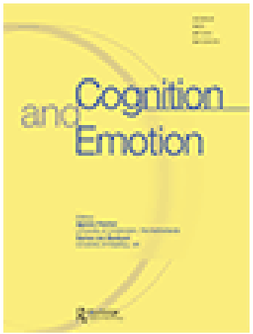

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BRIEF ARTICLE

Acute aerobic exercise helps overcome emotion regulation deficits

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ABSTRACT

Although colloquial wisdom and some studies suggest an association between regular aerobic exercise and emotional well-being, the nature of this link remains poorly understood. We hypothesised that aerobic exercise may change the way people respond to their emotions. Specifically, we tested whether individuals experiencing difficulties with emotion regulation would benefit from a previous session of exercise and show swifter recovery than their counterparts who did not exercise. Participants ($N = 80$) completed measures of emotion response tendencies, mood, and anxiety, and were randomly assigned to either stretch or jog for 30 minutes. All participants then underwent the same negative and positive mood inductions, and reported their emotional responses. Analyses showed that more perceived difficulty generating regulatory strategies and engaging in goal-directed behaviours after the negative mood induction predicted more intense and persistent negative affect in response to the stressor, as would be expected. Interactions revealed that aerobic exercise attenuated these effects. Moderate aerobic exercise may help attenuate negative emotions for participants initially experiencing regulatory difficulties. This study contributes to the literature on aerobic exercise's therapeutic effects with experimental data, specifically in the realm of emotional processing.

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Emotion regulation; aerobic exercise; depression

We are surrounded by messages encouraging us to exercise. Blog posts, advertisements, doctors, and peers all affirm the emotional and physical advantages of working out. Beyond colloquial wisdom, research shows that in both psychiatric and nonpsychiatric populations, regular exercisers tend to report greater emotional well-being and fewer depressive symptoms than people who are sedentary (Harris, Cronkite, & Moos, 2006; Tordeurs, Janne, Appart, Zdanowicz, & Reynaert, 2011). Although the physical health advantages of aerobic exercise likely contribute to emotional well-being, the psychological impact of physical activity is not entirely explained by these changes. Furthermore, results for clinical interventions targeting exercise have been inconsistent in their results (e.g. Blumenthal et al., 2007; Krogh, Videbech, Thomsen, Gluud, & Nordentoft, 2012) and many trials suffer from the potential confound that voluntary engagement in exercise habits may reflect recovery or stable mood rather than be the source of positive change. Given the numerous studies that have shown general positive associations between exercise and mood, more research is needed to understand the nature of these effects. This work would help develop more targeted, consistently efficacious interventions. To this end, we hone in on individual sessions of exercise and their effect on emotional experiences.

One hypothesis holds that aerobic exercise relieves depressive symptoms by accumulating recurring mood enhancements. Hence, if a bout of exercise boosts affect, chronic exercise should foster long-term mood elevation. This is how many people think about exercise in their own lives; when they feel upset, they go for a run or head to the gym to feel better. And this approach can work, for some people, some of the time. However, though some studies have found post-exercise mood improvement (e.g. Yeung, 1996), others have not (e.g. Rejeski, Gauvin, Hobson, & Norris, 1995); moreover, others have even found post-event declines in mood, and

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that exercise can be aversive for beginners, at too high intensities, or in competitive contexts (Salmon, 2001). Yet, despite variations in session-to-session mood effects, in the long-term regular exercisers usually enjoy overall mood benefits from consistent activity.

Alternatively, aerobic exercise may change the way a person responds to emotional events. Everyone becomes upset at times. Although some people can smoothly shift their attention away from this distress when it arises, thereby recovering quickly, others cannot. This latter group is vulnerable to chronic difficulties with emotion regulation, persistent negative affect, and at the extreme, depression and related psychopathology. Physiologically, physically fit individuals return to pre-stress levels more quickly than do nonfit ones following a stressor, and for individuals with greater baseline physiological reactivity, exercise training improves their ability to weather stress (Blumenthal et al., 1988; Calvo, Szabo, & Capafons, 1996). This effect may apply to emotional stress as well, though research is limited (Salmon, 2001). We hypothesised that physical exertion could help individuals who would otherwise exhibit delayed returns to their emotional baseline to rebound from distress more quickly. In this way, regular aerobic exercise could help prevent the onset or worsening of depressed mood for individuals with limited emotional flexibility (e.g. Strawbridge, Deleger, Roberts, & Kaplan, 2002).

