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ORIGINAL PAPER

Effects of physical activity on cognitive performance: a controlled clinical study in depressive patients

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Abstract

Physical activity is a common adjunctive therapy in psychiatric and psychosomatic hospitals. In the present study, we assessed the effects of an exercise program, integrated into routine inpatient treatment, on cognitive performance and subjective severity of depression in a sample of patients suffering from major depression. We randomized $n = 38$ patients with unipolar depression to either physical exercise ($n = 18$) or occupational therapy as an active control treatment ($n = 20$). Both treatments were delivered in group format over a period of 3–4 weeks. Data indicate that there were significant improvements of cognitive functions and depressive symptoms in both groups, with specific treatment effects in reaction time and in short-term verbal memory favoring the physical activity group. In conclusion, we found physical exercise to be a feasible, easy-to-implement add-on therapy for depressive patients with promising effects on cognitive performance. However, these results need to be replicated in larger samples with an extended follow-up.

Keywords Depression · Physical activity · Physical exercise · Endurance training · Cognition · Treatment

Introduction

Representative cross-sectional and longitudinal studies point towards beneficial effects of physical activity, and in particular endurance training, on the development and course of psychiatric disorders [4, 18, 19]. Positive effects of improved physical fitness on psychological process variables such as self-esteem, sense of autonomy, self-efficacy, social interaction, and (dys)functional cognitions have been described [13]. On a neurobiological level, changes with regard to neuroplasticity, neuroprotective/neuroregenerative effects, neurotransmission and anti-inflammatory effects have been proposed and could explain these outcomes [18, 26].

Physical exercise has not only been associated with a reduction of depressive symptoms [5], but also with effects on cognitive performance (for a review, see [18]). Deficits in attention, memory and/or executive function are frequent in depression. It has been estimated that apart from altered mood and reduced activity, up to two-thirds of patients with depressive disorders suffer from cognitive impairments [25, 27]. In up to half of depressed patients, cognitive deficits have been reported to persist even after remission of depressive symptoms [1, 24]. Cognitive deficits are crucial determinants of psychosocial functioning, and their persistence predicts poorer outcome of psychosocial rehabilitation [8]. Research has not been able to identify a clear profile of deficits, neither for the acute, nor the residual phase of depression and cognitive dysfunctions should not be regarded as mere epiphenomena of depressive psychopathology, but should be diagnosed and treated as core symptoms of the disorder [25]. Since psychopharmacological agents have little modulatory effects on cognitive functions in depression [21], non-pharmacological approaches are becoming increasingly important in the treatment of cognitive deficits.

So far, evidence of the effects of physical exercise on cognitive performance in depressed patients is scarce and mixed (for a review, see [18]). Two studies found immediate effects on attention and executive control after one 30-min training session [17, 28]. Oertel-Knöchel et al. reported evidence of the efficacy of a 4-week endurance training on cognitive and

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psychopathological parameters in both schizophrenic and depressed patients [22]. By contrast, Hoffman et al. were unable to demonstrate any effects on cognitive performance of a 4-month endurance training compared to several control conditions in a large sample of depressed patients ($n = 202$) [15]. Besides, a recent meta-analysis including eight trials with a total of 637 patients could not observe a substantial benefit of physical exercise in depression neither on global cognition nor on specific cognitive domains [3]. However, the authors address critical aspects in the enclosed randomized controlled trials and admit some limitations inherent to the meta-analytic approach that should be taken into consideration before drawing definite conclusions. Taken together, it remains questionable, whether physical activity, apart from its approved effects on emotional well-being, may also have a positive impact on cognitive performance in depressed patients or not.

The primary goal of the present study was to investigate the effects of physical activity on cognitive performance and psychopathological symptoms in depressed inpatients in a naturalistic setting at a psychiatric hospital.

Materials and methods

A total of $n = 43$ psychiatric inpatients at the kbo-Inn-Salzach-Klinikum, Wasserburg am Inn/Germany, who were diagnosed with unipolar depression without psychotic symptoms according to ICD-10 criteria, were screened and included in this study. All patients but three received antidepressant medication at inclusion. Exclusion criteria were comorbid psychiatric disorders—except comorbid ICD-10 diagnoses of the chapters F4, F5 and F6—cardiovascular or neurological disease, intellectual disability, and incapacity to provide informed consent. The study was approved by the ethics committee of the University of Munich (LMU). In accordance with the Declaration of Helsinki, written informed consent was obtained from all patients prior to inclusion after the study procedures had been explained to them. Figure 1 shows the flow diagram of the number of participants.

