Mental Health & Prevention 15 (2019) 200173

Contents lists available at ScienceDirect

Mental Health & Prevention

journal homepage: www.elsevier.com/locate/mhp

Optimizing mental health benefits of exercise: The influence of the exercise environment on acute stress levels and wellbeing

Sandra Klaperski[a,b,*], Elena Koch[b,c], Daniel Hewel[b], Anja Schempp[b], Jana Müller[b,d]

[a] Department of Life Sciences, Whitelands College, University of Roehampton, Holybourne Avenue, SW15 4JD London, United Kingdom
[b] Institute of Sports Science, University of Freiburg, Schwarzwaldstr. 175, 79117 Freiburg, Germany
[c] Institute of Sports and Sports Science, Karlsruhe Institute of Technology, Engler-Bunte-Ring 15, 76131 Karlsruhe, Germany
[d] National Center for Tumor Diseases, German Cancer Research Center, Im Neuenheimer Feld 460, 69120 Heidelberg, Germany

ARTICLE INFO

Keywords:
Green exercise
Acute exercise
Exercise environment
Mood
Stress
State anxiety

ABSTRACT

Previous studies indicated that exercising in natural settings could have more positive mental health effects than other types of exercise. This article further investigates the role of different exercise environment characteristics and compares effects of indoor and outdoor exercise sessions on acute wellbeing and stress levels. A field study with $N = 140$ collegiate sports participants was conducted. Mood, state stress and state anxiety as well as perceived exercise intensity and the naturalness and calmness of the exercise environment were assessed by means of questionnaires immediately before and after engagement in an indoor or an outdoor exercise session. Results strongly support previous evidence on the beneficial effects of acute exercise on wellbeing and stress levels. Engagement in outdoor exercise did not per se lead to more beneficial changes than engagement in exercise sessions indoors. However, outdoor exercise environments were perceived as more calming and exercise sessions in more calming environments were associated with more stress-reductive effects. Thus, future studies should further investigate the impact of exercise environment characteristics as this could help to maximize beneficial preventive health effects of physical exercise.

1. Introduction

It is indisputable that regular recreational physical exercise is crucial to health promotion and disease prevention. Considerable evidence has shown that engagement in regular physical exercise improves physical as well as mental health (e.g., Biddle, Mutrie & Gorely, 2015; Das & Horton, 2012; Raglin & Wilson, 2012; Rethorst, Wipfli, & Landers, 2009; Warburton, Nicol, & Bredin, 2006). However, only little is known about what particular exercise types individuals should engage in to maximize positive health effects (e.g., Asztalos et al., 2012; Biddle et al., 2015). Over the past 15 years, there has been growing interest in the health benefits of exercise in natural environments (Barton, Wood, Pretty & Rogerson, 2016): Because the sole exposure to nature or natural scenes/objects is known to have positive effects on health (e.g., Herzog, Maguire, & Nebel, 2003; Park & Mattson, 2008; Ulrich, 1984; van den Berg, Maas, Verheij, & Groenewegen, 2010), especially when compared to negative effects of exposure to urban environments (e.g., Lederbogen et al., 2011; Peen et al., 2010), it is hypothesized that the combination of exercise and natural environments, so-called “green exercise”, leads to a synergistic health benefit (Pretty, Peacock, Sellens & Griffin, 2005). The study at hand investigates the significance of this synergistic benefit as well as the role of different exercise environment characteristics with regard to exercise-induced improvements in mental health.

Numerous studies found green exercise to have positive health effects, in particular, green exercise was found to reduce anxiety and stress, and to improve mood, self-esteem, attention, concentration and physical health (e.g., Barton et al., 2016; Rogerson, Brown, Sandercock, Wooller, & Barton, 2016). To determine whether green exercise has more positive health effects than other types of exercise, researchers have applied a variety of methodological approaches. In an overview of the evidence, Barton and colleagues (2016) discussed the evidence separately for (a) studies contrasting indoor with outdoor exercise, (b) studies contrasting exercise in urban/built environments with exercise in natural environments and (c) studies contrasting exercise while viewing urban/built or natural scenery in a laboratory. Each research approach finds evidence which does point towards greater benefits of green exercise (e.g., Brown, Barton, Pretty, & Gladwell, 2014; Pretty et al., 2005; Thompson Coon, Boddy, Stein, Whear, Barton & Depledge, 2011). In line with the focus of the current study, evidence on the

* Corresponding author at: Department of Life Sciences, Whitelands College, University of Roehampton, Holybourne Avenue, SW15 4JD, London, United Kingdom.
E-mail address: sandra.klaperski@roehampton.ac.uk (S. Klaperski).

https://doi.org/10.1016/j.mhp.2019.200173
Received 23 September 2018; Received in revised form 5 August 2019; Accepted 6 August 2019
Available online 06 August 2019
2212-6570/

comparison of outdoor and indoor exercise effects will be illustrated in more detail.

