Obsessive healthy eating and orthorexic eating tendencies in sport and exercise contexts: A systematic review and meta-analysis

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REVIEW ARTICLE

ABSTRACT

Background: Orthorexia Nervosa (ON) and exercise addiction (ExAdd) are two phenomena believed to overlap. We conducted a meta-analysis exploring the link between ON and (addictive) exercise behaviors. *Methods:* A systematic review of major databases and gray literature was carried out for studies reporting on ON and (addictive) exercise behaviors. Random effects meta-analyses were undertaken calculating correlations between ON and (addictive) exercise behaviors. A sub-group analysis investigated gender differences. *Results:* Twenty-five studies with 10,134 participants (mean age = 25.21; 56.4% female) were included. Analyses showed a small overall correlation between ON and exercise (21 studies, $r = 0.12$, 95% CI |0.06–0.18|) and a medium overall correlation between ON and ExAdd (7 studies, $r = 0.29$, 95% CI |0.13–0.45|). Gender differences were negligible. *Conclusions:* Orthorexic eating correlated slightly and moderately with exercise and ExAdd, respectively, expressing some unique and shared variance of these behaviors. While this does not suggest ON and addictive exercising to be independent, it does not indicate substantial comorbidity. Future research should focus on clinical relevance, underlying mechanisms, vulnerability, and risk factors.

INTRODUCTION

There is much empirical evidence for the beneficial effects of exercising regularly and maintaining a healthy diet on physical and mental health (GBD 2017 Diet Collaborators, 2019; Warburton, Nicol, & Bredin, 2006). However, both behaviors also bear the risk when pursued obsessively and become the focus of life. Healthism, a lifestyle that prioritizes health and fitness over anything else, shapes beliefs about how to achieve the 'healthiest health'; and eating healthy and keeping fit are seen as the most important means (Håman, Barker-Ruchti, Patriksson, & Lindgren, 2015; Kirk & Colquhoun, 1989; Wright, O'Flynn, & Macdonald, 2006). Excessive exercise and pathological eating behaviors often go hand in hand with idealized body images and disturbed bodily perceptions contributing to both behaviors and its shared features (Gardner, 2001).

In terms of exercise addiction (ExAdd) or exercise dependence, proposed criteria reflect the components of behavioral addiction (Griffiths, 1996) and the criteria for substance use disorders listed in the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; APA, 2013): salience, mood modification, tolerance, withdrawal symptoms, conflict, and relapse. ExAdd is not listed as a disorder in current classification systems but has been proposed to be classified in the addictions and related disorders section as a non-substance behavioral addiction (Cook, Hausenblas, & Freimuth, 2014). Future research, however, will require clear

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criteria to differentiate exercise as a healthy habit from ExAdd (Freimuth, 2008). Prevalence estimates were shown to be low in the general population (<1%) but higher among regular exercisers and athletes (3–6%), and up to 20% in elite endurance athletes. Generally, men are more often affected than women (Dumitru, Dumitru, & Maher, 2018). More interestingly, ExAdd, and eating disorders frequently co-occur with comorbidity rates of 40–50% (Freimuth, Moniz, & Kim, 2011). In a current meta-analysis, Trott et al. (2020) reported that people diagnosed with an eating disorder are over three times more likely to be at risk of ExAdd. One possible reason might be that excessive exercise is a strategy to compensate for a subjectively excessive calorie intake in several eating disorders.

Recently, new eating patterns have received much media and scientific interest, including the interest in eating healthy, termed healthy orthorexia, or the pathological form of an unhealthy obsession with eating healthy, Orthorexia Nervosa (ON) (Strahler & Stark, 2020). Depending on the instrument employed, prevalence estimates vary widely. While health-oriented eating patterns are becoming more common, ON prevalence estimates of 1–3% are considered most likely and valid (McComb & Mills, 2019; Strahler & Stark, 2019). The current assumption is that the obsession with healthy nutrition has two subcomponents, a healthy part and the pathological obsession with healthy eating, which is called Orthorexia Nervosa (Barthels, Barrada, & Roncero, 2019). Research on predictors of orthorexic eating indicated that overweight preoccupation, appearance orientation, and physical appearance motivation might be essential drivers of ON (Barnes & Caltabiano, 2017). In addition, groups like health professionals, dieticians, medical doctors, yoga practitioners, or people practicing sports show comparably high levels of orthorexic eating and are thus considered populations at risk of developing ON (Asil & Sürücüoğlu, 2015; Bo et al., 2014; Malmborg, Bremander, Olsson, & Bergman, 2017; Valera, Ruiz, Valdespino, & Visioli, 2014). Therefore, it is not surprising that the pathological obsession with healthy eating and excessive and compulsive exercising is assumed to be closely related. Some authors suggest that it is the same lifestyle phenomenon (Håman et al., 2015, Håman, Lindgren, & Prell, 2017) or that excessive exercise always occurs together with an eating disorder (Mond, Hay, Rodgers, Owen, & Beumont, 2004). Whether there is an overlap between orthorexic eating and ExAdd or exercise dependence is mostly unexplored and like ExAdd, ON is not listed as a disorder in current classification systems. Indeed, subjects with ON tend to exercise more frequently than the average population (Eriksson, Baigi, Marklund, & Lindgren, 2008; Segura-García et al., 2012; Varga, Thege, Dukay-Szabó, Túry, & van Furth, 2014). Only a few studies investigated the relation between ExAdd using validated tools to quantify the various forms of problematic exercise and orthorexic eating tendencies. Correlations were of small to moderate degree (e.g., $r = 0.14$ in Freire et al., 2020; $r = 0.52$ in White, Berry, & Rodgers, 2020). Another study (Rudolph, 2018) employed the Exercise Addiction Inventory (EAI) and the Duesseldorf Orthorexia Scale

(DOS) among German fitness club members. Analyses showed that 2.3% of individuals showed both risky levels of ExAdd and ON. In compliance with the other reports, EAI and DOS correlated to a moderate extent.

Despite the emerging scientific evidence and the comprehensible theoretical discussion, it is still mostly unclear to what extent sport and exercise play a role in Orthorexia. Current assumptions vary from considering regular exercisers and athletes a risk group (Eriksson et al., 2008; Malmborg et al., 2017; Segura-García et al., 2012) to including regular exercising in the symptom catalog of ON (Varga et al., 2014). The purpose of this systematic review and meta-analysis was to collate current scientific knowledge of the link between obsessive healthy eating or ON and exercise behaviors, including ExAdd. According to previous studies and assumptions, a moderate correlation between ON and exercise was expected. Correlations should be more pronounced for studies investigating compulsive and/or addictive exercising (Oberle, Watkins, & Burkot, 2018; Rudolph, 2018). The second objective was to explore and promote the debate on whether there are gender differences in the relationship correlation between obsessive healthy eating or ON and exercise behaviors. Based on evidence for a direct link between exercise behavior and eating pathology in women but not in men (Meulemans, Pribis, Grajales, & Krivak, 2014), this relationship was expected to be stronger in females. We additionally explored whether effects differed based on employed instrument, studied population (i.e., convenience sample or a sample with a particular interest in exercise or exercising, mean age of the sample, percentage of women), and study quality. A better understanding of this link will contribute to the current debate of the overlap between orthorexic eating and (addictive) exercise.