Five patients refused participation to the study after enrolment, thus 38 patients were assigned to either the exercise group (EG) or the control group (CG) in a balanced block-randomized design (10 blocks of 4 patients). The EG experienced physical activity sessions in form of endurance training of 30 min. each, 2–3 times/week over a period of 3–4 weeks; the sessions were led by a sports therapist with experience in working with psychiatric patients and comprised outdoor walking, Nordic walking, or running in groups of up to five patients. Before the first training session ($t0$), prior to the intervention, EG-participants' fitness level (resting, during exercise, and recovery heart rates) was assessed in a 15-min endurance test on a stationary bicycle (ergo fit cardio line 3000) once. Exercise intensity was adapted to the individual patient's fitness level. Additionally, for each training unit, resting, during exercise, and recovery heart rates were checked, to bring the patients into the optimal training range. 85% of the mean maximal heart rate, calculated as 200 minus age in years [16], was taken as the upper limit. In adverse weather conditions, patients exercised indoor on stationary bicycles. The CG received 2–3 times per week (30 min) additional sessions of occupational or art therapy in a group up to eight persons, led by an occupational or art therapist. Interventions used to improve, e.g. sensory

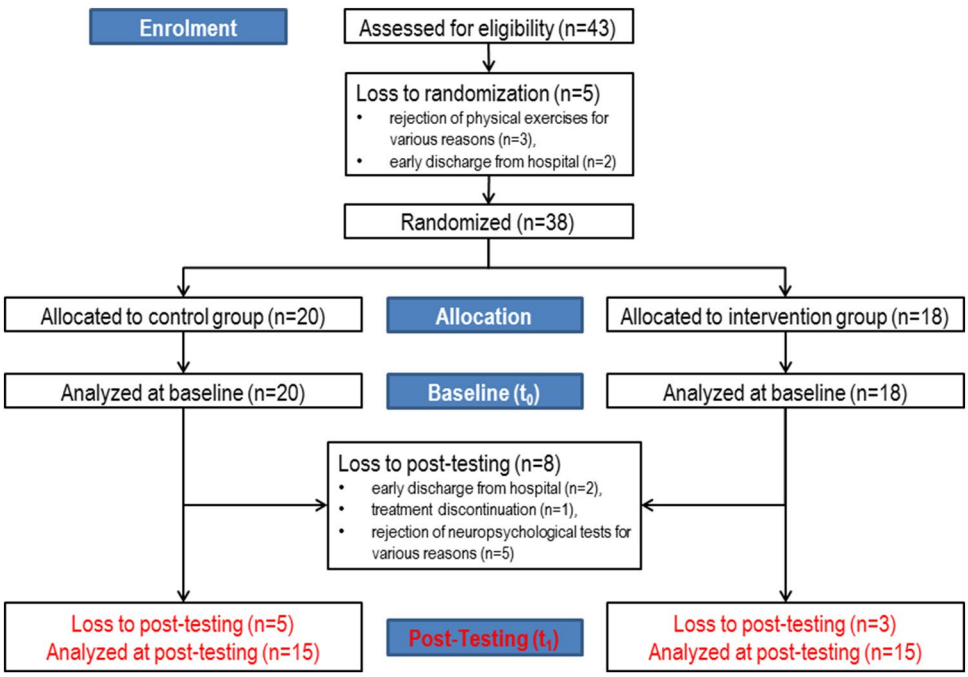

Fig. 1 Flow diagram outlining enrolment, allocation, baseline and post-testing assessment of participants

integration or gross motor skills varied with respect to the methods and techniques applied (e.g. clay, wood, etc.) and were conducted in an individual manner. All patients underwent an extensive neuropsychological test battery before (t0) and immediately after (t1) the treatment period.

Cognitive performance

To assess attention, the subtests "alertness" (for simple reaction times) and "divided attention" (with audio-visual conditions) from the test battery for the assessment of attention (*Testbatterie zur Aufmerksamkeitsprüfung*, TAP) were conducted [31].

