Marathon running improves mood and negative affect

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1. Introduction

Major depressive disorder (MDD) ranks third place in causing global years lived with disability (YLD) (GBD, 2017 Diseases and Injury Incidence and Prevalence Collaborators, 2018) and is associated with an increased all-cause mortality (Walker et al., 2015). One major reason for the increased mortality rates is the high incidence of cardiovascular diseases in this cohort (Correll et al., 2017). Moreover, the inverse relationship is well-documented as patients with chronic physical diseases often exhibit comorbid depressive symptoms (Moussavi et al., 2007; Eker, 2018; Solaro et al., 2018). Physical activity has the potential to improve MDD as well as comorbid depressive symptoms in physical diseases (Kvam et al., 2016; Roeh et al., 2019b). Physical activity is protective against the emergence of depressive symptoms for all age groups (Schuch et al., 2018) and high cardiorespiratory fitness correlates with a decreased risk for mental health disorders (Kandola et al., 2019).

According to the American College of Sports Medicine (ACSM) guidelines, healthy adults should engage in moderate aerobic exercise training for ≥30 min per day on ≥ five days per week, vigorous aerobic exercise training for ≥20 min per day on ≥ three days per week, or a combination of both moderate and vigorous aerobic training in order to

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develop or maintain cardiorespiratory and muscular fitness. On another two to three days, healthy adults should perform resistance exercises for each of the major muscle groups and flexibility exercises for each major muscle-tendon groups on ≥ two days per week (Garber et al., 2011). WHO recommendations state similar amounts: 150 min of moderate aerobic exercise per week or for more health benefits up to 300 min per week or 150 min of vigorous aerobic activity (World Health Organisation (WHO) 2011). Contrary to these recommendations, patients with MDD often live a sedentary lifestyle (Vancampfort et al., 2017).

However, engaging in ultra-high amounts of physical activity does not seem to have protective effects against the development of MDD. Prior research indicated similar prevalence rates in elite athletes compared to the general population (Rice et al., 2016). Possible unique risk factors in this cohort could be injuries, overtraining or involuntary career termination (Wolanin et al., 2015). Exercise of more than 3 h per session or more than five sessions per week were associated with poorer mental health compared to the before-mentioned amounts (Chekroud et al., 2018).

Apart from clinical manifestations of MDD, subclinical changes of mood and affect can be further distinguished. Both consider two dimensions: mood is defined to be sustained and internal whereas affect is more momentary and external (Serby, 2003).

To the best of our knowledge, data regarding depressive symptoms, internal mood, affect and functioning among recreational, healthy marathon runners compared to sedentary controls and the relationship to marathon training in this population is lacking. As recreational marathon runners are very likely to fulfill (or exceed to a certain extent) all training recommendations of ACSM and WHO, this design allows to test the hypothesis whether training according to the recommendations has a positive impact on mood, affect and functioning in non-depressed adults. Or if the contrary applies, and negative effects occur as a consequence of longer and more frequent training sessions (Chekroud et al., 2018).

In our trial, we addressed these unanswered scientific issues and compared marathon runners to an age- and sex-matched healthy, but sedentary control group with regard to several parameters of depressive symptoms, affect and functioning. Subsequently, we evaluated how marathon training and marathon running further affects these functions in the cohort of marathon runners.

2. Material and methods

The ReCaP trial ("Running effects on Cognition and Plasticity") is a longitudinal observational study of marathon runners who were registered for the Munich Marathon 2017. The detailed study protocol was previously published (Roeh et al., 2019a).

Briefly, inclusion criteria for the marathon group contained an age range between 18 and 60 years and successful registration for Munich Marathon 2017. All participants must have completed at least one half-marathon prior to study inclusion, must have sufficient german language skills and must have given written informed consent. Exclusion criteria contained relevant documented neurological, cardiovascular or psychiatric diseases, pregnancy and cannabis abuse.

The same exclusion criteria applied for the sedentary age- and sex-matched control group. A sedentary lifestyle was defined as less than an average of 25 min of physical activity per day (Cabrera de León et al., 2007) and sedentary controls were not allowed to have completed a (half-) marathon run in the past.

