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ORIGINAL ARTICLE

Psychometric properties of the Teruel Orthorexia Scale (TOS) among a French–Canadian adult sample

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Abstract

Background Psychometric properties of the Teruel Orthorexia Scale (TOS) have been examined in several languages (Arabic, English, Portuguese, Spanish, and Turkish), but not in French.

Purpose The objective was to examine the psychometric properties of the TOS among a French-Canadian adult sample.

Methods Participants were 296 French-speaking Canadian adults ($M = 34.2$ years, $SD = 11.9$, 85.1% women). They completed the TOS alongside with several other measures (e.g., alcoholic consumption, cigarette smoking, disturbed eating attitudes and behaviors, frequency of physical activities, intuitive eating, vegetarian diet, and negative affect).

Results The results supported the a priori two-factor representation (orthorexia nervosa and healthy orthorexia) of the French version of the TOS and provided further support for the superiority of an exploratory structural equation modeling approach, relative to a confirmatory factor analytic approach. Furthermore, the results supported no differential item functioning as a function of respondents' characteristics (age, body mass index, diagnosis of eating disorders, frequency of physical activities, gender, and vegetarian diet). Latent mean differences were found in healthy orthorexia and orthorexia nervosa factors as a function of respondents' characteristics. Finally, significant correlations were found between TOS factors and convergent measures (alcohol consumption, cigarette smoking, disturbed eating attitudes and behaviors, intuitive eating, and negative affect).

Conclusion The present study confirmed that the French version of the TOS has satisfactory psychometric properties (i.e., factor validity and reliability, no differential item functioning, and convergent validity).

Level of evidence V, cross-sectional study.

Keywords Orthorexia nervosa · Healthy orthorexia · Teruel Orthorexia Scale · Exploratory structural equation modeling · Differential item functioning · Psychometrics

Introduction

The concept *orthorexia* is a combination of two Greek words, orthós (correct) and órexis (appetite) that refers to eating right. The pathological dimension of orthorexia, called *orthorexia nervosa* (OrNe), includes an obsessive focus on healthy eating with emotional distress (e.g., guiltiness and self-punishment) when self-imposed eating rules are broken and social impairment arises due to those dieting rules [1, 2]. A non-pathological dimension of orthorexia has also been suggested. This dimension, named *healthy orthorexia* (HeOr), consists in an interest in healthy food and eating behaviors. Individuals high on this dimension tend to perceive healthy eating as part of their identity or as a way of life [3]. In recent years, several self-reported instruments have been developed and validated to assess orthorexia (e.g.,

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Düsseldorf Orthorexia Scale: [4]; Eating Habits Questionnaire: [5]; French Orthorexia Scale: [6]; Orthorexia Nervosa Inventory: [7]; ORTO-15, [8]). They essentially focused on some aspects of OrNe, thus neglecting the healthy interest in diet and eating behaviors (e.g., content validity). This limitation led to the development and validation of the Teruel Orthorexia Scale (TOS), which measures both HeOr and OrNe [9].

The TOS includes 17 items, with nine measuring HeOr and eight measuring OrNe. Respondents indicate their degree of agreement with the items, using a four-point Likert scale ranging from 0 = *completely disagree* to 3 = *completely agree*. This instrument was developed and validated by Barrada and Roncero [9] in a sample of women and men ($N = 942$, $M = 24.01$ years, $SD = 6.4$, 76% women) from Spain. The results from an exploratory factor analysis (EFA) with a parallel analysis test provided support for a satisfactory solution encompassing two moderate correlated factors ($r = 0.43$) with an acceptable internal consistency (Cronbach's alpha): HeOr (9 items; $\alpha = 0.85$), and OrNe (8 items; $\alpha = 0.81$). Additionally, their results provided support for the test–retest correlations of the two-factor scores ($r_{HeOr} = 0.73$, $r_{OrNe} = 0.82$) over an 18-month period. Finally, the convergent validity of the TOS was supported with measures of obsessive–compulsive symptoms (only for OrNe; $r = 0.32$), disturbed eating attitudes and behaviors ($r = 0.22$–0.65), negative affect (only for OrNe; $r = 0.28$), appearance evaluation ($r = 0.11$ for HeOr; $r = -0.25$ for OrNe), and perfectionism (only for OrNe; $r = 0.41$). The low correlations between the TOS scores and the ORTO-15 scores highlighted some concerns about the validity of the latter scale, in line with what has been repeatedly stressed in recent studies [10, 11].