In 2011, Thompson Coon et al. conducted a narrative review of eleven studies which compared effects of exercise in outdoor natural environments with effects of indoor exercise on physical or mental wellbeing. The authors found that "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" (Thompson Coon et al., 2011, p. 1761). This conclusion corroborates findings from an earlier, more unspecific systematic review which looked at the effects of exposure to natural environments in general (Bowler, Buyung-Ali, Knight, & Pullin, 2010). However, Thompson Coon et al. (2011) warned that existing evidence had often been of limited methodological quality and that the heterogeneity of designs and outcome measures hampered comparisons. The authors' caution reflects two issues in the field of green exercise research which make it difficult to generalize findings. *First*, the environments used as outdoor conditions often differ greatly (e.g., Kerr, Fujiyama, Sugano, Okamura, Chang, & Onouha, 2006; Peacock, Hine, & Pretty, 2007; Ryan et al., 2010), with some studies even describing rather urban/build environments (Focht, 2009). Considering alternative research approaches described above (exercise in urban/build vs. natural environments), it seems necessary to examine the actual meaning and role of "naturalness" and/or "greenness" better. Findings from Pretty et al. (2005) suggest, for instance, that positive environment-related effects are not only related to the naturalness of an environment but also to its pleasantness. How calming an environment is being perceived could influence how much activities in this environment reduce stress (Lohr & Pearson-Mims, 2000). Thus, it is of interest to assess and quantify environment characteristics to better understand the role of the environment and to enable more suitable comparisons between studies. In a unique study from 2010, Mackay and Neill tried to address this limitation by investigating the influence of green exercise environment characteristics on state anxiety levels in six different types of green exercise. Results indicated that engagement in a green exercise session in general led to a significant reduction in participants' state anxiety levels; furthermore, regression analyses showed that the degree of perceived environmental greenness/naturalness was negatively associated with anxiety levels after the exercise session, while exercise intensity and exercise duration did not predict post-exercise anxiety levels. Even though this finding supports the importance of environment characteristics the approach chosen by Mackay and Neill (2010) has not yet been adopted in other studies.

A *second* issue in the field of green exercise research identified by Thompson Coon et al. (2011) is the appropriateness of generalizations of findings when derived from (a) (walking and running-based) activities of often very short duration (e.g., 10 min walks [Focht, 2009]) and (b) comparisons with unrealistic or no indoor control conditions. The authors highlighted that more research is needed to examine whether more positive effects of green exercise can also be found for repeated, more genuine physical activity sessions and for different types of exercise. The latter applies especially to control exercise conditions green exercise is compared with; a walk inside a shopping center (Peacock et al., 2007), in a series of underground hallways (Ryan et al., 2010) or on a treadmill in a laboratory (Focht, 2009) are barely realistic indoor exercise control conditions. Results from a study with 53 mental health patients corroborate the assumption that interesting alternative activities can be a suitable alternative to green exercise (Barton, Griffin, & Pretty, 2012): While regular countryside and urban park walking sessions were found to lead to significant improvements in self-esteem and mood, the same held true for the two alternative activity programmes swimming and engagement in a social club. Similarly, Turner and Stevinson (2017) found no differences in positive affective responses during and after high-intensity exercise in an outdoor and an indoor setting. And even though Mackay and Neill (2010) inferred from their study (see above) that green exercise in more natural environments can lead to short-term reductions in anxiety, claims for particular mental health benefits of green exercise should not be made without examining a realistic non-green exercise control group, as various non-green types of exercise have also been found to reduce state anxiety levels (e.g., Taylor, 2000).

Thus, in order to optimize recommendations for engagement in physical exercise so the largest preventive effects can be reached, it is crucial to further test the assumption that exercising outdoors results in more beneficial effects than exercising indoors. Taking into account the discussed limitations and the need for replication in the field of research, the current study adopted and expanded Mackay's and Neill's (2010) quasi-experimental approach and further investigated the role of the exercise environment characteristics "naturalness" and "calmness" by means of contrasting acute mental health effects of genuine outdoor and indoor exercise sessions. In a field study, pre- and post-exercise mood, state anxiety, and perceived state stress levels of collegiate sports participants engaging in outdoor or indoor exercise sessions which differed with regard to the degree of the exercise environment's naturalness were examined. In line with previous findings, we expected all exercise sessions to lead to improvements in mood and to reductions of state anxiety and state stress. Furthermore, considering existing evidence on green exercise, it was hypothesized that the green exercise condition would lead to significantly greater beneficial changes than the indoor condition. Lastly, in accordance with previous findings on the influence of exercise environments' characteristics, we assumed that the naturalness and calmness of the exercise environment would be positively related to beneficial post-exercise mental health levels.