To quantify memory function, we assessed short-term verbal memory by means of the "digit span forward" of the German adaptation of the revised Wechsler Memory Scale (WMS-R) [10]. We further measured verbal learning and memory using the verbal learning and memory test (*Verbaler Lern- und Merkfähigkeitstest*, VLMT), version A at baseline ($t0$), parallel-version C post-intervention ($t1$) [12]. This is a well-established test consisting of a list of 15 target words, which are read aloud to the patient 5 times, followed by an inference list of distractor words. Verbal memory of the target words is assessed immediately after each reading and after a 30-min interval.

We operationalized executive function with three separate tests. Using the standard progressive matrices (SPM) [23], we assessed logical-deductive reasoning. Verbal working memory was measured with the "digit span backwards" of the German adaptation of the revised Wechsler Memory Scale (WMS-R) [10]. With the computer-assisted card-sorting procedure (*Computergestütztes Kartensortierverfahren*, CKV) [7], conceptualization and mental flexibility were assessed.

Psychopathology

Depressive symptoms were quantified with the revised version of the Beck Depression Inventory (BDI-II) [11]. To state severity of depression from an external view, we additionally administered the Toronto HAMD-7, a shortened version of the Hamilton Depression Rating Scale (HAM-D), in which seven items with the greatest frequency of occurrence and sensitivity to change with treatment are identified [20].

Statistical analysis

All statistical analyses were computed with the SPSS software package, version 16.0. The significance level was set at $\alpha < 0.05$. Sociodemographic and clinical data were analyzed using non-parametric tests (Chi-square and Mann–Whitney U tests). To test for group differences at both measurement points, independent t tests were conducted. Product moment correlation between changes in cognitive functions and depressive symptoms was computed using Pearson correlation coefficient. Cognitive parameters were evaluated with mixed-design ANOVAs and ANCOVAs with the between-subject factor group (EG, CG) and the within-subject factor time ($t0$, $t1$). Significant simple effects were localized with post hoc t tests for independent samples. Additionally, we calculated effect sizes (partial eta square, η^2) to gauge the magnitude of the differences.

Results

Sociodemographic and clinical measures

Initially, $n = 38$ patients (EG: $n = 18$; CG: $n = 20$) took part in the study, but only $n = 30$ participants (EG: $n = 15$, CG: $n = 15$) completed the intervention and post-testing ($t1$). EG and CG did not differ significantly in terms of age, gender, marital status or years of education (all p's > 0.05); there was a nonsignificant trend towards higher educational level in the EG ($p = 0.07$). There were no significant differences between the groups with regard to clinical measures at baseline (diagnosis, comorbidity, severity of depression or days after admission at $t0$) (again, all $p > 0.05$) (see Table 1).

Comorbid mental disorders were other mood disorders (EG: $n = 1$), neurotic, stress-related and somatoform disorders (EG: $n = 1$; CG $n = 3$), and disorders of adult personality and behaviour (EG: $n = 1$; CG: $n = 1$). Further, groups did not differ over the course of the entire treatment with regard to number of treatment sessions received in this study (EG: mean = 10.00 (SD = 2.95); CG: mean = 14.27 (SD = 8.18); $t = 1.90$, $p = 0.07$), psychopharmacological treatment ("no antidepressive mediation", "tri-/tetracylics", "selective antidepressants"; $t0$: $\chi^2 = 7.78$, $p = 0.34$; $t1$: $\chi^2 = 14.85$, $p = 0.06$), change in medication ("yes"/"no"; $\chi^2 = 0.04$, $p = 0.55$), medication side effects ("present"/"absent"; $t0$: $\chi^2 = 0.63$, $p = .43$; t1: $\chi^2 = 0.25$, $p = 0.062$) or concomitant medication ("present"/"none"; $t0$: $\chi^2 = 21.47$, $p = 0.37$; $t1$: $\chi^2 = 24.00$, $p = 0.35$). For a detailed description of psychotropic drugs prescribed see "Appendix 1".

Physical fitness

Fitness level of the EG participants (resting, during exercise, and recovery heart rates) did not change over time (all $p > 0.05$).

Cognitive performance

At intake ($t0$), groups differed with regard to divided attention (TAP Divided Attention, omissions: $t = -2.27$; $p = 0.03$), verbal learning (VLMT Learning: $t = 2.28$; $p = 0.03$), and in the executive functions logical-deductive reasoning (SPM: $t = 2.99$; $p = 0.01$) and cognitive flexibility and categorization (CKV, perseveration: $t = -2.37$; $p = 0.02$).

