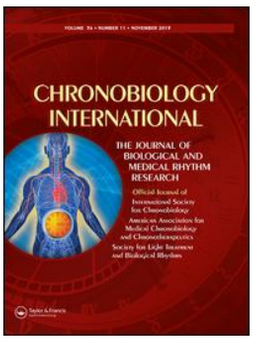

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Chronobiological traits predict the restrained, uncontrolled, and emotional eating behaviors of female university students

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ABSTRACT

Although significant associations between diurnal preference and restrained eating behaviors were previously reported, such reports are scarce and, in some respects, inconclusive. In this cross-sectional survey of 567 female university students aged between 17 and 23 years, we tried to clarify and extend the previous findings on chronobiological correlates of these behaviors. We administered the three-Factor-Eating-Questionnaire Revised and three questionnaires designed to assess trait-, ability-, and state-like differences in the domain of chronobiology, the Morningness-Eveningness Questionnaire (MEQ), the Sleep-Wake Pattern Assessment Questionnaire, and the Munich ChronoType Questionnaire, respectively. Statistical analyses included factor, correlation, and regression analyses. We found that any of three aspects of unhealthy eating behaviors (i.e., lack of cognitive eating restraint, uncontrolled eating, and emotional eating) was linked to one or more dimensions of individual chronobiological differences. We explained the previously reported inconclusive results by the differential relationship of two subconstructs of diurnal preferences to eating behaviors. For instance, such relationship was found for two (morning and evening) subscales of the MEQ. Cognitive eating restraint and uncontrolled eating were related to the morning subscale, while emotional eating was related to the evening subscale. These associations were supported by the associations revealed for morning vs. evening components of earliness-lateness assessed with two other questionnaires, (e.g., morning lateness and sleep offset vs. evening lateness and sleep onset, respectively). We conclude that unhealthy eating behaviors seem to be linked to unhealthy sleep-wake habits and behaviors and to inabilities to wake or sleep on demand at certain times of the day.

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TFEQ-R; MEQ; restricted eating; uncontrolled eating; emotional eating; chronotype

Introduction

One of the unique traits of the today postindustrial societies is the increasing prevalence of overeating, obesity and other eating related problems. These problems are not uncommon even among adolescents and young adults (White 2000). The eating restraint has become an important component of human eating behavior aimed on controlling body weight and shape. The research of intentional attempts of food intake regulation includes the studies of different cognitive, behavioral, and emotional aspects of eating habits (Elfhag and Linné 2005; Karlsson et al. 2000). One of the other unique traits of the today societies is the wide usage of the artificial light sources permitting active human functioning during the dark phase of the natural 24 h light-dark cycle. The shifts of meal timing on inappropriate times of the day might contribute to the increased prevalence of overeating, obesity, and other eating-related problems, e.g., in the populations of shift and night workers (Liu et al. 2018). Chronic circadian disruption can increase the risk for metabolic disorders (Mohebbi et al. 2012). Moreover, the results of the experiments on rodent models indicate that body weight can be normalized and life span can be lengthened not only by restricted feeding but also by restricted feeding time, even without reduction of caloric intake (Acosta-Rodríguez et al. 2017; Chung et al. 2016; Hatori et al. 2012; Longo and Panda 2016).

Having control over the artificial lights, people of the today's society reveal a wide range of individual differences in the preferred timing for their sleep and wakefulness (reviewed by Adan et al. 2012; Levandovski et al. 2013; Putilov 2017). The most known aspect of such individual variation of the sleep-wake behaviors is diurnal (time-of-day) preference or chronotype. It is usually determined as the propensity to sleep and to be most (physically or mentally) active at a particular time during a 24 h period. Evening preference (i.e., later chronotype) has been

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Supplemental data for this article can be accessed on the publisher's website.

associated with higher rates of many pathologies including metabolic dysfunction (Merikanto et al. 2013; Yu et al. 2015). Moreover, such preference in obese individuals compounds the cardiovascular risk associated with obesity (Lucassen et al. 2013). In the recent fight against overeating, obesity, and other eating related problems, knowledge of chronotype seems to be of practical importance. It might, in particular, help in optimizing treatments for metabolic diseases. As recently suggested by the results of one of the studies on hypocaloric dietary treatment for obesity, a diet adjusted to the one's chronotype (i.e., either morning or evening) is more effective than general dietary recommendations (Galindo Muñoz et al. 2020).

