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Is improved fitness following a 12-week exercise program associated with decreased symptom severity, better wellbeing, and fewer sleep complaints in patients with major depressive disorders? A secondary analysis of a randomized controlled trial

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ABSTRACT

Major depressive disorder (MDD) is one of the most burdensome disorders worldwide. While exercise training in patients with MDD contributes to clinically relevant improvements in cardiorespiratory fitness, whether and to what degree changes in cardiorespiratory fitness impact depressive symptom severity has not yet been addressed systematically in prior research. The purpose of our study was threefold. Firstly, to examine whether baseline levels and improvements in objectively assessed VO_2max and subjectively perceived fitness predicted endpoint levels and change in depressive symptoms, wellbeing and sleep. Secondly, to determine whether exercise modality (sprint interval training [SIT]) versus continuous aerobic exercise training [CAT]) predicted depressive symptoms, wellbeing and sleep. Thirdly, whether the affective responses during and following exercise predicted depressive symptoms, wellbeing and sleep. All measurements were taken in a sample of inpatients diagnosed with MDD. The sample consisted of 53 participants (41 women and 12 men, M_{age} = 36.3 years, SD = 11.3) with unipolar depression who were randomly assigned to SIT and CAT. Data were assessed at baseline and after four weeks of exercise training (including three weekly 35 min sessions). Multiple linear regression analyses showed that improvements in VO_2max were associated with fewer depressive symptoms, better mental wellbeing, and better sleep after completion of the intervention. Additionally, improvements in perceived fitness were associated with fewer dysfunctional sleep-related cognitions and higher mental toughness post-intervention. Improvements in VO2max and perceived fitness were also associated with favorable changes in depressive symptoms, mental wellbeing, and sleep. More research is needed to find out which fitness tests are most time- and cost-efficient in a clinical setting and most acceptable for psychiatric patients.

1. Introduction

Patients with MDD are more likely to develop cardiovascular and other non-communicable diseases (Correll et al., 2017). Patients with MDD are also less likely to engage in health-enhancing behaviours such as physical activity (Schuch et al., 2018), although regular exercise training has a positive impact on patients' depressive symptom severity (Schuch et al., 2016). While still little is known about dose-effect relationships and the most beneficial exercise modalities (Stubbs et al., 2018), Dunn et al. (2005) showed that public health doses are needed to trigger positive effects.

Patients with MDD also have lower cardiorespiratory fitness levels compared to healthy controls (Voderholzer et al., 2011). Results of a meta-analysis suggested that exercise training in patients with MDD contributes to clinically relevant improvements of cardiorespiratory fitness (Stubbs et al., 2016). Nevertheless, only few studies (e.g., Chu et al., 2009) have addressed whether and to what degree changes in cardiorespiratory fitness predict depressive symptoms among patients with MDD. Moreover, our understanding is limited regarding the question of whether and to what extent affective valence during and after exercise moderates the effects of exercise interventions among psychiatric patients. This contrasts with the notion that both cognitive

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factors and affective processes are involved in the regulation of exercise behavior (Rebar et al., 2016). For instance, previous research has shown that positive affective valence during exercise is associated with higher exercise enjoyment (Robbins et al., 2004), and contributes to more voluntary engagement in moderate to vigorous physical activity (Schneider et al., 2009). Accordingly, Ekkekakis et al. (2011) argued that exercise guidelines should take into consideration more strongly whether specific exercise modalities result in increased or decreased pleasure.

Given this background, the objectives of our study are as follows: To examine whether depressive symptoms, wellbeing, sleep, and cognitive factors associated with depression can be predicted independently by (i) two different exercise modalities (sprint interval training [SIT] versus continuous aerobic exercise training [CAT]), (ii) baseline levels and improvements in objectively assessed VO_2max as well as subjectively perceived fitness, and (iii) participants' affective responses during and after exercise in a sample of in-patients diagnosed with MDD. A distinction is made between objectively assessed and subjectively perceived fitness because perceived fitness has been associated with health markers in previous studies (Gerber et al., 2010).