2. Method

2.1. Participants and procedure

One hundred forty-two participants were recruited to take part in the study. To be eligible for the study, participants had to be at least 18 years old and they had to participate in an amateur collegiate sports session offered by the University of Freiburg. In particular, participants exercising in environments which differed with regard to the degree of naturalness were recruited from nine different types of indoor and outdoor sports. Indoor sports (later referred to as "indoor group" [IN]) were: aerobics (n = 15), aqua aerobics (n = 14), basketball (n = 13), fencing (n = 11), swimming (n = 22), volleyball (n = 17); outdoor sports ("outdoor group" [OUT]) were: running (n = 20), football (n = 19), mountain biking (n = 11; MTB). The environments of the outdoor groups can be described as follows: Soccer took place on a green lawn soccer field with buildings on the one side and a view on a river and a forest on the other side; the running and mountain biking groups both took place in a hilly forest with hardly any urban views. All exercise classes were open to students and employees of the university and lasted between 1 and 2.5 h. Instructors of all exercise classes were contacted and informed about the study and agreed that data collection could take place. All exercise group members who volunteered to participate in the study received a questionnaire before and after their exercise session at their exercise location. Speaking German for less than two years served as only exclusion criterion; two participants were excluded, resulting in a final sample of N = 140 participants. Data were collected within two weeks in late spring 2014.

2.2. Measure

All participants were asked to complete a questionnaire immediately before (pre-questionnaire) and immediately after their exercise session (post-questionnaire). The pre-questionnaire assessed sociodemographic information on age, sex and type of profession as well as the level of proficiency with regard to the performed exercise and the amount of exercise engagement in general. Participants were also asked

to indicate for how long they spoke German at the time of the study if German was not their first language.

2.2.1. Pre-post comparisons

In line with Mackay and Neill (2010), we assessed mood-, anxiety- and stress-related changes due to engagement in the acute exercise session. First, the German version of the Multidimensional Mood State Questionnaire (MMSQ; Steyer, Schwenkmezger, Notz, & Eid, 1997) was used to measure calmness and mood. The MMSQ consists of 24 items with a 5-point scale ("definitely not" [1] to "very much" [5]) and the three subscales *calm-nervous* (eight items, e.g., "Right now I feel restless"; in this study, higher values reflect higher restlessness levels), *good-bad mood* (eight items, e.g., "Right now I feel great"; in this study, higher values reflect higher bad mood levels) and *awake-tired* (eight items, e.g., "Right now I feel energetic"). The subscales calm-restless (Cronbach's α before/after exercise = 0.85/0.83) and good-bad mood (Cronbach's α before/after exercise = 0.89/0.88) showed good internal consistencies; the subscale awake-tired was not used as it was not of interest for the study. Second, state anxiety was assessed using the German subscale "state anxiety" of the State Trait Anxiety Inventory (STAI; Laux, Glanzmann, Schaffner, & Spielberger, 1981). The state scale of the STAI consists of 20 items and participants rate on a 4-point scale from "not at all" (1) to "very much so" (4) how they feel at the moment (e.g., "I feel upset"). The state scale of the STAI showed good internal consistencies (Cronbach's α before/after exercise = 0.86/0.82). Third, in the absence of standardized instruments to measure state stress, an adapted version of the German 10-item Perceived Stress Scale (PSS; Cohen, Kamarck & Mermelstein, 1983; Klein et al., 2016) was used to measure acute perceived stress levels (Mackay, 2008). In line with Mackay (2008) and Rogerson, Brown, et al. (2016) the PSS items were reworded from statements about how participants felt during the last month into statements about how participants felt at the moment. For example, "In the last month, how often have you felt nervous and 'stressed'?" was altered to "I feel nervous and 'stressed'"; answers were rated on a 5-point scale from "Strongly disagree" (1) to "Strongly agree" (5) (Mackay, 2008). The adapted PSS showed satisfactory internal consistencies (Cronbach's α before/after exercise = 0.75/0.79).

