Exercise addiction measured at a naturalistic marathon-event – associations of the EAI with the general level of functioning, affect and performance parameters

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ABSTRACT

Endurance sports carry a high risk of exercise addiction (EA) compared to other physical activities. Previous research has established a link between EA and depressive symptoms. The aim of this study was to evaluate a sample of amateur marathoners concerning risk of EA and investigate the relationship to fitness measures, affect and the general level of functioning. We included 72 (19.4% female) marathon runners. The Exercise Addiction Inventory (EAI), the global assessment of functioning (GAF), the international physical activity questionnaire (IPAQ), the Beck-Depression Inventory (BDI) and the Positive and Negative Affect Schedule (PANAS) were assessed alongside demographic measures, maximum oxygen uptake (cardio pulmonary exercise test), BMI and training volume. In this sample five individuals at-risk could be identified (6.94%). No significant associations were found regarding demographics and EA. Higher values of EA were associated with a reduced level of general functioning ($r = -.35$; $p = .003$), higher values of depressive symptoms ($r = .36$; $p = .003$) and negative affect ($r = .27$; $p = .022$) while no increased training volume or higher performance were observed. A regression analysis identified the IPAQ as predictor for risk of EA (PANAS-NA marginally significant). Marathon running at the amateur level showed a lower risk of developing an exercise addiction than expected. Important associations of EA could be identified in our study (IPAQ, PANAS-NA, GAF, BDI).

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1. Introduction

Physical activity plays a key role in maintaining and building physical and mental health (World Health Organization, 2020). However, excessive levels of physical activity, described as "Exercise Addiction" (EA), can lead to harmful consequences. EA is characterised by showing excessive exercise behaviour despite exceeding personal limits (e.g., injury, marital strain, interference with work, lack of time for other activities) to regulate emerging states of depression, irritability, and agitation (Anshel, 1991; Landolfi, 2013; Lichtenstein et al., 2018).

EA is frequently defined based on the criteria for behavioural addictions and substance abuse in the DSM-5 (American Psychiatric Association, 2013) or the "components model of addiction" (Griffiths, 2005). There is a large overlap between the two conceptualizations.

According to the components model, respective symptom domains include salience (constantly thinking of exercising), mood modification (training is used to regulate emotions), conflict in (personal) relationships and with interests/work, symptoms of withdrawal (e.g., irritation, bad mood), tolerance (more is needed to achieve the desired effect) and relapse (after reduction there is a quick return to the previous extent).

Estimates of the prevalence of EA strongly depend on the measurement, the population and the type of sport. The Exercise Addiction Inventory (EAI, based on the "components model") has often been used to estimate the risk of developing EA in populations of endurance sports (cycling, ultra-marathoners, triathletes, long-distance runners; Di Lodovico et al., 2019) with good psychometric properties (e.g., Szabo et al., 2013). A systematic review ($N = 16244$; Di Lodovico et al., 2019) reports the proportion of people at risk for developing EA (measured with the EAI) among endurance athletes the highest (14.2%), followed by mixed disciplines (10.4%), fitness centre attendees (8.2%) and power disciplines (6.4%), while a proportion of 3% is estimated being at risk in the general population.

Several models to describe the development of exercise addiction are available. In the following, we describe briefly the pathways to exercise addiction based on the "interactional model" (for a detailed description, see Dinardi et al., 2021; Egorov & Szabo, 2013). This model incorporates the antecedents of sport/exercise participation, situational factors, and subjective life events and provides explanation approaches for progressive and spontaneous onsets of EA.

According to this model, personal factors, situational factors, life-stress and exercise-related stressors are involved in the development of an EA. The personal factors consist of the relationship to and experiences with exercise (e.g., childhood experiences, Lukács et al., 2019), self-concept (e.g., athlete, de la Vega et al., 2016), personality (e.g., narcissism, Bruno et al., 2014), interests, abilities and regulatory resources (Bernstein & McNally, 2017; Goodwin et al., 2014). Situational factors describe the framework of the type of exercise: alone or in a group (Szabo et al., 2013), social aspects, values, accessibility and alternatives. The link between these characteristics and the exercise are the incentives (e.g., health, performance, enjoyment): the model discriminates between a therapeutic orientation and a mastery orientation to exercise. Stressors in forms of sudden or progressive life-stress and exercise-related stressors (e.g., performance anxiety, failure to meet expectations) are further parts of the model. Several pathways lead to exercise addiction: (I) through the interplay of personal factors & situational factors, (II) through a therapeutic orientation, and (III) through a mastery orientation (directly or via exercise related stressors).