2. Materials and methods

2.1. Study design

Data from this study were based on a two-armed randomized controlled trial (RCT) designed to compare two different endurance exercise modalities, namely SIT and CAT. Results of this trial have been published previously pointing towards similar and large improvements in depressive symptom severity and cardiorespiratory fitness in both exercise conditions (Hanssen et al., 2017; Minghetti et al., 2018). Gerber et al. (2018) further showed that both SIT and CAT are associated with large improvements in intrinsic motivation and perceived fitness. In the present study, we performed a secondary analysis of the aforementioned RCT.

2.2. Participants

Eligible participants were in-patients receiving treatment at a clinic in the Northwestern part of Switzerland who had a clinical diagnosis of MDD (ICD-10: F32.1/2 or F33.1/2). The following exclusion criteria were applied: (a) eating disorders such as anorexia, bulimia, or binge-eating, (b) addiction disorder or current detoxification treatment, (c) schizophrenia, (d) bipolar disorder, (e) panic disorder and/or (f) somatic disorders such as cardiovascular diseases, stroke, thrombosis, epilepsy, other neurological disorders, pulmonary diseases, or diabetes.

We screened 195 patients for eligibility, whereby 123 participants were not included in the study, either because they did not meet inclusion criteria (n = 20) or because they were not interested in participating (n = 99). Seventy-two participants participated in the baseline assessment. Thirteen were excluded from further analyses because of insufficient adherence to the exercise program, and six participants were excluded because of missing data in one of the outcome or predictor variables, leaving a total sample of 53 participants (41 women and 12 men, M_{age} = 36.3 years, SD = 11.3). No substantial baseline differences were found in any of the study variables between participants who were excluded versus included in the data analyses.

Patients were assigned randomly to SIT or CAT. The intervention period lasted four weeks, including three weekly exercise sessions of 35 min, under the supervision of an experienced exercise coach. Each session consisted of a standardized warm-up (5 min) and cool-down (5 min) period. Based on the maximal power output derived from the maximal fitness test, training intensity was prescribed individually to each participant. CAT consisted of 20 min continuous aerobic exercise on a bicycle ergometer with an intensity level of 60% of the maximal power output. By contrast, SIT included 25 repetitions of 30 s high intensity burst at 80% of maximal power output, which was followed by 30 s of total rest (see Minghetti et al., 2018 for more details).

Data assessment took place one week prior to the start and after patients had completed the intervention period. A minimum of 11 completed training sessions were required for patients to be included in the analyses. Neither the patients nor the assessors were blinded because we did not have any specific hypotheses regarding which mode of exercise training would be more beneficial. Affective valence was assessed in each exercise session before, during, and after training. Patients continued their usual (multimodal) treatment during the entire intervention period, including pharmacological treatment (if prescribed by their physician). The study was approved by the local ethical review board (EKNZ: 2014–374). All participants gave written informed consent prior to study enrollment.

2.3. Measures

The severity of depressive symptoms was assessed with the 21-item Beck Depression Inventory II (Beck et al., 1996). Mental and physical wellbeing were assessed with the 12-Item Short-Form Health Survey (Ware et al., 1994), whereas subjective sleep complaints were assessed with the 7-item Insomnia Severity Index (Gerber et al., 2016b). Dysfunctional sleep-related cognitions were measured with the 23-item FEPS II (Fragebogen zur Erfassung allgemeiner Persönlichkeitsmerkmale Schlafgestörter) (Hoffmann et al., 1996). The FEPS II consists of two subscales describing levels of focusing (proneness to worry continuously about sleep difficulties) and rumination (tendency to think about and feel preoccupied with unresolved problems). To assess mental toughness, we administered the 18-item short form of the Mental Toughness Questionnaire (Clough et al., 2002). This instrument measures the ability to handle the demands of environmental stressors. To assess perceived physical fitness, a single item was applied ranging from 1 (very poor fitness) to 10 (excellent fitness) (Plante et al., 2000). Finally, we used the single-item Feeling Scale (FS) to measure affective valence during and after exercise (Hardy and Rejeski, 1989). Participants responded to the questions according to how they felt in that moment. The FS is designed as an 11-point bipolar measure of pleasure and displeasure, with scores ranging from −5 (very bad) to +5 (very good). In each session, the FS was completed three times, before, in the middle, and after the training session. We averaged the difference scores across all sessions to obtain two separate baseline-controlled indices. Cardiorespiratory fitness (maximal oxygen uptake) was measured with an established test protocol on a bicycle ergometer (Ergometrics 900®, Ergoline). During a ramp-protocol, beginning at 25 W, regular increases of intensity of 10 W/min were applied until subjective perceived exhaustion was reached (for more details see Minghetti et al., 2018).