2.2.2. Post-questionnaire

In addition to the mood, anxiety and stress scales, the post-questionnaire assessed the naturalness and calmness of the environment in which participants had exercised and the perceived exercise intensity. A 0-10 naturalness scale developed by Mackay and Neill (2010) was implemented to measure participants' perceptions of the degree of naturalness in the exercise environment. Participants were asked "Overall, how would you rate the naturalness or the environment you have just exercised in?" and rated their answers from "Very artificial/urban" with a high-rise building icon underneath to "Very natural" with a tree icon underneath (see Mackay & Neill, 2010, p. 241). Furthermore, we adopted a 0-10 scale assessing the calmness of the exercise environment in which participants were asked to rate the exercise environment from "Very stressful" to "Very calming" (Mackay, 2008). Lastly, perceived intensity of the exercise session was assessed by means of the Borg-scale (Borg, 1998); participants rated their level of perceived exertion during the exercise session on a 15-point scale from "no exertion at all" to "maximal exertion".

2.3. Statistical analyses

We used *t*-tests for independent samples to test for systematic differences between the indoor group and the outdoor group with regard to age, baseline values of the four outcome variables (restlessness, bad mood, state anxiety, perceived state stress) and exercise engagement. Chi-squared tests were applied to test for systematic differences with regard to sex and exercise proficiency level. Subsequent, we used four different 2 (pre-post) × 2 (indoor group, outdoor group) split-plot analyses of variance to examine changes in the outcome variables. To examine the effect of the type of exercise, paired sample *t*-tests were used to analyze pre-post exercise session changes in the four outcome variables for each of the nine exercise types (Mackay & Neill, 2010). For each outcome variable a Bonferroni adjusted alpha level of 0.006 was used to control for alpha-error accumulation.

Three independent *t*-tests were used to test whether groups differed with regard to their perception of naturalness and calmness of the exercise environment and with regard to perceived exercise intensity. Finally, replicating Mackay's and Neill's (2010) approach, we conducted hierarchical multiple regression analyses, with baseline scores partialled out in the first step of the regression, to examine whether naturalness and/or calmness of the exercise environment and/or exercise intensity would predict the four outcome variables (Step 2); as the indoor and outdoor group significantly differed with regard to age and sex, age and sex were included in the multiple regression analyses as further predictors.[1] Cohen's d_z and Cohen's d_s were calculated for paired and independent *t*-tests respectively (Lakens, 2013).

A statistical a priori power analysis for sample size calculation had been calculated for the two main analyses of the study – the indoor–outdoor group comparison split-plot analysis of variance and the exercise environment characteristics regression analysis (Faul, Erdfelder, Lang, & Buchner, 2007). The latter required a bigger sample size, namely $N = 77$, based on a small to medium effect size (Mackay & Neill, 2010), an alpha error probability of 0.05 and a power of 0.80. All data were analyzed with SPSS Statistics version 21.0.

3. Results

3.1. Participant characteristics

The indoor group (IN: $n = 90$; 54 females; age: $M = 23.6$, $SD = 3.0$) and outdoor group (OUT: $n = 50$; 14 females; age: $M = 25.2$, $SD = 4.2$) did significantly differ with regard to age ($F(1,137) = 6.98$, $p < .01$, $\eta_p^2 = 0.05$; not reported: $n = 1$) and sex distribution ($p < .001$, Fisher's Exact Test). Participants did not significantly differ with regard to their proficiency level in the exercise they engaged in ($p = .17$, Fisher's Exact Test), with 29 indoor group vs. 10 outdoor group participants classifying themselves as beginners and 61 indoor group vs. 40 outdoor group as advanced in their type of exercise. Likewise, participants did not differ regarding the amount of regular exercise in general ($p = .42$), with indoor group participants exercising on average 6.2 h/week ($SD = 5.0$) and outdoor group participants exercising on average 6.8 h/week ($SD = 4.6$). Before the exercise session, the two exercise type groups did not differ with regard to any of the four outcome variables (see *t*-test column in Table 1). Of the final sample, 116 participants were students (IN: $n = 79$), 23 participants were employed (IN: $n = 10$), one indoor group participant stated he was unemployed.

3.2. Pre-post changes in mood and state stress

Variance analyses revealed that, independently of the type of exercise, engagement in an acute exercise sessions led to significant reductions of restlessness ($F(1,136) = 22.06$, $p < .001$, $\eta_p^2 = 0.14$), bad mood ($F(1,136) = 27.43$, $p < .001$, $\eta_p^2 = 0.17$), perceived stress levels ($F(1,138) = 42.65$, $p < .001$, $\eta_p^2 = 0.24$) and state anxiety ($F(1,137) = 12.71$, $p < .001$, $\eta_p^2 = 0.09$) (see Table 1 factor "time"). No significant interaction effects between time and group factor emerged. Further dependent *t*-tests showed that both groups reported similar

[1] In line with the goal of following Mackay's and Neill's (2010) data analysis approach and due to only having nine exercise type groups as well as small to medium intraclass correlation coefficients, we did not take the exercise type clusters into account in the analyses.

