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Acute effects of outdoor and indoor exercise on feelings of energy and fatigue in people with depressive symptoms

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ABSTRACT

Objective: People with depressive symptoms often report low energy and fatigue. Though acute and chronic exercise can improve energy and fatigue, less is known about how the environment influences exercise response. This study quantified the effects of exercise completed outdoors and indoors on feelings of energy and fatigue among adults with depressive symptoms.
Method: 18 young adults with depressive symptoms completed three counterbalanced 20-min conditions (outdoor exercise, indoor exercise, sedentary control). Exercise involved running for 20 min at moderate intensity. Participants completed self-reported measures of vigour-energy and fatigue immediately before and following each condition.
Results: Compared to the sedentary control condition, exercise resulted in statistically significant and large improvements in feelings of energy. Improvements did not statistically differ between outdoor and indoor exercise. Exercise effects on feelings of fatigue were not statistically significant.
Conclusion: Findings did not support that environment moderates the effects of exercise on feelings of energy in people with depressive symptoms.

Mood states (e.g., tension, energy, fatigue) are transient feelings that can range from minutes to weeks. The mood state of energy is conceptualized as feelings of having the capacity to complete mental or physical activities; whereas, the mood state of fatigue refers to feelings of having a reduced capacity to complete mental or physical activities (O'Connor, 2004). Though low energy and fatigue often accompany depressive symptoms and disorders (American Psychiatric Association, 2013), studies focused on depressed patients with low energy have been scarce to date (e.g., Demyttenaere, De Fruyt, & Stahl, 2005), potentially because low energy may be interpreted as a symptom of somatic illness and lead to searches for medical treatments rather than to treatment for depression. However, low energy may have important influences on treatment response, compliance, and disability in individuals with depressive symptoms. Baseline low energy and loss of interest in activities have predicted lack of remission with antidepressant treatment (Moos & Cronkite, 1999), and energy loss in depression strongly correlates with days in bed, days of lost work, low productivity, and poor social functioning (Swindle, Kroenke, & Braun, 2001).

Dozens of meta-analyses conducted and published since the mid 1990s indicate that regular physical activity can significantly reduce depressive symptoms (meta-analytic effect size of −0.60 to −0.90; e.g., Krogh, Hjorthøj, Speyer, Gluud, & Nordentoft, 2017; Cooney et al., 2013), possibly due to a stimulating effect of exercise on energy-regulating systems (e.g., Pinchasov, Shurgaja, Grischin, & Putilov, 2000). Though less well-documented, a single bout of exercise (i.e., "acute" exercise) has also been found to improve depressed mood in patients with major depression (Meyer, Koltyn, Stegner, Kim, & Cook, 2016), which may similarly be related to a direct effect of acute exercise on feelings of energy (Bartholomew, Morrison, & Ciccolo, 2005).

There have been recent calls for acute exercise studies to rigorously investigate the potential moderating effects of specific features of exercise (e.g., intensity, duration, setting, etc.) to facilitate the development and implementation of exercise training programs to improve depression (Meyer et al., 2016). In particular, previous studies have suggested that walking in nature may be especially effective in lowering depression and improving mental well-being (e.g., Marselle, Irvine, & Warber, 2014). These previous

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findings lend support to the theory of affective response to natural environments (Ulrich, 1983), which argues that exposure to outdoor natural environments can enhance affective functioning to a greater extent than urban or human-made surroundings because humans are biologically entrained to respond positively to environmental features including possibilities for survival, such as water and vegetation.

To date, only two prior studies have directly examined the affective benefits of exercise in natural vs. non-natural environments among participants with depression (Berman et al., 2012; Frühauf, Niedermeier, Elliott, & Ledochowski, 2016). Berman et al. (2012) showed that positive affect improved to a greater extent after a nature walk compared to an urban walk; but one important limitation of this study was that no information was reported regarding exercise intensity. This is important because affective responses to acute exercise can vary substantially as a function of exercise intensity (for review, see Ekkekakis, Parfitt, & Petruzzello, 2011). In brief, people usually derive relatively pleasant affect from exercise performed at low or moderate intensities, whereas at higher intensities the majority of individuals experience a sense of displeasure. In another study by Frühauf et al. (2016), outdoor exercise appeared to increase "activation" more than indoor exercise. Within the *Mood Survey Scale* (MSS; Abele-Brehm & Brehm, 1986), which was the instrument used by Frühauf et al. (2016), "activation" assesses feelings of energy through broad evaluation of the high-arousal/pleasure quadrant from the valence-arousal circumplex model of emotion (Russell, 1980). However, several methodological weaknesses, including no counterbalancing of interventions and different exercise types for outdoor and indoor conditions, somewhat limit meaningful interpretation of these findings.

