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Abstract: Abstract

Objective: The aim of this study was to explore the short-term effects of "green exercise" on state anxiety, and to examine the influence of exercise type, intensity, duration, and degree of greenness. Method: A quasi-experimental design involved eight pre-existing outdoor exercise groups (N = 101) who completed pre- and post-exercise questionnaires.

Results: Results indicated a significant reduction in participants' state anxiety following green exercise experiences ($d = .47$). However, there was a significant interaction between anxiety changes and the type of green exercise, with effect sizes for the groups ranging between 0.14 and 1.07. Exercise intensity and duration did not impact on state anxiety changes, however higher degrees of perceived environmental greenness were associated with larger reductions in anxiety.

Conclusions: Green exercise effected moderate short-term reductions in anxiety, with greater reductions evident for some exercise groups and for participants who perceived themselves to be exercising in more natural environments. These findings support claims for mental health benefits of green exercise but they also highlight the need to better understand individual and group differences and the role of perceived environmental "greenness".

Suggested Reviewers: Jules Pretty

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The submitted article is based on research conducted by Professor Jules Pretty on "green exercise".

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Dr. Jo Barton (nee Peacock) has worked alongside Jules Pretty in researching the area of green exercise



~~3 August 2009~~ ~~August 2009~~

~~August 2009~~

Dear Editor,

I am enclosing a submission to Psychology of Sport and Exercise entitled: "The Effect of "Green Exercise" on State Anxiety and the Role of Exercise Duration, Intensity, and Greenness: A Quasi-Experimental Study". In this manuscript we report on an empirical study ($N = 101$) which examines the influence of the level of greenness, duration, and intensity of green exercise on state anxiety of participants from pre-existing outdoor exercise groups.

We attest that only original material is presented within this manuscript. The manuscript has not been previously published, is not under consideration elsewhere, nor will it be submitted to any other journal until which time the Psychology of Sport and Exercise renders it final decision. We have followed the journal guidelines and the submission conforms to the latest edition of the American Psychological Association (APA). The co-author and I have no interests that might be interpreted as influencing the research process of results, and both national regulations as well as APA 6th edition ethical standards were followed in the conduct of the studies.

~~The manuscript is submitted electronically including the following files:~~

- ~~1. The present cover letter (PDF)~~
- ~~2. Identification Page plus Title, indicating our Names, Affiliations, Addresses, and Order of Authorship (PDF)~~
- ~~3. The Manuscript plus Title plus Tables plus Figures, with no names, no affiliation or any detail that might reveal the identity of the authors. The manuscript is paginated. At the end of the manuscript Tables and Figures are reported (the manuscript is submitted both in PDF and Word Format)~~
- ~~4. Figure 1 (TIFF format)~~

Both authors have examined and agreed to the submitted version of the manuscript. Both authors listed on the by-line have agreed to the by-line order and to submission of the manuscripts in this form.

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I have assumed responsibility for being the corresponding author, and keeping my co-author informed of our progress through the editorial process, the contents of the reviews, and any revisions made. I understand that, if accepted for publication, a certification of authorship form will be required that all co-authors will sign.

Yours sincerely,

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Running Head: GREEN EXERCISE AND STATE ANXIETY

The Effect of “Green Exercise” on State Anxiety
and the Role of Exercise Duration, Intensity, and Greenness:
A Quasi-Experimental Study

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This research was carried out by the first author as part of an honours thesis in psychology at the authors' affiliated institution in 2008.

Abstract

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6 state anxiety, and to examine the influence of exercise type, intensity, duration, and degree of
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13 = 101) who completed pre- and post-exercise questionnaires.
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47 **KEYWORDS:** green exercise; anxiety; exercise intensity; exercise duration; greenness
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The Effect of “Green Exercise” on State Anxiety and the Role of Exercise Duration,
Intensity, and Greenness: A Quasi-Experimental Study

Introduction

There is good evidence that regular physical activity contributes to physical and psychological health (e.g., Biddle, Fox, & Boutcher, 2003; Netz, Wu, Becker, & Tenebaum, 2005; Penedo & Dahn, 2005; Salmon, 2001; Scully, Kremer, Meade, Graham, & Dudgeon, 1998; Warburton, Nicol, & Bredin, 2006). There also exists a notable body of research about physical and psychological benefits from exposure to natural environments (e.g., Frumkin, 2001; Kaplan, 2001a; Maller et al., 2008; Pretty, Griffin, Sellens, & Pretty, 2003; Ulrich, 1979, 1984; Ulrich et al., 1991; Vemuri & Constanza, 2006). Combining physical exercise and natural environments, then, would seem to offer the prospect of potentially greater benefits than either undertaken in isolation. Hence, the notion of “green exercise” has developed (Larkin, 2000; Mind, 2007; Pretty, Griffin, Sellens, & Pretty, 2003; Pretty, Peacock, Sellens, & Griffen, 2005). Green exercise, in its simplest form, is exercise performed in (relatively) natural environments. Much remains unknown, however, about green exercise’s physical and psychological processes, and particularly about possible causal elements involved in facilitating desirable psychological outcomes.