2.4. Statistical analyses

Descriptive statistics were calculated for the total sample. Repeated measures analyses of covariance (ANCOVAS) were performed to test whether the study variables changed from baseline to post-intervention in the entire patient sample. Finally, a series of multiple linear regression analyses were performed to discover whether exercise modality, baseline levels, changes in fitness, as well as affective valence during and after exercise predict (a) post-intervention scores and (b) change scores in the outcomes. After controlling for potential confounders and baseline scores of the respective outcomes, backward exclusion strategy was used to gradually exclude predictors that did not explain sufficient variance (based on probability of F: 0.05 for entry and removal). To account for intention-to-treat effects, missing data were imputed using an expectation maximization (EM) algorithm among dropouts or participants excluded because of insufficient adherence or missing data.

Table 1
Sample characteristics, medication at baseline and descriptive statistics and time effects from baseline to post-intervention.

	Baseline	
	M	*SD*
Age	36.3	11.3
Height	169.0	9.1
Weight	68.1	14.5
BMI (m/kg^2)	23.8	4.1
	n	**%**
Gender		
Female	41	78
Male	12	23
Nationality		
Swiss	46	87
Foreign	7	13
First language		
German	42	79
Other	11	21
Smoker		
Yes	15	28
No	38	72
Exercise modality		
Sprint interval training	26	49
Continuous aerobic exercise training	27	51
Medication at baseline	***n***	**%**
SNRIs		
Velafaxin (75, 175, 225 mg)	7	13
Mirzapin (7.5, 15, 30 mg)	11	21
Wellbutrin (150 mg)	2	4
SSRIs		
Trittico (25, 50, 100 mg)	6	11
Escitalopram (10, 20 mg)	12	23
Citalopram (20 mg)	5	9
Fluoxetin (20, 40 mg)	2	4
Paroxetin (20 mg)	1	2
Cipralex (60 g)	1	2
Seralin (50 mg)	1	2
Atypical neuroleptic medication		
Quetiapin (25, 50, 150, 300 mg)	4	8
Trimipramin (50 mg)	1	2

	Baseline		*Post-intervention*		*Time effects*	
	M	*SD*	*M*	*SD*	*F*	η^2
Depressive symptoms (BDI-II)[a]	33.1	10.4	21.0	11.7	112.4***	.68
Physical health (SF-12)	44.6	11.0	48.6	9.3	10.0**	.16
Mental health (SF-12)	25.1	6.8	34.7	9.8	63.4***	.55
Insomnia symptoms (ISI)[b]	14.0	6.7	10.9	6.7	21.4***	.29
Dysfunctional sleep-related cognitions (FEPS II)						
Rumination[c]	3.3	0.7	2.9	0.8	22.2***	.30
Focusing[d]	2.9	1.0	2.5	1.0	22.6***	.30
Mental toughness (MTQ18)[e]	2.5	0.5	2.8	0.6	19.4***	.27
Cardiorespiratory fitness (VO_2max)	32.3	7.0	33.3	7.4	6.2*	.11
Perceived fitness	3.9	2.0	5.2	1.8	48.6***	.48
Valence (during exercise)[f,g]	0.5	0.6	–	–	–	–
Valence (after exercise)[g,h]	1.2	0.9	–	–	–	–