Table 1
Descriptive statistics (mean, *SD*) and statistical comparisons of restlessness, bad mood, state stress and state anxiety levels in the indoor and outdoor exercise group before and after the exercise session.

Variables		Indoor group	Outdoor group	*t*-test *p*	ANOVA *p* time	*p* group	*p* time x group
Restlessness	T1	2.35 ± 0.64	2.21 ± 0.70	.27	**.000**	.10	.78
	T2	***2.06 ± 0.66	**1.89 ± 0.53	.10	η_p^2 = .14		
Bad mood	T1	1.89 ± 0.57	1.86 ± 0.59	.78	**.000**	.43	.43
	T2	***1.67 ± 0.47	**1.57 ± 0.59	.20	η_p^2 = .17		
State stress	T1	2.42 ± 0.54	2.35 ± 0.43	.41	**.000**	.14	.16
	T2	***2.23 ± 0.57	***2.05 ± 0.50	.06	η_p^2 = .24		
State anxiety	T1	1.86 ± 0.37	1.82 ± 0.38	.50	**.001**	.26	.61
	T2	**1.76 ± 0.37	*1.68 ± 0.31	.18	η_p^2 = .09		

Note. Data are expressed as $M \pm SD$; T1 = assessment point before the exercise session, T2 = assessment point after the exercise session; significant differences are highlighted by bold type and for dependent *t*-test indicated as follows:
* $p < .025$ (Bonferroni adjusted).
** $p < .01$.
*** $p < .001$.

significant reductions in all four outcome variables due to the exercise session (see Table 1). When examining changes in the four outcome variables for each of the nine exercise types, paired *t*-tests indicated that only a few indoor and outdoor exercise sessions led to improvements in mood and state stress when using the Bonferroni adjusted alpha level of 0.006: As can be seen in supplementary Table 4 (see suppl. material online), only swimming, running and mountain biking led to significant improvements in mood and/or stress. While running led to reductions in restlessness and bad mood respectively ($t(19) = 3.33$, $p = .003$, $d_z = .75$; $t(19) = 3.85$, $p = .001$, $d_z = 0.86$) state stress reductions were found after swimming ($t(21) = 3.20$, $p = .004$, $d_z = 0.68$) and mountain biking ($t(10) = 3.82$, $p = .003$, $d_z = 1.15$). Supplementary Figs. 1 and 2 illustrate the changes in mood, stress and anxiety outcomes (see suppl. material online).

3.3. Influence of the exercise environment and exercise intensity

Comparisons of the outdoor and the indoor group with regard to exercise environment variables showed that the outdoor group rated their exercise environment as significantly more natural and calming compared to the indoor group members' ratings (see Table 2 for descriptive and statistical values). The two exercise type groups did not differ with regard to the perceived exercise intensity they experienced in their exercise sessions.

When looking at the naturalness values for the nine separate exercise types, all three exercise types classified as outdoor exercise received ratings above the theoretical scale mean value of 5 (soccer: $M = 6.83$, $SD = 1.80$; running: $M = 8.21$, $SD = 1.91$; MTB: $M = 8.59$, $SD = 1.40$); naturalness values for indoor exercise ranged from 2.15 to 4.20 (aerobics: $M = 2.15$, $SD = 1.83$; swimming: $M = 2.40$, $SD = 2.31$; aqua aerobics: $M = 3.01$, $SD = 2.72$; fencing: $M = 3.53$, $SD = 3.14$; volleyball: $M = 3.77$, $SD = 2.94$; basketball: $M = 4.20$, $SD = 2.57$). With regard to the calmness of the environment, outdoor exercise environments received the highest ratings (soccer: $M = 7.44$, $SD = 1.49$; running: $M = 7.46$, $SD = 2.80$; MTB: $M = 8.98$, $SD = 0.91$) and mean values in the indoor exercise types ranged from 3.17 to 6.76 (basketball: $M = 3.17$, $SD = 1.82$; aqua aerobics: $M = 4.79$, $SD = 2.33$; aerobics: $M = 5.05$, $SD = 1.74$; swimming: $M = 5.17$, $SD = 2.52$; volleyball: $M = 6.64$, $SD = 1.88$; fencing: $M = 6.76$, $SD = 2.47$). We furthermore found a significant correlation between naturalness and calmness of the exercise environment ($r = 0.56$, $p < .000$).