Marathon runners were recruited by announcements in local newspapers, running groups and the newsletter of the Munich Marathon 2017. The sedentary controls were mainly recruited by announcements in local newspapers and other channels (e.g. social media).

The study timeline is presented in Fig. 1.

The first assessment (visit −1) was performed 10–12 weeks and the second assessment (visit 0) one to two weeks prior to the marathon. The third assessment (visit 1) was performed immediately after successful completion of the marathon. The fourth and fifth assessment (visit 2.1 and 2.2 at 24 h and 72 h post-marathon, respectively) represented the short-term recovery period. Follow-up examinations for the long-term recovery period were performed about 10–12 weeks after the Munich marathon (visit 3, sixth assessment). All visits after visit −1 were exclusively performed in marathon runners, the sedentary group participated in one baseline visit (visit −1).

2.1. *Physical activity assessment*

The International Physical Activity Questionnaire (IPAQ) was used to assess detailed information about daily activity including physical exercise as well as physical activity in daily routines (e.g. usage of the bicycle for work) (Craig et al., 2003). Previous studies revealed high correlations of activity measured with accelerometers to the questionnaire (Mäder et al., 2006). The IPAQ was performed at baseline visit in both marathon runners and sedentary controls, and a second time at the end of the study period exclusively in the marathon runners.

In the marathon group, we further documented the training kilometers per week, the mean weekly training duration (mean of the 12 weeks prior to the marathon) and the mean number of weekly sessions with training protocols. We measured the endurance capacity with a spiroergometry (visit −1 and visit 0) to objectively assess fitness levels of the participants. The main outcome parameter for these analyses was VO_2max (milliliters of oxygen used in 1 min per kilogram of body weight ($mL*kg^{-1}*min^{-1}$)).

2.2. *Questionnaires on mood, affect and functioning*

Two rating scales for depressive symptoms were included. One of them was the self-rating Beck Depression Inventory (BDI) (Beck et al., 1961), the other one the observer-rating Hamilton Depression Scale (HAMD) (Hamilton, 1960). Overall happiness was assessed with the Oxford Happiness Questionnaire (Hills and Argyle, 2002), affect with the Positive and Negative Affect Schedule (PANAS; PANAS-NA for negative affect, PANAS-PA for positive affect) (Watson et al., 1988). A short global impression of well-being (general mood state) was administered with the visual analogue scale (a continuous line without subdivisions and scales 1–10, whereas "1" represents sad mood, "5" balanced mood and "10" a euphoric state; VAS) (Huang et al., 2020). Furthermore, the Global Assessment of Functioning (GAF) was applied to rate different dimensions of individual functioning (Goldman et al., 1992; Endicott et al., 1976). We administered BDI and HAMD at four visits: V-1, V0, V2.2 and V3; PANAS, OHQ and VAS at all six visits.

2.3. *General conditions*

Marathon runners were asked to maintain their usual dietary habits

Fig. 1. Study timeline.

during the study period and not to consume dietary supplements. In the three days prior to each visit, dietary habits were documented in unstructured food diaries to control for these specifications. To avoid interactions with long-distance running (other than the marathon event), participants were requested to restrict their training in the three days prior to each visit to short distance running.

2.4. Ethics and registration

The study proceedings agreed with Good Clinical Practice guidelines, the guiding principles of the Declaration of Helsinki, and local laws and regulations. The study protocol had been approved by the ethics committees of both the Ludwig-Maximilians University Munich (approval reference number 17–148) and the Technical University Munich (approval reference number 218/17 S). The study was registered at https://www.drks.de/(DRKS-ID: DRKS00012496). All participants provided written informed consent prior to inclusion in the study.

2.5. Statistical analysis

All analyses were carried out in SPSS 25 (IBM, Armonk, NY, USA), with a significance level of alpha = 0.05. Demographic and clinical differences between groups of marathon runners and sedentary controls were assessed using independent t-tests and χ^2-tests. Homogeneity of variances was tested with the Levene's test and, if violated ($p < 0.05$), a correction of degrees of freedom was applied.