Consequently, the first objective of the present experiment was to quantify the effects of a 20 min running bout performed at a fixed (i.e., "moderate") intensity on feelings of energy in individuals with depressive symptoms. Because feelings of fatigue and feelings of energy are related symptoms, these were also measured pre- and post-interventions. A second aim was to investigate the potential moderating effect of an outdoor nature *versus* indoor exercise environment.

1. Methods

1.1. Participants

A priori power analysis, assuming an effect size of $f = 0.30$ based on previous reports of acute exercise effects on feelings of energy among participants with depression (Bartholomew et al., 2005), alpha of .05, and correlation among repeated measures of 0.50, indicated that 17 participants were required to reach 90% statistical power.

Because prevalence of depression is 2.5–2.8 times higher among people with low socioeconomic status, (Murphy, Laird, Monson, Sobol, & Leighton, 2000), the authors contacted residents from a subsidized housing complex (located in Reims, northeastern France). Two public talks were presented to residents of the housing complex, presenting information about study aims and the environments in which interventions would take place. One staff member also placed copies of the research agenda in the hall reception area for public viewing. It was stated that the authors were seeking individuals experiencing low mood/depression to take part in a study exploring the affective effects of physical activity. Both our talk and recruitment letter specified that participation was voluntary, and that, for their effort, participants would receive a EUR 30 Decathlon Sport™ gift card to be used at any Decathlon Sport™ accessory store.

Of the 85 residents who responded, 27 fulfilled the main inclusion criteria. Study inclusion criteria included elevated depressive symptoms (Beck Depression Inventory-II score ≥ 14; Beck, Steer, & Brown, 1996), no medical contraindication to participation in moderate intensity exercise, fewer than 30 min of moderate-intensity physical activity per day on most days of the week, and no current pregnancy. Seven of 27 declined participation in the experiment (incompatible schedule due to job demands), and one withdrew just one day before involvement in the study. Finally, one participant was removed for completing only the first session, leaving 18 participants with complete data (12 women and 6 men, $M_{age} = 26.3 \pm 5.7$ yrs-old (Fig. 1).

Mean Beck Depression Inventory-II score was 22.6 ± 6.9 (range: 14–32). All participants provided informed consent approved by the Institutional Ethics Board of the University of Reims and were enrolled in the study within one week following completion of screening.

1.2. Design and procedure

A within-subject design was used, in which all participants completed three different experimental sessions, outdoor exercise (OE), indoor exercise (IE), and sedentary control (SC), in counterbalanced order, each separated by three to six days. All sessions were conducted between the beginning of April and early June 2017, and were scheduled at the same time of the day (between 5 p.m. and 7 p.m.). Weather was dry and reasonably warm (17 °C-23 °C). Of the six possible combinations of conditions, three were randomly selected: (1) OE-SC-IE, (2) IE-SC-OE, and (3) SC-OE-IE. Participants were randomly assigned to one of these three selected orders with restrictions for equal number of participants and balanced gender composition.

1.3. Environments

1.3.1. Outdoor exercise (OE)

The outdoor environment was the Verzy Regional Nature Park, a 500 sq. km vegetation and wildlife reserve in the Reims Mountains, on the sandstone massif between Epernay and Reims, northeastern France. This park is a plateau with more than 200 km of waymarked hiking trails. Free parking was available onsite. Participants were driven by van from their apartment block to the park (travel time: 20 min). Upon arrival, subjects completed two subscales from the Profile of Mood States (POMS; McNair, Lorr, & Droppleman, 1992) that measured feelings of vigour/energy (POMS-V) and feelings of fatigue (POMS-F). Then they were instructed to run at 64%–77% of age-specific maximal heart rate (MHR, American College of Sports Medicine, 2009). It reflects exercise of "moderate" intensity and has appeared to be most favored in studies using exercise for the alleviation of depression (Perraton, Kumar, & Machotka, 2010). This target heart rate (HR) zone was determined and entered manually in a Polar HR monitor (Polar Electro Oy, Finland) for each participant. Polar monitors were set to beep when HR went out of the preset range. The duration of exercise was 20 min, which falls within the recommended range of optimal durations (7 min–35 min) to derive affective benefits from acute exercise (Reed & Ones, 2006). Two staff members accompanied participants during the exercise sessions to ensure compliance with instructions. Conversation between participants was allowed but not encouraged. Water was provided on request during and after exercise. Upon their return, participants again completed the POMS-V and POMS-F subscales, and then were driven back home afterwards.