Table 1 Sociodemographic and clinical characteristics of the study sample at baseline (*t*0)

	Exercise group (EG $n=15$)	Control group (CG $n=15$)	Statistic	
Age M (SD)	47.27 (6.84)	47.47 (8.47)	$t=-0.07$	$p=0.94$
Gender (m/f)	6/9	5/10	$\chi^2=0.14$	$p=0.70$*
Marital status				
Single	3	0	$\chi^2=4.68$	$p=0.20$*
Married	10	12		
Divorced	1	2		
Widowed	1	1		
Level of education				
No qualification	0	1	$\chi^2=8.65$	$p=0.07$*
Lower secondary	2	8		
O-level	8	3		
HEEQ	3	1		
Higher education	2	2		
Years of education M (SD)	13.27 (1.94)	12.20 (2.68)	$t=1.25$	$p=0.22$
Diagnosis				
F32.1	0	4	$\chi^2=6.22$	$p=0.10$*
F32.2	7	5		
F33.1	1	1		
F33.2	7	5		
Comorbidity				
Yes	3	4	$\chi^2=0.19$	$p=0.67$*
No	12	11		
Days after admission at *t*0, *M* (SD)	18.87 (13.04)	15.80 (9.90)	$t=0.73$	$p=0.47$
Severity of depression				
BDI-II M (SD)	22.40 (8.53)	18.27 (11.56)	$t=0.95$	$p=0.35$
HAMD-7 M (SD)	11.00 (3.42)	9.67 (4.21)	$t=0.85$	$p=0.31$

BDI-II Beck's Depression Inventory, *HAMD-7* Toronto short-version of the Hamilton Depression Scale, *HEEQ* higher education entrance qualification, *M* mean, *SD* standard deviation, *m* male, *f* female

*Likelihood-ratio statistic

Attention

There were significant time effects in both groups on reaction times and divided attention. Further, a significant interaction with a large effect size was found for reaction time. Post hoc *t* tests revealed that a decrease could only be seen in the EG ($t = 3.44$, $p = 0.00$) (see Table 2; Fig. 2).

To exclude that time by group interaction was not primarily driven by baseline differences—albeit not significant—we additionally conducted an ANCOVA including baseline reaction-time measure as a covariate. Re-analyses confirmed our previous results showing again significant interaction effects for alertness [$F(1; 27) = 4.79$; $p = 0.00$; $\eta^2 = 0.59$].

Memory

There were significant main effects of time with large effect sizes on learning performance and short-time memory. Further, we found a significant time × group interaction on short-term memory; post hoc analyses showed that improvements could only be seen in the EG ($t = 3.08$, $p = .01$) (see Table 2; Fig. 3).

Executive function

ANOVA revealed a significant main effect of time on logical-deductive thinking and cognitive flexibility/categorization. However, there was no significant interaction effect on either measure of executive function (see Table 2).

Controlling for level of education and psychopathology

As there was a trend towards higher educational level in the exercise group, we also computed an ANCOVA including level of education as a covariate. Re-analyses yielded significant interaction effects for alertness