Validation in other languages-countries

The TOS has been cross-validated in another Spanish sample [3] and validated in other languages, such as English-American [12, 13], Arabic-Lebanese [14], Portuguese-Brazil [15], and Turkish [16]. The results from these studies replicated the two-factor structure in samples of adolescents and/or adults using EFA [12, 16], confirmatory factor analysis (CFA) [14–16] or exploratory structural equation modeling (ESEM) [3, 12, 13]. Results from studies using a CFA approach revealed that the TOS factors are highly correlated (e.g., $r = 0.74$) [14–16]. This inflated latent correlation may be explained by the fact that in CFA items from the TOS are only allowed to load on either the HeOr or the OrNe latent construct and cross-loadings across these two latent constructs are constrained to be zero [17, 18]. Nevertheless, this assumption is highly improbable and unrealistic given that items from one factor of the TOS may overlap and be associated with the other factor, even if this association remains small [17, 18]. Inversely, studies using an ESEM approach [3, 12, 13] have shown that TOS latent factor correlations were moderate ($r_{mean} = 0.45$). Also, these previous studies revealed relevant cross-loading problems in some items (items 9, 13, 15). Therefore, the use of the ESEM approach seems to be more appropriate with the TOS given that it results in less inflated bias in parameter estimates (due to the non-estimation of cross-loadings) and in a more accurate estimation of the HeOr and OrNe latent constructs [19].

Additionally, several studies provided support for the convergent validity between TOS factors and measures of orthorexia, demographics and anthropometrics participants' characteristics, eating and healthy behaviors, and psychological well-being. More specifically, OrNe and HeOr were found to be highly positively correlated ($r = 0.72$–0.80) to the Düsseldorf Orthorexia Scale [13, 14], as well as moderately negatively correlated ($r = -0.31$ and -0.44) to the ORTO-R [14]. Additionally, studies focusing on demographics and anthropometrics participants' characteristics found: (a) small negative correlations ($r = -0.12$ to -0.20) between OrNe and age [3, 13, 14] and a small positive correlation ($r = 0.13$) between the HeOr and age [3]; (b) significantly higher scores on OrNe in females compared to males [14, 15]; and (c) small positive ($r = 0.13$) [3, 14] or negative correlations ($r = -0.15$ and -0.22) between OrNe and body mass index [13, 15] and small negative correlations ($r = -0.14$ and -0.28) between the HeOr and body mass index [3, 13]. Moreover, studies focusing on eating or healthy behaviors showed: (a) a significantly higher score on OrNe among current smokers relative to non-smokers [13]; (b) moderate to high positive correlations between both TOS factors and disturbed eating attitudes and behaviors ($r = 0.30$–0.61; global score of the Eating Attitudes Test) [12, 16] or eating behaviors ($r = 0.12$ and 0.33; short form of the Eating Disorder Examination Questionnaire) [13]; (c) small to moderate positive correlations ($r = 0.24$ and 0.47) between TOS factors and problematic drinking behaviors [13]; and (d) small to moderate positive correlations ($r = 0.12$ and 0.45) between TOS factors and vegetarianism [13]. Finally, studies focusing on psychological well-being found: (a) moderate positive correlation ($r = 0.34$–0.45) between OrNe and body image dysphoria, health anxiety or perfectionism [12]; (b) small to moderate positive correlations between OrNe and negative affect ($r = 0.15$ and 0.31) or obsessive–compulsive symptoms ($r = 0.24$ and 0.32) [12, 16]; (c) moderate positive correlation ($r = 0.43$) between OrNe and social appearance anxiety [15]; and (d) small to moderate negative correlations between both TOS factors ($r = -0.28$ to -0.43) and subjective health status [13]. In sum, results from the Spanish [3, 9] and cross-linguistics [3, 12–16] validation studies of the TOS suggest that (a) OrNe and HeOr are two distinct constructs of orthorexia with moderate associations; (b) OrNe is mostly associated with eating symptomatology, mainly restrained eating; and

(c) HeOr is more likely to be associated with healthy behaviors and psychological well-being.

Currently, to our knowledge, the validity and reliability of the two-factor structure of the TOS has not been examined among a French-speaking population. Therefore, this situation limits the generalizability of TOS factor structure with French-speaking population and precludes its utilization among such population. The present study was designed to contribute to this limitation by proposing and validating a French version of the TOS. This effort is particularly important, given that the TOS is the sole questionnaire measuring both HeOr and OrNe. Practically, this French version will facilitate the evaluation of orthorexia both for research and clinical purposes among French-speaking population living in European (e.g., Belgium, France, Luxembourg, Switzerland), American (Canada, Haiti, French Guiana) and African (e.g., Algeria, Morocco, Tunisia, Mali, Cameroon) countries.