To evaluate the course of depressive symptoms, mood and affect over time in marathon runners, a RM-ANOVA with the factor TIME (V-1, V0, V2.2 and V3 for BDI, HAMD and GAF; V-1, V0, V1, V2.1, V2.2 and V3 for VAS, OHQ and PANAS, GAF) was performed on complete datasets for each variable (listwise deletion of records). Sphericity was tested with the Mauchly's test and, if necessary (Mauchly's test < 0.05), Greenhouse–Geisser correction was applied. In case of a significant main effect of TIME, within-subject contrasts were calculated testing a given post-baseline time point against baseline.

3. Results

We recruited 100 amateur marathon runners and 46 sedentary age- and sex-matched controls. Over the course of the study period, 37 marathon runners had to be excluded (18 due to occupational commitments, 6 due to infections, 7 due to orthopedic injuries, 4 due to discontinuation of the marathon event, 1 due to personal reasons, 1 due to contraindications for marathon participation in baseline visit). For final analysis, further 21 participants had to be excluded (10 missed single complete examinations within the study period, 11 missed either a cognitive and/or vascular examination at one visit). 42 marathon runners remained for final analysis with complete data sets. In the sedentary group, 3 of the included 46 participants missed the examinations due to occupational commitments. The resulting number of participants for each parameter and the descriptive values at baseline are presented in Table 1.

Runners and sedentary controls showed significant differences in the smoking status and BMI. All other demographic parameters did not differ between both study groups (see Table 1). As expected, levels of activity according to IPAQ differed between both groups.

Baseline comparisons of the evaluated mood and affect parameters between marathon runners and sedentary controls are displayed in Table 2. Analyses showed significant differences in most parameters (BDI, OHQ, VAS, PANAS-PA, GAF). Sedentary controls exhibited higher levels of depressive symptoms, lower levels of positive affect and reduced levels of functioning, without reaching the clinical diagnostic cut-offs (e.g. >9 points in the BDI would indicate a mild depressive disorder). Significant difference between both groups were detected in the HAMD.

We conducted an additional sub-analysis with only those runners who finished the marathon (N = 71). Compared to the first analysis, similar results were observed, see supplementary Tables 1 (demographic data) and 2 (mood parameters).

We further analyzed the marathon group with regard to the changes of mood and affect throughout the study period (see Table 3). While all parameters were within a non-pathological range (low levels of depressive symptoms and negative affect), four parameters showed significant improvements over time. Negative affect according to PANAS-NA showed a significant effect of TIME ($p < 0.001$): levels of negative affect decreased significantly immediately after the marathon with minimal values after 24 h and were still decreased at the end of the study period compared to baseline (V1 vs V-1: $F_{(1,38)} = 12.049$, $p = 0.001$; V2.1 vs V-1: $F_{(1,38)} = 46.225$, $p < 0.001$; V2.2 vs V-1: $F_{(1,38)} = 50.336$, $p < 0.001$; V3 vs V-1: $F_{(1,38)} = 5.049$ $p = 0.031$). Level of Functioning (GAF) was significantly decreased at follow-up compared to baseline measurements (V0 vs V-1: $F_{(1,45)} = 3.913$, $p = 0.054$ (trend); V2.2 vs V-1: $F_{(1,45)} = 13.650$; $p = 0.001$; V3 vs V-1: $F_{(1,45)} = 20.866$, $p < 0.001$). VAS showed a significant effect of TIME ($p = 0.029$) with a significant improvement immediately after the marathon and returned to baseline at short-term follow-up (V1 vs V-1: $F_{(1;20)} = 4.554$, $p = 0.045$).

Table 1
Baseline characteristics of marathon group and sedentary controls.

	N (MA/SC)	MA		SC		Statistics		
						Chi^2	df	p
Demographics								
Gender (male: female)	146 (100/46)	80:20		35:11		0.288	1	0.591
Smoking (yes: no)	126 (85/41)	1:84		10:31		18.706	1	<0.001
		Mean	SD	Mean	SD	t	df	p
Age (years)	142 (96/46)	43.6	10.0	40.8	11.0	1.529	140	0.128
Education (years)	130 (88/42)	15.0	3.9	14.3	3.3	1.040	128	0.300
BMI (kg/m^2)	135 (93/42)	23.5	2.7	24.8	2.7	−2.544	133	0.012
IPAQ visit −1	132 (92/40)	7410.2	7450.4	3378.1	6526.7	2.963	130	0.004
IPAQ visit 3	55 (55/0)	4995.5	5550.4					
Finishing time (min)	71 (71/0)	236.8	37.6					
training km/week	80 (80/0)	44.6	20.5					
running min/week	72 (72/0)	281.8	131.4					
training sessions/week	78 (78/0)	3.6	1.3					
VO_2max visit −1 (mL/kg/min)	92 (92/0)	46.5	6.6					