In the present pilot study, we examined the acute effects of aerobic exercise for emotional processing. Specifically, we tested how a bout of moderate aerobic exercise altered the emotional effects of subsequent exposure to a sadness-inducing film clip. Theoretically, a bout of physical activity could facilitate flexible coping by boosting a person's regulatory ability, perhaps through increased self-efficacy or executive control. We chose to examine the specific, potentially protective relationship between exercise and persistent self-reported negative affect. This framework implies that exercise before a negative experience should mitigate consequential emotional responses. However, as noted above, not everyone struggles to regulate negative emotions. In a brief, experimental paradigm like this, we would expect a ceiling effect such that some people naturally follow a smooth, quick course back to baseline over the study period. For these people, any regulatory boost that aerobic exercise, or any other intervention, could provide may not be evident. Yet this enhancement should be evident for people struggling to regulate their emotions, and hence have room to improve. We therefore asked participants to report on a broad, though non-exhaustive, range of emotion regulation difficulties to test for an effect as a prelude to identifying mechanisms.

We hypothesised that all participants would report increased negative affect in response to a stressor and that regardless of condition – exercise or no exercise – some would emotionally recover more quickly than others. For those participants experiencing difficulty with regulation in the moment, such as feeling stuck in the induced mood state or overwhelmed, a previous session of exercise should foster recovery compared to their counterparts who did not exercise. Therefore, we administered repeated measures of state affect as well as measures of baseline mood symptoms and state emotion regulation difficulties following the stressor.

Method

Participants

Participants (40 women, 40 men, M_{age} = 22.3 years, *SD* = 15.4, age range: 18–58) completed the study between 2014 and 2015.[1] The ethnic/racial composition of the final sample was 62% Caucasian, 11% African-American, 18% Asian, 9% multiracial or other, and 10% identified as Hispanic or Latino. They were recruited from the Harvard University Study Pool and by flyers posted in the community. Participants included students, university employees, and community members. Harvard University's Committee on the Use of Human Subjects approved the study protocol, and participants provided informed consent prior to initiation of any study procedure.

Eligible participants were at least 18 years of age, were able to read and sign the consent form, and reported regular exercise, defined as at least three days per week of moderate activity for 30 minutes, as recorded on the International Physical Activity Questionnaire: Short Form (IPAQ-S; Besson, Brage, Jakes, Ekelund, & Wareham, 2010). Exclusion criteria were pregnancy, possible pregnancy, or failure to answer the question concerning possible pregnancy. Additionally, we excluded participants who endorsed any question on the 7-item Physical Activity Readiness Questionnaire (PAR-Q; Adams, 1999; Thomas, Reading, & Shephard, 1992) or scored above the clinical cut-off (>24) on the 6-item Exercise Addiction Inventory: Short Form (EAI; Terry, Szabo, & Griffiths, 2004). The

PAR-Q assesses diagnosed or perceived contraindications to participating in aerobic exercise and the EAI assesses risk for exercise addiction, as respondents indicate how much they agree with each item (e.g. exercise is the most important thing in my life). These pre-screening measures were used for participant safety and to avoid potential confounds of extreme attitudes towards physical activity.

Procedure and materials

After completing the informed consent process, participants answered a battery of self-report questionnaires embedded in an online survey. Participants completed the pre-screening items (IPAQ-S, PAR-Q, and EAI) and provided information about their demographics, emotion response tendencies, and mood. To verify that the groups did not differ at baseline in emotion response tendencies that could influence their reactions to the stressor, we included trait measures of emotion regulation. We asked participants to complete the Affect Intensity Measure – Simplified (AIM; Bryant, Yarnold, & Grimm, 1996; Geuens & De Pelsmacker, 2002; Larsen, 1984), Emotion Regulation Questionnaires (ERQ; Gross & John, 2003), and Ruminative Responses Subscale of the Response Style Questionnaire (RRS; Treynor, Gonzalez, & Nolen-Hoeksema, 2003) before randomisation. The AIM is a 20-item scale measuring the strength of a person's emotional experiences, with good validity and reliability (Geuens & De Pelsmacker, 2002). The 10-item ERQ captures how respondents think or behave in order to manage or change their emotions in various situations; we examined the six items constituting the cognitive reappraisal subscale, which has good reliability and validity (Gross & John, 2003). The 22-item RRS has good internal consistency and moderate to high test-rest reliability, and it assesses two factors of rumination: reflective pondering and brooding. We also included baseline measures of mood and anxiety symptoms, as related pathology can influence the intensity and duration of emotional experiences. The Depression Anxiety Stress Scales, 21-item (DASS-21; Lovibond & Lovibond, 1995) was used to evaluate participants' mood during the past week. This measure distinguishes between depressive, physical, and psychological arousal or tension, and agitation, and shows internal consistency and concurrent validity (Antony, Bieling, Cox, Enns, & Swinson, 1998). This measure yields three subscales: depression, anxiety, and stress.

