities such as gardening or conservation activities.
3) The identified studies were of relatively poor methodological quality and were subject to bias and confounding. Randomization and treatment allocation procedures were not described in any of the papers, and no attempt was made at "blinding" (keeping subjects unaware of which type of intervention they would experience). While it may not have been possible to "blind" participants to the intervention they received, assessment of outcome measures could have been conducted by assessors independent of those involved in organizing the exercise sessions to

Table 4. Reported Results of Included Studies

		results		
study	outcomes	indoor mean (sd)	outdoor mean (sd)	reviewer comments
		Short-Term Studies − Walking (n = 7)		
Focht, 2009 [30]	***Exercise Induced Feeling Questionnaire***[a]			
	revitalization subscale − during exercise	6.09 (2.41)	7.17 (2.92)	significantly higher during outdoor (d = 0.42)*
	revitalization subscale − after exercise	6.74 (2.80)	8.03 (3.02)	
	positive engagement − during exercise	6.17 (2.70)	7.69 (2.69)	significantly higher during outdoor (d = 0.58)*
	positive engagement − after exercise	6.49 (2.79)	7.69 (3.08)	
	tranquillity − during exercise	6.14 (2.87)	7.14 (3.10)	no significant main effects or interactions.
	tranquillity − immediately after exercise	6.29 (2.99)	7.03 (3.02)	no significant main effects or interactions.
	Feeling Scale[b]			
	during exercise	2.82 (1.32)	3.67 (1.08)	significantly higher during outdoor (d = 0.43).
	immediately after exercise	3.20 (1.66)	3.86 (1.26)	
	Felt Arousal Scale[c]			
	during exercise	4.09 (1.07)	4.54 (0.88)	significantly higher during outdoor (d = 0.42)
	immediately after exercise	4.17 (1.27)	4.46 (0.98)	
	Enjoyment[d]	6.57 (1.42)	7.91 (1.17)	greater following outdoor (d = 1.03; p < 0.001)
	Intention[e]	69.43 (20.28)	85.14 (13.79)	greater following outdoor (d = 0.92; p < 0.001)
Ryan, 2009 [34]	***Subjective vitality***[f]			
	after exercise	2.3	5.4	increase in outdoor walk participants over time (p < 0.01)
Plante, 2007 [29]	***AD-ACL***[g]			
	energy − after exercise	13.68 (2.89)	13.91 (3.38)	no significant effects or interactions for indoor vs outdoor.
	calmness − after exercise	10.00 (2.83)	9.75 (3.55)	
	tension - after exercise	8.86 (2.95)	7.64 (2.11)	
	tiredness − after exercise	10.46 (3.07)	8.11 (3.51)	
	Physical Activity Enjoyment Scale[h]	88.77 (13.77)	96.41 (14.97)	Those who exercised outdoors with or without a friend found greater satisfaction with their workout than those who exercised indoors (p < 0.05).
Teas, 2007 [33]	***Positive Affect Scale***[i,j]			
	pleased	−0.9 (95% CI −1.69 to −0.10)		Feeling pleased is greater when exercising outside (p = 0.03).
	joy	−0.6 (95% CI −1.23 to 0.05)		N.S
	delighted	−0.9 (95% CI −1.75 to −0.02)		Feeling delighted is greater when exercising outside (p = 0.05).
	happy	−0.6 (95% CI −1.34 to 0.45)		N.S
	Negative Affect Scale[i,j]			
	frustration	0.9 (95% CI 0.12 to 1.63)		Feelings of frustration are lower when exercising outside (p = 0.03).
	worry	0.9 (95% CI 0.17 to 1.62)		Feelings of worry are lower when exercising outside (p = 0.02).
	anger	0.8 (95% CI −0.06 to 1.60)		N.S
	sad	0.4 (95% CI −0.40 to 1.21)		N.S
Peacock, 2007[16]	***Rosenberg Self-esteem scale***[p]			
	self-esteem (after walk)	21.8	19.0	p < 0.05
	Profile of Mood States			
	depression (after walk)	40.8	39.4	p < 0.05
	anger (after walk)	41.1	39.2	p < 0.05
	tension (after walk)	37.7	34.4	p < 0.01
	vigor (after walk)	38.7	42.1	N.S
	fatigue (after walk)	39.0	37.1	N.S
	confusion (after walk)	39.5	36.5	p < 0.05
	Total Mood Disturbance[k]			
	total mood disturbance (after walk)	159.4	144.4	p < 0.01