Past reports have revealed significant associations of such individual chronobiological trait as morning-evening preference with the factors of the Three-Factor-Eating-Questionnaire (TFEQ), either in the whole sample (Schubert and Randler 2008; Konttinen et al. 2014; Walker et al. 2015) or only in a male subsample (Aoun et al. 2019). In these previous reports on the associations of time-of-day differences with the three scales of the reduced version of the TFEQ (TFEQ-R) (Konttinen et al. 2014; Walker et al. 2015; Aoun et al. 2019), a trait-like individual chronobiological variation was assessed with the 19-item Morningness-Eveningness Questionnaire (MEQ; Horne & Östberg 1976). When positive findings were reported in such a study, healthy eating behavior was related to morningness (i.e., a high score on the Restrained Eating scale), whereas unhealthy eating behavior was related to eveningness (i.e., high scores on two other, Uncontrolled and Emotional Eating, scales). However, negative findings were also reported. For example, associations with none of the three scales were found in a sample of female university students (Aoun et al. 2019), and an association was not found between the score on the whole morning-evening preference scale and the score on the Emotional Eating scale in the studies of Walker et al. (2015) and Aoun et al. (2019), etc. (see Supplementary for more details on the previously reported research). Overall, the literature suggests that studies aimed on testing the relationships of diurnal preference with the individual variation in cognitive, behavioral, and emotional aspects of restrained eating remain scarce and, sometimes, they provided inconclusive results. For example, some of the results pointed at the necessity to account for a possible differential relationship of several subconstructs of the morningness-eveningness construct with the TFEQ-R's scales (Konttinen et al. 2014).

Individual variation in the fields of chronobiology can be assessed not only as the trait-like differences, but also as state-like and ability-like differences (e.g., in the current timing of sleep and wakefulness in certain environmental condition and in the abilities to sleep or wake on demand in the morning or evening or night hours). The questionnaires designed to assess these state- and ability-like differences, such as the Munich ChronoType Questionnaire (MCTQ; Roenneberg et al. 2003) and the 72-item Sleep-Wake Pattern Assessment Questionnaire (SWPAQ; Putilov 2007), respectively, also allow the differentiation of morning behavior and habits (e.g., sleep offset and morning lateness scoring, respectively) from evening/night behavior and habits (e.g., sleep onset and evening lateness scoring, respectively). Therefore, we administered, for the first time, these three rather than just one chronobiological questionnaire (e.g., the MEQ) to clarify and extend the previously reported findings on chronobiological correlates of restrained eating behavior. Namely, to score trait-like chronobiological variation, the MEQ was included in the present analysis either as a single scale or as a set of three subscales, and two other questionnaires (MCTQ and SWPAQ) were administered to assess state- and ability-like variation in sleep-wake behaviors, respectively. We predicted that the differences between individuals in any of three factorial dimensions of eating behaviors assessed with the TFEQ-R might be linked to, at least, one of the dimensions of trait-, state-, and ability-like chronobiological differences. We also predicted that healthy eating behaviors might be associated with: 1) healthy traits and states of the sleep-wake cycle assessed by the MEQ and MCTQ, respectively, and 2) abilities to either wake or sleep at certain times of the day assessed by the SWPAQ.

Materials and methods

Participants

The invitation to participate in this cross-sectional survey that applied several questionnaires in Google-formant were delivered by e-mail to 1099 university students. From 652 respondents, 631 were analyzed in the present study after excluding 21 respondents with either incomplete data or ages either younger than 17 or older than 23 y. Due to the gender bias in this student population, we did not expect to obtain a subsample of male respondents that would be of sufficient size for a search for correlation between, most possibly, only weakly related variables, but we used the collected subsample of 64 male students for the examination of gender gaps in these variables (see Supplementary Table S1).