Complementing the description of the model, there are variables that show a connection to EA. In general, male sex (Dumitru et al., 2018) and younger age (Bruno et al., 2014; Costa et al., 2013; Nogueira et al., 2019; Zeulner et al., 2016) are independent risk factors for developing EA. The number of training hours are associated with higher EA scores (Gonzalez Hernandez et al., 2019; Lukács et al., 2019). However, high volumes of exercise are not an appropriate criteria for predicting exercise addiction for all populations, and the results are sometimes contradictory. Thus, the concept of a threshold for training volume was introduced. Above a certain mandatory volume, training volume might not be associated with EA (Mayolas-Pi et al., 2017). Especially in the field of professional athletes, false positive diagnoses can occur, as the items of questionnaires (e.g., on training volume) can hardly discriminate in this population and can be misunderstood and misinterpreted (Szabo et al., 2015).

The most used questionnaires differentiate between asymptomatic individuals, symptomatic individuals and at-risk individuals (e.g., EDS, Hausenblas & Downs, 2002; EAI, Terry et al., 2004). To date, there is no questionnaire that can be used to diagnose exercise addiction, as this condition is not yet established as a diagnosis. In the at-risk population negative consequences on mental health are well documented (depression (Levit et al., 2018; Weinstein et al., 2015), anxiety (Lukács et al., 2019; Mayolas-Pi et al., 2017), quality of life (Mayolas-Pi et al., 2017)). However, in at-risk individuals, there are no established adverse consequences related to physical health or performance measures (e.g., due to overtraining). The available evidence indicates that at-risk individuals show better performance and no negative physical consequences (Bueno-Antequera et al., 2020; Mayolas-Pi et al., 2017). So far, the data on performance and EA is scarce. Only in rare cases are objective criteria such as maximum oxygen uptake capacity taken into account.

In the present study, we evaluated a population of amateur marathon runners, who participated in a local marathon event. Since endurance sports are suspected to have a high risk for the development of exercise addiction, we aimed to investigate how high this risk is in mainstream endurance sports. In the population of amateur marathoners, we expected a high variability of training volume and a significant positive association of EA with training volume.

To the best of our knowledge no data of the EAI in endurance athletes in combination with the general level of functioning or the maximum oxygen uptake capacity ($\dot{V}O_2max$) is available. Based on prior literature (Egorov & Szabo, 2013; Freimuth et al., 2011; Weinstein & Weinstein, 2014), we expected a reduced general level of functioning in at-risk individuals in our cohort. Mental health seems to be negatively related to exercise addiction (Levit et al., 2018; Lukács et al., 2019; Mayolas-Pi et al., 2017; Weinstein et al., 2015).

Furthermore, we expected higher fitness scores in the at-risk group (Bueno-Antequera et al., 2020; Mayolas-Pi et al., 2017). As described above, there are no studies that show negative effects on physical performance in at-risk individuals. Negative effects of EA on physical performance and other negative physical effects are only known from case studies, in people who present the full picture of the disease (e.g., all criteria according to the components model are fulfilled, Griffiths, 1997). Individuals at-risk, who complete self-rating questionnaires even showed better fitness parameters (Bueno-Antequera et al., 2020; Mayolas-Pi et al., 2017). This should be reflected in shorter marathon times and increased oxygen uptake capacity ($\dot{V}O_2max$).

2. 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 presented sample is part of this trial and the sample size calculations are based on the primary outcome of the above-mentioned trial, not the EAI. Therefore, this analysis is exploratory. The study protocol was previously published (Roeh et al., 2020).