Notes. BDI-II = Beck Depression Inventory (second version); SF-12 = 12-item Short Form Health Survey; ISI = Insomnia Severity Index; FEPS II = Fragebogen zur Erfassung allgemeiner und spezifischer Persönlichkeitsmerkmale Schlafgestörter ("Questionnaire for the assessment of general and specific personality traits of insomniacs"); MTQ18 = 18-item Mental Toughness Questionnaire; VO_2max = maximal oxygen uptake.

[a] Cronbach's alpha = .92 (baseline) and .94 (post-intervention).
[b] Cronbach's alpha = .87 (baseline) and .91 (post-intervention).
[c] Cronbach's alpha = .78 (baseline) and .85 (post-intervention).
[d] Cronbach's alpha = .89 (baseline) and .92 (post-intervention).
[e] Cronbach's alpha = .75 (baseline) and .85 (post-intervention).
[f] Cronbach's alpha = .85 (session 1–12).
[g] M and SD represent aggregated scores across all 12 sessions. Change was not tested because the scores of all exercise sessions were aggregated into two overall valence scores (during exercise versus after exercise).
[h] Cronbach's alpha = .92 (session 1–12).

Table 2
Backward linear regression analyses to predict post-intervention and change scores in the health outcomes (including intention-to-treat analyses)

	Prediction of post-intervention scores						
	Depressive symptoms (BDI-II)[a,b]	Physical health (SF-12)[a,b]	Mental health (SF-12)[a,b]	Insomnia symptoms (ISI)[a,b]	Rumination (FEPS)[a,b]	Focusing (FEPS)[a,b]	Mental toughness (MTQ18)[a,b]
	β	β	β	β	β	β	β
Gender (0 = female, 1 = male)	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns.* (.15*)	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*
Age	−.21* (-.20*)	*ns. (ns.)*	*ns. (ns.)*	.20* (.23**)	*ns.* (-.16*)	*ns. (ns.)*	*ns. (ns.)*
BMI	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*
Smoking status (0 = smoking, 1 = non-smoking)	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*
Exercise modality (0 = SIT, 1 = CAT)	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*
Baseline score in outcome	.66*** (.68***)	.59*** (.61***)	.52*** (.52***)	.69*** (.65***)	.71*** (.74***)	.81*** (.82***)	.67*** (.56***)
VO_2max (baseline)	−.27** (-.33***)	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*
VO_2max (change)	−.21* (-.17*)	*ns. (ns.)*	.38** (.30**)	-.25** (-.23**)	-.27** (-.17*)	*ns. (ns.)*	*ns. (ns.)*
Perceived fitness (baseline)	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	-.29** (-.32**)	-.23* (-.23**)	*ns.* (.25*)
Perceived fitness (change)	*ns. (ns.)*	*ns. (ns.)*	*ns.* (.21*)	*ns. (ns.)*	-.41*** (-.42***)	-.22* (-.22**)	.28** (.41***)
Valence (during exercise)	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*
Valence (after exercise)	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*
R^2	.65*** (.63***)	.35*** (.38***)	.39*** (.38***)	.63*** (.67***)	.64*** (.63***)	.69*** (.70***)	.47*** (.49***)