Table 2 Results of ANOVAs of outcome measures

	Time	Exercise group (EG: $n=15$)	Control group (CG: $n=15$)	Main effect time	Main effect group	Time × group
Attention						
TAP tonic alertness RS (RT) (SD)	*t*0	286.47 (83.19)	252.60 (37.79)	F(1;28) = 9.46; $p=$ **0.00**	F(1;28) = 0.29; $p=0.60$	F(1;28) = 7.77; $p=$ **0.01**
	*t*1	235.07 (43.05)	250.07 (40.81)	$\eta^2=0.25$	$\eta^2=0.01$	$\eta^2=0.22$
TAP-divided attention RS (omissions) (SD)	*t*0	2.20 (2.15)	4.80 (3.88)	F(1;28) = 9.85; $p=$ **0.00**	F(1;28) = 5.02; $p=$ **0.03**	F(1;28) = 2.04; $p=0.16$
	*t*1	1.60 (1.55)	3.20 (2.83)	$\eta^2=0.26$	$\eta^2=0.35$	$\eta^2=0.07$
Memory						
WMS-R short-term memory RS (SD)	*t*0	6.93 (1.39)	7.07 (1.94)	F(1;28) = 8.20; $p=$ **0.01**	F(1;28) = 0.83; $p=0.37$	F(1;28) = 5.49; $p=$ **0.03**
	*t*1	8.27 (1.28)	7.20 (1.57)	$\eta^2=0.33$	$\eta^2=0.03$	$\eta^2=0.26$
VLMT learning, total RS (SD)	*t*0	51.60 (8.58)	43.33 (11.12)	F(1;28) = 15.84; $p=$ **0.00**	F(1;28) = 5.24; $p=$ **0.03**	F(1;28) = 0.54; $p=0.47$
	*t*1	55.73 (6.54)	49.33 (10.80)	$\eta^2=0.36$	$\eta^2=0.16$	$\eta^2=0.02$
VLMT recall RS (SD)	*t*0	10.53 (2.77)	9.80 (3.01)	F(1;28) = 0.96; $p=0.34$	F(1;28) = 0.88; $p=0.36$	F(1;28) = 0.08; $p=0.78$
	*t*1	11.13 (2.53)	10.13 (3.07)	$\eta^2=0.03$	$\eta^2=0.03$	$\eta^2=0.00$
Executive function						
WMS-R working memory RS (SD)	*t*0	6.27 (1.94)	6.20 (1.97)	F(1;28) = 1.51; $p=0.23$	F(1;28) = 0.26; $p=0.62$	F(1;28) = 0.67; $p=0.42$
	*t*1	6.93 (1.87)	6.33 (2.23)	$\eta^2=0.05$	$\eta^2=0.01$	$\eta^2=0.02$
SPM logical thinking RS (SD)	*t*0	49.13 (5.33)	41.47 (8.37)	F(1;28) = 7.04; $p=$ **0.01**	F(1;28) = 7.72; $p=$ **0.01**	F(1;28) = 0.46; $p=0.50$
	*t*1	50.40 (5.57)	43.60 (9.29)	$\eta^2=0.40$	$\eta^2=0.22$	$\eta^2=0.02$
CKV categorization perseveration, % (SD)	*t*0	20.27 (19.34)	36.99 (19.36)	F(1;28) = 11.93; $p=$ **0.00**	F(1;28) = 6.72; $p=$ **0.01**	F(1;28) = 0.44; $p=0.51$
	*t*1	11.03 (12.21)	23.33 (19.31)	$\eta^2=0.30$	$\eta^2=0.19$	$\eta^2=0.02$
Psychopathology						
BDI-II RS (SD)	*t*0	22.40 (8.53)	18.87 (11.56)	F(1;28) = 23.64; $p=$ **0.00**	F(1;28) = 0.56; $p=0.46$	F(1;28) = 21.60; $p=0.42$
	*t*1	14.07 (8.17)	12.93 (9.13)	$\eta^2=0.46$	$\eta^2=0.02$	$\eta^2=0.02$
HAMD-7 RS (SD)	*t*0	11.00 (3.42)	9.67 (4.21)	F(1;28) = 29.92; $p=$ **0.00**	F(1;28) = 0.53; $p=0.47$	F(1;28) = 0.20; $p=0.66$
	*t*1	7.20 (3.88)	6.44 (3.43)	$\eta^2=0.58$	$\eta^2=0.02$	$\eta^2=0.01$

Results significant at the p < .05 - level are outlined bold

ANOVA analysis of variance, *TAP* Testbatterie zur Aufmerksamkeitsprüfung, *WMS-R* Wechsler Memory Scale-Revised, *VLMT* Verbaler Lern- und Merkfähigkeitstest, *SPM* standard progressive matrices, *CKV* Computergestütztes Kartensortierverfahren, *BDI-II* Beck's Depression Inventory, *HAM-D7* Toronto short-version of the Hamilton Depression Scale, *RT* reaction time, ms, *SD* standard deviation, *RS* raw score

[F(1;27) = 5.33, p = .03; η^2 = 0.16] and short-term memory [F(1;27) = 5.88, p = .02; η^2 = 0.18], confirming results of differential effects of our first analyses.