METHODS

Data collection process and eligibility criteria

The online academic databases PubMed, ScienceDirect, and Web of Science were screened to obtain peer-reviewed articles that would allow for an analysis of ON in sport and exercise contexts (search terms *orthorexia, orthorexic, fitness, exercise, sport, athlete*). A study was included in this meta-analysis if it: (a) had a group of athletes (irrespective of the type of sport or standard of competition) and a control group of non-athletes, or (b) it allowed for the assessment of an association between frequency-based exercise measures and orthorexic/obsessive healthy eating, and (c) the results included means and standard deviations, r values or percentages for the relevant variables. We did not include studies that only included muscle dysmorphia as an outcome variable or only examined attitudes towards exercise and fitness or fitness orientation. However, we considered master's or doctoral theses if they (a) provided all relevant data to compute standardized effect sizes and (b) provided sufficient information to evaluate study quality. We ensured that data was not published in a peer-reviewed
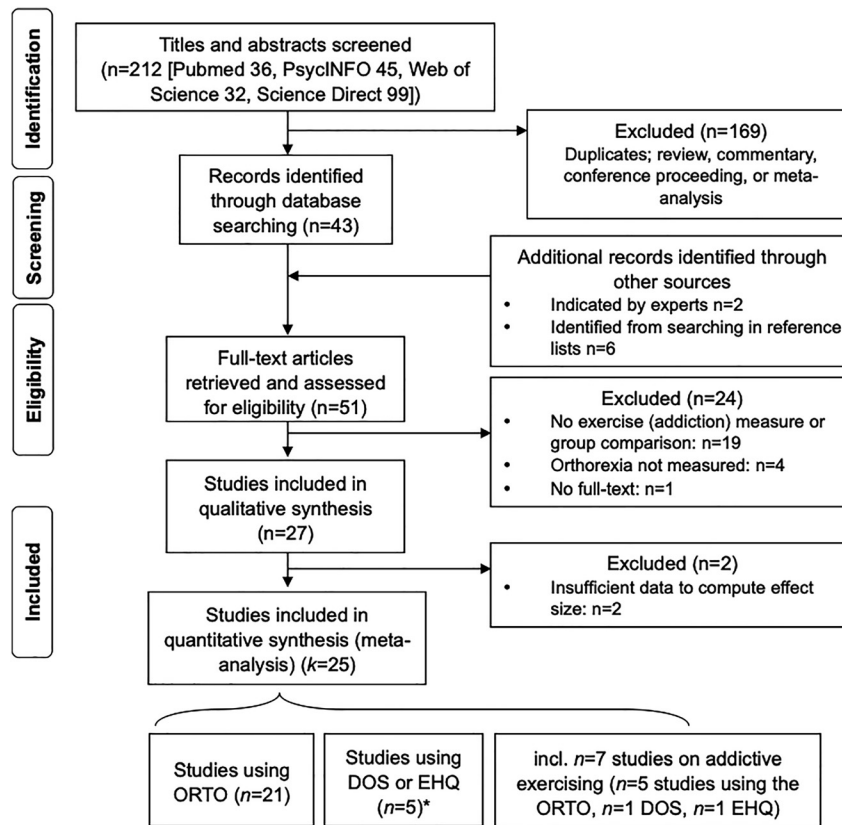
Fig. 1. Flow of information through the different phases of the review.
Notes: Search terms ("orthorexia" OR "orthorexic") AND ("fitness" OR "sport" OR "athlete" OR "exercise") from very first publication until October 6th, 2020.
*One study employed both, the ORTO-15 and the EHQ. For the overall effect size, data were combined. In the subgroup analysis, both effect sizes were considered.

journal in the meantime. All studies published before October 2020 were eligible for inclusion. Articles in English, German, French, Swedish, Polish, Turkish, Spanish, and Portuguese were screened. On completion of database searching, additional records were identified through checking reference lists of each article collected and by consulting experts. The corresponding authors were contacted directly in cases where studies were unobtainable or insufficient data of relevance for the meta-analysis. The first and second authors independently assessed eligibility; disagreements were discussed with all authors. For the flow of information through the different phases of the review, see Fig. 1. Twenty-seven studies met the inclusion criteria. Two of these studies did not report sufficient data for computing standardized effect sizes, and corresponding authors were unresponsive. Twenty-five studies were thus included in the analyses.

Data extraction

Study characteristics and data necessary for computing standardized effect sizes were coded according to the country of origin of the sample, total sample size and/or the number of participants in each experimental group and the control group(s), participant demographics (age, gender distribution), the measure of obsessive healthy or orthorexic eating, and operationalization of exercise (addiction). Quantitative data varied depending on the study design. For group comparisons, the mean and standard deviation of the independent variable for each group on the measure used, the dependent variable or subcategory of the measure used, or the statistic parameter for each comparison in the analysis were extracted. Correlation coefficients between orthorexic eating and exercise (addiction) were extracted when available. For frequency tables, percentages of cases and non-cases for the measures were extracted. Data extraction was conducted by the first or second author and confirmed by the other authors; disagreements were resolved by discussion between all authors.

Risk of bias of individual studies

Study quality was examined using a modified set of the quality criteria for primary research, as proposed in the Evidence Analysis Manual of the Academy of Nutrition and Dietetics (2016). Our final scoring sheet (see supplementary material) included 12 criteria (e.g., sampling adequately described and free from bias, clearly defined outcomes, reliability estimates of measures given, appropriate statistical procedures) with each criterion rated as "positive" if present (= 2 points), "neutral" if the presence is ambiguous or when research is not exceptionally strong on this issue (= 1 point),

or "negative" if not present (= 0 points). We computed the quality score as the mean of responses across criteria that could be evaluated. Hence, scores could range between 0 and 2. This procedure also allowed us to examine study quality as a more-defined moderator of effects in meta-regression models. The initial inter-rater reliability was high, as indicated by Krippendorff's Alpha of $r = 0.89$. Coding was discussed among all authors until 100% agreement was achieved.

Moderator variables

Instrument. The measure to screen for obsessive healthy or orthorexic eating was recorded. Included studies employed either the ORTO-15 or one of its versions (Donini, Marsili, Graziani, Imbriale, & Cannella, 2005; Roncero, Barrada, & Perpina, 2017), the DOS (Barthels, Meyer, & Pietrowsky, 2015), or the Eating Habits Questionnaire (EHQ; Gleaves, Graham, & Ambwani, 2013). A subgroup analysis was conducted to examine the difference between studies using one of the ORTO versions and studies employing the DOS or the EHQ. This should also take into account the fact that the instruments have different validity and reliability. Results' interpretation will reflect on this possible bias. Because a difference was assumed between studies examining the relation between orthorexic eating and general exercise activity compared to studies examining compulsive or addictive exercising, this meta-analysis reported effects separately for these constructs.

Age. As orthorexic and exercise behaviors could differ between age groups and therefore introduce heterogeneity of study effect sizes, the mean age of the sample was considered a continuous moderator in the meta-regression.