MA (marathon group), SC (Sedentary Controls), BMI (Body Mass Index), IPAQ (International Physical Activity Questionnaire), MA Finishing time (Finishing time of Munich Marathon 2017), MA training km/week (weekly training kilometers), MA training min/week (weekly training minutes, exclusively running), MA sessions/ week (weekly running sessions), VO_2max (maximal oxygen uptake).

Table 2
Comparison of baseline mood parameters and general functioning in marathon runners and sedentary controls.

	N (MA/SC)	MA		SC		Statistics		
		mean	SD	mean	SD	t	df	p
VAS	121 (85/36)	6.6	1.7	5.8	1.8	2.323	119	0.022
OHQ	125 (87/38)	4.8	0.7	4.4	0.8	2.928	60.026	0.005
PANAS-NA	129 (90/39)	14.8	4.5	16.4	5.9	−1.524	57.587	0.133
PANAS-PA	129 (90/39)	35.7	4.9	32.7	6.6	2.546	56.777	0.014
BDI	128 (89/40)	2.9	4.1	7.1	8.4	−3.121	47.299	0.003
HAMD	133 (90/43)	2.1	3.4	2.8	3.7	−1.139	131	0.257
GAF	133 (90/43)	93.4	6.9	81.5	9.7	8.121	63.193	<0.001

MA (marathon group), SC (sedentary controls), VAS (visual analogue scale), OHQ (Oxford Happiness Questionnaire), PANAS-NA (negative affects in PANAS questionnaire), PANAS-PA (positive affects in PANAS questionnaire*),* BDI (Beck Depression Inventory), HAMD (Hamilton Depression Scale), GAF (Global Assessment of Functioning).

Table 3
Mood parameters in the course of the study period within the marathon group; VAS (visual analogue scale), OHQ (Oxford Happiness Questionnaire), PANAS_NA (negative affects in PANAS questionnaire), PANAS_PA (positive affects in PANAS questionnaire), PANAS_NAPA (combination of positive and negative affects in PANAS questionnaire). BDI (Beck Depression Inventory), HAMD (Hamilton Depression Scale), GAF (Global Assessment of Functioning).

	N	V-1		V0		V1		V2.1		V2.2		V3		Effect over time		
		Mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	mean	SD	F	df	p
VAS	21	6.66	1.30	6.49	1.11	7.47	1.30	7.07	0.97	6.63	1.19	6.48	1.35	3.066	3.386	0.029
OHQ	28	4.72	0.70	4.78	0.64	4.82	0.54	4.86	0.57	4.83	0.63	4.75	0.77	0.843	3.616	0.492
PANAS_NA	39	15.08	4.65	14.33	5.58	12.41	3.44	11.13	2.57	11.26	2.58	13.92	5.52	14.569	2.988	<0.001
PANAS_PA	39	35.70	4.86	35.13	5.77	35.18	6.00	33.95	5.07	33.51	6.45	34.44	5.73	2.133	3.375	0.092
PANAS_NAPA	39	48.26	10.55	49.46	6.10	47.59	5.66	45.08	6.01	44.77	6.81	48.36	6.50	3.299	2.246	0.036
BDI	39	3.10	4.04	3.28	4.54					2.18	3.41	2.72	5.16	2.751	2.569	0.055
HAMD	46	2.30	3.58	1.89	3.74					1.48	1.86	1.37	3.26	1.455	2.489	0.235
GAF	46	93.87	7.22	91.09	8.45					88.63	8.13	87.78	8.24	7.242	3	<0.001

4. Discussion

In our study, we evaluated different established parameters of mood, positive/negative affect and global functioning in a cohort of marathon runners and compared them to sedentary controls. As major mental disorders were a priori excluded, none of the groups reached the cut-off for the diagnosis of a depressive disorder. However, sedentary controls exhibited more depressive symptoms, less positive affect and a reduced level of general functioning compared to marathon runners.