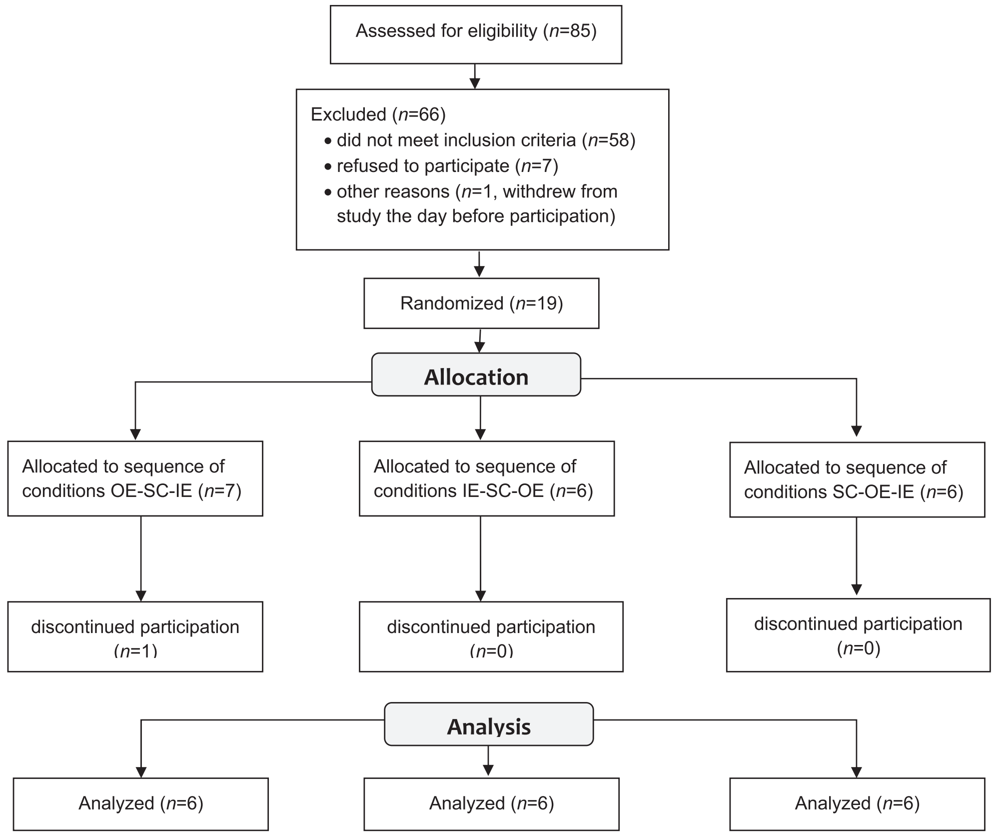

Fig. 1. Participants through each stage of the study. *Note*: OE = Outdoor Exercise; IE = Indoor Exercise; SC = Sedentary Control.

1.3.2. *Indoor exercise (IE)*

The indoor environment was a full-sized (44 m × 24 m, and 12 m high) gym at the University of Reims. Participants were also driven by van from their home to the gym (and return), and commuting time was roughly similar (15 min). The exercise stimulus (i.e., type, intensity, duration) and procedures (i.e., staff members in charge of running the operations, instructions to participants, live HR monitoring, pre- and post-exercise assessments of mood) were kept consistent with those described above.