Due to numerically greater reduction of BDI scores in the EG compared to CG we conducted an analysis of covariance with BDI-difference scores (pre–post) as a covariate. Results of this re-analyses indicate a significant time effect for verbal short-term memory [F(1;27) = 7.26; p = .01; η^2 = 0.21] and a significant time by group effect [F(1;27) = 5.95; p = .02; η^2 = 0.18] confirming results of our first analyses.

Psychopathology

In both groups, subjective severity of depression improved significantly over time; there was no significant time by group effect (see Table 2).

Drop-out rate and intention-to-treat analysis (ITT)

A total of n = 38 patients were included in the study. Of these, eight participants (EG: 3, CG: 5) were excluded from the study before the second neuropsychological testing (*t*1) due to early discharge from hospital (n = 2), treatment discontinuation by the patient (n = 1), or rejection of the neuropsychological tests for various reasons (n = 5) (overall dropout rate: 21%). Thus, a final sample of n = 30 participants (EG: n = 15, CG: n = 15) was included in data analysis.

Last observation carried forward (LOCF) method was used for missing data from dropouts as an intent-to-treat analysis (ITT). The ITT analysis indicated significant time effects for alertness [F(1;36) = 6.77, p = .01; η^2 = 0.16], short-term memory [F(1;36) = 8.40, p = 0.001; η^2 = 0.19], learning [F(1;36) = 13.98, p = 0.001; η^2 = 0.28], logical thinking [F(1;36) = 6.58, p = 0.01; η^2 = 0.15] and categorization [F(1;36) = 10.82, p = 0.01; η^2 = 0.23]. With respect to

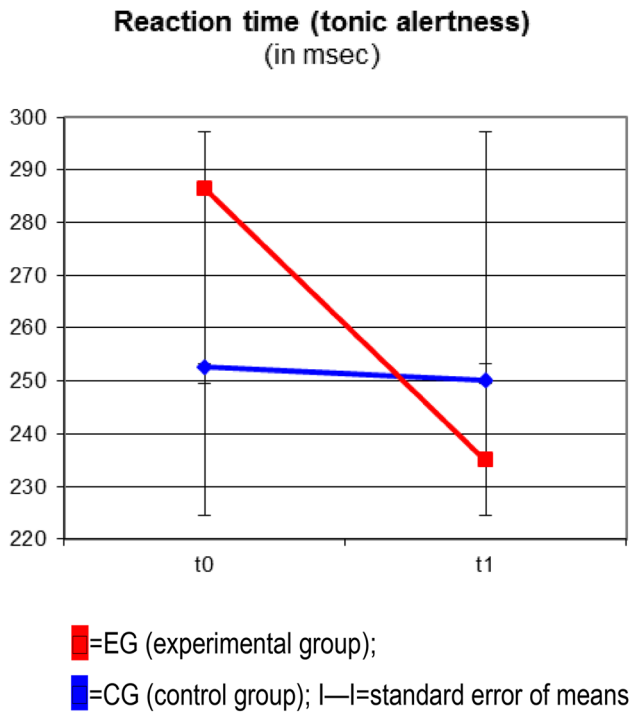

Fig. 2 Significant treatment effect on reaction time favoring EG

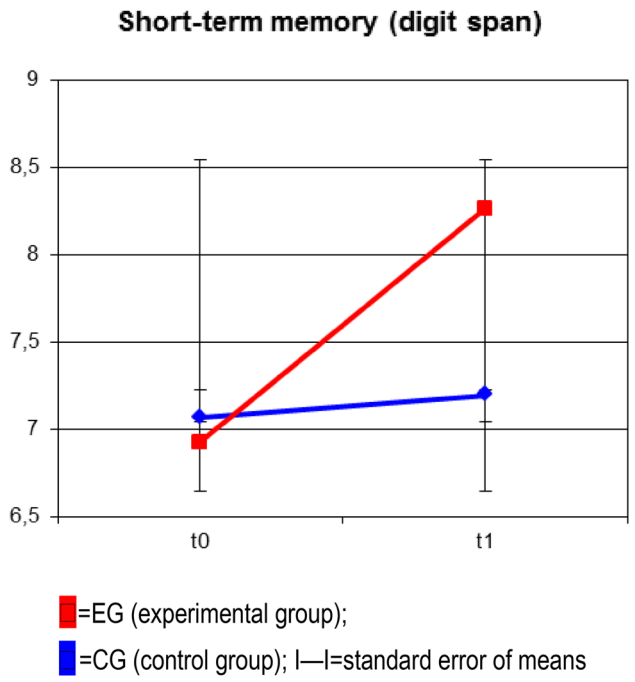

Fig. 3 Significant treatment effect on short-term memory favoring EG

affective symptoms a significant improvement over time in both groups could be confirmed—BDI-II [F(1;36) = 20.95, $p = 0.001$; $\eta^2 = 0.37$] and HAMD-7 [F(1;36) = 24.15, $p = 0.001$; $\eta^2 = 0.47$].