Gender distribution. As another contributor to heterogeneity, gender distribution (percentage women, continuous) was examined in a meta-regression. Men and women's distribution differed markedly between studies, with women being typically overrepresented (18 out of 25 studies, percentage women: 0–97.1%, Median: 60.7%).

Study quality. This moderator was entered in the meta-regression to examine a possible contribution of the quality of included reports to the overall heterogeneity of effect sizes.

Study population. Six studies provided data from a convenience sample, and 15 studies included data from a sample with a special interest in exercise or exercising. A subgroup analysis was conducted to examine this binary factor (convenience sample, exercise-oriented sample).

Statistical analysis

To integrate and synthesize the effect sizes provided by each study, overall sample analyses and subgroup meta-analysis applying random effects models were performed using Meta-Essentials: Workbooks for meta-analysis (Version 1.5,

as described in Suurmond, van Rhee, & Hak, 2017). The final effect size analyzed was bivariate correlation r to meet this study's objective, that is investigating the association between obsessive healthy eating or ON and (addictive) exercise behaviors. All effect size estimates were checked and adjusted if necessary so that positive-signed correlations indicate increasing (addictive) exercise behavior with higher ON scores. Twenty-five original studies (which differed in design) provided differences in means (Hedge's g), risk ratio (Odds ratio), or correlation (Pearson's r) as principal summary measures. For detailed information about conversion of effect sizes stemming from different statistical procedures (according to guidelines proposed in Cooper, Hedges, & Valentine, 2019; Hunter & Schmidt, 2004; Rosenthal, 1991; Walter, 2000), see the supplementary material. If two group means had to be combined to receive one score (i.e., one exercise group and more than one control group or vice versa), the weighted mean of both groups was calculated to satisfy the assumption of independence. If a study allowed the calculation of more than one effect size (i.e., more than one correlation), individual effect sizes were combined via Fisher z-transformation of r's, calculation of the arithmetic mean of z-scores, and finally reverse transformation using the inverse hyperbolic tangent function, before entering meta-analytic procedures. According to the benchmarks proposed by Cohen (1988) for point-biserial correlation, coefficients of 0.1, 0.24, and 0.37 will be considered small, medium, and large, respectively.

Cohen's q was used as an effect size for the difference of two correlations to examine gender differences. According to Cohen (1988, p. 109), both female and male samples' correlations were Fisher's z-transformed, male scores were subtracted from female scores. Positive signs of q indicate a stronger correlation in women, with values <0.1 interpreted as no effect, values from 0.1 to 0.3 representing small effects, values from 0.3 to 0.5 representing intermediate effects, and values >0.5 representing large effects.

Each of the five assumed moderator variables (ON instrument, age, percentage of females in the sample, study quality, and study population) was analyzed separately in a meta-regression or subgroup analysis to identify its impact on the association of obsessive healthy eating and exercise behavior. The first sub-group analysis gave a combined effect size for the ORTO studies and another combined effect size for the EHQ and DOS studies. The second sub-group analysis compared effects sizes derived from convenience samples to studies including an exercise-oriented sample.

Since only seven studies (including two theses) contained information about the association between ON and ExAdd, a descriptive comparison of these studies was provided. Inverse variance weighting was applied to increase estimates' efficiency and give studies that have greater precision more weight. One study (Bert, 2019) provided two final effect size estimates for the two ON measures ORTO and EHQ. For the overall sample meta-analysis, both correlations were merged (same procedure as described above). Both estimates individually entered the sub-group analysis investigating the ON instrument's moderating effect.

To assess the heterogeneity and consistency of the estimated correlations, Cochran's Q test and I^2 were used. While the Q test informs whether heterogeneity is present or not, the I^2 indicated the percentage of variation caused by heterogeneity. To detect a possible publication bias, funnel plots mapping each study's correlation estimates against their standard errors were visually inspected. The Egger test complemented this. Funnel plots and the complementing Egger Test were performed for the overall sample and the subgroup analysis of gender differences.

Ethics

No previously published protocol nor pre-registration exists for this meta-analysis. All included studies collected an informed consent; therefore, an ethical approval was not obtained. However, this meta-analysis complied with the most recent version of the Declaration of Helsinki.

RESULTS

Study selection

The searches yielded 212 citations. After excluding duplicates, reviews, meta-analyses, commentaries, conference proceedings, and presentations, and identifying additional sources (reference list search, contacting experts), 51 full-texts were reviewed for inclusion. The final sample comprised 25 studies, including 10,134 participants in total (Table 1).

Study characteristics

The participants' average age was $M_{pooled} = 25.21$ years ($SD_{pooled} = 8.75$), and 56.4% were female. 15.4% each of the trials were conducted in Italy, in the United States of America, and in Turkey. Of the 25 studies, 20 employed the ORTO-15 or one of its versions, three studies used the DOS and, one employed the EHQ. One additional study examined both the ORTO-15 and the EHQ (Bert et al., 2019). As meta-analyses are integrations of conceptual replications from different samples of a population, samples must be independent. Thus, the overall effect size analysis included a combined effect size for the study from Bert and colleagues (2019) for this report. The subgroup-analysis, however, considered both the ORTO and the EHQ effect size. As samples were not independent of one another, this might have introduced some bias.

Only seven studies included a measure of addictive or compulsive exercising. Among them, three studies employed the ORTO-15 or ORTO-7 and the Exercise Dependence Scale (EDS)-21. Another report included the ORTO-15 and the Scale of Dedication to Exercise (SDE). One further study used the DOS and the EAI. One study employed the EHQ and both the EAI and the two Compulsive Exercise Test (CET) subscales "avoidance and rule-driven behavior" and "exercise rigidity", one study used the ORTO-11 and a single item asking for feeling guilty skipping training.

Thirteen studies provided data to statistically examine gender differences in the correlation between obsessive healthy eating and exercise. Only four out of the seven studies measuring addictive or compulsive exercising provided gender-specific data. Due to the low number, these studies will be described but not meta-analytically examined.

Internal validity of individual studies

The study quality-coding scheme can be found in the supplementary material. All studies were rated to be of at least moderate quality; scores ranged from 0.82 to 1.73, with a mean of 1.41 ($SD = 0.24$).

Results of individual studies and gender comparison

Studies measuring any exercise measure in relation to obsessive healthy eating. We computed the average correlation as effect size across all studies examining any exercise measure (number of studies = 21, number of subjects = 9,292). The results revealed a small overall correlation, $r = 0.12$, 95% CI $|0.06–0.18|$, $P < 0.001$ ($Q = 126.70$, $P < 0.001$, $I^2 = 84.21\%$). When divided by ON instrument, only studies employing the DOS or the EHQ ($r = 0.19$, 95% CI $|0.04–0.32|$; $Q = 35.69$, $P < 0.001$, $I^2 = 88.79\%$) but not studies using the ORTO ($r = 0.09$, 95% CI $|0.03–0.16|$; $Q = 67.11$, $P < 0.001$, $I^2 = 76.16\%$) yielded a combined effect size of at least small magnitude. However, there was no significant difference between the two categories, QM ($df = 1$) $= 2.47$, $P = 0.116$, $Pseudo\text{-}R^2 = 8.73\%$. The effect size across all studies and effect sizes of the single studies separately for each ON instrument are shown in Fig. 2. Overall, the thirteen studies on gender differences showed a combined effect size of $q = 0.04$, 95% CI $|−0.03–0.11|$, $P = 0.088$ ($Q = 1642.51$, $P < 0.001$, $I^2 = 99.27\%$), indicating similar associations between exercise and obsessive healthy eating among men and women (see Fig. 3). The different ON instruments did not differ in terms of gender differences, QM ($df = 1$) $= 0.17$, $P = 0.679$, $Pseudo\text{-}R^2 = 1.11\%$.