Measurement of invariance and latent mean differences

To date, and to our knowledge, there is very little evidence that the TOS provides reliable information when used to compare subpopulations of respondents having different attributes or characteristics, such as age, body mass index (BMI), and gender. An exception is da Silva et al. [15] who examined the measurement invariance of the two-factor structure of the TOS as a function of the gender of the respondents. They found evidence of weak (i.e., equivalence of the item factor loadings across men and women), strong (i.e., equivalence of item thresholds across men and women), and strict invariance (i.e., equivalence of item uniquenesses or residuals across men and women). Additionally, none of the previous TOS validation studies has examined any form of measurement invariance or the presence of differential item functioning (DIF; i.e., the presence of systematic responses tendencies that differ between groups), and possible latent mean differences on the TOS factors as a function of the age of the respondents, BMI, diagnosis of eating disorders, participation in physical activities, and vegetarianism. This is surprising given that these characteristics are frequently considered in research focusing on orthorexia and used to compare mean scores of orthorexia among subpopulations with these characteristics. Indeed, previous studies, mostly using the ORTO-15, have reported mean differences in or significant associations between orthorexia and age (for a review see [20]), BMI (for a review see [20]), diagnosis of eating disorders (for reviews see [21, 22]), exercise involvement (for a review see [20]), and vegetarianism (for a review see [23]). Therefore, there is no current evidence that the TOS can reliably (i.e., without biases) be used for mean comparisons based on some of these characteristics or to evaluate associations between orthorexia factors and these characteristics. It is pending to demonstrate that the TOS performs equivalently irrespective of respondents' levels on these characteristics, and thus, group invariance has not been proven.

Overview of the study

The main objective of this study was to examine the psychometric properties (i.e., factor validity and reliability, DIF, and convergent validity) of the French version of the TOS among a sample of French-speaking Canadian adults. First, the TOS was translated into French (see Method section for a detailed description of the procedure). Second, the factor validity and reliability of the two-factor model found in Spanish [3, 9] and cross-cultural studies [12–16] was examined using CFA and ESEM approaches. Third, the presence of DIF and latent means differences in responses to the TOS subscales were examined as a function of the age of respondents, BMI, diagnosis of eating disorders, frequency of physical activities, gender, and vegetarianism. Finally, the convergent validity of the TOS subscales was also investigated with measures of alcohol consumption, cigarette smoking, disturbed eating attitudes and behaviors, and negative affect. These measures were chosen because they have been significantly related to orthorexia [12, 13, 21, 23, 24]. We also included a measure of intuitive eating, which can be defined as an adaptive way of eating that maintains a strong connection with the internal physiological signs of hunger and satiety [25]. Intuitive eating, as measured by the Intuitive Eating Scale-2 (IES-2) [26], has four main dimensions, namely: *Unconditional Permission to Eat* when hungry and to eat whatever food is desired; *Eating for Physical Rather than Emotional Reasons*; *Reliance on Hunger and Satiety Cues* to determine when and how much to eat; and *Body-Food Choice Congruence*, which measures the extent to which individuals match their food choices with their bodies' needs. Considering that unconditional permission to eat is highly (and negatively) related with restrained eating [27], the OrNe was expected to be negatively correlated with this IES-2 subscale. Conversely, a positive association between HeOr and the Body Food-Choice Congruence scale of the IES-2 was expected.

Method

Participants and procedure

A convenient sample of 296 French-speaking Canadian adults participated in this study. Descriptive statistics of the participants are found in Table 1. This research was authorized by the research ethics committee of the first two

Table 1 Descriptive statistics of participants

Characteristics of participants	*M* or %	SD	Range
Age	34.2	11.9	18–69.4
Gender			
Men	14.9%	–	–
Women	85.1%	–	–
Body mass index (in kg/m^2)	24.9	6.2	15.2–55.8
Vegetarian			
No	81.2%		
Yes	18.8%		
Eating disorders diagnosis			
No	85.8%	–	–
Yes	14.2%	–	–
Frequencies of physical activities			
Do not exercise	8.1%	–	–
Do some occasionally	35.1%	–	–
Do several times per month	15.2%	–	–
Do several times per week	41.6%	–	–
Alcohol consumption			
Never	6.1%	–	–
Once per month or less	20.6%	–	–
Between 2 and 3 times per month	25.3%	–	–
Between 1 and 2 times per week	29.4%	–	–
Between 3 and 6 times per week	18.2%	–	–
Everyday	0.3%	–	–
Cigarette smoking	0.9	3.9	0–25

M, mean; %, percentage; SD, standard deviation

author's university. Recruitment was conducted at the first two author's university, in the community, in community organizations, and in private clinics located in the Canadian province of Quebec. The participants were invited to participate by generic announcements sent in a local newspaper and via messaging (emails), social network (Facebook and Instagram), community organizations and private clinics websites. To be included in the study, participants had to be aged 18 years old and over. Pregnant women were excluded given that their condition could influence their eating behaviors. Participants completed an online informed consent form prior to anonymously answering online questionnaires through the LimeSurvey platform.