Table 4. Continued

		results		
study	outcomes	indoor mean (sd)	outdoor mean (sd)	reviewer comments
Plante, 2006 [28]	***AD- ACL***[q]			
	energy −after exercise - male	12.07 (2.37)	12.35 (4.29)	More energy was experienced when exercising outside ($p < 0.05$).
	energy - after exercise - female	9.90 (3.11)	13.68 (3.62)	No significant results for indoor vs outdoor.
	calmness − after exercise − male	11.20 (2.98)	10.88 (2.50)	Participants exercising outside were the least calm ($p < 0.05$).
	calmness − after exercise - female	12.90 (2.69)	10.64 (2.42)	No significant results for indoor vs outdoor.
	tension − after exercise − male	6.53 (1.51)	8.24 2.75	No significant main effects or interactions for indoor vs outdoor.
	tension − after exercise - female	6.00 (1.45)	8.59 (2.38)	No significant results for indoor vs outdoor.
	tiredness − after exercise − male	5.53 (2.64)	6.41 (1.84)	Participants exercising outside were least tired ($p < 0.001$).
	tiredness − after exercise - female	8.30 (2.72)	5.55 (2.56)	no significant results for indoor vs outdoor
	Physical Activity Enjoyment Scale[h]			
	male	78.60 (21.75)	78.70 (22.83)	Exercise outside was reported to be the most enjoyable ($p < 0.05$).
	female	63.55 (14.12)	93.88 (14.37)	no significant results for indoor vs outdoor
Plante, 2003 [26]	***AD-ACL***	indoor	outdoor	
	energy −after exercise - male	14.00 (2.12)	12.90 (3.20)	no significant results for indoor vs outdoor
	energy - after exercise - female	11.92 (3.20)	15.50 (2.83)	higher for outdoors than indoors ($p < 0.01$)
	calmness − after exercise − male	10.50 (2.60)	10.27 (4.08)	no significant results for indoor vs outdoor
	calmness − after exercise - female	10.32 (2.48)	8.65 (2.74)	no significant results for indoor vs outdoor
	tension − after exercise − male	7.12 (1.80)	7.27 (2.15)	no significant results for indoor vs outdoor
	tension − after exercise - female	7.36 (2.74)	8.85 (3.08)	no significant results for indoor vs outdoor
	tiredness − after exercise − male	8.92 (3.04)	8.55 (4.57)	no significant results for indoor vs outdoor
	tiredness − after exercise − female	11.48 (3.93)	8.62 (3.05)	lower for outdoors than indoors ($p < 0.01$)
		Short-Term Studies − Running ($n = 3$)		
Kerr, 2006 [25]	***Tension and Effort Stress Inventory***[l]			
	Recreational runners			
	overall pleasant emotions	28.27 (6.27)	28.18 (5.38)	In ***recreational runners*** no significant interaction was found between emotions and running environment.
	overall unpleasant emotions	16.41 (5.84)	13.41 (4.64)	Posthoc analyses showed a significant indoor/outdoor effect for pride (2.86 vs 3.25 for indoor vs outdoor respectively; $p < 0.05$).
	overall pleasant somatic emotions	15.05 (3.09)	14.27 (2.37)	
	overall unpleasant somatic emotions	8.68 (3.82)	6.86 (2.51)	In ***competitive runners*** no significant interaction was found between emotions and running environment.
	overall pleasant transactional emotions	13.23 (4.64)	13.91 (4.00)	
	overall unpleasant transactional emotions	7.73 (3.06)	6.55 (2.87)	
	competitive runners			
	overall pleasant emotions	24.32 (8.22)	23.41 (7.24)	
	overall unpleasant emotions	12.50 (4.90)	11.82 (4.00)	
	overall pleasant somatic emotions	13.68 (2.98)	13.77 (3.21)	
	overall unpleasant somatic emotions	6.68 (3.06)	6.09 (2.62)	
	overall pleasant transactional emotions	10.64 (6.42)	9.64 (5.47)	
	overall unpleasant transactional emotions	5.82 (2.77)	5.73 (2.12)	