Table 2
Descriptive statistics (mean, *SD*) and statistical comparisons of levels of perceived naturalness of the exercise environment, calmness of the exercise environment and perceived exercise intensity levels in the indoor and outdoor exercise group.

Variables	Indoor group	Outdoor group	*t*	df	*p*	d_s
Naturalness[a]	3.07 ± 2.60	7.74 ± 1.89	11.98	121	**.000**	1.96
Calmness[a]	5.23 ± 2.40	7.81 ± 2.05	6.57	107	**.000**	1.13
Intensity[b]	8.81 ± 3.05	9.29 ± 2.38	0.96	134	.34	

Note. Data are expressed as $M \pm SD$; significant differences are highlighted by bold type.
[a] $n = 89$ indoor group and $n = 47$ outdoor group participants included in analyses due to missing data.
[b] $n = 88$ indoor group and $n = 48$ outdoor group participants included in analyses due to missing data.

Regression analyses examining the predictive value of the independent variables (see Table 3) revealed that the model provided a significant fit of the data for all outcome variables: restlessness (Step 1: $F(1,130) = 17.01$, $p < .001$; Step 2: $F(6,125) = 4.11$, $p < .001$), bad mood (Step 1: $F(1,130) = 53.51$, $p < .001$; Step 2: $F(6,125) = 9.60$, $p < .001$), perceived state stress (Step 1: $F(1,132) = 126.67$, $p < .001$; Step 2: $F(6,127) = 24.24$, $p < .001$), and state anxiety (Step 1: $F(1,131) = 35.98$, $p < .001$; Step 2: $F(6,126) = 6.64$, $p < .001$). When entering calmness, naturalness, exercise intensity, age and sex in Step 2, only perceived calmness of the exercise environment and sex significantly predicted state stress ($\beta = -0.16$, $p = .03$) and restlessness levels ($\beta = -0.18$, $p = .04$) respectively: Post-exercise state stress levels were found to be lower when the exercise environment had been perceived as more calming, and restlessness after the exercise session was higher in men than in women. Adding the additional variables in Step 2 significantly improved the overall fit only when predicting perceived state stress (change in $R^2 = 0.04$, $p = .04$). Baseline values significantly predicted corresponding outcome variables in both Step 1 and Step 2.

4. Discussion

The current research investigated the effects which have been accredited to exercise taking place in natural settings, so-called green exercise (Pretty et al., 2005). We conducted a field study to test whether participants engaging in genuine green exercise sessions outdoors experienced more beneficial changes in mood, state stress and state anxiety than participants engaging in genuine non-green exercise sessions indoors. Furthermore, the role of the naturalness and calmness of the exercise environment has been examined.

The first main finding was a main effect for time (pre-post exercise session) for all outcome variables, indicating that exercise in general led to improvements in mood and to reductions in state stress and state anxiety. This finding supports our first hypothesis and corresponds with a plethora of evidence showing that acute exercise sessions lead to improvements in mood and other wellbeing-related variables (Biddle

Table 3
Hierarchical linear regression with naturalness and calmness of the exercise environment and perceived exercise intensity as predictors of the four outcome variables restlessness, bad mood, state stress and state anxiety.

	Restlessness[a]					Bad mood[a]					State stress[b]					State anxiety[c]				
	b	β	t	p	R^2	b	β	t	p	R^{2*}	b	β	t	p	R^2	b	β	t	p	R^2
Step 1					0.12***					0.29***					0.49***					0.22***
Baseline value	0.319	0.340	4.13	**.000**		0.490	0.540	7.32	**.000**		0.739	0.700	11.26	**.000**		0.434	0.464	6.00	**.000**	
Step 2					0.17					0.32					0.53*					0.24
Baseline value	0.323	0.344	3.90	**.000**		0.469	0.517	6.76	**.000**		0.717	0.679	10.94	**.001**		0.448	0.479	5.79	**.001**	
Naturalness	0.019	0.096	0.97	.334		−0.004	−0.022	−0.25	.805		−0.005	−0.032	−0.44	.662		−0.002	−0.021	−0.22	.824	
Calmness	−0.042	−0.175	−1.73	.087		−0.017	−0.086	−0.94	.347		−0.034	−0.163	−2.21	**.029**		−0.011	−0.079	−0.83	.407	
Intensity	0.005	0.024	0.28	.778		−.006	−.035	−0.46	.646		−0.009	−0.048	−0.78	.439		−0.000	−0.001	−0.01	.995	
Age	−0.016	−0.089	−1.01	.314		−0.007	−0.051	−0.63	.528		−0.015	−0.100	−1.53	.129		−0.002	−0.024	−0.28	.779	
Sex	−0.230	−0.184	−2.07	**.040**		−0.132	−0.127	−1.62	.107		−0.080	−0.074	−1.15	.253		−0.103	−0.144	−1.72	.088	