The inclusion criteria for the marathon group contained an age range between 18 and 60 years and successful registration for Munich Marathon 2017 and prior participation in at least one half-marathon, sufficient knowledge of German language, and written informed consent. Participants reporting relevant neurological, cardiovascular, or psychiatric disease, pregnancy, or cannabis abuse were excluded. Study physicians verified inclusion and exclusion criteria by a personal interview supplemented by a demographic questionnaire. Marathon runners were recruited through announcements in local newspapers, running groups, and the Munich Marathon 2017 newsletter. Participants were recruited between May and August 2017.

2.1. Measurements

The International Physical Activity Questionnaire (IPAQ) was used to obtain detailed information about daily activities (e.g., usage of the bicycle for work) and physical exercise (Craig et al., 2003). We measured endurance capacity as an indicator of the endurance performance with a cardio pulmonary exercise test (CPET, maximal oxygen uptake $\dot{V}O_2max$ (millilitres of oxygen used in 1 min per kilogram of body weight ($mL*kg^{-1}*min^{-1}$))) on a treadmill. The participants filled out training protocols with training kilometres per week. EA was measured using the German translation of the "Exercise Addiction Inventory" (Ziemainz et al., 2013), a self-rating questionnaire consisting of 6 items with a cut-off value of 24 and higher (EAI, Terry et al., 2004) for being at risk of EA. Using the self-rating scale Beck Depression Inventory (BDI-II) (Hautzinger et al., 2009), we assessed depressive symptoms. We administered the Positive and Negative Affect Schedule (PANAS; PANAS-NA for negative affect, PANAS-PA for positive affect) for affective states (Krohne et al., 1996). Furthermore, the Global Assessment of Functioning (GAF) was applied to rate different dimensions of individual functioning (Endicott et al., 1976; Goldman et al., 1992).

2.2. Procedures

All measurements including CPET (cardio pulmonary exercise test) were done with individual appointments on the premises of the Technical University of Munich at the Clinic for Prevention and Sports Medicine. Trained staff from the Department of Psychiatry and Psychotherapy at the Ludwigs-Maximilians-University of Munich (psychologists or physicians) administered the psychological clinician ratings (GAF; on a scale of 1–100).

Both state (e.g., PANAS) and trait (e.g., EAI) measures are part of the trial. The assessment of all questionnaires and the CPET (cardio pulmonary exercise test) was conducted 10–12 weeks prior to the marathon event during the training period in order to minimise the risk of distortion due to acute effects before or after the marathon (Szabo & Ábel, 2021). The participants filled out training protocols. These protocols documented the training kilometres per week.

2.3. Ethics and registration

The study protocol complied with Good Clinical Practice guidelines, Declaration of Helsinki guidelines, and local laws and regulations. Both, the ethics committees of the Ludwig-Maximilians University Munich (approval reference number 17-148) and the Technical University of Munich (approval reference number 218/17 S) approved the study procedure. The study was registered in the "German Clinical Trials Register" at https://www.drks.de/ (DRKS-ID: DRKS00012496).

2.4. Statistical analysis

SPSS statistics Version 25 (IBM, Armonk, NY, USA, 2017) was used to perform the statistical analysis. A significance level of $\alpha = 0.05$ was used. Quantitative data are described by mean and standard deviation, for categorical variables absolute and relative frequencies are presented (Table 1).

The two groups "High Risk of Exercise Addiction" (HREA) and "Low Risk of Exercise Addiction" (LREA) were created using the cut off score of equal to or higher than 24 according to available literature (Terry et al., 2004). For comparison of categorical data (sex and smoking status) Fisher's exact tests were performed. Mann–Whitney U-Tests were used to compare distributions of continuous data across groups. Effect size of the U-Tests was calculated based on the AUC of the ROC curves with 95% confidence intervals provided (Table 1).

In addition, Spearman correlations were calculated (Table 2) to detect differences that are not dependent on the cut-off for at-risk individuals. For the variables $\dot{V}O_2$max and finishing time the calculations were corrected for sex since we assume that the subjects perform differently due to their sex; the sample was separated in two groups. Group differences that are not taken into account can distort correlations, and can produce or neutralise associations.

After checking the normal distribution of the residuals, heteroscedasticity, and multicollinearity, a regression analysis was computed to determine the extent to which the statistically significant correlations can predict the risk of EA (Table 3).