1.3.3. *Sedentary control (SC)*

Participants were shown a 20-min educational movie about sport, exercise, and health ("Practicing sport is all about physics and chemistry"). This took place in a dedicated studio space in the lab, which is equipped with a high definition audio/video system (ceiling-mounted projector). The output image was projected on a large screen facing the participants. Comfortable lounge chairs and sofas were available. The program content was pre-screened for emotionally charged images or topics. Participants were instructed not to sleep or do any other activity while watching. Consistent with the OE and IE conditions, participants were transported (and transported back home) by van to attend the video sessions (travel time: 15 min), completed the POMS-V and POMS-F subscales immediately before and after TV-watching, and had water available at all times.

1.4. *Instruments*

1.4.1. *Depressive symptoms*

The self-report Beck Depression Inventory (BDI-II, Beck et al., 1996) was used to assess the magnitude of depressive symptoms at study entry. It was preferred over other commonly used measures of depression (e.g., the Hamilton Depression Rating Scale) that have to be administered by a health care professional. The BDI-II has 21 items evaluating symptoms and attitudes related to major depressive disorder (MDD) in the past week. Each item includes four statements numbered from 0 to 3, with higher numbers indicating more severe symptoms. Respondents are asked to circle the statement that best describes their symptoms related to a particular aspect of MDD (e.g., feeling of guilt). Beck et al. (1996) suggest the following cut-score guidelines: scores of 14–19 indicate "mild" depression, 20–28 indicate "moderate" depression, and 29–63 indicate "severe" depression.

1.4.2. *Energy and fatigue*

Feelings of energy and fatigue were measured with the vigour and fatigue subscales of the Profile of Mood States (POMS; McNair et al., 1992), validated in French language by Cayrou et al. (2000). In the French POMS, the Energy-Vigour subscale (POMS-V) has seven items assessing feelings of alertness, vitality, and physical energy. The Fatigue subscale (POMS-F) also has seven items that assess feelings of weariness and physical fatigue. Participants were instructed to respond "based on how you feel right now", and rated items using a 5-item Likert scale from 0 (*not at all*) to 4 (*extremely*). Internal consistency for both subscales of the French POMS has been found to be high (0.82 < Cronbach's alphas < .92; Cayrou et al., 2000).

1.4.3. *Data analysis*

Three condition × two time repeated-measures ANOVAs examined differences in pre-to post-condition changes in feelings of energy and fatigue between conditions. Assumption of sphericity was tested using the Mauchley's test. Any significant interaction was examined using Bonferroni-corrected *t*-tests. The magnitude of change was quantified using Cohen's *d* $((M_{exercise}-M_{control})/SD_{pooled})$. As recommended by Morris and DeShon (2002), we corrected for dependence among means by accounting for the correlation between the two variables under scrutiny. Intensity of exercise in the outdoor and indoor conditions was compared using a paired *t*-test. All analyses were performed using Statistica 8.0.

2. Results

2.1. Physiological effects

In the outdoor exercise condition, mean heart rate was 144.7 ± 14 bpm (i.e., 76.7% of age-specific maximal HR), which did not significantly differ ($t_{(17)} = 0.43$, $p = .673$) from the mean heart rate in the indoor exercise condition (142.3 ± 22 bpm; i.e., 75.4% of age-specific maximal HR). Based on the classification of physical activity intensity proposed by the American College of Sports Medicine (ACSM, 2009), exercising at 75%–76% of one's age-specific maximal HR (MHR) can be considered to reflect exercise of "moderate" (64%–76% MHR) to "vigorous" (77%–93% MHR) intensity.

2.2. Effect of conditions on changes in feelings of energy

Sphericity was not violated ($\chi^2_{(2)} = 3.14$, $p = .208$). Significant Time ($F_{(1, 17)} = 7.83$, $p = .012$, $\eta^2_p = 0.32$) and Condition × Time ($F_{(2, 34)} = 3.91$, $p = .030$, $\eta^2_p = 0.18$) effects were found. Both the natural and indoor exercise conditions resulted in moderate-to-large increases in feelings of energy ($d = 0.77$ and $d = 0.71$, respectively). Bonferroni-corrected *post-hoc* pairwise *t*-tests demonstrated significant energy improvements pre-to post-session for the OE ($t_{(17)} = 3.19$, $p = .005$) and IE ($t_{(17)} = 2.34$, $p = .032$) conditions, but not for the control condition ($t_{(17)} = -0.23$, $p = .820$). In addition, feelings of energy did not change differentially for the outdoor run compared to the indoor run ($t_{(17)} = 0.31$, $p = .758$). Condition order was not a significant predictor for changes in feelings of energy when it was included as a between-subjects factor in the ANOVAs.