Eligible participants were then randomly assigned to the aerobic exercise or no exercise (stretching) condition and completed the experimental session. Randomisation was blocked by gender. To avoid demand characteristics, we told participants that they would be engaging in low-to-moderate physical activity during the study, but we did not tell them that there were two conditions. Participants were also instructed not to exercise on the day of the session.

At the beginning of the experimental session, a participant's resting heart rate was manually measured twice. Participants then used an affective circumflex measure to report their affect (Barrett & Russell, 1998; Nezlek, 2005). They indicated how much they felt each emotion at that moment on a visual analogue scale ranging from 0 to 100 (positive: happy, excited, content; negative: sad, angry, anxious/worried). Immediately thereafter, the exercise group jogged for 30 minutes at a moderate pace. The exact pace was dictated by the participants themselves, for comfort and ecological validity, but guided by the experimenter with the following parameters: during moderate exercise you should notice an increase in breathing, you should still be able to speak without difficulty, and on a scale from 0 (sitting) to 10 (breathless, running as fast as possible), your effort exerted should be 5. Participants randomised to the no exercise group were led through 30 minutes of stretching. The stretching served as a control condition to isolate the effect of exercise, as it does not involve aerobic exertion, but it is physically active. Both activity conditions took place in an indoor track. Study staff monitored participants' adherence to the instructions.

After the aerobic exercise or stretching, the mood inductions and remaining measures were delivered and completed through an online survey that took approximately 20 minutes to complete. A participant's heart rate had to return to within 10% of his or her baseline average before he or she began the final survey. Affective ratings were repeated and then immediately followed by a negative mood induction in which all participants watched a brief clip from the movie *The Champ*. This clip reliably induces negative emotion, namely sadness (Gross & Levenson, 1995). Participants then completed affective ratings and measures of emotion regulation. Emotional clarity and regulation were measured with a modified version of the Difficulties in Emotion Regulation Scale (DERS; Gratz & Roemer, 2004). This self-report measure

included three sections of the DERS (difficulties engaging in goal-directed behaviour, limited access to emotion regulation strategies, and lack of emotional clarity). Similar to the adapted scale used by McLaughlin, Mennin, and Farach (2007), this questionnaire asked participants to rate how much each statement applies to them *right now* rather than in general, thus serving as a state measure. Higher scores indicate more difficulty with regulation and less clarity. Finally, coping self-efficacy was assessed with the 26-item Coping Self-Efficacy Scale (CSE; Chesney, Neilands, Chambers, Taylor, & Folkman, 2006). Participants are asked to rate how much they believe that they could perform various behaviours related to coping on a scale from 0 ("cannot do at all") to 10 ("certain can do"). Scores range from 0 (no self-efficacy) to 260 (maximum self-efficacy). After a 60-second delay, the six affective circumplex ratings were then repeated three more times, each at 60-second intervals between which participants sat quietly and waited for the next set to appear. Lastly, all participants engaged in a positive mood induction, watching a brief clip from the film *When Harry met Sally*. This clip reliably induces positive affect, especially amusement or happiness (Gross & Levenson, 1995). The clip was followed by a final affective circumflex rating.

Statistical analysis

Descriptive data for the final sample are presented as means with standard deviations (SD) for continuous variables and counts with proportions for categorical variables. We conducted chi-square analyses to evaluate group differences in gender, race, and ethnicity, and independent sample *t*-tests to evaluate group differences in age, trait measures of emotion regulation, depressive, anxious, and stress-related symptoms, and baseline measures of state affect. We also used *t*-tests to confirm that before the mood inductions began, participants in the exercise group experienced a significantly greater increase in heart rate from baseline than did participants in the stretching group, as intended by the manipulation. Pearson correlations corrected for multiple comparisons were computed for baseline DASS scores, baseline state affect reports, and DERS scores, given known associations between mood symptoms, emotion regulation, and affect. Multivariate regression analyses were conducted to examine the unique and interactive effects of group assignment and state measures of emotion regulation on state levels of sadness immediately following the negative mood induction and at the end of the study, and happiness immediately following the positive mood induction. Clinical measures (DASS scales) were also included as current mood symptoms frequently occur with on-line regulatory deficits and heightened negative affect. To examine changes in affect across time points, we conducted mixed effects regression analyses, with group assignment serving as a between-subjects predictor and time as a within-subjects factor. Reported analyses satisfied assumptions of linearity and normality of residuals. Furthermore, we applied the Benjamini–Hochberg procedure for multiple comparisons to control the false discovery rate, which was set to .05, and only report surviving effects (Benjamini & Hochberg, 1995).