Measures

Participants' information

Participants were asked to self-report their age, gender (0 = women; 1 = men), height (in foot and inches or meters), weight (in pounds or kilograms) and: (a) whether they were vegetarian or not (0 = no; 1 = yes); (b) whether they had already received or not an eating disorder's diagnosis (0 = no; 1 = yes); (c) the frequency of their physical activity (including sports) practices during their leisure time (0 = don't exercise to 3 = several times per week; see [28]); (d) how often they had consumed any alcoholic beverages in the last 12 months (0 = never to 5 = everyday; see [28]); and (e) on average how many cigarettes a day they smoked. Their self-reported height and weight were used to calculate their BMI (in kg/m^2).

Disordered eating attitudes and behaviors Participants completed the French version [29] of the Eating Attitudes Test-26 (EAT-26) [30]. This instrument comprises 26 items and assesses three factors: Dieting, Bulimia-Food Preoccupation, and Oral Control. Participants were asked to answer each item using a six-point response scale ranging from *never* = 1 to *always* = 6. In the present study, the internal consistency of the three factors was acceptable (Dieting: $\alpha = 0.91$; Bulimia-Food Preoccupation: $\alpha = 0.85$; and Oral Control: $\alpha = 0.69$).

Intuitive eating Participants completed the French version [31] of the Intuitive Eating Scale-2 (IES-2) [26]. This instrument comprises 23 items and assesses four factors (Unconditional Permission to Eat, Eating for Physical Rather than Emotional Reasons, Reliance on Hunger and Satiety Cues, and Body-Food Choice Congruence). Participants were asked to respond to each item using a 5-point response scale ranging from *strongly disagree* = 1 to *strongly agree* = 5. In the present study, the internal consistency of the four factors of the IES-2 was acceptable (Unconditional Permission to Eat: $\alpha = 0.79$; Eating for Physical Rather than Emotional Reasons: $\alpha = 0.93$; Reliance on Hunger and Satiety Cues: $\alpha = 0.93$; and Body-Food Choice Congruence: $\alpha = 0.85$).

Negative affect

Participants completed the negative affect subscale from the French version [32] of the Positive and Negative Affect Scales (PANAS) [33]. This subscale comprises 10 items that participants were asked to answer using a 5-point response scale ranging from *not at all or very slightly* = 1 to *extremely* = 5. In the present study, the internal consistency was excellent ($\alpha = 0.90$).

Orthorexia

Two independent professional bilingual translators and two members of the research team were involved in the development of the French version of the TOS. This version was developed using standardized translation back-translation techniques [34]. First, the original items were translated into French by a professional bilingual translator (not familiar with the TOS). Second, the translated items were discussed

in committee by two members of the research teams familiar with cross-linguistic psychometric adaptation procedures. Perceived discrepancies between the translated items and the original items were discussed and resolved by consensus. Third, the approved French items were back-translated by a second independent professional bilingual translator who was not aware of the original items. Fourth, the back-translated items were compared with the original items in committee. Inconsistencies were discussed and resolved by consensus. The final French version of the TOS is presented in Table S1 (see online Supplementary Information).

Data analyses

Given the ordinal nature of the TOS' answer scale, the analyses were performed using robust weighted least squares estimator with mean and variance adjusted statistics (WLSMV) in Mplus (version 8.7) [35]. With the WLSMV estimator the very few missing responses at the item level (0–0.34%; $M = 0.08\%$) were handled using a pairwise present approach (that rely on the full information provided by the participants without relying on the deletion of cases) that works in a similar way (but slightly less efficiently) to the Full Information Maximum Likelihood [36]. The a priori two-factor structure of the TOS was examined using CFA and ESEM. In CFA, the TOS answers were explained by two correlated factors (HeOr and OrNe) and no cross-loading or correlated uniqueness was allowed. The a priori ESEM model was estimated using confirmatory target rotation [37] in which answers to the TOS were explained by two correlated factors defined as in CFA, but all cross-loadings were freely estimated and "targeted" to be as close to zero as possible.

Model fit was examined using established cutoff criteria (see e.g., [38, 39]). comparative fit index (CFI) and Tucker–Lewis index (TLI): ≥0.90 and >0.95; suggest acceptable and good fit, respectively; root mean square error of approximation (RMSEA): ≤0.08 and ≤ 0.06 suggest an acceptable and good fit, respectively; and the standardized root mean square residual (SRMR): ≤0.08 suggests an acceptable fit. For all models, McDonald's [40] omega (ω) coefficient was used to estimate the composite reliability of the TOS factors.