Psychological Effects of Exercise

The psychological benefits of exercise are less well understood than the physical benefits, although evidence has been progressively accumulating (e.g., Emery, Shermer, Hauck, Hsiao, & MacIntyre, 2003; International Society of Sport Psychology, 1992; Netz et al., 2005; Scully et al., 1998; Seraganian, 1993) and include improvements in cognitive functioning (Cassilhas et al., 2007; Tomporowski & Ellis, 1986), mental health (Landers, 1997; Richardson et al., 2005), and psychological well-being (Hansen, Stevens, & Coach,

1 2001; Scully et al.). Amongst the most researched psychological outcomes of physical
2 exercise is anxiety.
3

4 *Effects of Exercise on Anxiety.* There appears to be a small-moderate anxiety-reducing
5 effect of physical exercise, based on state, trait, and psychophysiological measures (Landers,
6 1997; Seraganian, 1993). Tuson and Sinyor (1993) noted that anxiety-reduction was the only
7 reliable effect of exercise when examining various affective states. Six meta-analyses have
8 found that acute and chronic physical exercise significantly reduces anxiety levels (Landers).
9 The largest of these meta-analyses found an overall standardised mean effect size of 0.24 for
10 state-anxiety reduction effects of physical exercise (104 studies; Petruzzello, Landers,
11 Hatfield, Kubitz, & Salazar, 1991). More recently, Wipfli, Rethorst, and Landers' (2008)
12 meta-analysis only examined 49 studies of the effects of exercise on anxiety which used
13 randomised-controlled trials. Results indicated moderate reductions in anxiety amongst
14 exercise groups ($g = -0.48$) compared to other forms of anxiety treatment (e.g. group therapy,
15 relaxation, pharmacotherapy; $g = -0.19$), providing strong evidence for the anxiolytic effects
16 of exercise.
17

18 Although numerous exercise and participant variables need to be considered, research
19 evidence tends to support the notion that acute bouts of exercise are effective in reducing
20 state anxiety levels (Althiler & Motta, 1994; Landers, 1997; Millet, Groslambert, Barbier,
21 Rouillon, & Candau, 2005). However, studies focusing on moderating variables are less
22 common. The largest meta-analysis of physical exercise effects on anxiety identified only one
23 significant moderating variable: exercise duration (Petruzzello et al., 1991).
24

25 *Exercise Duration.* The duration of exercise required to achieve positive
26 psychological effects remains unclear. Exercise bouts of 15 to 30 minutes, three times per
27 week (expending approximately 4,000 to 10,000kJ / week; Selig, 2003) have been
28 recommended for physical and psychological benefits (Berger, 1994; Leith, 1998). However,
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1 some research has found improved levels of vigour and reduced levels of fatigue and total
2 negative mood to occur after as little as 10 minutes of exercise (Hansen et al.). Despite this,
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4 longer and more regular periods of 20 minutes or more appear to have the greatest
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6 psychological benefit (Hansen et al; Pate et al., 1995).
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9 *Exercise Intensity.* Despite a multitude of research studies investigating the
10 relationship between exercise intensity level and psychological benefits, there is currently no
11 definitive answer about optimal intensity. Some research has shown exercise intensity not to
12 be a significant factor in attaining psychological benefits (King, Taylor, & Haskell, 1993),
13 including self-reported state anxiety (Petruzzello et al., 1991). Other research has suggested
14 that a low-intensity exercise program of 60 minutes duration provided significant positive
15 improvements in self-reported health and self-efficacy for exercise (Temple et al., 2008).
16 However, most studies recommend moderate to high exercise intensity (Carr, 2001). In older
17 adults, moderate intensity exercise appears to benefit psychological well-being to the greatest
18 extent, with low intensity benefiting the least (Netz et al., 2005).
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34 *Green Exercise*

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37 An additional potential moderating factor in physical exercise's psychological effects
38 is the surrounding environment. There is recent, growing interest in the potential benefits of
39 exercising in natural environments – or “green exercise”. Green exercise refers to physical
40 activities undertaken whilst exposed to natural environments (Pretty et al., 2005). Sugiyama,
41 Leslie, Giles-Corti, and Owen (2008) define “green” environments as vegetated areas such as
42 parks, open spaces, and playgrounds. Further conceptualisation and measurement of
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65 “greenness”, however, remains largely unexplored.