Table 4. Continued

study	outcomes	results: indoor mean (sd)		results: outdoor mean (sd)	reviewer comments
Harte, 1995 [27]	***Profile of Mood states***	internal	external		
	tension/anxiety	4.5 (3.8)	2.6 (2.2)	2.8 (1.9)	lower for outdoor exercise vs indoor-internal ($p < 0.01$)
	depression/rejection	2.3 (2.5)	2.5 (2.5)	0.2 (0.6)	lower for outdoor exercise vs both indoor conditions ($p < 0.01$)
	anger/hostility	11.6 (7.5)	1.3 (1.6)	2.3 (1.6)	lower for outdoor exercise vs indoor-internal ($p < 0.01$)
	confusion/bewilderment	4.6 (2.5)	2.9 (1.9)	3.5 (1.6)	no significant differences seen
	vigor/activity	10.5 (3.8)	15.8 (9.2)	1.3 (7.6)	lower for outdoor exercise vs indoor-internal ($p < 0.01$)
	fatigue/inertia	12.4 (4.7)	7.3 (1.6)	6.0 (5.4)	lower for outdoor exercise vs indoor-internal ($p < 0.01$)
	Evaluation of Activity[m]	0.9 (0.9)	3.2 (1.6)	6.4 (1.3)	outdoor run evaluated most positively ($p < 0.0001$)
Mc Murray, 1988 [31]	***General Affect Scale***[n]	12.8 (2.3)		14.2 (5.1)	Scores obtained during the tenth mile were significantly lower than at rest but were not affected by the environment.
		Other Study Designs ($n = 1$)			
Hug, 2008 [35]		indoor		outdoor	
	Frequency of exercise − more than 1/wk	93 (71%)		83 (61%)	no significant difference
	Questionnaire − restorative outcomes[o]				
	stress reduction	1.37 (1.28)		1.18 (1.35)	interaction effect between environment and restoration ($p = 0.03$)
	physical well-being	1.36 (0.84)		1.20 (0.88)	
	mental balance	0.66 (1.13)		0.80 (1.04)	
	everyday hassles	0.43 (1.26)		0.64 (1.17)	
	Questionnaire − attitude to environment				
	looking forward to exercising again	3.86 (0.92)		4.20 (0.98)	Participants look forward to exercising again outdoors ($p < 0.01$).
	glad to leave the present site	2.43 (1.15)		1.39 (0.72)	indoor participants more eager to leave ($p < 0.001$)
	better restorative effect at other site	3.10 (1.24)		1.40 (0.73)	Outdoor participants did not believe that indoor was better ($P < 0.001$).

[a] Exercise Induced Feeling Questionnaire scores range from 0 (do not feel) to 4 (feel very strongly). [b] Feeling scale scores range from minus 5 (very bad) to 5 (very good). [c] Feeling arousal scale scores range from 1 (low arousal) to 6 (high arousal). [d] Enjoyment scores range from 1 (not at all) to 10 (extremely enjoyable). [e] Intention scores range from 0 (not at all interested in walking in this environment again) to 100 (very interested). [f] Subjective vitality scores range from 1 (not at all) to 7 (very true). [g] Results shown for indoor alone and outdoor alone only. [h] Physical Activity Enjoyment Scale (PACES) includes 18 bipolar items on which individuals rate themselves on a 7-point Likert scale. [i] Positive Affect Scale and Negative Affect Scale include a brief list of 6 mood states; participants mark how they feel on a scale ranging from 0 (not at all) to 6 (extremely). [j] Beta estimate of effect of indoors vs outdoors. [k] Total mood disturbance calculated by summing the POMS subscale T-scores of anger, confusion, depression, fatigue, and tension and then subtracting the T-score for vigor. [l] Somatic emotions included relaxation, anxiety, excitement, boredom, placidity, anger, provocativeness, sullenness; transactional emotions included pride, humiliation, modesty, shame, gratitude, resentment, virtue, and guilt. [m] A structured interview designed to gain information about subjects attitudes to the test activities and running in general. [n] General Affect Scale includes 13 bipolar adjectives arranged on a 7-point Likert scale. [o] Questionnaire scores were obtained on rating scales ranging from 1 (not at all) to 5 (very much). [p] The lower the score the higher the self-esteem. [q] AD-ACL − activation − deactivation adjective checklist.

avoid any potential for bias that may be introduced from preconceived ideas about the trial.

4) Due to the heterogeneity of the outcome measures used in the trials we were unable to conduct a meta-analysis. A total of 17 different outcome measures were described and used in these studies. Comparability of the magnitude of the changes seen in the different measures used to assess changes in mood was unclear and whether the changes seen were of clinical relevance is also uncertain.

The results of our review are in keeping with those reported by Bowler and colleagues in 2010.[36] These authors used similar methods to collate the results of studies that compared activity performed in a natural environment with that performed in a synthetic environment. Synthetic environments included nongreen outdoor built environments and indoor environments. The authors conclude that the combined results of included studies are suggestive that natural environments may have beneficial effects on well-being.

As was pointed out earlier, there is currently growing interest in the use of natural environments to promote health and wellbeing and in the concept of 'green exercise'. This new momentum is in part driven by the need to reduce the cost of the burden of disease to health services. Exercising brings health benefits and the idea that exercising outside may be better still is an attractive proposition. Half of the studies we examined were published in the last three years and many UK organizations e.g. BTCV, Countryside Recreation Network, Natural England, Forestry Commission and MIND have published reports examining the potential health benefits of spending time in natural environments.[10,16,20] The situation elsewhere in Europe is less clear.