Measurement bias of the TOS as a function of respondents' age, BMI, diagnosis of eating disorders, frequency of physical activities, gender, and vegetarianism was examined using DIF test. This test was conducted using the best factor solution (i.e., CFA or ESEM) retained in the previous step and a multiple indicators multiple causes approach (MIMIC). The MIMIC approach was retained because, in contrast to previous taxonomy of invariance tests that require arbitral categorical grouping of respondent characteristics (i.e., younger vs. older respondents), it allows to assess the presence of DIF in item responses to a questionnaire as a function of continuous characteristics (e.g., [41]). For DIF analysis, as recommended by Marsh et al. [42] and Morin et al. [41], the following models were examined: (a) null effects (the paths from the predictors to the TOS latent factors and item responses thresholds were constrained to be zero); (b) saturated (the paths from the predictors to the TOS item responses thresholds were freely estimated, while the paths from the predictors to the TOS latent factors were constrained to be zero); and (c) factors-only (the paths from the predictors to the TOS latent factors were freely estimated, while the paths from the predictors to the TOS item responses thresholds were constrained to be zero). The improvement in fit (ΔCFIs/TLIs ≥ 0.01 and ΔRMSEAs ≥ 0.015) between the factors-only models and the saturated models relative to the null effects model suggests the presence of associations between the predictors and the TOS latent factors and the item responses. However, improvement in fit between the saturated and the factors-only models indicates DIF. All the predictors were introduced in the same model.

Convergent validity was examined using the best factor solution (i.e., CFA or ESEM). The latent factors of the best factor solution (i.e., CFA or ESEM) were correlated with observed scores of alcohol consumption, cigarette smoking, disturbed eating attitudes and behaviors, intuitive eating, and negative affect.

Results

Factor validity and reliability

As illustrated in Table 2, results showed poor fit indices for the two-factor CFA solution of the TOS (CFI = 0.899, TLI = 0.883, RMSEA = 0.115, SRMR = 0.087). Nevertheless, the fit indices of the ESEM[1] solution are good (CFI = 0.980, TLI = 0.973, RMSEA = 0.055; SRMR = 0.038). The estimates of parameters extracted from the CFA are presented in Table S2 (see online Supplementary Information) and those from the ESEM solutions are presented in Table 3, respectively. In the two-factor CFA solution, all factor loadings of the TOS (λ range = 0.528–0.917, $M_{\lambda} = 0.743$) were satisfactory and

[1] A power estimation was conducted based on the CFA and ESEM data fit using an online calculator developed by Preacher and Coffman [46]. The following parameter from the: (a) CFA model were selected: α = .05, df = 118, sample size = 296, Null RMSEA = .08, Alt. RMSEA = .115; and (b) ESEM model were selected: α = .05, df = 103, sample size = 296, Null RMSEA = .08, Alt. RMSEA = .055. Results revealed a power of 99% and 98% for CFA and ESEM models, respectively. Additionally, they indicated that in this sample 74 and 164 participants would be necessary to reach a power of 80% in CFA and ESEM models, respectively.

Table 2 Goodness-of-fit statistics of confirmatory factor analyses (CFA) and exploratory structural equation modeling (ESEM) for the TOS

Models	No.	Description	$W\chi^2$	*df*	CFI	TLI	SRMR	RMSEA	RMSEA 90% CI		CM	$\Delta W\chi^2$	*df*	*p*	ΔCFI	ΔTLI	ΔRMSEA
									LB	UB							
Measurement	1–1	CFA	582.418*	118	0.899	0.883	0.087	0.115	0.106	0.125	–	–	–	–	–	–	–
	1–2	ESEM	196.245*	103	0.980	0.973	0.038	0.055	0.043	0.067	–	–	–	–	–	–	–
	1–3	Convergent validity	389.393*	253	0.973	0.962	0.043	0.043	0.034	0.051	–	–	–	–	–	–	–
DIF: age, BMI, ED diagnosis, frequency of PA, gender, vegetarianism	2–1	MIMIC Null effects	558.615*	205	0.910	0.895	0.137	0.082	0.074	0.090	–	–	–	–	–	–	–
	2–2	MIMIC Saturated	172.612*	103	0.982	0.959	0.030	0.051	0.037	0.064	2–1	356.995	102	< 0.001	+ 0.072	+ 0.064	− 0.031
	2–3	MIMIC Factors-only	296.624*	193	0.974	0.967	0.068	0.046	0.035	0.056	2–1	103.831	12	< 0.001	+ 0.064	+ 0.072	− 0.036

TOS, Teruel Orthorexia Scale; DIF, differential item functioning; PA, physical activities; BMI, body-mass index; ED, eating disorders; MIMIC, multiple indicators multiple causes; $W\chi^2$, robust weighed least square (WLSMV) chi-square; *df*, degrees of freedom; CFI, comparative fit index; TLI, Tucker–Lewis index; RMSEA, root mean square error of approximation; 90% CI, 90% confidence interval of the RMSEA; LB, lower bound; UB, upper bound; SRMR, standardized root mean square residual; CM, comparison model; Δ, change from the previous model; $\Delta W\chi^2$, WLSMV chi square difference test (calculated with the Mplus DIFFTEST function)