Engagement with Nature

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3 Pretty (2004) proposed three levels of engagement with nature: viewing nature, being
4 in the presence of nature, and active participation and involvement with nature, each of which
5 may play a role in understanding the psychological effects of green exercise.
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10 *Viewing Nature.* Ulrich's (1984) seminal study found benefits of having a hospital
11 room with a nature view on recovery, whilst Kaplan's (1973, 1984, 2001a) research identified
12 psychological benefits of gardening, outdoor challenge programs, and naturalness of home
13 environments. Numerous other studies followed, particularly on the mood benefits of nature
14 scenes (e.g., Kweon, Ulrich, Walker, & Tassinary, 2008). Kaplan's (2001a) study of residents
15 of low-rise apartments has provided further evidence that there are individual well-being
16 benefits of viewing nature.
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21 *Presence of Nature.* As urbanisation increases, people find themselves
22 concentrated in neighbourhoods of impoverished biodiversity, bringing with it the possible
23 loss of the opportunity to appreciate and benefit from nature (Louv, 2008; Turner, Nakamura,
24 Dinetti, 2004). Exposure to green space has numerous psychological and physical health
25 benefits (Groenewegan, van den Berg, de Vries, & Verhij, 2006). Sugiyama et al. (2008)
26 found that perceived greenness of the local neighbourhood had a strong positive relation with
27 perceived mental health. The presence of greenness in the immediate surroundings was also
28 positively associated with recreational walking, social cohesion, and local social interaction.
29 Exposure to nature while engaging in some form of activity generally reduces stress and
30 increases health benefits (Pretty, 2004). Whilst residential access to natural environments
31 appears to be associated with better quality of life (Henderson-Wilson, 2005) and health
32 (Mitchell & Popham, 2007), the relationship may not be straightforward, with confounding
33 variables likely to play a role (e.g., income deprivation; Maas, Verheij, Spreeuwenberg, &
34 Groenewegen, 2008).
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Participation with Nature. Outdoor education programs have been found to improve a variety of personal and social outcomes (Hattie, Marsh, Neill, & Richards, 1997; Pryor, 2003; Pryor, Carpenter, & Townsend, 2005). For example, a multi-method study by Hartig, Mang, and Evans (1991) found that experiences in natural settings (wilderness backpacking) had psychologically restorative effects (compared to non-wilderness vacationers and a control group).

It should be noted, that participation in nature does not necessarily need to be intensely physically active in order to be beneficial. Gardening, for example, is well recognised as a restorative activity (Hartig, 2006; Kaplan, 1973). From viewing nature to being actively involved in it, engaging with nature seems to afford positive psychological benefits.

Nature, Mental Health, and Restoration. Natural environments are often hypothesised to be restorative (Hartig, 2004). “Restorative” refers to the “process of renewing, recovering, or reestablishing physical, psychological, and social resources or capabilities diminished in ongoing efforts to meet adaptive needs” (Hartig, p. 273). Two major theories have been proposed to explain restorative environments: psychophysiological stress recovery theory (Ulrich et al., 1991) and attention restoration theory (Kaplan, 2001b; Kaplan & Kaplan, 1989).

Psychophysiological stress recovery theory focuses on patterns of affective and aesthetic response to visual stimulus characteristics of an environment (Ulrich et al., 1991). It proposes that restoration can occur when a scene elicits feelings of mild to moderate interest, pleasantness, and calm, and that whilst viewing nature, positive affect replaces negative affect resulting in lower physiological arousal (Hartig, 2004).

Attention restoration theory refers to how our direct attention mechanism, which is largely under voluntary and effortful control, becomes fatigued (Kaplan, 2001b). Restorative

1 environments, such as natural environments, are proposed to facilitate recovery from directed
2 attention fatigue.
3