3. Results

The EAI was completed by 72 of the 100 marathon runners. Table 1 presents the baseline demographic data. The sample consisted of 14 (19.4%) women and 58 (80.6%) men. Across all included participants EA was on average 18.83 (± 3.3). Descriptive analysis revealed 6.94% (95% CI [3–15,25%], $n = 5$) of 72 subjects to be at risk of EA (score equal to or above 24 on the EAI). We defined two groups using the at-risk cut-off and labelled

Table 1. Baseline characteristics of marathon runners at high risk (HR) and low risk (LR) of EA.

	N (LR/ HR)	Low Risk		High Risk		Statistics			
Demographics						Phi			*p*
Gender (male : female)	72 (67 / 5)	54 : 13		4 : 1		−.004			1.000
Smoking (yes : no)	69 (64 / 5)	1 : 63		0 : 5		.034			1.000
		M	SD	M	SD	*U*	*Z*	AUC 95%CI [lower – upper]	*p*
Age (years)	72 (67 / 5)	42.33	9.91	47.20	9.20	121.50	−1.020	.637 [.398–.876]	.318
Education (years)	67 (63 / 4)	11.98	1.26	11.50	2.65	98.00	−.788	.611 [.231–.991]	.482
BMI (kg/m^2)	72 (67 / 5)	23.17	2.62	24.48	1.21	105.00	−1.385	.687 [.549–.825]	.175
IPAQ	71 (66 / 5)	6458.64	5497.77	9345.60	5378.84	113.00	−1.169	.658 [.358–.957]	.256
Training km/week	66 (61 /5)	44.09	20.76	42.00	19.24	146.50	−.146	.520 [.277–.762]	.888
Finishing time (min) F	12 (11 / 1)**	247.63	38.24	341.35	–	–	–	–	–
Finishing time (min) M	47 (44 / 3)	231.92	32.20	233.01	33.84	66.00	.000	.500 [.161–.839]	1.000
Finishing time (min) Total	59 (55 / 4)	235.06	33.71	260.10	60.81	89.00	−.633	.595 [.253–.938]	.550
$\dot{V}O_2$max (mL/kg/ min) F	14 (13 / 1)	44.34	5.20	25.4	–	–	–	–	–
$\dot{V}O_2$max (mL/kg/ min) M	57 (53 / 4)	48.45	6.37	47.33	5.91	101.00	−.156	.524 [.247–.800]	.892
$\dot{V}O_2$max (mL/kg/ min) Total	71 (66 / 5)	47.62	6.34	42.94	11.06	137.00	−.629	.585 [.298–.872]	.548
BDI	70 (65 / 5)	2.51	3.47	7.00	6.04	73.00	−2.088	.775 [.591–.960]	.040*
GAF	72 (67 / 5)	94.43	6.71	90.20	5.72	86.00	−1.867	.743 [.591–.896]	.072
PANAS-NA	70 (65 / 5)	13.97	3.47	19.20	6.83	64.50	−2.251	.802 [.652–.951]	.022*
PANAS-PA	70 (65 / 5)	35.97	4.74	35.60	5.64	156.50	−.137	.518 [.225–.812]	.895

Note: EA (Exercise Addiction), BMI (Body-Mass-Index), IPAQ (International Physical Activity Questionnaire), Finishing time (Finishing time of Munich Marathon 2017, separated in Female (F) and Male (M)), training km/week (weekly training kilometres), $\dot{V}O_2$max (maximal oxygen uptake, separated in female (F) and male (M)), BDI (Beck-Depression-Interview), GAF (Global Assessment of Functioning), PANAS (Positive and Negative Affect Schedule); *p-value < .05; ** calculation not possible, since $n = 1$.

them LREA (“low risk of exercise addiction” < 24) and HREA (“high risk of exercise addiction” ≥24).

Comparisons between groups revealed significant differences. First, the HREA group (*Mdn* = 15) scored significantly higher on negative affect (PANAS) than the LREA (*Mdn* = 13), $U = 64.5$, $Z = -2.251$, $p = .022$. Second, the HREA (*Mdn* = 4.0) showed significantly higher scores for depressive symptoms (still in the subclinical range) (BDI) than the LREA (*Mdn* = 1.0), $U = 73.0$, $Z = -2.088$, $p = .040$. All other variables did not show any group differences.