*$p \leq 0.01$

Table 3 Standardized parameters estimates from the exploratory structural equation model of the TOS

Items	HeOr (λ)	OrNe (λ)	δ
1	0.605	*0.065*	0.590
2	0.818	*− 0.021*	0.348
3	0.915	− 0.175	0.291
6	0.723	0.103	0.393
7	0.483	0.341	0.488
8	0.916	− 0.128	0.260
11	0.428	0.151	0.729
13	0.330	0.401	0.600
15	0.399	0.240	0.689
4	*− 0.078*	0.765	0.467
5	0.187	0.719	0.316
9	0.610	0.381	0.252
10	*0.021*	0.802	0.339
12	− 0.159	0.983	0.164
14	0.322	0.490	0.500
16	− 0.123	0.961	0.178
17	*− 0.001*	0.746	0.443
ω	0.878	0.928	

TOS, Teruel Orthorexia Scale; HeOr, Healthy Orthorexia; OrNe, Orthorexia Nervosa; λ, factor loadings; δ, Uniquenesses; ω, McDonald's omega

Non-significant loadings ($p > 0.05$) are underlined and italicized

they present acceptable composite reliability coefficients ($\omega = 0.897$ and 0.933, $M_\omega = 0.915$). Nevertheless, the high level of correlation between HeOr and OrNe ($r = 0.689$) suggests some level of conceptual overlap. Inversely, in the ESEM solution, the correlation between HeOr and OrNe was largely reduced to 0.495. This slight level of overlap of factors could be explained by the presence of cross-loadings ($|\lambda|$ range = 0.001–0.610, $M_{|\lambda|} = 0.184$) rather than a true conceptual overlap at the factor level. Moreover, although most cross-loadings were small, the results suggest that item 13 ("I prefer to eat a small quantity of healthy food rather than a lot of food that may not be healthy") tended to present a similar pattern of association with both TOS factors suggesting that it might tap into some similar orthorexia processes. Additionally, item 9 ("My concern with healthy eating takes up a lot of my time") tended to present a higher level of association with the HeOr factor rather than with the a priori factor (i.e., OrNe). Finally, the ESEM solution also resulted in well-defined (λ range = 0.330–0.983, $M_\lambda = 0.674$) and reliable latent factors ($\omega = 0.878$ and 0.928, $M_\omega = 0.903$). Based on these results, the ESEM solution was favored, and therefore retained for subsequent analyses.

Differential item functioning and latent mean differences

The results from the DIF analysis are presented in Table 2. They showed a substantial improvement in model fit for the saturated (models 2–2) and the factors-only models (models 2–3) relative to the null effects model (models 2–1). Additional results also showed comparable levels of fit between the saturated and factors-only models (ΔCFI/ΔTLI $\leq$ 0.01; ΔRMSEA $\leq$ 0.015). Therefore, the present results confirm no DIF and the presence of associations between scores on the TOS and predictors (i.e., age, BMI, diagnosis of eating disorders, physical activities frequency, gender, and vegetarianism; Table 2).

More precisely, the results show that: (a) participants with a higher frequency of physical activities tended to score significantly higher on HeOr (estimate = 0.405, $p < 0.001$) and OrNe (estimate = 0.139, $p = 0.033$) compared to those involved in less frequent physical activities; (b) older participants had significantly higher scores on HeOr (estimate = 0.145, $p = 0.017$) than younger participants; (c) participants with a higher BMI reported significantly higher OrNe (estimate = 0.145, $p = 0.019$) than participants with a lower BMI; (d) participants with a diagnosis of eating disorders tended to score significantly higher on OrNe (estimate = 0.346, $p < 0.001$) relative to those without such a diagnosis; (e) men scored significantly lower on HeOr (estimate = − 0.111, $p = 0.045$) than women; and (f) vegetarian participants tended to score significantly higher on HeOr (estimate = 0.185, $p = 0.001$) and OrNe (estimate = 0.159, $p = 0.010$) relative to those that were not vegetarian.

Convergent validity

The goodness of fit of the convergent validity model resulted in a good level of fit to the data (CFI = 0.973, TLI = 0.962, RMSEA = 0.043, SRMR = 0.043). The results from these analyses[2] are reported in Table 4, and show that the HeOr factor is significantly and (a) negatively related to cigarette smoking ($r = -0.151$) and unconditional permission to eat ($r = -0.498$); and (b) positively related to disturbed eating attitudes and behaviors (dieting, bulimia-food preoccupation, and oral control; *r*s range = 0.243–0.319), and, to a higher degree, body-food choice congruence ($r = 0.641$). Moreover, the OrNe factor is significantly and (a) negatively related to alcohol consumption ($r = -0.191$) and intuitive eating, mainly unconditional permission to eat ($r = -0.707$), but also with eating for physical rather than emotional reasons ($r = -0.278$), and reliance on hunger and satiety cues ($r = -0.464$); and (b) positively related to negative affect ($r = 0.452$), and disturbed eating attitudes and behaviors (dieting, bulimia-food preoccupation, and oral control; *r*s range = 0.495–0.758).