4 5 *Green Exercise Research* 6

7
8 Although research into the effects of green exercise is in its early stages, several
9 promising studies have been conducted. Pretty et al. (2005) randomly allocated 100 adult
10 participants to four experimental groups and one control group, and then had participants
11 engage in “fairly light” exercise on a treadmill for 20 minutes whilst viewing a range of rural
12 or urban scenes displayed on a screen. The four groups were exposed to images which were
13 either rural pleasant (e.g., countryside with trees and water), rural unpleasant (e.g.,
14 countryside with abandoned car), urban pleasant (e.g., tall buildings with sky reflected in
15 water) or urban unpleasant (e.g., city scene with broken windows and graffiti). The control
16 group exercised on a treadmill but was not shown any images. Before activity, and again on
17 completion, participants’ blood pressure was taken and they completed a battery of mood,
18 self-esteem, and health questionnaires. Overall results showed significant reductions in blood
19 pressure (systolic, diastolic, and mean arterial pressure) and increases in self-esteem. There
20 were also significant improvements in vigour and reductions in confusion-bewilderment and
21 tension-anxiety. However, only the groups which viewed rural pleasant scenes (green
22 exercise) experienced significant reductions in all three measures of blood pressure (Pretty et
23 al., 2005). Exposure to urban scenes appeared to negate the potential advantages of exercise
24 on blood pressure. All treatment groups improved in the tension-anxiety mood measure ($d = -$
25 .79), however exercising in pleasant environments (urban and rural) more positively affected
26 psychological indicators (self-esteem, mood and anxiety).
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54 In a further study by Pretty et al. (2007), the effects of green exercise on mood and
55 self-esteem for participants in pre-existing outdoor activity groups were assessed. Using a
56 quasi-experimental, pre-post design, 10 pre-existing green exercise groups (including
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1 bushwalking, horse riding, cycling, fishing, conservation volunteers, mountain biking, and
 2 boating) were assessed ($N = 263$). Results indicated small-moderate, significant pre-post
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 4 improvements for self-esteem ($d = 0.31$), anger-hostility (0.45), confusion-bewilderment
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 6 (0.40), depression-dejection (0.38), and tension-anxiety (0.49). Results further indicated that
 7
 8 these changes did not vary significantly by age, gender, low or high self-esteem, type of
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 10 exercise group, exercise intensity, or exercise duration.
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14 *Hypotheses*

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 18 The current study sought to partially replicate and extend Pretty et al.'s (2007) quasi-
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 20 experimental green exercise study. It was hypothesised, firstly, that green exercise would
 21
 22 reduce participants' state anxiety. Secondly, it was hypothesised that there would be no
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 24 between-group differences in the amount of pre-post change in anxiety. Finally, it was
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 26 hypothesised that duration, intensity, and greenness of exercise would positively predict
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 28 changes in anxiety.
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32 *Method*

33 *Participants*

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 37 Data was collected from 101 participants in eight pre-existing outdoor exercise groups
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 39 (Road Cycling, Mountain Running, Orienteering, Cross-Country Running, Boxercise,
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 41 Mountain Biking, Kayaking, and Walking) in the Australian Capital Territory (ACT) region,
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 43 in and surrounding Canberra, the "bush capital" of Australia (see Table 1). There were 59
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 45 males and 41 females, with gender data missing for one participant. The average age of
 46
 47 participants was 43.83 years ($SD = 16.65$), with males aged between 23 and 81 years ($M =$
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 49 47.34, $SD = 14.09$) and females aged between 20 and 66 years ($M = 39.07$, $SD = 14.29$).
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 Insert Table 1 about here

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3 *Measures*
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6 A questionnaire was developed to measure state anxiety before and after exercise and
7 several predictor variables, particularly duration, intensity, and greenness.
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10 *Pre-Test.* The pre-test questionnaire collected demographic data and established
11 baseline state anxiety using the 20 items from Form Y-1 of the State-Trait Anxiety Inventory
12 for Adults (STAI; Spielberger, 1983). Participants rated how they feel at the moment in
13 relation to apprehension, tension, nervousness, and worry. An example statement is “I feel
14 calm”. A four-point Likert response scale was used with response options ranging from (1)
15 “Not At All” to (4) “Very Much So”. Responses for half of the items were reverse-scored and
16 then averaged to provide overall state anxiety scores. Higher scores indicated higher levels of
17 state anxiety. The state anxiety items of the STAI have been found to be internally reliable (α
18 = .93) in samples of working adults, college students, and military recruits (Spielberger).
19
20 Overall, the STAI has been shown to be a valid tool for assessing state anxiety as evidenced
21 by concurrent, convergent, divergent, and construct validity (Spielberger). In the present
22 study, Cronbach’s α for the pre- and post-exercise state anxiety measures were .91 and .89,
23 respectively.
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42 *Post-Test.* The STAI (Form Y-1) was used to measure state anxiety post-exercise. In
43 addition, a single-item scale aimed at measuring perceived greenness was incorporated.
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45 Finally, participants rated exercise intensity using the Borg scale (Borg, 1998).
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50 *Greenness Rating Scale.* An extensive literature search did not reveal a suitable
51 measure of “greenness”. As such, a 10-point rating scale was developed to measure
52 participants’ perceptions of the degree of greenness in the exercise environment. The item
53 asked participants to rate the naturalness of the experience recently undertaken. The term
54 “naturalness” was used in the questionnaire instead of “greenness” (although for clarity and
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1 consistency green/greenness is used throughout the present study) as the surrounding
2 environment may be relatively natural, yet not necessarily be “green” (e.g., in drought-
3 affected areas). The opposite end to “naturalness” was termed “artificial”. The 10-point
4 Likert response scale ranged from (1) “100% artificial; 0% natural” to (10) “0% artificial;
5 100% natural. A high-rise building icon was shown at the artificial end of the scale and a tree
6 icon was shown at the natural end of the scale.