Russian version of the 18-item Three-Factor-Eating-Questionnaire Reduced (TFEQ-R)

The 18-item TFEQ-R (Karlsson et al. 2000) is a shortened and revised version of the original 51-item questionnaire (Stunkard and Messick 1985) designed to assess three different aspects of eating behavior, i.e., uncontrolled,

restrained, and emotional eating. The first (9-item) scale measures the tendency to eat more than usual due to a loss of control over food intake accompanied by subjective feelings of hunger (UE); the second (6-item) scale assesses conscious restriction of food intake for controlling body weight or promoting weight loss (CR); and the third (3-item) scale measures the tendency to eat in response to negative emotions (EE). The TFEQ-R of the present study is a translated into Russian list of items published by De Lauzon et al. (2004). Information on psychometrical features of this version is reported in the Results.

Russian version of the 19-item Morningness-Eveningness Questionnaire (MEQ)

The 19-item MEQ is the first English-language scale for self-assessment of morning-evening preference (Horne and Ostberg 1976). The questions ask about timing of appetite, alertness, tiredness, mental and physical performance, sleep inertia, etc. Some of these questions ask the best time for physical exercise and preferred bed- and rising times. Each of the answers is assigned to a specific value. A total score in the range from 16 to 86 is calculated by adding up the values of the individual items (Horne and Östberg 1976; Terman and Terman 2005). Soon after its publication, the MEQ was been translated into many languages and, until recently, it remains the most popular questionnaire instrument for conducting research on chronobiological differences between individuals (see Adan et al. 2012; Di Milia et al. 2013; Levandovski et al. 2013; Putilov 2017, for review). The Russian translation was made by AAP and Konstantin Danilenko from the version adapted for American English speakers by Terman and Terman (2005) and Terman et al. (2001), New York State Psychiatric Institute, 1051 Riverside Drive, Unit 50, New York, NY, 10032; https://cet.org/wp-content/uploads/2019/12/MEQ-SA-2019.pdf). The translation was approved by Terman. The results on factor analysis of the MEQ, its division into subscales in accord with the results of this analysis and some other results on psychometric evaluation of the MEQ's scale and subscales are reported in Results and in Tables 1 and 2.

The 72-item Sleep-Wake Pattern Assessment Questionnaire (SWPAQ)

The SWPAQ was originally developed in the Russian language in the framework of the methodology pioneered by Folkard et al. (1979) to allow a multidimensional assessment of sleep-wake adaptabilities rather than traits (reviewed by Putilov 2017). These adaptabilities determine the success or failure of adjustment to a certain temporal condition, such as shift or night work (Folkard et al. 1979). The SWPAQ (Putilov 2007, 2010) includes six 12-item scales designed to assess Morning Lateness and Evening Lateness (the abilities to wake or work on demand in the morning and evening hours, M and E, respectively), Anytime Wakeability and Daytime Wakeability (the abilities to wake in inappropriate time and during the day, W and V, respectively), and Anytime

Table 1. Correlations among 17 chronobiological assessments.

		1EM		2 M		3E	
19-item MEQ Assessments	Whole MEQ scale	Subscale	Factor 1	Subscale	Factor 2	Subscale	Factor 3
MEQ	1	0.851***	0.636***	0.797***	0.541***	0.708***	0.440***
MEQ 1EM	0.851***	1	0.864***	0.496***	0.210***	0.484***	0.250***
Factor 1 (1EM)	0.636***	0.864***	1	0.333***	−0.035	0.262***	−0.008
MEQ 2 M	0.797***	0.496***	0.333***	1	0.864***	0.366***	0.118**
Factor 2 (2 M)	0.541***	0.210***	−0.035	0.864***	1	0.196***	0.000
MEQ 3E	0.708***	0.484***	0.262***	0.366***	0.196***	1	0.866***
Factor 3 (3E)	0.440***	0.250***	−0.008	0.118**	0.000	0.866***	1
SWPAQ E	−0.415***	−0.486***	−0.414***	−0.159***	0.016	−0.348***	−0.311***
SWPAQ M	−0.614***	−0.445***	−0.289***	−0.679***	−0.580***	−0.302***	−0.146***
SWPAQ W	0.220***	0.099*	0.066	0.420***	0.462***	−0.057	−0.210***
SWPAQ V	0.327***	0.232***	0.167***	0.466***	0.484***	0.033	−0.136***
SWPAQ F	−0.182***	−0.194***	−0.163***	−0.156***	−0.093*	−0.084*	−0.057
SWPAQ S	0.021	0.013	0.003	0.093*	0.159***	−0.094*	−0.157***
MCTQ wSOn	−0.376***	−0.370***	−0.320***	−0.263***	−0.144***	−0.271***	−0.189***
MCTQ wSOff	−0.171***	−0.189***	−0.229***	−0.104*	−0.013	−0.089*	−0.025
MCTQ fSOn	−0.510***	−0.445***	−0.362***	−0.360***	−0.224***	−0.432***	−0.307***
MCTQ fSOff	−0.565***	−0.480***	−0.374***	−0.523***	−0.372***	−0.310***	−0.178***