Results

Baseline characteristics of the sample are presented in Table 1. Prior to testing, participants in the stretching and exercising groups did not differ in age, $t(50.15) = 1.37$, $p = 0.18$, gender, $\chi^2(1) = 0.0$, $p = 1.0$, or baseline trait measures of affect intensity (AIM), $t(77.74) = -1.0$, $p = 0.32$, rumination (RRS), $t(74.60) = .45$, $p = 0.66$, reappraisal (ERQ-Reappraisal), $t(68.07) = -.50$, $p = 0.62$, depressive symptoms (DASS-Depression), $t(72.41) = .79$, $p = 0.43$, anxious symptoms (DASS-Anxiety), $t(77.80) = -.15$, $p = 0.88$, or stress (DASS-Stress), $t(75.46) = .43$, $p = 0.67$. Before and after 30 minutes of stretching or exercising, the two groups did not differ in their reports of sadness, $t(70.36) = .01$, $p = 0.99$, $t(63.11) = .34$, $p = 0.74$, happiness, $t(77.84) = .43$, $p = 0.67$, $t(78.0) = -.08$, $p = 0.94$, overall positive affect (feeling excited, happy, or content), $t(77.92) = .20$, $p = 0.84$, $t(77.86) = .10$, $p = 0.92$, or overall negative affect (feeling anxious, angry, or sad), $t(71.75) = .16$, $p = 0.87$, $t(67.05) = .14$, $p = 0.89$. Groups also did not differ in their emotional responses captured in the repeated measures of sadness, happiness, or overall negative or positive affect after the negative film clip: sadness post-negative clip, $t(72.79) = .31$, $p = 0.76$, sadness post-positive clip, $t(60.16) = .98$, $p = 0.33$, happiness post-negative clip, $t(74.50) = .38$, $p = 0.70$, happiness post-positive clip, $t(77.98) = -.64$, $p = 0.52$, negative affect post-negative clip, $t(74.70) = .15$, $p = 0.88$, negative affect post-positive clip, $t(61.51) = 1.31$, $p = 0.19$, positive affect post-negative clip, $t(76.61) = .11$, $p = 0.91$, positive affect post-positive clip, $t(77.66) = -.50$, $p = 0.62$. See Table 1 for a summary of these reports. Finally, there were no group differences in reported coping

Table 1. Demographic and affect self-report variables.

Measure	Whole sample *N* (%)	Stretching group *N* (%)	Exercise group *N* (%)	χ^2-test (*p*-value)
Gender				1.00
Female	40 (50%)	20 (50%)	20 (50%)	
Race				.86
Caucasian	50 (62.5%)	24 (60%)	26 (65%)	
African-American	9 (11.25%)	6 (15%)	3 (7.5%)	
Asian American	14 (17.5%)	7 (17.5%)	7 (17.5%)	
Other	2 (2.5%)	1 (2.5%)	1 (2.5%)	
Multiracial	5 (6.25%)	2 (5%)	3 (7.5%)	
	Whole sample (M±SD)	Stretching group (M±SD)	Exercise group (M±SD)	t-test (p-value)
Age	22.26 ± 6.49	23.25 ± 8.53	21.28 ± 3.26	0.18
AIM	3.29 ± 3.1	3.26 ± 0.32	3.33 ± 0.30	0.32
RRS	42.96 ± 12.16	43.58 ± 13.47	42.35 ± 10.84	0.66
ERQ-reappraisal	27.99 ± 6.94	27.60 ± 8.20	28.38 ± 5.49	0.62
DASS-depression	19.2 ± 6.79	19.80 ± 7.70	18.60 ± 5.79	0.43
DASS-anxiety	18.25 ± 6.06	18.15 ± 6.25	18.35 ± 5.94	0.88
DASS-stress	23.1 ± 8.32	23.50 ± 9.10	22.70 ± 7.56	0.67
Sadness				
Baseline	12.13 ± 21.57	12.15 ± 25.04	12.1 ± 17.78	0.99
Post-activity	8.81 ± 17.51	9.48 ± 21.46	8.15 ± 12.63	0.74
Post-negative clip	32.25 ± 24.15	33.1 ± 27.35	31.4 ± 20.79	0.76
Post-positive clip	6.59 ± 14.66	8.2 ± 18.22	4.98 ± 9.89	0.33
Happiness				
Baseline	61.14 ± 22.23	62.2 ± 21.84	60.08 ± 22.84	0.67
Post-activity	60.56 ± 24.1	60.35 ± 24.19	60.78 ± 24.32	0.94
Post-negative clip	40.34 ± 25.98	41.45 ± 23.12	39.23 ± 28.81	0.70
Post-positive clip	54.08 ± 26.08	52.2 ± 25.98	55.95 ± 26.38	0.52
Heart rate				
Baseline	71.49 ± 10.74	69.85 ± 10.65	73.18 ± 10.72	0.17
Post-activity	73.24 ± 11.20	68.65 ± 9.29	77.95 ± 11.14	<0.001
Change	1.75 ± 6.65	−1.2 ± 3.86	4.77 ± 7.55	<0.001