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14 *Borg Scale.* The Borg Scale, also known as the Rate of Perceived Exhaustion, was
15 used to assess participants’ self-perceived intensity of exercise based on physical sensations
16 experienced during physical activity. The 15-point rating scale ranges from (6) “No Exertion
17 At All” to (20) “Maximal Exertion”. The higher the score, the higher the perceived
18 exhaustion. The Borg Scale is a moderately reliable ($r = 0.64$ to 0.78 ; Pfieffer, Pivarnik,
19 Womack, Reeves, & Malina, 2002) and valid measure of perceived intensity (validity
20 coefficients = 0.57 to 0.72 , calculated using product-moment correlations with heart rate and
21 oxygen uptake as criterion measures; see also Chen, Fan, & Moe, 2002).

22 23 24 25 26 27 28 29 30 31 32 33 34 35 *Procedure*

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38 Contact details for a range of pre-existing outdoor exercise groups were obtained from
39 the local phone directory and internet sites. Leaders of the groups were contacted via email or
40 telephone requesting permission to survey the group’s members at a convenient time. Of 20
41 contacted exercise group, eight agreed to participate (see Table 1) whilst the other 12 groups
42 either did not respond, did not respond in the research timeframe, or refused to participate,
43 giving a response rate of 40%.

44
45 Meeting times were arranged with the exercise group leaders, and the researcher met
46 participants at their designated exercise site. An information sheet outlining the study was
47 provided to participants who were offered the chance to win a \$50 book voucher as an
48 incentive for participation. Participants were then given the pre-test questionnaire
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1 approximately 15 minutes before the start of the exercise. On completion of the exercise
 2 (within approximately 15 minutes), participants were asked to also complete the post-test
 3 questionnaire. It was estimated that the less than 10 people refused to complete the survey,
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 5 however due to time restrictions some potential participants were not able to complete the
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 7 questionnaire, providing an overall response rate of approximately 75%.
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12 *Results*

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 16 Four univariate outliers (extreme scores on pre- and post-exercise anxiety or intensity)
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 18 were re-coded as missing.
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21 *Changes in State Anxiety for Different Exercise Groups*

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 24 Descriptive statistics for State Anxiety before and after green exercise for each group
 25
 26 are shown in Table 2. A split-plot analysis of variance (SPANOVA) was conducted with
 27
 28 Time (2) as the within-subject factor and Exercise Group (6) as the between-subject factor.
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 30 Two of the original eight exercise groups were excluded due to low participant numbers
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 32 (Walking and Kayaking). Results indicated a significant main effect for Time, with post-
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 34 exercise State Anxiety levels significantly lower than pre-exercise levels (Wilks' $\lambda = 0.75$, F
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 36 (1, 76) = 25.91, $p = .000$, partial $\eta^2 = .25$; $d = -.47$). Moreover, the results revealed a
 37
 38 significant interaction effect between Time and Exercise group (Wilks' $\lambda = 0.86$, F (5, 76) =
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 40 2.42, $p = .04$, partial $\eta^2 = .14$), indicating that the amounts of change in State Anxiety differed
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 42 according to exercise group.
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 49 A series of follow-up paired sample t -tests, using a Bonferroni-adjusted critical alpha
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 51 level of .008 to control for Type 1 family-wise error rates for multiple comparisons, were
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 53 conducted to analyse pre-post anxiety changes for each of the green exercise groups. Cohen's
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 55 d was also calculated for each group (see Table 2). Results indicated a significant reduction in
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 57 anxiety for participants in Road Cycling ($t(18) = 3.36$, $p = .00$) and Boxercise ($t(8) = 4.45$, p
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= .00), with non-significant reductions in anxiety for Mountain Running ($t(14) = 0.50$, $p = .63$), Orienteering ($t(14) = 0.71$, $p = .49$), Cross-country Running ($t(14) = 1.48$, $p = .63$), and Mountain Biking ($t(8) = 2.32$, $p = .05$). According to the effect sizes, however, there were large reductions in anxiety for Road Cycling ($d = -0.84$), Boxercise (-0.99), and Mountain Biking (-1.02), and small reductions for Mountain Running (-0.14), Orienteering (-0.14), and Cross-country Running (-0.24).