Correlation analyses underlined the above-mentioned group differences. See Table 2 for detailed results. EA correlated positively with depressive symptoms, r (68) = .36, p

Table 2. Spearman-correlations with EAI.

		r	*p*	*N*
1	EAI x Education (years)	.00	.993	67
2	EAI x Training km/week	−.05	.714	66
3	EAI x BMI	−.07	.546	72
4	EAI x IPAQ	.27	.021*	71
5	EAI x $\dot{V}O_2max$ (F)	−.47	.090†	14
6	EAI x $\dot{V}O_2max$ (M)	−.02	.899	57
7	EAI x $\dot{V}O_2max$ (Total)	−.12	.337	71
8	EAI x Finishing time (min., F)	.12	.715	12
9	EAI x Finishing time (min., M)	.00	.991	47
10	EAI x Finishing time (min, Total)	.07	.597	59
11	EAI x BDI	.36*	.003**	70
12	EAI x GAF	−.35*	.003**	72
13	EAI x PANAS-NA	.27*	.022*	70

Note: BMI (Body-Mass-Index), IPAQ (International Physical Activity Questionnaire), training km/week (weekly training kilometres), $\dot{V}O_2max$ (maximal oxygen uptake), F (Female), M (Male) Finishing time (Finishing time of Munich Marathon 2017), BDI (Beck-Depression-Interview), GAF (Global Assessment of Functioning), PANAS (Positive and Negative Affect Schedule); †*p*-value < .10; **p*-value < 0.05; ***p*-value < 0.005.

Table 3. Regression analysis, dependant variable: EAI.

	β	SE	*t*	*p*
(Constant)	–	7.24	2.946	.004**
IPAQ	.24	.00	2.181	.033*
BDI	.11	.13	.701	.486
GAF	−.14	.07	−1.004	.319
PANAS-NA	.25	.11	1.854	.068†

Note: $F(4,64) = 5.23$, $p = .001$, $R = .50$, $R^2 = .25$, $R^2_{adjust} = .20$, $N = 68$, IPAQ (International Physical Activity Questionnaire), BDI (Beck-Depression-Interview), GAF (Global Assessment of Functioning), PANAS (Positive and Negative Affect Schedule); †*p*-value < .10; **p*-value < 0.05; ***p*-value < 0.005.

= .003; and with the level of negative affect, *r* (68) = .27, *p* = .022. The IPAQ showed a positive correlation with EA, *r* (69) = .27, *p* = .022. In addition, EA correlated negatively with the level of general functioning (GAF), *r* (70) = −.33, *p* = .004. There were no significant correlations of EA with training parameters (km/week) or performance level ($\dot{V}O_2max$, finishing time). However, we identified a trend for a negative association of EA and $\dot{V}O_2max$ in the female sample, *r* (12) = −.47, *p* = .090.

A multiple linear regression was computed to predict EA. We included the significant associations of EA in one block to the analysis as predictors (IPAQ, GAF, BDI, PANAS-NA). The results of the regression indicated that the model explained a significant part of the variance and was a significant predictor of EA, $F(4,64) = 5.23$, $p = .001$, $R^2 = .25$, $R^2_{corrected} = .20$. The IPAQ contributed significantly to the model. There was a trend toward prediction of EA by PANAS-NA ($p = .068$). The predictors GAF and BDI could not explain a significant proportion of the variance. See Table 3 for the results in detail.

4. Discussion

This is the first study to examine the risk of EA in amateur marathon runners in combination with maximum oxygen uptake capacity, the affect and the general level of functioning. Our study was conducted in the context of a naturalistic marathon event. We identified 5 of 72 marathoners (6.94%, 95%CI [3–15,25%]) at-risk for EA. The results suggested that exercise addiction is negatively associated with the general level of functioning. Positive associations indicated a positive relationship of EA with depression and negative affect. Contrary to our expectations, we could not identify a correlation between EA and fitness measures or training volume. Nevertheless, there was evidence of an association with physical activity in general (IPAQ). A regression analysis identified the IPAQ as a significant predictor of EA.