2.3. Effects of conditions on changes in feelings of fatigue

Sphericity was not violated ($\chi^2_{(2)} = 2.19$, $p = .335$). Neither main nor interaction effects were statistically significant (see Table 1). Fatigue non-significantly decreased in the exercise conditions, but with a small-to-moderate effect size ($d = -0.57$ and $d = -0.27$ for the IE and OE conditions respectively). Condition order was not a significant predictor for changes in feelings of fatigue when it was included as a between-subjects factor in the ANOVAs.

3. Discussion

Given recent calls for acute exercise studies to rigorously investigate the potential moderating effects of specific features of exercise (e.g., intensity, duration, environment, etc.), this study was designed to examine the moderating effect of environment on the relationship between physical exercise, feelings of energy, and feelings of fatigue in a sample of individuals with depressive symptoms. The primary finding of the current investigation was that, compared to a sedentary attention-control condition, an acute bout of aerobic exercise significantly improved feelings of energy among adults with depressive symptoms. The moderate-to-large magnitude improvements in feelings of energy reported here are consistent with both previously documented effects of acute exercise on feelings of energy among primarily healthy adults (Loy, O'Connor, & Dishman, 2013; McDowell, Campbell, & Herring, 2016), young women with persistent fatigue (Herring & O'Connor, 2009), and people with Multiple Sclerosis (Ensari, Sandroff, & Motl, 2016).

However, contrary to previous reports suggesting an additional benefit of exposure to nature during exercise in participants with depressive symptoms (Berman et al., 2012; Frühauf et al., 2016), environment was not found to moderate the effect of exercise in the current study. Such inconsistencies in findings could be due to different measures of participants' feelings of energy. For example, Frühauf et al. (2016) used the "activation" mood subscale from the *Mood Survey Scale* (MSS, Abele-Brehm & Brehm, 1986). This subscale captures individual differences in the intensity of positive-activated affect (PAA). Though PAA includes vigour-energy, it also incorporates other constructs such as positive well-being, positive engagement, pleasantness, joy, and euphoria (Reed & Ones, 2006). Previous studies have found a similar lack of differences in affective responses to exercise between natural and non-natural environments (e.g., Bodin & Hartig, 2003; Kerr et al., 2006). In trying to explain their findings, Bodin and Hartig (2003) suggested that this may have been because participants exercising at vigorous intensity tended to focus more on physical sensations associated with exercise, such as heart pounding or heavy legs, than on the particular exercise environment. Still another explanation could lie in the fact that, according to Ulrich's theory of affective response to natural environments (Ulrich, 1983), not all natural settings can lead to positive changes in mood. More specifically, several properties of the environment, including visual complexity, visual depth, or ground surface texture, have been proposed to influence participants' affective reactions. For example, it is hypothesized that lack of visual depth (e.g., dense wooded areas) may elicit negative affective reactions, as it might create an impression of there being hidden dangers. The influence of these variables was beyond the scope of the present study, but is of critical importance to explore in future studies in order to more accurately describe the differential effects of outdoor and indoor exercise on feelings of energy and fatigue in people with depression.

In the present study, post-exercise feelings of fatigue did not statistically differ from pre-exercise levels. These findings are consistent with previous reports among people with depression

Table 1
Means, standard deviations, and analysis of variance (ANOVA) results for feelings of energy (POMS-V) and feelings of fatigue (POMS-F) as a function of condition and time of assessment.

Measure	OE		IE		SC		Time		Condition × Time	
	M	*SD*	*M*	*SD*	*M*	*SD*	$F_{(1,17)}$	*p*	$F_{(2,34)}$	*p*
POMS V - pre	13.33	8.01	12.22	7.54	13.00	8.25				
POMS V - post	17.78	5.78	16.22	5.07	12.72	7.48	7.83	.012	3.91	.030
POMS F - pre	7.81	6.60	8.22	6.86	8.94	8.07				
POMS F - post	6.94	5.54	6.83	7.15	9.39	8.10	0.22	.643	0.78	.469