 Insert Table 2 about here

Effects of Greenness, Duration, and Intensity of Green Exercise

A hierarchical multiple linear regression was performed to examine the extent to which Duration, Intensity, and Greenness of exercise could linearly predict changes in State Anxiety. Bivariate correlations and the regression co-efficients are presented in Table 3. In Step 1, pre-exercise State Anxiety levels accounted for 37% of the variance in post-exercise State Anxiety ($R^2 = .37$, adjusted $R^2 = .36$, $F(1, 70) = 40.93$, $p < .001$). In Step 2, Duration, Intensity, and Greenness were added to the model and accounted for a non-significant additional 6% of the variance in post-exercise anxiety ($\Delta R^2 = .06$, $F(3, 67) = 2.50$, $p = .07$). Duration ($\beta = -.13$, $t(67) = -1.30$, $p = .20$) and Intensity ($\beta = .00$, $t(67) = 0.04$, $p = .97$) were not significant predictors of post-exercise Anxiety. Greenness, however, was significantly negatively associated with post-exercise Anxiety ($\beta = -.22$, $t(67) = -2.33$, $p = .02$), indicating that greater reductions in anxiety were reported by participants who perceived that they were in more natural environments. Greenness uniquely accounted for 5% of the variance in post-exercise State Anxiety after controlling for pre-exercise anxiety levels.

 Insert Table 3 about here

Discussion

This study sought to measure the effects of green exercise on state anxiety. Moreover, it sought a greater understanding of the influence of exercise type, duration, intensity, and greenness of exercise on changes in state anxiety.

Changes in State Anxiety Following Green Exercise

The present study found that green exercise significantly reduced participants' state anxiety ($d = -0.47$), a very similar result to Pretty et al. (2007) for tension-anxiety ($d = -0.49$; $N = 263$). These results are approximately twice the size of the effects reported in Petruzzello et al.'s (1991) meta-analysis of 104 studies on physical exercise and state-anxiety reduction ($d = -.24$) and more specifically, the 94 physical exercise studies involving state-anxiety reduction measured using the STAI ($d = -0.23$). However, the present study's results are very similar to Wipfli et al.'s (2008) meta-analysis of random control studies of the physical exercise effects of anxiety ($d = -0.48$), thus it remains unclear how much of the observed anxiolytic effects in the current study were due to exercise, the natural environment, or an interaction between exercise and environment.

Changes in State Anxiety for Different Green Exercise Groups

In contrast to Pretty et al.'s (2007) findings, the current study found substantial variation in anxiety reduction outcomes for the green exercise groups, with road cycling, boxercise, and mountain biking participants reporting large reductions in anxiety, whilst mountain running, orienteering, and cross-country running participants reported small reductions.

Effects of Level of Greenness, Duration, and Intensity of Green Exercise on State Anxiety

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3 Exercise duration and intensity were not linearly related to changes in state anxiety,
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5 consistent with Pretty et al. (2007). However, the perceived level of naturalness and the type
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7 of exercise were related to anxiety changes. Petruzzello et al.'s (1991) meta-analysis found
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9 that duration of exercise was the only significant variable, with exercise lasting more than 21
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11 minutes necessary to achieve significant anxiety reductions. In the current study, however,
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13 short durations were not tested in this study, with most participants involved in exercise bouts
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15 considerably longer than 20 minutes (see Table 1). It is noted that the two running groups had
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17 the lowest average duration (approximately 20 minutes) compared to all other groups (all
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19 over 60 minutes) and that participants in these groups reported small, non-significant
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21 reductions in anxiety. It should also be recognised that duration and intensity of exercise are
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23 interrelated (Pollock et al., 1998). The average intensity in the present study was classified as
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25 "somewhat hard" (according to the Borg rating scale). The effects of duration and intensity
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27 may also be confounded by fitness levels.
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Nature, Greenness and Exercise