Notes: AIM, Affect Intensity Measure – Simplified; RRS, Ruminative Responses Subscale of the Response Style Questionnaire; ERQ, Emotion Regulation Questionnaire; DASS, Depression Anxiety Stress Scales.

self-efficacy (CSE), $t(77.94) = -.39$, $p = 0.70$ or emotion regulation (DERS-goals, $t(77.56) = -.51$, $p = 0.61$, DERS-strategies, $t(76.11) = -.17$, $p = 0.86$, DERS-clarity, $t(77.77) = -1.13$, $p = 0.26$) scores after the negative mood induction.

Mixed effects analyses served as a manipulation check; as expected, there was a significant increase in reports of sadness following the negative mood induction, $t(390) = 8.48$, $p < 0.001$, $B = 23.63$, and a significant increase in happiness following the positive mood induction, $t(390) = 3.07$, $p = 0.002$, $B = 9.65$, regardless of group assignment. Additionally, as expected, participants in the exercise group exhibited a reliable increase in heart rate after running, whereas participants in the stretching group did not; groups did not differ in baseline heart rate, $t(76.92) = -1.39$, $p = 0.17$, but differed both in post-activity heart rate, $t(73.90) = -4.02$, $p < 0.001$, and change in heart rate, $t(56.31) = -4.41$, $p < 0.001$. See Table 1 for descriptive summaries.

Significant correlations emerged between baseline symptoms of depression (DASS-depression) with baseline sadness and overall negative affect, as well as limited access to regulatory strategies (DERS-strategies) and difficulty engaging in goal-directed behaviour (DERS-goals) following the negative mood induction. Baseline symptoms of anxiety (DASS-anxiety) were similarly associated with baseline feelings of sadness, overall negative affect, and DERS-strategies scores. A summary of baseline associations is included in Table 2.

Given baseline correlations between baseline state reports of affect, mood symptoms, and state emotion regulation measures, we controlled for baseline sadness in the multivariate multiple regression analyses. Although models did not show main or interactive effects of mood symptoms (i.e. DASS-Depression, Anxiety, and Stress subscales), all $ps > .05$, they revealed significant findings for patterns of online emotion regulation. Multivariate analyses first showed that reports of more limited access to regulatory strategies (DERS-strategies) following the negative mood induction predicted more sadness at the end of the study, and revealed a significant

Table 2. Correlations between baseline symptoms of depression and anxiety, baseline reports of affect, and difficulties with emotion regulation.

	DASS		DERS	
	Depression	Anxiety	Goals	Strategies
DASS-depression	1.00	.	.	.
DASS-anxiety	0.79**	1.00	.	.
DERS-goals	0.47**	0.28	1.00	.
DERS-strategies	0.61**	0.44**	0.56**	1.00
Sadness	0.49**	0.39**	0.07	0.51**
Happiness	−0.20	−0.14	−0.31*	−0.29
Negative affect	0.55**	0.4**	0.23	0.57**
Positive affect	−0.16	−0.07	−0.31*	−0.27

Notes: Values corrected for multiple comparisons. DASS, Depression Anxiety Stress Scales; DERS, Difficulties in Emotion Regulation Scale, Baseline ratings of affect.
*$p < 0.05$
**$p < 0.01$.