	Prediction of change scores						
	Depressive symptoms (BDI-II)[c]	**Physical health (SF-12)[d]**	**Mental health (SF-12)[d]**	**Insomnia symptoms (ISI)[c]**	**Rumination (FEPS)[c]**	**Focusing (FEPS)[c]**	**Mental toughness (MTQ18)[d]**
	β	**β**	**β**	**β**	**β**	**β**	**β**
Gender (0 = female, 1 = male)	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns.* (-.22*)	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*
Age	.29* (.27*)	*ns. (ns.)*	*ns. (ns.)*	−.27* (−.33**)	*ns.* (.23*)	*ns. (ns.)*	*ns. (ns.)*
BMI	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*
Smoking status (0 = smoking, 1 = non-smoking)	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*
Exercise modality (0 = SIT, 1 = CAT)	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*
Baseline score in outcome	.33* (.33**)	.59*** (.59***)	*ns. (ns.)*	.42*** (.47***)	*ns. (ns.)*	.26* (.25*)	*ns.* (.34**)
VO_2max (baseline)	.38** (.44***)	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*
VO_2max (change)	.29* (.23*)	*ns. (ns.)*	−.44*** (−.35**)	.34** (.33**)	.36** (.23*)	*ns. (ns.)*	*ns. (ns.)*
Perceived fitness (baseline)	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	.34* (.38**)	.38* (.38**)	*ns.* (-.31*)
Perceived fitness (change)	*nsz. (ns.)*	*ns. (ns.)*	*ns.* (−.24*)	*ns. (ns.)*	.54*** (.55***)	.36* (.36**)	−.38** (−.49***)
Valence (during exercise)	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*
Valence (after exercise)	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*	*ns. (ns.)*
R^2	.32*** (.31***)	.35*** (.35***)	.19** (.19**)	.30*** (.33***)	.40*** (.40***)	.22*** (.21**)	.14*** (.26***)

Notes. BDI-II = Beck Depression Inventory (second version); SF-12 = 12-item Short Form Health Survey; ISI = Insomnia Severity Index; FEPS = Fragebogen zur Erfassung allgemeiner und spezifischer Persönlichkeitsmerkmale Schlafgestörter ("Questionnaire for the assessment of general and specific personality traits of insomniacs"); MTQ18 = 18-item Mental Toughness Questionnaire; VO_2max = Maximal oxygen uptake; SIT = Sprint interval training; CAT = Continuous aerobic exercise training.

*$p < 0.05$. **p < 0.01. ***$p < 0.001$.

[a] In brackets: Coefficients after controlling for intention-to-treat effects.

[b] Low VIF (variance inflation factor) scores were found in the initial models for most of the predictors (gender, age, BMI, smoking status, exercise modality, baseline scores, VO_2max baseline, VO_2max change, fitness baseline, and fitness change), with scores varying between 1.08 and 3.03. Elevated scores pointing towards potential issues with multicollinearity were found for valence during exercise (VIF scores ranging between 4.41 and 4.52 across outcomes) and valence after exercise (VIF scores ranging between 5.05 and 5.28 across outcomes). These elevated VIF scores are due to the fact that valence during and after exercise are highly correlated with each other ($r = .85$, $p < .001$). However, none of these variables was associated with the outcomes in the initial model, and both variables were excluded during the backward variable elimination process.

[c] To obtain a change score, we subtracted the T2 score (post-intervention) from the T1 score (baseline). Thus, higher change scores are reflective of stronger decreases in depressive symptoms, insomnia symptoms, rumination, and focusing

[d] To obtain a change score, we subtracted the T2 score (post-intervention) from the T1 score (baseline). Thus, higher change scores are reflective of stronger decreases in physical health, mental health, and mental toughness.

3. Results

Table 1 contains information about the sample characteristics and prescribed medication at baseline. Table 1 also shows that in the entire patient sample significant changes occurred in all predictor and outcome variables.

The results of the multiple linear regression analyses with the post-intervention scores as outcome measures are summarized in Table 2. It shows that substantial amounts of variance in the post-intervention scores were explained in each model. Throughout all analyses, the baseline scores in the respective outcomes turned out to be the strongest predictor. Of the covariates, only age was associated with depressive