Note. Results are presented as unstandardized regression coefficients (b), standardized β-coefficient, t-values, p-values and R^2; significant p-values are printed in bold, significant changes in F (R^2) are indicated as follows:
* $p < .05$.
*** $p < .001$.
[a] $n = 132$ included in analysis due to missing data.
[b] $n = 134$ included in analysis due to missing data.
[c] $n = 133$ included in analysis due to missing data.

et al., 2015; Giacobbi, Hausenblas, & Frye, 2005; Kanning & Schlicht, 2010; Reichert et al., 2017; Rogerson, Brown, et al., 2016) as well as to reductions in state anxiety (Taylor, 2000). So far, only a few studies have looked at the effects of acute exercise sessions on perceived state stress levels; our findings support previous findings from Mackay (2008) and Rogerson, Brown, et al. (2016), who found reductions in perceived state stress due to engagement in a single green exercise session. On a broader level, our findings also correspond with studies which found acute exercise sessions to reduce acute physiological stress responses (Hamer, Taylor, & Steptoe, 2006) and with evidence revealing a negative relationship between exercising and perceived stress levels in general (Klaperski, 2017); yet, more studies specifically examining the effects of exercise on state stress are needed.

The *second main finding* of the present research was the absence of significant meaningful interaction effects, thus our hypothesis that green exercise would lead to greater benefits than other types of exercise had to be rejected. These results are in line with findings from Turner and Stevinson (2017) and Barton et al. (2012) who did not find differences between outdoor and indoor conditions either. However, when examining changes in the four outcome variables for each of the nine exercise types, paired t-tests indicated that, using the Bonferroni adjusted alpha level of 0.006, only swimming, running and mountain biking led to significant improvements in mood and/or stress. Running had the strongest reduction effects on restlessness ($d_z = 0.75$) and bad mood levels ($d_z = 0.86$) and mountain biking had the strongest reduction effects on state stress levels ($d_z = 1.15$). Furthermore, as can be seen in supplementary Figs. 1 and 2, different types of exercise had different effects on the four outcome variables; only the outdoor running group reported large improvements for all outcome variables, also when comparing it with groups with similar or higher baseline values (see supplementary Table 4). This could nonetheless suggest that green exercise, and running outdoors in particular, has stronger positive effects on acute mood and perceived stress levels than non-green types of exercise. Clear support for the assumption that green exercise leads to more positive health effects, like previously found (e.g., Barton et al., 2016; Thompson Coon et al., 2011), is however not provided by this non-experimental study, as no general green exercise effect was found and as alternative explanations for the findings cannot be ruled out.

As *third main finding* of this research it can be stated that the calmness of the exercise environment but not the environment's greenness or perceived exercise intensity were negatively associated with perceived state stress levels. This result indicates that exercise sessions in environments which were perceived as more calming had greater stress-reductive effects than exercise in less calming environments. These findings support our original assumptions only partly and are not in line with Mackay's and Neill's (2010) findings who identified naturalness as significant predictor. However, perceived naturalness and calmness of the exercise environment were moderately positively correlated ($r = 0.6$), indicating that natural environments were generally perceived as being less stressful. Thus, green exercise might have more beneficial effects on state stress levels because natural environments are often being perceived as calming. This result also corresponds with findings from Pretty et al. (2005) who showed that not the naturalness but the pleasantness of the environment determined whether participants experienced positive effects. However, the effects found in the current study were small and exercise environment predictors only significantly improved the fit of the regression model for perceived state stress. Notwithstanding the inconsistent main findings of the current study, the calmness and naturalness scales used proved to be helpful instruments to systematically quantify exercise environment characteristics. Future studies should use these scales to further facilitate the investigation of the impact of exercise environment characteristics on mental health benefits; this will make it easier to optimize exercise recommendations (for a detailed discussion of differences in the general perception of exercise environment and intensity characteristics in the study see supplementary material).