Table 5. Summarized Results of Included Studies[a]

	short-term studies - walking							short-term studies - running			other study designs
	Focht, 2009 [30]	Ryan, 2009 [34]	Plante, 2007 [29]	Teas, 2007 [33]	Peacock, 2007 [16]	Plante, 2006 [28]	Plante, 2003 [26]	Kerr, 2006 [25]	Harte, 1995 [27]	McMurray, 1988 [31]	Hug, 2008 [32]
effects on positive emotions	↑+	-	-	↑+	↑+	-	-	→	-	→	↑+
effects on negative emotions	-	-	-	↑+	↑+	-	-	→	↑+	→	↑+
effects on feelings of tension	→	-	→	-	↑+	↓+	→	-	↑+	→	-
effects on feelings of energy and revitalization	↑+	↑+	→	-	→	↑+	↑+	-	?	→	↑+
enjoyment of activity	↑+	-	↑+	-	-	↑+	-	-	↑+	-	↑+
intention to repeat activity	↑+	-	-	-	-	-	-	-	-	-	↑+

[a] 'Positive emotions' included positive engagement, pleased, joy, delighted, happy, self-esteem, pleasant emotions, general affect scale, mental balance. 'Negative emotions' included frustration, worry, anger, sad, depression, anger, unpleasant emotions, general affect scale, stress reduction, everyday hassles. 'Feelings of tension' included calmness, tension, tranquillity, tension/anxiety, general affect scale. 'Feelings of energy and revitalization' included revitalization subscale, subjective vitality, energy, tiredness, vigor, fatigue. 'Enjoyment of activity' included enjoyment, physical activity enjoyment scale, evaluation of activity, looking forward to exercising again. 'Intention to repeat activity' included intention, looking forward to exercising again.↑+ a statistically significant difference was reported for one or more outcomes included in this category; the direction of the effect was beneficial. ↓+ a statistically significant difference was reported for one or more outcomes included in this category; the direction of the effect was not beneficial. → one or more outcomes included in this category was measured in the study − no statistically significant differences were reported. - no outcomes in this category were measured in the study.

The natural environment includes many different types of green space such as wilderness areas, allotments, urban parks, open countryside, country parks, woodlands, and wildlife reserves. Although the impact of different types of green space on wellbeing has begun to be investigated,[42] the interaction of this impact with physical activity has yet to be clarified. Green space typology may be an important moderator in the association between access to green space and physical activity.[37] There is also interest in the influence of the aquatic environment on wellbeing.[38] Preliminary research suggests that individuals tend to rate the restorative quality of images containing water more highly than those devoid of water,[39] and it is possible that physical activity initiatives in coastal areas may prove an especially useful means of encouraging and facilitating outdoor activity. Unfortunately, due to the lack of variation in the type of green space utilized in the trials included in this review, most were conducted on University campuses in the United States. With the limited descriptive detail provided, we were unable to add further to the debate on the relationship between green space typology and benefits from physical activity. A more subtle point that future studies might consider is the impact of the perceived quality of the environment on mental and physical wellbeing outcomes. It may be that the existing studies, in addition to their methodological weaknesses, have failed to recognize the effect of differences in environment (indoor or outdoor) on outcomes. For example, outdoor exercise in a busy urban environment may have less effect on mental wellbeing and adherence than an aesthetically appealing and supportive indoor environment. Additionally, different subgroups of the population may respond differently to the quality and quantity of green space available. In a recent study, Richardson and Mitchell found that cardiovascular disease and respiratory disease mortality rates decreased with increasing access to green space in males but no significant associations were found in women.[41] The authors conclude that it is important not to assume uniform health benefits of urban green space for all population subgroups.[41] Further trials in which the effects of physical activity in various green spaces in different population subgroups are studied are needed.

Although increasing the level of physical activity across the whole population will have a greater overall impact on the health of nations, larger individual benefits may be seen in specific populations e.g. people with mild depression or people who are overweight and obese. Exercise is recommended as a treatment option for people with depression by both the National Institute of Clinical Excellence (NICE) and the National Service Framework for Mental Health. A recently published Cochrane Review of the literature in this area concluded that regular moderate exercise may boost mental wellbeing, although the methodological quality of many of the studies included in the review lead the authors to draw cautious conclusions.[40] It is possible that the magnitude of the effects seen in these trials would be greater in people with mild depression.

This review has revealed the paucity of good quality evidence on which to base recommendations and reveals an undoubted need for further research in this area. Large, well designed trials in which the effects of long-term physical activity interventions conducted indoors and out in nature on mental and physical wellbeing are compared in different groups of people are urgently needed. Easily transferrable outcome measures (e.g., assessment of health related quality of life), administered both immediately after activity and after a period of rest to assess the sustainability of the effects of activity are also required. Measures to assess the adherence to different physical activity programs should also be included.

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