Studies measuring exercise addiction or compulsive exercising in relation to obsessive healthy eating. We computed the average correlation as effect size across all seven studies examining any ExAdd measure (number of subjects = 2,791). The results revealed a medium overall correlation, $r = 0.29$, 95% CI $|0.13–0.45|$, $P < 0.001$ ($Q = 62.57$, $P < 0.001$, $I^2 = 90.41\%$). The effect size across all studies is shown in Fig. 4. Due to the low number of studies ($n < 10$), subgroup-analyses of the ON measure in use and gender were not performed. Descriptively, the DOS and EHQ studies yielded higher effect sizes ($r = 0.32$ and $r = 0.40$) than the five ORTO studies ($r = 0.03$, $r = 0.15$, $r = 0.17$, $r = 0.42$, $r = 0.52$). Effect sizes in the four studies allowing assessments of gender differences were all $q < |0.10|$ and thus considered negligible by conventional standards. Specifically, this was $r_{women} = 0.27$ versus $r_{men} = 0.31$ (Henriksson & Herrey, 2014), $r_{women} = 0.39$ versus $r_{men} = 0.47$ (Oberle et al., 2018), $r_{women} = 0.45$ versus $r_{men} = 0.42$ (Rudolph, 2018), as well as $r_{women} = 0.23$ versus $r_{men} = 0.14$ (Freire et al., 2020).

Table 1. Summary of study characteristics included in the meta-analysis

Authors	Country	Sample Type	Total sample age (M ± SD)	ON measure used (cut-off)	Ex(Add) measure used (cut-off)	M <> F	Quality (0...2)
Aksoydan and Camci (2009)	Turkey	28 ballet dancers (20 f) 44 opera singers (24 f) 22 orchestra musicians (11 f)	33.2 ± 10.9	ORTO-15	3 groups: dancers, singers, musicians	x	0.82
Almeida et al. (2018)	Portugal	193 gym members (113 f)	32.8 ± 11.6	ORTO-15 (35)	4 groups: never, sometimes, often, always exercising >3x/wk	–	1.20
Bert et al. (2019)	Italy	549 participants in local sports events (139 f)	26.7 ± 5.4	ORTO-15 (35), EHQ	3 groups: no sport, <150, >150 min/wk	x	1.42 (ORTO)
						x	1.50 (EHQ)
Bo et al. (2014)	Italy	53 Dietetics (41 f) 200 Exercise and Sport Sciences (65 f) 187 Biology (132 f)	19.8 ± 1.8	ORTO-15 (35)	3 groups: dietetics, sport, biology students	–	1.36
Bóna et al. (2019)	Hungary	207 with interest in sport and fitness (140 f)	31.9 ± 8.7	ORTO-11Hu	3 groups: <1x daily, 1x daily, >1x daily	x	1.55
Çiçekoğlu and Tunçay (2018)	Turkey	31 vegan/vegetarian (22 f) & 31 nonvegan/ nonvegetarian (16 f)	33.6 ± 7.0	ORTO-11	2 groups: no sports, exercise regularly	x	0.91
Clifford and Blyth (2019)	United Kingdom	215 students (141 f)	21 ± 1.5	ORTO-15	2 groups: no sports, sports; 2 groups: <10, >10 h/wk	–	1.33
Dunn, Gibbs, Whitney, and Starosta (2017)	United States of America (ethnically diverse, 78% white)	275 students (188 f)	21.7 ± 4.8	ORTO-15	5 groups: 0, 1–2, 3–4, 5–6, 7> x/wk exercise	x	1.50
Duran, Çiçekoğlu, and Kaya (2020)	Turkey	215 male nursing students 215 male sport science students	21.3 ± 2.6	ORTO-11 (23)	2 groups: nursing, sport students	–	1.08
Freire et al. (2020)	Brazil	60 exercise practitioners (38 f)	26.6 ± 7.8	ORTO-15	SDE	x	1.55
Gorrasi et al. (2019)	Italy	330 health science (236 f) 325 economic- humanistic (178 f) 263 sport science (89 f)	20.2 ± 1.7	ORTO-15	3 groups: health science, economic, sport students; h/ wk	–	1.73
Henriksson and Herrey (2014)	Sweden	226 high-school students (185 f)	18.0 ± ??	ORTO-15 (35)	EDS (at-risk, symptomatic, asymptomatic)	x	1.18
Kiss-Leizer et al. (2019)	Hungary	739 with interest in sport and diet (585 f)	29.7 ± 10.2	ORTO-11Hu	times/wk, h/wk, guilty when skipping training	–	1.55
Lewis (2012)	United States of America (all African American)	427 athletes (188 f)	20.5 ± 1.2	ORTO-15 (40)	EDS (at-risk, asymptomatic)	–	1.42
Malmborg et al. (2017)	Sweden	110 exercise science students (59 f) 78 business students (48 f)	22.8 ± 2.2	ORTO-15 (35)	IPAQ (low, moderate, high); 2 groups: sport, business students	x	1.33

(continued)

Table 1. Continued

Authors	Country	Sample Type	Total sample age (M ± SD)	ON measure used (cut-off)	Ex(Add) measure used (cut-off)	M <> F	Quality (0...2)
Oberle et al. (2018)	United States of America (ethnically diverse, 38% white)	Sample 1: 228 psychology students (204 f)	20.3 ± 1.9	EHQ	h/wk (aerobic, strength); EAI, CET subscales rule-driven behavior & exercise rigidity	x	1.64
Özdengül, Yargic, Solak, Yaylali, and Kurklu (in press)	Turkey	514 sedentary (312 f) 271 recreationally active (143 f) 92 competitive athletes (46 f)	29.1 ± 11.2	ORTO-R	3 groups: sedentary, recreational, competitive	x	1.67
Roncero and Barrada (2017)	Spain	Sample 2: 241 adults (152 f)	24.9 ± 7.1	ORTO-11	2 groups: no sports, exercise regularly	x	1.70
Rudolph et al. (2017)	Germany	759 fitness club members (539 f)	23.5 ± 3.2	DOS (30)	3 groups: occasional (i.e. ≤1x/wk or ≤90min/wk), regular (2x/wk ≥45min or ≥3x/wk at light intensity), intensive (i.e. ≥3x/wk ≥45min at moderate to high intensity) sport	x	1.55
Rudolph (2018)	Germany	1008 fitness club members (449 f)	29.4 ± 11.6	DOS (30)	x/wk, h/wk; EAI (at risk 29–36, endangered 15–28, asymptomatic 6–14)	x	1.55
Segura-Garcia et al. (2012)	Italy	577 athletes (189 f) 217 sedentary controls (79 f)	22.8 ± 5.4	ORTO-15 (35)	2 groups: controls, athletes (i.e. minimum of 3x 1.5 h sessions/wk for at least 3 yrs)	x	1.45
Surała, Malczewska-Lenczowska, Sadowska, Grabowska, and Białecka-Dębek (2020)	Poland	273 competitive athletes (125 f)	20.9 ± 4.7	ORTO-15	h/wk	x	1.09
Strahler, Hermann, Walter, and Stark (2018)	Germany	713 adults (569 f)	29.4 ± 11.2	DOS (30)	GPPAQ (active, moderately active, moderately inactive, and inactive)	x	1.73
White et al. (2020)	United States	103 male students	19.8 ± 1.7	ORTO-7	EDS	–	1.45
Worsfold and Sheffield (in press)	Australia	35 psychologists (34 f) 50 natural therapists (48 f) 30 fitness instructors (22 f)	40.8 ± 10.8	ORTO-8 (18.66)	3 groups: psychologists, natural therapists, fitness instructors	–	1.45