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38 In the current study, there was a linear relationship between perceived greenness of
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40 the exercise environment and anxiety reduction, accounting for 5% of the variance in anxiety
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42 reduction. Although greenness has not been previously investigated in green exercise
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44 research, this result is consistent with other greenness and mental health research (e.g.,
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46 Sugiyama et al., 2008; Vemuri & Constanza, 2006). However, not all individuals express a
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48 preference for natural wilderness settings (Thompson, Aspinall, & Montarzino, 2007). For
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50 some people the music and chrome of a gymnasium setting may have more meaning than the
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52 sounds of nature. Thus, the self-selecting nature of the green exercise group participants in
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54 the present study and studies such as Pretty et al. (2007) may have a prior preference for the
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56 outdoors, possibly helping to explain why reductions in anxiety were observed. However,
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1 cross-sectional studies such as by Sugiama et al. and Vemuri and Constanza, and
2 experimental studies such as Pretty et al. (2005) have generally supported the notion that
3 environments with more natural features tend to be preferred and that they tend to be
4 associated with more positive mental health outcomes.
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10 *Mechanisms for Anxiety Reduction from Green Exercise*

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13 For future green exercise research it may be beneficial to move beyond the study of
14 outcomes to the reasons for the psychological outcomes. Numerous mechanisms have been
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posited for changes in psychological states following physical exercise. Physiological changes, including increased body temperature, increased beta endorphins, increased parasympathetic activity, reduced muscle tension, and reduced excitability of the central nervous system, may cause the anxiety reducing effects of exercise (Petruzzello et al., 1991; Taylor, 2003). The exercise groups in the present study consisted of moderately intense aerobic-type activity. The abdominal rhythmic breathing accompanied by aerobic exercise may also be responsible for the positive effects (Berger, 1994).

Of particular relevance to green exercise may be the distraction hypothesis (Morgan, 1985) which suggests that part of the reduction in anxiety is due not to the physical exercise per se, but rather to the temporary respite from life's worries and concerns. Some studies have found that anxiety is reduced by both exercise and by quiet rest (e.g., Brown, Morgan, & Raglin, 1993; Ruck & Taylor, 1991). However, the distraction hypothesis appears insufficient to explain changes in anxiety, as other studies have found that only exercise reduced anxiety (e.g., Roth, Bachtler, & Fillingim, 1990). It may therefore be necessary to study what participants are focusing their attention on during green exercise, whether this is the exercise itself or environmental stimuli.

Limitations and Future Directions

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3 It remains unclear what milieu of factors may be involved in determining the
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It remains unclear what milieu of factors may be involved in determining the
anxiolytic effects of physical exercise and green exercise. Other factors may include exercise
variables, participant characteristics, socio-cultural variables, cognitions, and measurement
considerations. For example, Peacock, Hine, and Pretty (2007) highlight that a key reported
feature of participating in green exercise activities is the opportunity for social interaction and
the social benefits of being involved with like-minded people (also see Sugiyama et al.,
2008). Future green exercise studies with groups may consider measuring and controlling for
sociability.

With regard to measurement, the current study relied on a single-item, self-perceived
greenness rating scale. A more objective measure of environmental naturalness could also be
useful. The sample included people who were already engaging in green exercise activities
and were thus likely to be relatively healthy and positively oriented towards nature (Pretty et
al., 2007). Future directions for research into green exercise include increasing the
generalisability and scope of the study through a larger, more representative sample from a
wider variety of exercise groups (of varying intensities and durations), social groups, and
those involving various degrees of “naturalness”. Exploring and developing the validity and
reliability of the greenness rating scale would help to improve our capacity to understand the
role of “greenness” in green exercise. For example, efforts to validate the scale could
investigate cultural and community-based attitudes and experiences of “greenness”.

Assessing the impact of green exercise on a wider range of psychological outcomes
(e.g. stress, anger-hostility, and emotional distress) and with different population samples
(e.g., non-regular exercisers, indoor exercisers, highly stressed and/or anxious individuals,
and individuals raised in non-urban areas) could also be beneficial, and this may be enhanced
by using other research methods such as experimental, longitudinal, and experiential

1 sampling studies. Also, whilst the present study focused on acute exercise it may be
2 advantageous to study the effects of longer-term green exercise programs. Randomised
3 controlled experiments with participants assigned to either an outdoor, indoor, or control
4 exercise groups, with a standardised exercise type or program, would also be desirable and
5 would build on Pretty et al.'s (2005; 2007) studies.
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12 *Conclusion*