interaction effect with group assignment, $F(4, 75) = 22.36$, $p < 0.001$, $R^2 = .54$. Although higher DERS-strategies scores were associated with more persistent sadness, $B = 2.43$, $p < 0.001$, a significant interaction with group showed this effect to be weaker among exercisers $B = -1.69$, $p = 0.001$. Second, reports of difficulty engaging in goal-directed behaviour after the negative mood induction (DERS-goals) predicted the degree to which sadness persisted at the end of the study, and there was a significant DERS-goals by randomised group interaction $F(4, 75) = 17.16$, $p < 0.001$, $R^2 = .48$. Specifically, more difficulty (higher DERS-goals scores) predicted more persistent sadness, $B = 2.27$, $p < 0.001$, even after the positive mood induction. Significant interactions showed this effect to be tempered in the exercise group as compared to the stretching group, $B = -1.76$, $p = 0.004$. Figure 1 depicts significant interactions. Results did not show a significant main, $B = 0.78$, $p = 0.1$, or interaction effect, $B = -0.13$, $p = 0.84$, for emotional clarity (DERS-clarity), $F(4,75) = 8.88$, $p < 0.001$, $R^2 = .32$.

Consistent findings emerged when average overall negative affect was the criterion variable. Again, significant interactions emerged between group assignment, DERS-goals, $F(4,75) = 17.34$, $p < 0.001$, $R^2 = .48$, and DERS-strategies, $F(4,75) = 19.01$, $p < 0.001$, $R^2 = .50$. Exercise attenuated the impact of difficulties with goal-directed behaviour, $B = -1.51$, $p = 0.02$, and with accessing regulatory strategies, $B = -1.38$, $p = 0.01$.[2] Analyses revealed no significant main, $B = 0.66$, $p = 0.19$, or interaction effect, $B = -0.07$, $p = 0.92$, for emotional clarity (DERS-clarity) as a predictor, $F(4,75) = 8.59$, $p < 0.001$, $R^2 = .31$.

Group assignment was unrelated to reports of happiness or overall positive affect. Only baseline affect emerged as a significant predictor when happiness was the criterion variable for DERS-goals, $F(4,75) = 9.72$, $p < 0.001$, $R^2 = .34$, $B = 0.53$, $p < 0.001$; DERS-strategies, $F(4,75) = 7.45$, $p < 0.001$, $R^2 = .28$, $B = 0.63$, $p < 0.001$; and DERS-clarity, $F(4,75) = 8.05$, $p < 0.001$, $R^2 = .30$, $B = 0.58$, $p < 0.001$. There were no main effects of group (DERS-goals, $B = 3.97$, $p = 0.76$; DERS-strategies, $B = 2.90$, $p = 0.84$; DERS-clarity, $B = -0.81$, $p = 0.35$) or interaction effects (DERS-goals, $B = 0.16$, $p = 0.89$; DERS-strategies, $B = 0.18$, $p = 0.88$; DERS-clarity, $B = -0.02$, $p = 0.99$). Similar results emerged when overall positive affect was included; only baseline affect was related to DERS-goals, $F(4,75) = 10.0$, $p < 0.001$, $R^2 = .35$, $B = 0.54$, $p < 0.001$; DERS-strategies, $F(4,75) = 9.13$, $p < 0.001$, $R^2 = .33$, $B = 0.61$, $p < 0.001$; and DERS-clarity, $F(4,75) = 8.96$, $p < 0.001$, $R^2 = .32$, $B = 0.57$, $p < 0.001$. There were also no main effects of group (DERS-goals, $B = 7.41$, $p = 0.53$; DERS-strategies, $B = -3.80$, $p = 0.77$; DERS-clarity, $B = -0.46$, $p = 0.55$) or interactions (DERS-goals, $B = -0.31$, $p = 0.77$; DERS-strategies, $B = 0.64$, $p = 0.52$; DERS-clarity, $B = 0.003$, $p = 1.0$).

Discussion

Although acute aerobic exercise did not prevent an increase in sadness in response to a subsequent stressor, results suggest that it may help people recover. Participants who had difficulty generating regulatory strategies, endorsing items such as "my emotions feel overwhelming", "I believe that there is nothing I can do to make myself feel better", and "I believe that I will remain this way for a long time", unsurprisingly experienced more intense and persistent sadness than did participants who did not endorse these items. Similarly, participants who struggled to engage in goal-directed behaviours after the stressor, such as reporting difficulties concentrating or thinking about other things, also felt worse across time than those who did not have this issue. However, those participants who had recently completed 30 minutes of moderate aerobic exercise were less affected by these initial perceived difficulties with emotion regulation as they reported less sadness at the end of the study than those who did not exercise.