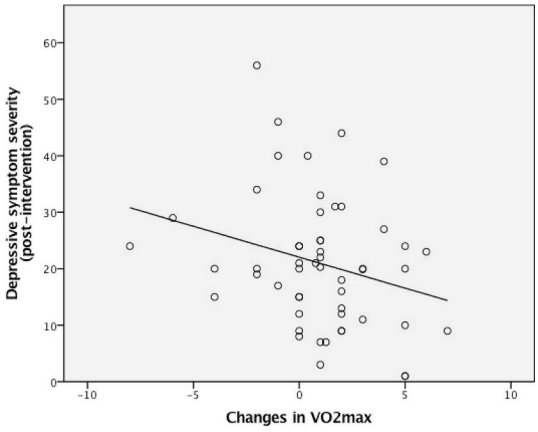

Fig. 1. Association between depressive symptom severity post-intervention and changes in cardiorespiratory fitness.

symptoms and sleep complaints, indicating that older participants reported a lower symptom severity, but perceived more sleep complaints. Regarding cardiorespiratory fitness, higher baseline levels and positive changes in VO_2max were associated with lower depressive symptom severity post-intervention (Fig. 1). Improvements in VO_2max were also associated with better mental wellbeing, fewer sleep complaints and a lower tendency to ruminate. Additionally, higher baseline levels of perceived fitness and positive changes in perceived fitness were associated with fewer dysfunctional sleep-related cognitions, whereas improvements in subjectively perceived fitness were associated with higher mental toughness levels post-intervention. The general pattern of associations remained unchanged after accounting for intention-to-treat effects.

Table 2 also includes a summary of the multiple linear regression analyses with the change scores as outcome. With the exception of physical health, the baseline scores less strongly predicted the change scores. With regard to mental health, rumination and mental toughness, baseline levels were not significantly associated with the change scores. With regard to the covariates, only age was associated with change in depressive symptoms and sleep complaints, indicating that older participants reported a stronger reduction in depression symptom severity, but improved less regarding their self-reported sleep complaints. Regarding cardiorespiratory fitness, higher baseline levels and positive changes in VO_2max were associated with a stronger decrease in depressive symptom severity over time. Improved VO_2max was also predictive of a stronger decrease in insomnia symptoms, and rumination, as well as a stronger increase in mental health. Moreover, higher baseline levels of perceived fitness and positive changes in perceived fitness were associated with stronger decreases in dysfunctional sleep-related cognitions, whereas improvements in subjectively perceived fitness were associated with stronger increases in mental toughness. A similar pattern of associations was found after accounting for intention-to-treat effects.

4. Discussion

The key findings of our study are that improvements in VO_2max from baseline to post-intervention were associated with fewer depressive symptoms, better mental wellbeing, and better sleep post-intervention. Moreover, improved VO_2max was associated with favorable changes in depressive symptoms, mental health, sleep and rumination. Additionally, we were able to show that improvements in perceived fitness were associated with fewer dysfunctional sleep-related cognitions and higher mental toughness post-intervention.

Some findings deserve special emphasis. Firstly, our findings show that improving patients' cardiorespiratory fitness levels not only holds promise to strengthen their cardiovascular health (Stubbs et al., 2016), but may also be predictive of more favorable mental wellbeing and sleep. This finding is at odds with a previous study of Chu et al. (2009) who compared the effects of aerobic exercise training with higher intensity, lower intensity, and stretching over a period of ten weeks. When correlating changes in aerobic capacity with changes in depressive symptoms, no significant association was found between these variables in their sample. However, this result must be interpreted with caution. Although the intervention lasted for 10 weeks, (small) improvements in cardiorespiratory fitness were only observed in the higher intensity training group. Furthermore, participants (all females) were selected based on self-reported depressive symptoms. Consequently, the sample also included participants who did not meet criteria for psychiatrist-diagnosed major depression. Moreover, it remained unclear what happens in depressed patients when exercise training leads to more substantial improvements in VO_2max. Milani and Lavie (2009) showed that improvements in fitness of $\geq$10% have the potential to modulate the relationship between psychological distress (including depression) and mortality, highlighting clearly that improving cardiorespiratory fitness is a meaningful target for clinical practitioners and health interventionists.