The analysis of group differences was constrained by the fact that there was only a small group of at-risk individuals in the sample. Since behavioural (including exercise) and substance addictions occur on a continuum, linear associations can be examined (McMurran, 1994). Therefore, we also performed correlations, as they may be superior to calculations of group differences based on cut-offs concerning this sample.

High scores of EA were associated with higher levels in negative affect and depression as well as a lower general functioning. It remains elusive whether the depressive symptoms and the negative affect fuelled addictive behaviours in athletes or whether these phenomena were symptoms of EA. The association of EA with depressive symptoms is in line with previous literature (Buck et al., 2018; Levit et al., 2018; Lukács et al., 2019; Weinstein et al., 2015). The lower scores of the general level of functioning could be a consequence of the higher depression scores as well as more frequent negative affective states.

In the applied regression model, negative affect, depression, and general level of functioning did not predict EA; only the general physical activity (IPAQ) was a significant predictor. Our results indicated that in some samples the general physical activity could be a better indicator for EA than training volume. This may be especially relevant for populations with a high mandatory or scheduled exercise such as professional athletes (Mayolas-Pi et al., 2017). The high scores of physical activity in everyday life could reflect a general urge to be physically active, which could be related to EA. The association of EA and general physical activity is in line with literature (Bueno-Antequera et al., 2020). Future research should address the interplay of the variables BDI, PANAS-NA and the general level of functioning in the context of EA. These factors address somewhat similar proportions of variance in theory and thus might not show significant results in the regression model.

In terms of the interactional model (Dinardi et al., 2021; Egorov & Szabo, 2013), several paths are possible that could explain the associations of depression symptoms as well as negative affect with EA and provide thought-provoking ideas for further investigation. An important question is whether the individual is currently experiencing significant life stress. The life stress itself could be primarily responsible for frequent negative affect and depression symptoms. Personal factors could cause a narrowing to exercise behaviour as a regulatory strategy (therapeutic orientation) if few alternatives are available to deal with negative feelings or self-states. Physical activity can be used to regulate emotions and compensate regulatory deficits (Bernstein & McNally, 2017; Goodwin et al., 2014).

Alternatively, the dynamics of addiction could explain the changes of negative affect and depression in symptomatic and in at-risk individuals. The (lack of) exercise behaviour could already trigger negative emotions (irritation) and self-states (restlessness, rumination) due to withdrawal symptoms. The emotional pressure to exercise may already have an impact on personal life and work. Here, the exercise behaviour itself is the stressor to which the response might be more exercising. Which mechanism is more prominent could represent different stages (Freimuth et al., 2011) or forms of EA. In most cases probably both are present to some extent.

In terms of EA and performance parameters, we expected at-risk individuals to have better marathon performance and fitness scores, but our results did not confirm this hypothesis. EA was not related to higher training volume or fitness measures. At-risk indoor cyclists show better cardiorespiratory fitness and muscular strength (Bueno-Antequera et al., 2020), measured with a self-report questionnaire (IFIS). No measurable negative effects on physical health or performance in individuals at risk have been reported in the literature. In contrast, our data (measured with a cardio pulmonary exercise test) suggest negative effects on fitness in the risk group. Specifically, for determining cardiorespiratory fitness, a performance assessment is superior to a self-report questionnaire. The women in our sample showed a negative trend of maximum oxygen uptake capacity with higher EA-scores. This is worth mentioning, because it represents the strongest association in the correlation table, $r = -.47$, $p = .090$. Healthy athletes showing symptoms of EA could develop inefficient training routines (e.g., short rest periods, overtraining, etc.). Long-term effects of a fully developed EA should result in a diminished performance, as phenomena like overtraining could be present causing negative effects on physical health. No prior study performed correlations of EA with $\dot{V}O_2max$. Therefore, we cannot compare our results with previous publications and future studies should focus on this observation to validate the results.