Findings lend support to preliminary work suggesting that physical activity helps people weather emotional stress (Girodo & Pellegrini, 1976; Salmon, 2001). Acute aerobic exercise facilitated the down-regulation of negative emotions among participants initially struggling with this process on their

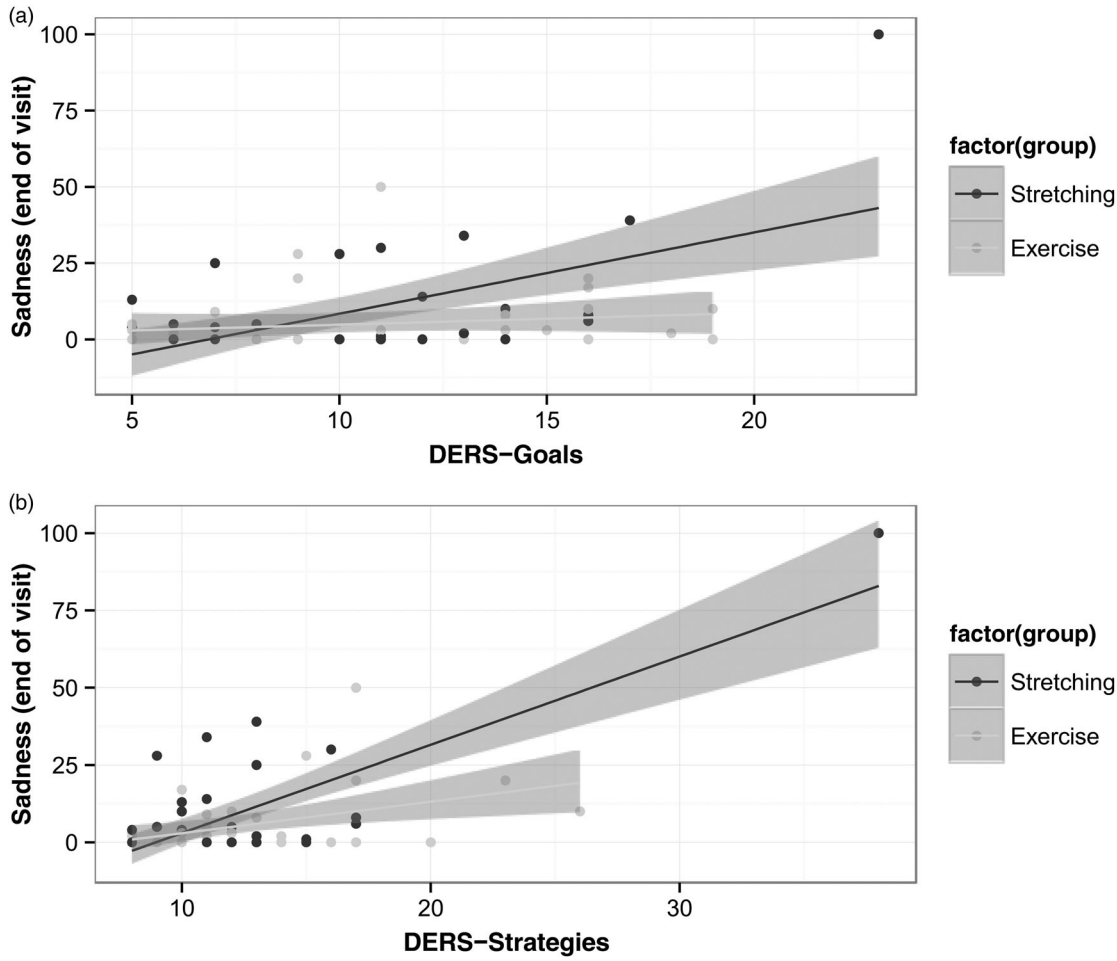

Figure 1. DERS by group effects on residual sadness. Note: 95% confidence intervals shown. DERS, Difficulties in Emotion Regulation Scale.

own. These interaction effects are consistent with studies showing that regular sessions of aerobic exercise may protect against the onset, recurrence, or worsening of mood symptoms (e.g. Strawbridge et al., 2002). Indeed, clinical depression is often characterised by an inability to repair or regulate one's mood once it has started to decline. This dysregulation and proneness to experiencing negative mood states are known to contribute to the onset and relapse of depression (e.g. Joormann & Vanderlind, 2014). The present study models the experience of encountering emotional stimuli in everyday life that could precipitate compounding or cumulative negative effects on mood. In this way, a bout of moderate aerobic exercise appears to have helped those participants potentially more vulnerable to problematic affective dysregulation to be less susceptible to the impact or lingering effects of the stressor.