Except for logical thinking [F(1;36) = 8.90, $p = 0.01$; $\eta^2 = 0.20$], no significant main effect of group could be shown in outcome measures.

The interaction effects on cognitive domains alertness and short-term memory remained statistically significant, favoring the exercise group—alertness [F(1;36) = 5.80, $p = .02$; $\eta^2 = 0.14$] and short-term memory [F(1;36) = 5.85, $p = .02$; $\eta^2 = 0.14$].

Discussion

The present study investigated the effects of a structured physical activity training program—compared to an active control treatment—on cognitive performance and psychopathology in depressive inpatients.

First, we found that physical exercise could be readily implemented and integrated into routine care, and was well received by patients, who completed on average 10 training sessions over 3–5 weeks. Likewise, the study design proved feasible; patients in the control condition (occupational/art therapy) attended their sessions regularly, too. At 21%, the drop-out rate appears moderate, and markedly below the drop-out rate of 32% reported in a comparable study [22].

Participants of both groups experienced a significant reduction of self-rated affective symptoms over the course of the intervention (see Table 2); however, for psychopathology, we could not demonstrate a superiority of physical activity, as reported in comparable studies [2, 14].

With regard to cognitive performance, participants of the EG improved significantly more than participants of the CG on measures of reaction time and short-term memory. These intervention effects were robust controlling for confounding factors such as level of education, changes in depressive symptoms and baseline differences in cognitive functions. By contrast, we found no specific effects of physical activity on executive function.

The comparison of our results with the literature is hampered by the mixed findings of studies investigating effects of physical exercise on cognitive functions in depressed patients. Despite a recent meta-analysis including eight trials, the state of evidence remains unsatisfactory and is more due to the lack of research rather than limited effects of physical activity, and thus does not negate neither its importance nor its effects on cognitive performance and psychopathology in depressed patients [13, 18]. Further, the study designs as well as the neuropsychological tests reported in the literature so far vary widely.

The positive effects on reaction time found in our study parallel findings by Kubesch et al. (2003). These authors reported significant improvements in mean reaction times (Stroop task, TAP GoNogo) after one session of physical activity in young and middle-aged depressed patients ($n = 24$),

while a healthy control group ($n = 10$) did not benefit [17]. In another study on $n = 10$ older depressed patients, Vasques et al. (2008) found improvements in attention and in reaction inhibition immediately after a 30-min session on the treadmill, compared to a second pre-/post-assessment without training in the same sample 1 month later [28]. Oertel-Knöchel et al. (2014) also reported significant improvements in information processing speed after 4 weeks of physical exercise in combination with computerized cognitive training [22].

With regard to verbal episodic memory functions, which are considered especially sensitive predictors of the clinical course of depression [6], patients in the EG attained better results in short-term memory than patients in the CG. While all participants increased their verbal learning performance significantly over time, we could not confirm superior effects of physical exercise on verbal learning. Again, these findings are in line with the results from Oertel-Knöchel et al. (2014), who found significant improvements favoring the exercise group on measures of information processing speed, working memory and visual learning [22].

As for executive function, no interaction effect favoring the EG could be found in the present study. Both groups improved significantly with treatment in cognitive flexibility and categorization. It should be taken into account that occupational therapy, too, has a stimulating effect on cognition. Wykes et al. compared a structured occupational intervention with cognitive remediation in schizophrenic patients and found improvements of cognitive performance in both groups [29, 30].

Finally, our data did not reveal a relevant correlation between cognitive and depressive difference scores. Thus, the time courses of cognition and psychopathology seem not to parallel each other but rather run parallel in terms of distinct symptoms of depression as already mentioned above.