Secondly, although our intervention lasted only four weeks, we found significant improvements in VO_2max in the total sample, most likely because the exercise intensity was relatively high in both training groups. However, this contrasts with other studies (e.g., Belvederi Murri et al., 2015) where longer intervention programs with a similar intensity resulted in less substantial improvement in VO_2max. We therefore argue that inter-individual differences regarding participants' responsiveness to exercise training should be taken into consideration more systematically. This omission may explain why the magnitude of effects was sometimes limited in previous exercise trials (Nebiker et al., 2018).

Thirdly, our findings highlight that, with regard to physical fitness, the psychological aspect of exercise training matters as well. Evidence shows that feeling competent is an important determinant of long-lasting exercise behavior (Teixeira et al., 2012). Building up confidence and exercise-related self-efficacy is particularly important among patients with MDD, as cognitive and social resources that regulate exercise behavior and contribute to a physically active lifestyle seem to be impaired in this specific population (Gerber et al., 2016a; Krämer et al., 2014).

Fourthly, the findings of our study indicate that exercise modality and affective valence do not predict health-related outcomes in patients with MDD. Our study expands previous research on affective reactions following exercise in patients with MDD (Bartholomew et al., 2005), in the sense that we did not find differences in affective valence between patients assigned to SIT and CAT. This finding is noteworthy as some scholars have raised doubts as to whether SIT is suitable from a public health perspective (Hardcastle et al., 2014).

The strengths of our study are that we focused on in-patients with relatively high symptom severity, the exercise intervention was carried out under controlled circumstances, affective valence was documented rigorously across all exercise sessions, VO_2max was tested via spirometry, all regression analyses were controlled for major covariates, baseline levels of the outcomes, and intention-to-treat-effects, and both endpoint and change scores were used as outcome measures. By contrast, the sample size was relatively small, female participants were over-represented, the intervention period was relatively short, and no follow-up data are available to judge whether fitness levels change after discharge and how this affects health outcomes. We also acknowledge that we discussed the findings from a unidirectional perspective. However, it might also be that improved depressive symptoms lead to improved cardiorespiratory fitness. This would be in line with previous studies showing that the relationship between depressive symptoms and physical activity is reciprocal (e.g., Lindwall et al., 2014). Moreover, in our sample, no significant correlation was found between baseline depression and baseline VO_2max ($r = -0.04$, $p = ns.$). While

this is at odds with previous investigations showing that these two constructs are cross-sectionally associated (Gerber et al., 2013), the lack of a significant association can be explained by the fact that our sample was more homogeneous with regard to depressive symptoms (all clinical in-patients) than the samples used in previous population-based studies. Further limitations are the low acceptance rate, the absence of a clinician-rated instrument to assess depressive symptoms, the lack of correction for multiple comparisons because of limited sample size, the lack of control for comorbid personality disorders, and the lack of information regarding change in medication until post-intervention.

5. Conclusion

From a practical point of view, we argue that exercise training in psychiatric care should be accompanied by regular fitness testing to ensure that participants improve their fitness levels and to help coaches to develop graded and individual exercise plans. Although more and stronger empirical evidence is needed to show that improvements in physical fitness contribute to enhanced depressive symptom severity and well-being, improved fitness is per se an important outcome of exercise training programs in psychiatric care, as low physical fitness is a well-established risk factor for cardiovascular and other non-communicable diseases.

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

Ethics approval and consent to participate

The study was approved by the local ethical committee (EKNZ, approval number: 2014–374) and all patients signed an informed consent to the study after receiving all relevant study information.

Consent for publication

Was obtained from the participants, collaborators and co-authors.

Availability of data and material

Data and the study proposal approved by the local ethical committee can be requested for further analyses or transparency reasons from the corresponding author.

Conflicts of interest

None.

Authors' contributions

MG, AM, JB, LZ, and LD developed the study design. MG conducted the statistics and wrote the manuscript. All authors contributed to the data interpretation, and the internal revision of the manuscript draft. All authors approved the final draft version.

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