Note: 'M<>F', study provided effect size for gender comparison.
Abbreviations: M, mean; SD, standard deviation; ON, Orthorexia nervosa; Ex(Add), exercise (addiction); ES, effect size; ORTO-15/11/11Hu/8/R, questionnaire for the assessment of Orthorexia nervosa and its versions; EHQ, Eating Habits Questionnaire; DOS; Duesseldorf Orthorexia Scale; SDE, Scale of Dedication to Exercise; EDS, Exercise Dependence Scale; EAI, Exercise Addiction Inventory; CET, Compulsive Exercise Test; IPAQ, International Physical Activity Questionnaire; GPPAQ, General Practice Physical Activity Questionnaire; f, females; h, hour(s); wk, week(s); yrs, years.
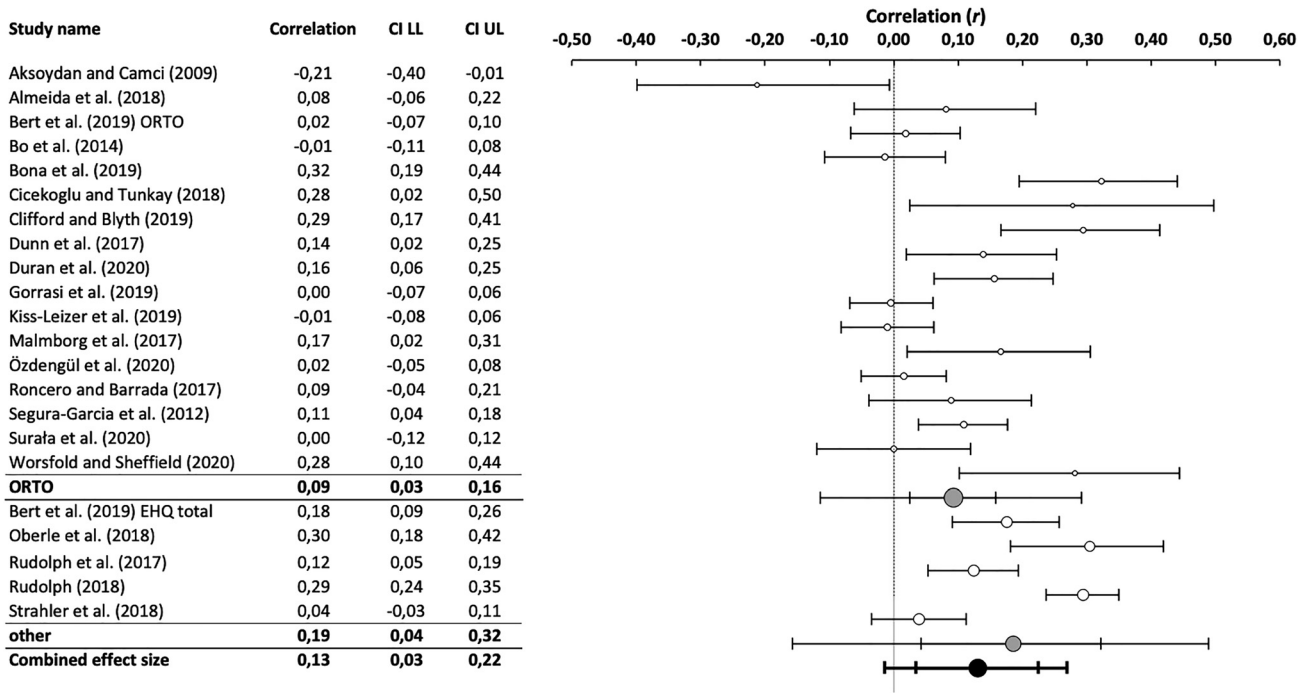
Study name	Correlation	CI LL	CI UL
Aksoydan and Camci (2009)	-0,21	-0,40	-0,01
Almeida et al. (2018)	0,08	-0,06	0,22
Bert et al. (2019) ORTO	0,02	-0,07	0,10
Bo et al. (2014)	-0,01	-0,11	0,08
Bona et al. (2019)	0,32	0,19	0,44
Cicekoglu and Tunkay (2018)	0,28	0,02	0,50
Clifford and Blyth (2019)	0,29	0,17	0,41
Dunn et al. (2017)	0,14	0,02	0,25
Duran et al. (2020)	0,16	0,06	0,25
Gorrasi et al. (2019)	0,00	-0,07	0,06
Kiss-Leizer et al. (2019)	-0,01	-0,08	0,06
Malmborg et al. (2017)	0,17	0,02	0,31
Özdengül et al. (2020)	0,02	-0,05	0,08
Roncero and Barrada (2017)	0,09	-0,04	0,21
Segura-Garcia et al. (2012)	0,11	0,04	0,18
Surała et al. (2020)	0,00	-0,12	0,12
Worsfold and Sheffield (2020)	0,28	0,10	0,44
ORTO	**0,09**	**0,03**	**0,16**
Bert et al. (2019) EHQ total	0,18	0,09	0,26
Oberle et al. (2018)	0,30	0,18	0,42
Rudolph et al. (2017)	0,12	0,05	0,19
Rudolph (2018)	0,29	0,24	0,35
Strahler et al. (2018)	0,04	-0,03	0,11
other	**0,19**	**0,04**	**0,32**
Combined effect size	**0,13**	**0,03**	**0,22**

Fig. 2. Forest plot of all studies examining any exercise measure, grouped by orthorexic eating measure. Effect size is represented as correlation r.

Notes: ORTO, studies employed a version of the test for the diagnosis of Orthorexia; other, studies either employed the Duesseldorf Orthorexia Scale or the Eating Habits Questionnaire (EHQ); CI, 95% confidence interval; LL, lower limit, UL, upper limit. Studies are provided in alphabetical order.

*Bert et al. (2019) employed both, the ORTO-15 and the EHQ. For the overall effect size, data from this report were combined. In the subgroup analysis, both effect sizes were considered. Studies are provided in alphabetical order.