A prior meta-analysis addressing the effects of physical exercise on depressive symptoms (mainly assessed with BDI and HAMD) revealed beneficial effects as single treatment and in combination with an antidepressant medication (Kvam et al., 2016). Our findings are correspond to these results and promote the association of physical exercise and reduced depressive symptoms. In our cohort of healthy participants, this was represented by lower values of BDI, higher levels of positive affect (PANAS-PA), higher levels of happiness (OHQ) and improved general well-being (VAS) in the marathon group. In contrast to the aforementioned results (Kvam et al., 2016), we could not find a significant difference of HAMD values. This is probably due to the low baseline severity in our clinically non-depressed cohorts.

Overall, the global level of functioning (as represented by GAF) was lower in the sedentary controls compared to marathon runners by more than 10 points. As each GAF interval corresponds to 10 points (e.g. from 51 to 60 points = moderate symptoms), this difference can be considered to be clinically relevant. Both groups had a similar educational background, similar age and were non-obese. One could speculate that a possible explanation for the observed differences in overall functioning is related to increased depressive symptoms or low levels of physical activity. As already pointed out, none of the groups reached the cut-off for the diagnosis of a depressive disorder and both groups had GAF scores above 80 points (representing only minimal symptoms). In the marathon group, GAF scores were above 90 points, which defines superior the superior functioning interval. For a preclinical setting, the GAF difference of more than 10 points (corresponding to a difference of one GAF interval (91–100 vs. 81 to 90) can be considered to be meaningful and could play an important role in the prevention of mental (and physical) diseases. It has been continuously shown that physical activity may prevent depressive symptoms (Mammen and Faulkner, 2013) and possibly a screening in the general population with a focus on slightly decreased levels of functioning and sub-depressive symptoms could help to identify reasonable candidates. For future research, it could be interesting to identify differences in distinct domains within global functioning: e.g. by applying the Social and Occupational Functioning Assessment Scale (SOFAS) to evaluate occupational deficits (Rybarczyk, 2011) or the Global Assessment of Relational Functioning Scale (GARF) (Stein et al., 2009) to evaluate relational functioning.

Our marathon runners exceeded the recommendations of 150 min/week aerobic exercise of the WHO and ACSM. Prior research indicated potential negative effects of >five training sessions/week or durations >180 min per session (Chekroud et al., 2018). Running durations of our marathon runners was in between the WHO/ACSM recommendations and these training extents (44.62 ± 20.49 training km/week, 281.80 ± 131.44 training minutes/week, 3.60 ± 1.30 running sessions/week). The beneficial effects still seem to outweigh possible negative effects of the amount of exercise in our cohort. Prior literature aimed at defining the transition range from beneficial effects to overtraining, but could not show definitive results. Recent studies suggested a longitudinal association of respiratory fitness and common mental health (Kandola et al., 2019), without defining cut-offs. One would assume – following this hypothesis – that professional athletes present fewer depressive symptoms or less mental health issues. However, the prevalence of MDD in elite athletes is similar to the prevalence in the general population (Rice et al., 2016). Based on our results, we can conclude that even higher amounts than the recommended 150 min/week of aerobic exercise can further improve overall well-being and mood parameters/affect. We could not define a possible cut-off for potential negative effects, as our participants were still below the suggested > five sessions/week and >180 min/session (Chekroud et al., 2018).

Our second analysis investigated the changes of affect over the study period with special regard to the event of marathon running. Our study had the aim to investigate whether the exhaustive participation in a marathon would further improve negative affect or whether the opposite impact in terms decreased levels of positive affect would be the consequence. The levels of negative affect (PANAS-NA) were decreased (minimum at 24 h after the marathon) and remained decreased until the last follow-up visit (compared to baseline measurements). Prior research mainly displayed euphoric mood states and not reduced levels of negative affect after long-distance running (measured with visual analogue scales for different mood items: for sadness, for happiness, for fear, for tension, for fatigue, for euphoria). Increased values for euphoria and happiness after a 2-h running period were described as "runner's high" (Boecker et al., 2008). In our study, the values for happiness and positive affect remained unchanged throughout the study period. But levels of negative affect significantly decreased immediately after the marathon and during short-term follow-up. We did not specifically ask the participants about running-related euphoria or "runner's high" in the past. Still, our results suggest that reduced levels of negative affect more than increased levels of positive affect could arise after long distance running.