Acute aerobic exercise appears to have moderated the effects of poor state emotion regulation most strongly at the end of the study, when we would expect to see the greatest separation between those participants with and without regulatory deficits. This suggests that participants who exercised were better able to overcome or compensate for initial difficulties drawing on regulatory strategies and with goal-directed cognition and behaviour than were peers who stretched. Unlike the clarity subscale of the DERS, for which no significant effects were identified, both the goals and strategies subscales seem to relate to executive control, including items about concentration, changing one's focus, perceived ability to change one's experience, and feeling overwhelmed. Deficits in executive control are associated with maladaptive emotional responding and regulation, as well as mood symptoms and stress (e.g.

Takeuchi et al., 2014). And recent work shows that self-reported attentional control is linked to more successful spontaneous emotional down-regulation after exposure to aversive stimuli (Morillas-Romero, Tortella-Feliu, Balle, & Bornas, 2015). Regular physical activity can strengthen cognitive control and flexibility (Guiney & Machado, 2013); even a single session of moderate aerobic exercise can yield post-event improvements in attention and inhibitory control in both healthy participants (e.g. Alves et al., 2014) and depressed patients (e.g. Kubesch et al., 2003). Cognitive control in the present study would be important for disengaging in mood-congruent or ruminative thoughts that maintain negative affect. Therefore, it is plausible that despite having similar early impressions of poor affective control, participants who had jogged experienced cognitive enhancements compared to their counterparts who stretched. However, this is just one possible mechanism. For example, alternatively, the effects may have motivational origins as much as cognitive ones. By engaging in an activity more rigorous than stretching, the runners may have experienced a boost in general self-efficacy that enabled them to deploy emotion regulation strategies with special vigour. Future studies should explore changes in cognitive function as a potential mechanism by which exercise facilitates better emotion regulation.

Our study has limitations. First, all participants were at least moderately active and not selected for clinical depression. Hence, it is unclear whether our results would generalise to sedentary individuals or to clinical populations. Second, we examined the effects of a single, brief session of moderate aerobic exercise over a relatively short period (<30 minutes). Whether our findings apply to other exercise intensities, types, or time durations is unknown. Third, it will be important for future studies to target other emotions beyond sadness. As different emotions bear different physiological and affective features, we cannot be certain that exercise will affect all negative experiences in the same way. Additionally, emotion measurements at the end of the study occurred following both film clips; therefore, follow-up studies should more thoroughly tease apart how exercise affects responses to negative versus positive experiences, as this separation cannot be made at present. Although stretching provides an active control against which to compare aerobic exercise, the absence of an inactive control could be conceived of as a limitation. For example, there may be important effects common to all types of physical activity (i.e. stretching and exercise) that would only emerge in comparison to a resting condition. Finally, all data were obtained via self-report. Psychophysiological measures may show important changes associated with exercise when concurrent behavioural measures yield null results (e.g. Kamijo, Nishihira, Higashiura, & Kuroiwa, 2007). Future studies could benefit from the inclusion of other types of assessment as well.

Still, results support the theory that aerobic exercise can improve emotional health by strengthening emotion regulation or recovery. Our study contributes to the literature on exercise's therapeutic effects with experimental data, specifically in the realm of emotional processing. By staving off some of the consequences of impairments in emotion regulation, acute aerobic exercise could serve as an adjunctive therapy tool, beyond behavioural activation, to traditional cognitive and behavioural approaches. Integrating physical activity directly into psychosocial interventions could bolster therapies designed to improve emotion regulation, such as exposure therapy and cognitive remediation. Participants could benefit from more emotional flexibility to successfully engage in this work. Overall, research in this area has the potential to provide a deeper understanding of regulatory processes and to inform more targeted clinical prevention and intervention efforts for individuals with or at risk for affective dysregulation.

Notes

1. Prior to examining data, we excluded 11 participants who experienced technical difficulties and were therefore unable to complete the mood inductions and subsequent questionnaires.
2. All reported predictors had variance inflation factors less than 10, suggesting that multicollinearity was not a significant issue. Furthermore, the main effects predictors that were reported (i.e. DERS-strategies, and DERS-goals) consistently had variance inflation factors below 2.5, which are acceptable even under more conservative guidelines.

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