Moderator analysis

As additional possible moderators of the link between ON and any exercise measure, the variables age, gender distribution, quality score, and study population were each included in a random-effects model. Neither the samples' age ($\beta = 0.09$, with QM ($df = 1$) = 0.20, $P = 0.657$) nor the percentage of women ($\beta = 0.13$, with QM ($df = 1$) = 0.39, $P = 0.530$) yielded a significant contribution to heterogeneity in effect sizes. Likewise, study quality ratings had no significant moderating effect ($\beta = 0.12$, with QM ($df = 1$) = 0.34, $P = 0.562$). Subgroup-analysis did not show

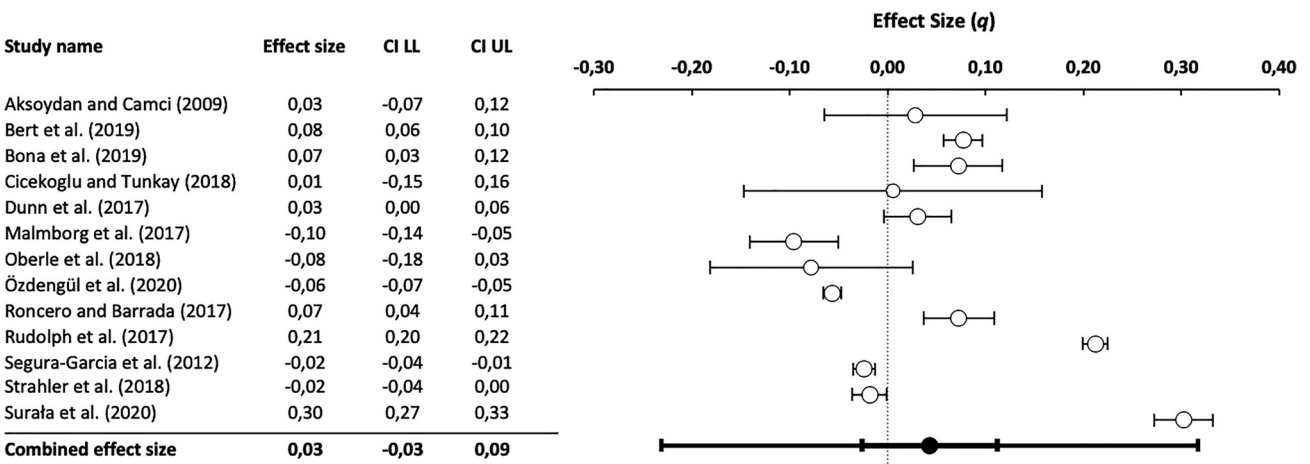| Study name	Effect size	CI LL	CI UL
Aksoydan and Camci (2009)	0,03	-0,07	0,12
Bert et al. (2019)	0,08	0,06	0,10
Bona et al. (2019)	0,07	0,03	0,12
Cicekoglu and Tunkay (2018)	0,01	-0,15	0,16
Dunn et al. (2017)	0,03	0,00	0,06
Malmborg et al. (2017)	-0,10	-0,14	-0,05
Oberle et al. (2018)	-0,08	-0,18	0,03
Özdengül et al. (2020)	-0,06	-0,07	-0,05
Roncero and Barrada (2017)	0,07	0,04	0,11
Rudolph et al. (2017)	0,21	0,20	0,22
Segura-Garcia et al. (2012)	-0,02	-0,04	-0,01
Strahler et al. (2018)	-0,02	-0,04	0,00
Surała et al. (2020)	0,30	0,27	0,33
Combined effect size	**0,03**	**-0,03**	**0,09**

Fig. 3. Forest plot of all reported gender differences. Effect size is represented as Cohen's q. Note that positive values indicate stronger correlations in the female sample.

Notes: CI, 95% confidence interval; LL, lower limit, UL, upper limit. Studies are provided in alphabetical order. Bert et al. (2019) employed both, the ORTO-15 and the Eating Habits Questionnaire (EHQ). For the overall effect size, data from this report were combined. In the subgroup analysis, both effect sizes were considered (ORTO $r = 0.02$, EHQ $r = 0.13$). Studies are provided in alphabetical order.
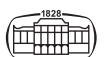
Study name	Correlation	CI LL	CI UL
Freire et al. (2020)	0,15	-0,12	0,39
Henriksson and Herrey (2014)	0,17	0,04	0,29
Kiss-Leizer et al. (2019)	0,42	0,35	0,47
Lewis (2012)	0,03	-0,07	0,12
Oberle et al. (2018)	0,40	0,28	0,50
Rudolph (2018)	0,32	0,26	0,38
White et al. (2020)	0,52	0,36	0,65
Combined effect size	**0,27**	**0,06**	**0,46**
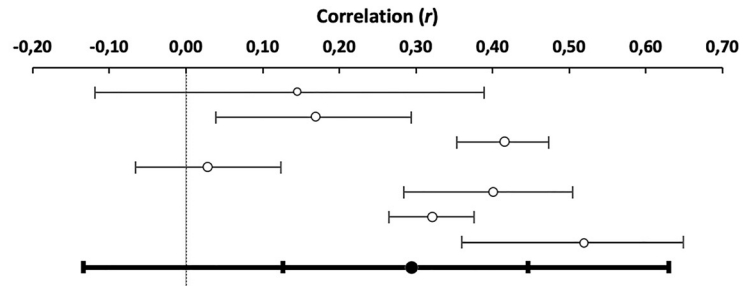
Fig. 4. Forest plot of all studies examining any exercise addiction measure. Effect size is represented as correlation *r*.
Notes: CI, 95% confidence interval; LL, lower limit, UL, upper limit. Studies are provided in alphabetical order.

significant differences in effect sizes between studies examining convenience samples ($r = 0.18$) and those studies that examined samples with a special interest in exercise or exercising ($r = 0.09$), QM ($df = 1$) = 1.87, $P = 0.171$, $Pseudo-R^2 = 8.47\%$.

Subgroup-analysis and meta-regressions were not performed for studies measuring ExAdd (due to small N).

Risk of bias across studies

For studies employing any exercise measure, funnel plots did not indicate a strong asymmetry (Fig. 5). This was supported by the Egger test, which appeared not significant with $t = -0.88$, $P = 0.390$. Visual inspection of funnel plots and the Egger test ($t = -0.80$, $P = 0.440$) indicated no publication bias for studies included in the gender comparison (Fig. 6). However, this assessment must be interpreted with caution due to the low number of studies and the high heterogeneity level. Publication bias was not assessed for the subset of studies measuring ExAdd or compulsive exercising. There were inadequate numbers of included trials to evaluate a funnel plot or more advanced regression-based assessments properly.

DISCUSSION

There seems to be general agreement that orthorexic behaviors and excessive, addictive exercise co-occur. However,

there is disagreement about the exact extent. Thus the present meta-analysis aimed to answer this question. It also informed the debate about possible gender differences in the correlation between obsessive healthy eating and exercise.