Interestingly, global functioning decreased over time, but still remained on a high level as expected for healthy participants. However, one could speculate that our marathon runners were exhausted due to the training, the marathon and during the recovery period and that this was mirrored by subtle deficits in functioning despite improvements in negative affect and overall well-being (as displayed by VAS). Another explanation could be the lower overall activity levels at the end of the study period compared to baseline measurements, as represented by lower IPAQ scores at the last visit.

4.1. Limitations

Some limitations need to be considered when interpreting our data. First, some of the within-subject contrast findings (VAS at V1 vs. V-1; PANAS-NA at V3 vs. V.1) would not survive a correction for multiple comparisons and these results must be considered as exploratory. Second, due to the nature of BDI and HAMD, a floor/ceiling effect must be presumed in healthy participants. Thus, an improvement in these parameters as shown for PANAS-NA was a priori unlikely. However, BDI and HAMD were suitable to differentiate between sedentary controls and marathon runners. Third, sedentary controls were more likely to smoke than marathon runners. The relationship between smoking and depressive symptoms is still discussed, with various possible interactions (Fluharty et al., 2017). In other parameters with an established impact on the development depressive symptoms, like education levels, gender distribution or age, no group differences were detected. Fourth, we did not evaluate plasma levels of vitamins, so interaction of vitamin intake via food consumption with mood/affect could not be analyzed and remain to be elucidated in future studies. Still, we asked the participants to maintain their dietary habits and not to consume dietary supplements throughout the study period. Fifth, our mood and affect questionnaires were administered only once per visit. Thus, we may have missed fluctuations in shorter time frames (e.g. fluctuations during single days, especially present in affect). Future studies should therefore apply repeated real-time assessments (Reichert et al., 2017) using e.g. the participants mobile phones or other smart devices.

4.2. Conclusive outcome and perspective

In our study, amateur marathon runners showed higher levels of positive affect, less depressive symptoms and higher scores of global functioning compared to matched sedentary controls. Within the marathon group, levels of negative affect further decreased throughout the study period (and not only immediately after the marathon event with possible effects of a "runner's high"). To the best of our knowledge, there is no study on prevalence rates of MDD in marathon runners, but according to our results, one could speculate that marathon runners may have a lower risk to develop MDD. The higher scores in general functioning in the marathon group could possibly indicate more successful careers or more harmonic relationships. Future studies could differentiate this finding with the more specific ratings (e.g. SOFAS and GARF).

Endurance training in prior research and in our study showed a beneficial, possibly even antidepressive effects without significant negative side-effects (in the absence of contra-indications for exercise). This resource should be more implemented in the everyday therapies for MDD. We could show that not only the recommended 150 min/week aerobic exercise, but even higher training amounts (and the marathon event itself) had positive effects on different mood/affect parameters. Analogous to cardiac rehabilitation groups after cardiac events, patients with MDD should be offered supervised aerobic exercise groups as integral part of multi-modal therapy. Screening tools for subdepressive symptoms in the general population (e.g. GAF scores and PANAS, BDI and VAS) could identify particularly suitable candidates for exercise programs and PANAS, GAF and VAS seem suitable for follow-up measurements even in healthy participants.

Role of funding

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

Contributors

AR, AH, JS, MH and PF wrote the study protocol. AR and BH undertook the statistical analysis. ML, BP, IP, MaxH and JuS performed the analyses during the study period. AR and AH wrote the first draft of the manuscript. All authors revised the manuscript critically and have approved the final manuscript.

Declaration of competing interest

The authors report no conflict of interest related to the outcomes of this study.

Acknowledgements

We thank all participants of the trial and the whole ReCaP study group.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpsychires.2020.08.005.

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