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16 The present study found that participants in green exercise had moderate pre-post
17 exercise reductions in state anxiety, strengthening previous green exercise research by Pretty
18 et al. (2007) which found that green exercise led to significant improvements in self-esteem
19 and decreases in mood disturbance. However, the nature of possible synergistic benefits of
20 physical activity and nature exposure remains largely unexplored. In this study, subjectively
21 perceived environmental naturalness helped to explain reductions in anxiety, warranting
22 further investigation. Future research may continue to explore not only duration, intensity,
23 and greenness, but also possibly sociability, fitness, preference for nature, and dynamic
24 psychological models such as the distraction hypothesis and the mastery hypothesis. Given
25 the economic and psychological cost of rising lifestyle-related illnesses, green exercise is
26 emerging as a potentially important contributor to public and environmental health.
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Table 1

Descriptive Statistics for Gender, Age, Intensity, Duration, and Greenness for Each Green Exercise Group

Exercise Groups	Description	Gender			Age (Years)		Intensity ^a		Duration ^b (min.)		Greenness ^c	
		Male	Female	Total	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Road Cycling	Group road cycle along highway overlooking bush	14	8	22	53.73	8.46	14.16	2.06	197.52	13.33	8.03	1.24
Mountain Running	Brief, intense run up a steep mountain	11	7	18	44.78	14.31	16.50	2.03	19.92	8.27	8.71	1.14
Orienteering	Casual session in local suburban bushland	14	3	18	50.76	15.32	14.00	2.36	62.18	23.08	8.27	1.03
Cross-Country Running	Midday run through suburban bushland	9	7	16	42.88	13.29	15.53	3.04	20.95	6.53	7.73	1.33
Boxercise ^d	Fitness boxing and near lake and at university oval	1	10	11	24.36	2.01	14.67	1.73	60.00	-	6.86	2.12
Mountain Biking ^e	Night ride through bushland	6	3	9	39.70	6.07	13.78	1.48	105.00	-	8.33	0.87
Kayaking ^f	Morning session on central ACT lake	1	1	2	21.50	2.12	11.50	0.71	75.00	-	8.00	-
Walking	Walk through suburban bushland	3	2	5	36.40	16.55	11.60	1.67	102.00	35.81	7.90	1.43
Total	-	59	41	101	43.83	16.65	14.55	2.48	91.56	68.74	8.06	1.30

Note. ^a *n* = 88; ^b *n* = 81; ^c *n* = 87; ^d Gender data missing for one participant; ^e This was a participant-pay, instructed group with a designated duration; ^f This group began and finished together and hence all participants had the same duration.

Table 2

Descriptive Statistics for Pre- and Post-Exercise State Anxiety for Each Green Exercise Group (N = 89)

Exercise Group	Pre-Exercise Anxiety				Post-Exercise Anxiety				Effect Size	
	<i>M</i>	<i>SD</i>	Skew	Kurt	<i>M</i>	<i>SD</i>	Skew	Kurt	<i>d</i>	<i>n</i>
Road Cycling	1.78	0.54	0.59	-0.09	1.42	0.32	0.94	1.65	0.84	19
Mountain Running	1.56	0.33	-0.24	-0.56	1.51	0.39	0.71	-0.16	0.14	15
Orienteering	1.62	0.50	0.92	0.25	1.56	0.33	-0.11	-1.22	0.14	15
Cross-Country Running	1.52	0.55	1.44	2.41	1.40	0.44	1.05	0.26	0.24	15
Boxercise	1.79	0.39	0.19	-1.08	1.41	0.38	0.54	-1.06	0.99	9
Mountain Biking	1.68	0.46	0.07	-1.72	1.31	0.23	0.26	-1.51	1.02	9
Total	1.64	0.48	1.64	0.48	1.44	0.36	1.44	0.36	0.47	82

Table 3

Hierarchical Linear Regression With Exercise Duration, Intensity, and Greenness as Predictors of Post-Exercise State Anxiety (N = 72)

Variables	<i>r</i>				Regression Co-efficients						
	Post-Anxiety	Greenness	Duration	Intensity	B (unique)	β	<i>t</i>	p	<i>r</i> _p	<i>sr</i> ^{2b}	
Step 1											
Pre-Anxiety	.61	-.11	.18	.03	0.43	.61 *	6.40	.00	.61	.37	
Step 2											
Pre-Anxiety	.61				0.43	.61 *	3.59	.00	.62	.35	
Greenness	-.28				-0.07	-.22 *	-2.33	.02	-.27	.05	
Duration	-.02	-.01			0.00	-.13	-1.30	.20	-.16	.01	
Intensity	.07	.03	-.34		0.00	.00	0.04	.97	.01	.00	

Note. *sr*² = the squared semi-partial correlations indicate the unique variance predicted by the independent variable

Figure 3. Error-bar graph showing mean State Anxiety and 95% confidence intervals before and after green exercise for each green exercise group.

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Figure1 MackayNeill Green Exercise
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