We identified 5 of 72 marathoners (6.94%, 95% CI [3–15,25%]) at risk for EA. The prevalence of EA varies across prior studies due to measurements and populations. Compared to the results of other studies investigating endurance sports with the EAI, this value seems a little low (Di Lodovico et al., 2019). However, many samples with higher prevalence included practitioners of extreme sports that are even more training-intensive than marathon-running: Ultramarathoners (17%, Szabo et al., 2013; 18.2%, Buck et al., 2018) and triathletes (20%, Youngman & Simpson, 2014). Nevertheless, the prevalence in our sample is still lower compared to recreational runners (12,5%; no marathon runners) (Di Lodovico et al., 2018). Only one study displayed lower results in a sample consisting of participants of German supra-regional running-, triathlon- and cycling- events (2.7%, Zeulner et al., 2016). They did not find a difference in the prevalence of EA in the comparison of amateur and professional athletes.

A possible explanation for the rather small number of HREA is the different composition in our sample compared to study populations with higher prevalence of EA (Buck et al., 2018; Di Lodovico et al., 2018; Szabo et al., 2013; Youngman & Simpson, 2014). First, the examined populations were younger, ranging from $age = 27.5 \pm 10.7$ to 38.4 ± 8.9 versus 42.7 ± 9 years in the present sample. Younger individuals have a higher risk to develop EA (Bruno et al., 2014; Costa et al., 2013; Nogueira et al., 2019; Zeulner et al., 2016). There may be a maturation process (Nogueira et al., 2019) that facilitates self-regulatory capabilities. For example, older individuals are better able to maintain a balanced mood: They can recover more quickly after a negative event (Kliegel et al., 2007). Second, in the mentioned studies the proportion of women is considerably higher ranging from 32.2% to 53.7% (Buck et al., 2018; Di Lodovico et al., 2018; Szabo et al., 2013; Youngman & Simpson, 2014) compared to 19.4% in our sample. However, this difference probably did not affect the prevalence of individuals at risk, as the results on sex differences in endurance sports are inconclusive (Dumitru et al., 2018; Nogueira et al., 2018).

In the present study, the EAI has proven to be a quick and efficient screening tool. Nevertheless, there is a lack of clarity about the phenomenon of exercise addiction. A recent systematic review (Colledge et al., 2020) of qualitative studies and case reports concludes that a behavioural disorder "exercise addiction" exists and a diagnosis could be created in terms of the clinical classification systems. Although the common tools (EAI, EDS) measure the risk of developing exercise addiction, the results are treated as prevalence. There is a difference between a risk assessment and clear symptoms that lead to a diagnosis. In this course, the development of a reliable measurement tool is essential to further examine the mechanisms of exercise addiction.

The following limitations are to be reported. First, a new scoring system for the EAI has been recently developed that improved the psychometric properties of the questionnaire. Response categories have been expanded from 5 to 6, eliminating the option to give a middle answer (Szabo et al., 2019). In our study the version with a 5-point Likert-scale was used, in line with prior research. A weakness of EAI may be its inability to distinguish between mandatory high volume of training (extreme sports, professional athletes) and symptoms of EA, leading to false positive cases. Second, there was no a-priori sample size calculation as this survey is embedded in a larger research project and the EAI was not a primary endpoint of this project. Third, no control group was considered in this analysis. Finally, the results should be interpreted with awareness of a relatively small sample size. Nonetheless, the here presented data is scarce.

5. Conclusion

This is the first study to apply the EAI in a sample of amateur marathon runners in combination with maximum oxygen uptake capacity as well as the general level of functioning. Although the prevalence of at-risk individuals was lower compared to other studies examining endurance athletes (Buck et al., 2018; Di Lodovico et al., 2018; Szabo et al., 2013; Youngman & Simpson, 2014), correlations replicated the previously established associations of EA with depressive symptoms (Buck et al., 2018; Levit et al., 2018; Lukács et al., 2019; Weinstein et al., 2015) and negative affect. In this sample, there was no evidence that risk for EA was positively related to objective fitness parameters (maximal oxygen uptake capacity, finishing time). Furthermore, results suggested that EA is associated with lower levels of general functioning. In a regression model the overall physical activity was a significant predictor of EA. In certain populations the overall physical activity could be a better discriminator than training volume. Future studies should further investigate the possible mechanisms of EA: Moderators (emotion regulation, personality, stress) could distinguish between different stages or forms of EA and identify important factors for specific sub-groups.

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Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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