Table 4 Convergent validity analyses of the TOS

	HeOr	OrNe
Alcohol consumption	− 0.039	− 0.191***
Cigarette smoking	− 0.151*	− 0.054
EAT-26—Dieting	0.319***	0.758***
EAT-26—Bulimia-Food Preoccupation	0.251***	0.664***
EAT-26—Oral control	0.243***	0.495***
IES-2—Unconditional Permission to Eat	− 0.498***	− 0.707***
IES-2—Eating for Physical Rather than Emotional Reasons	0.070	− 0.278***
IES-2—Reliance on Hunger and Satiety Cues	− 0.091	− 0.464***
IES-2—Body-Food Choice Congruence	0.641***	0.071
PANAS—Negative affect	0.055	0.452***

TOS, Teruel Orthorexia Scale; HeOr, Healthy Orthorexia; OrNe, Orthorexia Nervosa; EAT-26, Eating Attitudes Test-26; IES-2, Intuitive Eating Scale-2; PANAS, Positive and Negative Affect Scales

*$p \leq 0.05$; **$p \leq 0.01$; ***$p \leq 0.001$

Discussion

This study sought to examine the psychometric properties of a French version of the TOS among a sample of French-speaking Canadian adults. The results supported the a priori two-factor representation (HeOr and OrNe) of the French version of the TOS and provided further support for the superiority of an ESEM, relative to a CFA approach. Indeed, latent correlations between the TOS factors remained moderate ($r = 0.50$) when using ESEM, whereas they were highly correlated ($r = 0.69$) when using CFA. Therefore, the use of a CFA approach may be questioned for the estimation of the TOS latent constructs. This is consistent with previous studies on the TOS [9, 12–16] and may be attributed to the non-estimation of cross-loadings that are forced to be zero in CFA [17, 19, 43]. Based on the present results and those of previous studies it is recommended that future research studies using the TOS rely on an ESEM (or exploratory factor analysis) rather on a CFA approach that may be responsible for inflate latent factor correlations and model misspecification [17, 19, 43]. From our point of view, the convenience of using ESEM approaches instead of CFA should not be restricted to the TOS, but to any psychometric study where non-zero cross-loadings can be expected. A 'confirmatory' analysis that distorts the recovered parameters by imposing non-tenable restrictions cannot be taken as superior (and

[2] Convergent analyses were also examined with an ESEM model excluding items 9 and 13 and results were similar to those obtained with the ESEM model including all TOS items.

to be preferred) to a more flexible 'exploratory' analysis. Also, the better fit of the ESEM technique is not indicative of problems within the TOS. The potential problems that may arise depends on cross-loadings sizes and the degree in which those cross-loadings imply that the intended theoretical interpretation of the scales cannot be supported. This study provided support for the bidimensionality of the TOS factor structure and, by extension, the differentiation of orthorexia nervosa and healthy orthorexia.

Additionally, the standardized factor loadings identified in the present study were similar to those found in studies using an ESEM approach [3, 9, 12, 13]. The present results showed that almost every item of the TOS loaded on the factor it was supposed to represent, except for item 13 which tended to present a similar pattern of association with both TOS factors and item 9 which presented a higher level of association with the HeOr factor rather than with the OrNe. These items were also reported as suboptimal in recent studies using an ESEM approach among Spanish [3] and English-American adults [12]. For item 13, this may be explained by the respondents' belief that its focus is on the quantity of food rather than on its healthiness. For their part, the results for item 9 can be understood in light of the fact that another item of the TOS (item 2) covers time spent on eating healthy ("I spend a lot of time buying, planning, and or/preparing food so my diet will be as healthy as possible"). Thus, the wording of item 9 may lead respondents to believe that taking a lot of time to eat healthy is consistent with their values and their way of living. Accordingly, they may not find concerning or dysfunctional to spend a lot of their time on healthy eating. This indicates that time devoted to healthy eating should not be considered as a central element in the definition or assessment of OrNe. Similar claims have been made, for instance, in the area of Gaming disorder. Recently, Billieux et al. [44] indicated that "high involvement in video games exists and is not necessarily pathological" and the same can be said for other activities and interests. By including time spent as a marker of a disorder we risk to over-pathologize neutral or even healthy behaviors. As such, the present results might be attributed either to the issues related to the formulation of the items or to the sample specificity. Therefore, we consider that it is premature to exclude these items and they should be targeted for re-examination or reformulation in future studies. Finally, the composite reliability of both factors of the TOS was acceptable and aligned with reliability estimates found in other studies [3, 9, 12–16].