Limitations

One possible limitation of the present study is the small sample size. Further, duration and intensity of the two treatments with a mean of just 10 sessions of physical activity were low; although we did approach the recommendations of the American College of Sports Medicine, who regard 30 min on 5 days/week as optimal for attaining physical fitness, we did not meet them [9]. Another issue is the active control condition. While occupational therapy provides a good control of physical movement and muscle activity, this treatment also contains elements of cognitive stimulation, which might have exerted a positive influence on cognitive performance in the control group, possibly obscuring the effect of physical exercise in the exercise group. It would be worthwhile to compare physical activity to a waitlist control and to different active treatments in a larger sample. Furthermore, the CG received the intervention in a larger group compared to the exercise group, which may have resulted in a greater attention and, therefore, possible positive effects on outcome measures. However, since the EG tends to reach higher levels in the depression scales, possible increased attention does not seem to have had a relevant impact on psychopathology.

Finally, as patients were medicated according to clinical demands we could not systematically control for pharmacological effects.

Conclusion

In conclusion, physical exercise may be a promising add-on treatment for affective disorders with possible differential effects on cognitive function. Along with psychopharmacological and psychotherapeutic measures, physical exercise in the form of endurance training is feasible and should be integrated into a multimodal treatment program. However, further studies with larger samples, longer treatment periods, and an extended follow-up are needed before general conclusions can be drawn.

Take-home messages

1. Cognitive impairments are frequent in depressive disorders and may have a decisive influence on psychosocial functioning
2. Apart from a positive effect on psychopathology in depressed patients, physical activity may also improve cognitive performance
3. Physical exercise can be readily implemented as an element of inpatient treatment of depressed patients
4. Further research is needed with respect to specific effects of physical activity in depressive disorders on different cognitive functions and long-term outcome.

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Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest to declare for this study.

Appendix 1

See Table 3.

Table 3 Medications prescribed according to intervention groups and time of neuropsychological testing

Patient no.	EG		CG	
	*t*0	*t*1	*t*0	*t*1
1	Amitriptyline 75 mg	Amitriptyline 100 mg	Paroxetine 20 mg Pipamperone 40 mg	Venlafaxine 37.5 mg Promethazine 50 mg
2	Amitriptylinoxide 120 mg	Reboxetine 6 mg	Duloxetine 60 mg Quetiapine 450 mg	Duloxetine 120 mg Quetiapine 200 mg
3	Mirtazapine 45 mg	Venlafaxine 75 mg	Escitalopram 10 mg	Escitalopram 20 mg
4	Escitalopram 10 mg Pipamperone 40 mg	Escitalopram 10 mg Pipamperone 40 mg	Mirtazapine 30 mg	Mirtazapine 45 mg
5	Paroxetine 40 mg Quetiapine 100 mg	Duloxetine 150 mg Quetiapine 200 mg	Duloxetine 30 mg	Duloxetine 60 mg
6	Mirtazapine 45 mg	Duloxetine 90 mg	Escitalopram 20 mg	Escitalopram 20 mg
7	Escitalopram 10 mg	Escitalopram 20 mg	Mirtazapine 45 mg	Paroxetine 20 mg
8	Reboxetine 10 mg	Reboxetine 10 mg	Escitalopram 20 mg	Escitalopram 20 mg
9	Venlafaxine 150 mg Mirtazapine 30 mg	Venlafaxine 300 mg Mirtazapine 15 mg	No medication	Sertraline 100 mg
10	No medication	Mirtazapine 45 mg	No medication	No medication
11	Mirtazapine 45 mg	Sertraline 100 mg	Mirtazapine 45 mg	Mirtazapine 45 mg
12	Escitalopram 20 mg Olanzapine 5 mg Pregabalin 225 mg	Escitalopram 20 mg Risperidone 1 mg Pregabalin 450 mg	Mirtazapine 45 mg	Mirtazapine 45 mg
13	Venlafaxine 150 mg	Venlafaxine 150 mg	Venlafaxine 187,5 mg	Venlafaxine 225 mg
14	Duloxetine 90 mg	Duloxetine 90 mg	Amitriptyline 100 mg	Amitriptyline 100 mg
15	Escitalopram 10 mg	Escitalopram 20 mg	Agomelatine 25 mg Lorazepam 0,5 mg	Agomelatine 25 mg Promethazine 50 mg

EG experimental group, *CG* control group, *t0* baseline, *t1* post-testing

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