Note. POMS V = feelings of energy; POMS F = feelings of fatigue; OE = outdoor exercise; IE = indoor exercise; SC = sedentary control. *F* ratio and *p* values from repeated measures analysis of variance model.

showing that after acute exercise of moderate intensity, feelings of energy were increased whereas feelings of fatigue remained unchanged (Bartholomew et al., 2005; Frühauf et al., 2016), and recent meta-analytic evidence by Loy et al. (2013) that showed a medium-sized effect of acute exercise on feelings of energy ($\Delta = 0.47$) among healthy adults, but a null effect for feelings of fatigue ($\Delta = 0.03$). Future research to further examine potential paradoxical effects of acute exercise on feelings of energy and fatigue among adults with elevated depressive symptoms is needed. The present paradoxical results for feelings of energy and feelings of fatigue may be due partly to the timing of the mood measurements (immediately before exercise, and within the first 2 min of recovery). Indeed, though previous evidence has suggested that participants usually report being energized during and immediately after moderate-intensity exercise (e.g., Ekkekakis, Backhouse, Gray, & Lind, 2008), feelings of fatigue would be expected to be higher immediately following exercise at "vigorous" intensity than 10–30 min later. Thus, it is plausible that more favorable effects would have been observed had there been a greater delay between completion of exercise and measurement of fatigue. Interestingly, the non-significant pre-to post-exercise reduction in feelings of fatigue was accompanied by an effect size of medium strength for the indoor exercise condition in the current study ($d = -0.57$). This suggests that failure to detect statistically significant changes in feelings of fatigue was most likely due to small sample size and lack of power.

Previous studies that have examined associations between acute exercise and other mood states among individuals with depression had revealed more mixed results, with some studies showing benefits (e.g., Meyer et al., 2016), while others showed a negative rebound effect (i.e., increased depression and feelings of fatigue) 30 min after the end of exercise (e.g., Weinstein, Deuster, Francis, Beadling, & Kop, 2010). Of important note is that studies with negative or inconclusive results were conducted at higher intensity levels than the present investigation (e.g., 85% of maximal oxygen uptake – which is equal to 90% of maximal HR – during the last stage of exercise in Weinstein et al., 2010).

The present findings that a short bout of moderate intensity exercise (whether outdoors or inside) enhanced feelings of energy in people with elevated depressive symptoms have several implications. Although the literature is replete with research studies that outlined the positive effects of chronic exercise on depressive symptoms, dropout from exercise programs (rate of ~18%; Stubbs et al., 2016) is still a significant issue, as exercise adherence is critical to treatment success. Depressed individuals typically experience symptoms like fatigue, loss of interest, and lack of energy; yet a considerable amount of energy is required to actively engage in long-term exercise. The findings reported here provide initial support for encouraging people with elevated depressive symptoms to engage in multiple short (15–20 min) exercise bouts over the course of the week rather than in fewer bouts of 30–45 min length, because more frequent exercise may lead to a greater cumulative effect on feelings of energy. In addition, utilizing short bouts of exercise on a frequent basis may be particularly important since those with depression often choose unhealthy mood management strategies such as alcohol, drugs, and tobacco (Bartholomew et al., 2005).

In addition to our relatively small sample size that may have precluded the detection of a significant benefit of exercise for feelings of fatigue, the selected timing of mood measurements is another potential limitation of this study. Feelings of energy and fatigue were assessed immediately before and immediately after exercise completion. Consequently, we were unable to determine the time course of benefit. This issue is of fundamental importance as previous literature has suggested the existence of a delayed negative effect of acute exercise in participants with depression (Weinstein et al., 2010). A third limitation of this work is the lack of information on participants' perception of the exercise environment's restorative qualities. Past research has demonstrated that the perceived restorativeness of the exercise environment is related to affective experience during exercise (Korpela & Hartig, 1996).

4. Conclusion

Notwithstanding the aforementioned limitations, the present paper is the first within-subjects experimental study that compared the effects of a standardized exercise protocol in different environments on feelings of energy and fatigue among individuals with significant depressive symptoms. In summary, this study has two main findings. First, short bouts of moderate-to-vigorous exercise were effective in improving feelings of energy among people with depressive symptoms. Secondly, the positive effects of exercise on feelings of energy did not depend on whether exercise took place in an outdoor nature setting or an indoor gym.

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