To our knowledge, except for da Silva et al.'s study [15] which examined measurement invariance across gender, this study is the first to examine possible DIF in TOS responses and latent mean differences as a function of respondents' age, BMI, diagnosis of eating disorders, frequency of physical activities, and vegetarianism. The results supported no DIF as a function of the participants' characteristics. They indicate that observed and latent scores on HeOr and OrNe can be confidently used to compare adults as a function of their age, BMI, diagnosis of eating disorders, frequency of physical activities, and vegetarianism. Subsequent results revealed significant latent means differences in HeOr and OrNe as a function of respondents' characteristics. More specifically, latent scores of HeOr and OrNe are significantly higher in respondents involved in a higher frequency of physical activities or who report being vegetarian. Additionally, latent scores of HeOr are significantly higher in older respondents or women, whereas latent scores of OrNe are significantly higher in respondents with a higher BMI or a diagnosis of eating disorders. With regards to age (for HeOr), BMI, diagnosis of eating disorders, physical activity, and vegetarianism, these results are consistent with those from previous research conducted with the TOS [3, 13, 14] or with other measures of orthorexia [21–23]. Nevertheless, the results for gender (i.e., higher scores were observed in HeOr for women relative to men) are: (1) inconsistent with those found in previous studies using the TOS [14, 15]; and (2) consistent with other studies using other orthorexia measures [20]. These mixed results could be explained by differences between these studies and the present one as function of gender ratio, as well as by the fact that none of the previous studies used latent mean scores.

This study was also interested in the convergent validity of the TOS factors in relation to several criterion measures. Results concerning disturbed eating attitudes and behaviors, intuitive eating and negative affect are in the expected directions and consistent with previous research conducted with the TOS [9, 12, 13, 16] or other orthorexia measures [24]. However, results on alcohol consumption are inconsistent with a recent study which used the TOS and measured dependence to or abuse of alcohol [13], but consistent with other research measuring the frequency of alcohol consumption [45] as in the present study. Finally, results about cigarette smoking are inconsistent with a recent study with the TOS [13] and may be explained by differences in the nature of measures used (i.e., current smoker vs. non-smoker, and number of cigarettes per day).

Limitations and directions for future research

This study has limitations that must be considered. The French version of the TOS was only validated on a single convenience sample of adults, mostly composed of women. Therefore, it is important for future studies to cross-validate the present results on a larger and more representative sample (including a greater proportion of men), as well as with French-speaking adults living in European and African countries. Moreover, given that this is the first study to examine DIF and latent mean differences of the TOS as a

function of the respondents' characteristics, the generalizability of these results remains an open question that should be examined more thoroughly in future research. Furthermore, the test–retest reliability and the longitudinal invariance of the French version of the TOS were not examined and should thus be the focus of future research. Therefore, it is unknown whether respondents are able to provide consistent ratings (i.e., reflecting the same constructs in the same manner) in the TOS over time. Finally, the convergent validity of the French version of the TOS with other French questionnaires measuring orthorexia was not assessed in the present study. Therefore, this issue should be addressed in future research using French versions of the Düsseldorf Orthorexia Scale [47] or the French Orthorexia Scale [6].

Conclusion

The present study confirmed that the French version of the TOS shows satisfactory psychometric properties (i.e., factor validity and reliability, differential item functioning, and convergent validity). This questionnaire can be used to assess HeOr and OrNe reliably and validly in francophone samples of adults and in the context of group-based comparisons related to age, BMI, diagnosis of eating disorders, frequency of physical activities, gender, and vegetarianism.

What is already known on this subject?

The TOS was originally validated in Spanish and it has recently been cross-validated in English-American, Arabic-Lebanese, Portuguese-Brazil, Turkish, but not in French. Additionally, there is few evidence of the superiority of an exploratory structural equation modeling approach, relative to a confirmatory factor analytic approach, and very little evidence of the lack of measurement bias of the TOS as a function of the characteristics of the respondents.

What does this study add?

The present study supported the a priori two-factor representation of the TOS, and provided further support for the superiority of an exploratory structural equation modeling approach, relative to a confirmatory factor analytic approach. It can be used to assess orthorexia reliably and validly in francophone samples of adults and in the context of group-based comparisons related to age, BMI, diagnosis of eating disorders, frequency of physical activities, gender, and vegetarianism.

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Declarations

Conflict of interest The authors have no conflict of interests to disclose.

Ethical approval The authorization to conduct the present study was granted by the research ethics committee of the Université du Québec en Outaouais (2019-156, 3090). All procedures performed in studies involving human participants complied with the ethical standards of the institutional or national research committee, and with the *Declaration* of *Helsinki of* 1964 and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all participants included in the study.

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