Summary of findings

In this meta-analysis and systematic review, 25 studies, including 10,134 individuals, with women being typically overrepresented, were included. Of those, 21 studies provided sufficient data for any exercise measure, and seven studies reported data for ExAdd. Different measures for obsessive healthy or orthorexic eating (EHQ, DOS, ORTO-15, and its versions) were used in the original reports. Most of the studies employed the ORTO-15 or one of its versions (17 studies). The DOS was employed in three and the EHQ in two studies. The overall correlation between ON and exercise was only small. However, a medium overall correlation was found for the correlation between ON and ExAdd. In addition to the association between orthorexic behaviors and exercise (addiction) discussion, a debate was also triggered about gender-specific associations and the comparability of men and women in this regard (Oberle et al., 2018). The meta-analytical summary of the $n = 13$ underlying studies did not support gender differences regarding the ON and exercise association. Visual inspection of funnel plots for
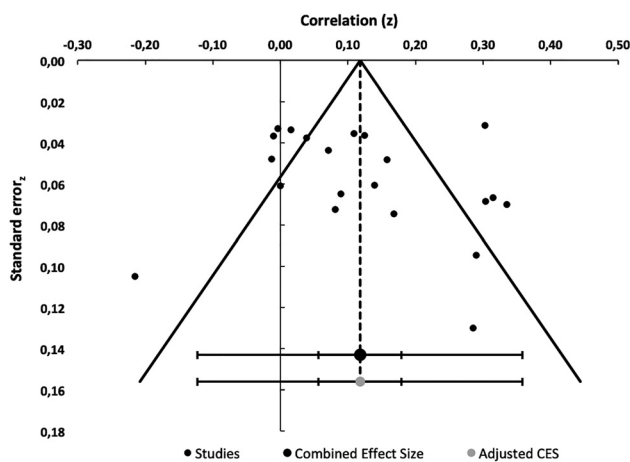

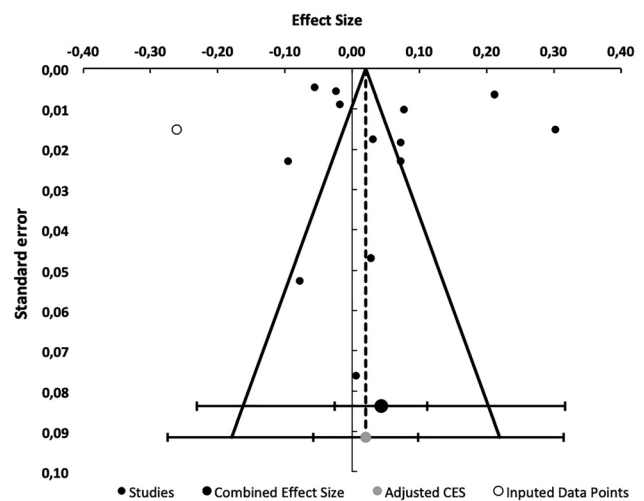*Fig. 5.* Funnel plot of all studies examining any exercise measure.

Fig. 6. Funnel plot of all studies reporting gender differences.

asymmetry and statistical testing demonstrated no significant publication bias. However, the interpretation of results also raised some caveats, which are described below.

Studies on the link between exercise measures and obsessive healthy eating

Contrary to the assumption, our analyses only showed a small overall correlation between the obsession for healthy eating or ON and exercise. Current literature on healthy lifestyles points out that ON eating habits and exercising have concurrently attained special recognition (Cinquegrani & Brown, 2018; Håman et al., 2017). From growing tendencies towards healthy lifestyles, a habitus of healthism has been developed (Bona, Szel, Kiss, & Gyarmathy, 2019; Håman et al., 2015; Oberle et al., 2018), a term that was described by Crawford (1980) when he was describing the 'new health consciousness'. The main tools of this kind of health practice are diet and exercise.

On the one hand, athlete populations such as fitness participants, gym attendees, and exercise students have been considered groups at risk for ON behaviors (Malmborg et al., 2017; Rudolph, 2018; Rudolph, Göring, Jetzke, Großbarth, & Rudolph, 2017). While on the other hand, there is also evidence for subjects with ON tendencies to do more (excessive) exercise, which might depict comorbid behavior to protect oneself from illnesses through diet and to keep one's body fit and healthy (Kiss-Leizer, Tóth-Király, & Rigó, 2019; Tiggemann & Zaccardo, 2015; Varga et al., 2014). Another possible explanation for the small, instead of the expected moderate, correlation between ON and exercise or ExAdd could be the studied population, that is convenience samples versus samples with a special interest in exercise or exercising. It is important to note that these primary studies employ various operationalizations for exercise, which ranged from pre-defined groups, single-item measures to validated procedures, (see also Table 1). Effect sizes in the exercise samples ranged from $r = -0.212$ to $r = 0.323$. The diversity of the samples consisting of varying subjects on the exercise spectrum, such as athletes (Segura-García et al., 2012), gym or fitness club members (Almeida, Vieira Borba, & Santos, 2018; Rudolph, 2018; Rudolph et al., 2017), ballet dancers (Aksoydan & Camci, 2009), or participants with interest in fitness (Bo et al., 2014; Bona et al., 2019; Gorrasi et al., 2019; Kiss-Leizer et al., 2019; Malmborg et al., 2017), might have added to this range in effect sizes. However, subgroup analysis did not support this possible explanation.

Lastly, the included studies employed different ON measures with varying psychometric properties. This may have also contributed to heterogeneity in effects and needs to be considered while interpreting the present results. Especially the ORTO questionnaire shows psychometric limitations and needs to be interpreted cautiously (Missbach et al., 2015). The analysis showed that studies using the ORTO did not show a correlation of at least small magnitude ($r = 0.09$), while studies employing the DOS or the EHQ did ($r = 0.19$). It seems worth noting that the survey by Bert and colleagues (2019) used both the ORTO and the

EHQ, and individual study results mirror the meta-analytic findings. These results may suggest that regular exercising may not be the most critical risk factor for developing ON.

Studies on the link between addictive exercising and obsessive healthy eating

Given previous literature, correlations between addictive exercising and obsessive healthy eating seem more pronounced. Thus, a stronger correlation was expected. However, results revealed a medium overall correlation which also indicates that each symptom accounts for some unique variance that the other symptom is not accounted for and that ExAdd and ON cannot be equated. This finding fits the literature which suggests that athlete populations such as fitness participants, gym attendees, or exercise students are to be considered groups at risk for orthorexic eating behaviors. Likewise, compulsive exercising is a prevalent symptom among individuals with eating disorders (Holland, Brown, & Keel, 2014).

While due to low sample size no subgroup-analyses in regard to the tool in use were performed, studies employing the DOS and EHQ yielded descriptively higher effect sizes than those using the ORTO questionnaire. Both DOS and EHQ also yielded higher study quality ratings (these factors were individually examined), which, again, highlights the diversity in ON measures' psychometric characteristics and, consequently, may bias present findings. As the studied populations were heterogeneous (ranging from students over gym and fitness club members to ballet dancers and competitive athletes), these individuals might not perfectly fit into the category of compulsive exercise, characterized by a craving for physical training and uncontrollable excessive exercise behavior, including harmful consequences, such as injuries and even impaired social relations (Lichtenstein, Hinze, Emborg, Thomsen, & Hemmingsen, 2017). In more detail, included studies recruited high school students (Henriksson & Herrey, 2014; White et al., 2020), psychology students (Oberle et al., 2018), student-athletes (Lewis, 2012), subjects with an interest in fitness (Kiss-Leizer et al., 2019) or gym members (Rudolph, 2018) and exercise practitioners (Freire et al., 2020). It remains unclear to what extent those groups differ from the general population and performance athlete populations in their actual exercise habits and addictive exercising. It may be assumed that the present analysis perhaps underestimates actual effects. Notably, this finding should also be interpreted with caution because of the small number of studies ($n = 7$). The current review and meta-analysis highlights the need to investigate more heterogeneous samples that include populations that are more prone to compulsive exercising and those that are not.