4.1. Strengths and limitations

The current research is an important contribution to existing evidence on effects of specific exercise environments and settings as it addresses two limitations in the field of green exercise research: potentially skewed results due to missing or unrealistic non-green exercise control conditions and a still unsatisfactory understanding of the importance of different exercise environment characteristics in indoor as well as outdoor exercise. A strength of our research is that it does not only allow us to find beneficial mental health effects of outdoor or green exercise but that it equally examines beneficial mental health effects of indoor exercise sessions. This is possible because we examined pre-existing outdoor and indoor exercise groups, which offers the advantage of an ecologically valid comparison of effects of genuine outdoor and indoor exercise sessions. However, this goes along with a risk of self-selection and systematic differences between exercise groups which could have influenced the results. Even though our analyses did not reveal any systematic differences for the important exercise-related study variables, there were differences regarding age and sex distributions in the groups, showing that the groups cannot be regarded as being fully alike. Furthermore, a no-exercise control group was missing, which means the positive effects found in this study cannot certainly be attributed to the exercise sessions. Therefore, evidence based on large randomized controlled trials with a genuine non-green exercise control group and a no-exercise control group is warranted to prevent self-selection effects and to experimentally examine long-term as well as short-term effects of outdoor and indoor exercise participation. A further strength of our study is that we adopted and expanded a design previously used by Mackay and Neill (2010) and that, unlike previous evidence in the field of research, findings stem from a non-English speaking sample. Considering the wide array of methods and designs which have been used to explore the effects of green exercise, there is a clear need for attempts to replicate findings.

In addition to the above-mentioned limitations linked to the study design, another limitation which applies to our findings is that only a small part of the effects which have been attributed to green exercise, namely acute short-term effects on mood, stress and anxiety levels, were investigated and discussed. Apart from direct health benefits of green exercise, natural environments have also been found to promote health indirectly, e.g. through greater exercise adherence and more social contact while exercising (Barton et al., 2016; Bowler et al., 2010). Thus, our findings do not support the assumption that outdoor exercise promotes short-term improvements in acute mood, stress and anxiety levels more than indoor exercise, but outdoor exercise might have greater long-term effects, or its unique effects might manifest themselves in variables we did not examine. This point is linked to the limited time frame of the current study, as only immediate short-term effects have been examined. Previous studies have shown that positive mental states persist for several hours or even a day (e.g., Basso & Suzuki, 2017) and the longevity of effects could possibly differ for different exercise environments. Apart from that, it must be critically acknowledged that some scales we used by adopting previously used study designs have not yet been validated. Like Mackay (2008) and Rogerson, Brown, et al. (2016), we used an adapted version of the Perceived Stress Scale (Cohen, Kamarck & Mermelstein, 1983) in the absence of a suitable scale measuring perceived state stress. The adapted PSS scale showed satisfactory internal consistencies but results with regard to perceived state stress still need to be regarded as exploratory at this stage. Similar limitations apply to the naturalness and calmness scales used; the scales have been developed by Mackay (2008) and Mackay and Neill (2010) as there were no existing validated scales available. Both scales seem to have the potential to become a valuable tool in (green) exercise research, however, quality criteria need to be further assessed. As Mackay and Neill already stated in 2010, the further exploration and standardization of "methodologies for measuring greenness would help to improve our capacity to understand the role of naturalness and other environmental variables in green exercise and other contexts" (p. 244), but so far only little progress has been made. Future studies should try to develop and use standardized methods to examine the effects of greenness/naturalness and related environmental variables.

4.2. Conclusion

The study at hand strongly supports previous evidence on the positive effect of acute exercise on mental health-related variables like mood, state stress and state anxiety. Contrary to our expectations, engagement in green exercise did not per se lead to more beneficial changes than engagement in exercise sessions indoors. However, exercise sessions in environments which were perceived as more calming had greater stress-reductive effects than exercise in more stressful environments, and green exercise environments were uniformly perceived as more calming than indoor exercise environments. Thus, based on our findings we can neither fully support nor fully reject the assumption that a greater, synergistic health effect can be found in green exercise. Notably, even though green exercise environments were perceived as more calming, which predicted lower state stress levels after the exercise session, some indoor exercise environments were also perceived as calming. Hence, in order to reduce stress levels by engaging in exercise, it might not be crucial to engage in green exercise but to engage in exercise in an (indoor or outdoor) environment which is being perceived as calming. In this case, exercise facilities should be intentionally designed in a calming way (e.g., no high noise levels). Future studies need to investigate this assumption by means of quantitative and qualitative methods to further understand the role of exercise environment characteristics, not only in green exercise but in exercise in general. This way, it could be possible to provide more specific exercise recommendations which maximize the preventive effects of exercise on mental health in the future.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declarations of Competing Interest

None.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.mhp.2019.200173.

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