Gender differences in the link between (addictive) exercising and obsessive healthy eating

It seems reasonable that men and women differ in specific characteristics of orthorexic eating (e.g., focusing on eating healthy, increasing physical fitness, or becoming healthier) and

exercise behaviors or ExAdd (for recent reviews see Dumitru et al., 2018; Strahler, 2019). However, initially revealed more pronounced relationships between orthorexic eating and exercise in women as compared to men (Oberle et al., 2018) were not confirmed herein. Instead, the present analysis showed similar correlation coefficients between female and male samples. Meulemans et al. (2014) showed that the association between exercise, ExAdd, and eating disorders differs between men and women. According to their analyses, exercise displays a direct effect on eating disorders in women but not in men. In their male sample, there seemed to be an indirect effect via addictive exercise behavior. In the present report, four out of seven included ExAdd studies allowed for an at least descriptive evaluation of gender differences, with one study showing slightly higher coefficients in men (Oberle et al., 2018), one study showing slightly higher coefficients in the female sample (Freire et al., 2020), and two showing comparable correlations (Henriksson & Herrey, 2014; Rudolph, 2018). Against the background of the small number of studies and an unpredictable publication bias, one might speculate about contributing factors such as the age range or socio-cultural differences (e.g., marriage, children, and education) of the samples examined. Studies on ExAdd prevalence rates among men and women were also ambiguous, which could partly be attributed to the type of exercise performed (Dumitru et al., 2018; Freimuth et al., 2011). From the current summary, it seems unlikely that gender is a major contributing risk factor. Still, more research is needed to understand gender-specific associations between ON and addictive exercising.

Moderator analysis

Similar to the binary moderators ON instrument and study population, the further considered moderators age, gender distribution, and study quality rating did not explain the variation in effect sizes. Including moderators in meta-analyses offers opportunities and harbors problems in the interpretation of moderators that are suboptimal (Hall & Rosenthal, 1991). In this meta-analysis, the original reports' age distribution was limited and thereby led to limited conclusions of the present moderator analysis. Even though the samples' age ranged between 18 and 75 years, it is essential to note that the distribution appeared limited and skewed to the left (as shown in the reported standard deviations). Although the study quality score was based on a validated procedure, we cannot guarantee whether our slightly adapted procedure is free of methodological weaknesses. In terms of the moderator study population, it needs to be mentioned that our two-group classification did only partial justice because included studies displayed great diversity in the exercise spectrum (i.e., student-athletes, participants with interest in fitness or gym members). One additional moderator that could not be meaningfully considered is the measure of exercise (addiction). Only $n = 3$ primary studies employed a validated exercise questionnaire. For ExAdd, all except one study employed validated tools with good psychometric properties. However, perhaps ExAdd measures measure different aspects of the same

phenomenon, and heterogeneity in effects is, therefore, to be expected. To elaborate further on this, the EDS-21 and the EAI are based on the general components of addiction applied to exercise. The CET assessed the compulsive need to exercise (subscale Rule-Driven Behavior) and the compulsive need to structure exercise activities (subscale Exercise Rigidity). Finally, the SDE evaluates positive feelings due to exercising, maintenance despite adverse effects, and the level of interference from the behavior.

Limitations

The previous sections already indicated limitations of the present meta-analysis, and results are to be interpreted with caution. First, many different measures and study designs were used in the original studies, which may have introduced some bias. The included studies employed different ON measures, showing different psychometric properties (Meule et al., 2020; Valente, Syurina, & Donini, 2019). Therefore, the dissatisfying reliability may also bias the results of the meta-analysis. Additionally, the measurement of the variable exercise was very diverse and thus limits the comparability of studies. Measures ranged from validated multi-item questionnaires to single items recording the frequenciy of training per week. All measurements were self-report and mostly not validated, and none used behavioral observations. One might also question whether presumably controls and athlete groups differ in exercise behaviors, as several studies carried out group comparisons with assumed differences in exercise levels without controlling for the actual exercise involvement (e.g., comparing students of different study disciplines).

Second, a meta-analysis' main aim is to make conclusions about the same population, whereby the different studies are considered independent samples. Therefore, one effect size estimate per study should be taken into account. 18 out of 41 effect sizes were created by averaging two estimates (for the details see Table 1). This averaging procedure may have introduced some other bias, thereby obscuring the true effect size.

Third, the recruitment methods of the individual studies could have contributed to heterogeneity. As noted above, the included studies' age ranges appeared skewed, examining mainly young adults. This makes it impossible to draw conclusions about older populations. Likewise, women were overrepresented in 18 out of 25 studies. Samples from across the full life span and of equal gender distribution are required to provide statements about the general population. Furthermore, sample recruitment is selective as it often includes keywords, which could encourage people with a particular interest in health and a healthy lifestyle to participate. A self-selection bias might be present. Random sampling strategies would be the gold standard to avoid this bias.

While our moderators did not explain variations in the effect sizes, there might be other moderators that do, e.g., cultural, social, and ecological conditions. Included studies originated from very different socio-cultural backgrounds, and the country of origin may have also produced

heterogeneity in effects. Future studies need to employ a wider variety of socio-cultural moderators, such as culture, religion, or education, to increase our knowledge of whether and to what extent such factors contribute to ON's nature and, thus, to the link between ON and exercise (addiction).

CONCLUSION

Neither ON nor ExAdd are included in the current clinical classification systems. Substantial overlap between these conditions would question their independence and raise doubts on whether each should be considered a disorder of its own. In this meta-analysis, we demonstrated that there is indeed a correlation between exercise (addiction) and orthorexic eating, which expresses some unique and some shared variance of both behaviors. Due to the limitations summarized above, one cannot conclude the independence of ON and addictive exercising. However, given the present findings, ON and addictive exercising do not appear very comorbid. Given this, the current debate on whether to include (excessive) exercise in the clinical classification of ON (Bratman, 2017; Varga et al., 2014) might not be the most appropriate solution, but one should rather understand ExAdd as a risk factor for ON.

The present results and their discussion point out limitations and the need for further investigations regarding the natures of ON and ExAdd, such as investigating a more comprehensive age range, equal gender distribution, and socio-culturally diverse samples. From a methodological point of view, another essential task is to establish and use validated measures of orthorexic eating, exercise behavior, and ExAdd. In consequence, future research should address the questions of the phenomena's clinical relevance and underlying mechanisms, vulnerability, and resilience factors.

APPENDIX A: SUPPLEMENTARY MATERIAL

The online version of this article offers supplementary material https://doi.org/10.1556/2006.2021.00004.

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