MEQ: Score on the 19-item Morningness-Eveningness Questionnaire (higher score indicates morningness); MEQ 1EM, 2 M and 3E or Factor (1EM), (2 M) and (3E): Subdivision of the MEQ into 6-, 7- and 6-item Subscales 1–3 in accord with the varimax rotated three-factor solution yielding Factors 1–3 interpreted as morning-to-evening comparison (1EM), morning behaviors (2 M), and evening or night behaviors (3E), respectively (any of higher scores indicates earliness); SWPAQ E and M, W and V, F, and S: Scores on the 12-item scales of Evening and Morning Lateness, Anytime and Nighttime Wakeability, and Anytime and Nighttime Sleeepability, respectively (a positive score suggests either lateness or ability). MCTQ wSOn, wSOf, fSOn, and fSOff: Four sleep times, Sleep Onset and Offset on weekdays and free days, respectively. Level of significance for Spearman coefficient of correlation: *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Sleepability and Nighttime Sleepability (the abilities to sleep at inappropriate time and at night, F and S, respectively). Positive scale's scores ranging from +2 to +12 indicate ability, while negative scores ranging from −12 to −2 indicate inability. The items of English and Russian versions of the 72-item SWPAQ are listed in Putilov (2007), Putilov (2010) and, in the previous publications the questionnaire in this (Putilov 2007, 2010) or the previous (40- and 52-items) versions was validated against various objective and subjective measures (e.g., Putilov et al. 2017, reviewed by Putilov 2010; 2017). In particular, the scales of the SWPAQ were cross-validated using student samples from the Novosibirsk State University and the University of Alaska Anchorage, and reliability of their English and Russian versions were shown to be similar to the reliabilities of the Russian and English versions of the MEQ (Putilov and Putilov 2005).

Self-reported sleep times from the Munich ChronoType Questionnaire (MCTQ)

The times of sleep onset and offset on free and weekdays (Tables 1–3, S1, S2) were obtained from answers to several questions of the MCTQ (Roenneberg et al. 2003). These times represent a current result of interaction of morning-evening predispositions and preferences with a particular temporal environment (see Putilov 2017, for review). An expected significant association of the MEQ score with sleep timing assessed with the MCTQ was found (Zavada et al. 2005), and both measures significantly correlate with the timing of melatonin secretion (Kantermann et al. 2015). Self-reported sleep times averaged over many samples are almost identical to the times predicted by a sleep-wake regulation model (Putilov et al. 2020; Putilov and Verevkin 2018). The translation of the MCTQ into Russian was made by Konstantin Danilenko and approved by the authors. Cronbach's α for four sleep times is given in Table 2 (along with αs for all other analyzed scales and subscales).

Statistical analyses

The $SPSS_{23.0}$ statistical software package (IBM, Armonk, NY, USA) was used for all statistical analyses. Factor analysis with varimax rotation was applied to determine factorial structures of the Russian-language versions of the 18-item TFEQ-R and the 19-item MEQ (see Results). To analyze the associations between the assessments in the female subsample, the Spearman's rho (ρ) was applied (Tables 1 and 2). Moreover, linear regression

Table 2. Correlations between chronobiological and eating assessments.

		18-item Three-Factor Eating Questionnaire Revised (TFEQ-R18)						
		Uncontrolled Eating		Cognitive Restraint		Emotional Eating		
Assessments Scale/Factor Assessments	Alpha	Scale	Factor 1	Scale	Factor 2	Scale	Factor 3	BMI
Uncontrolled Eating	0.874	1	0.908***	−0.010	−0.024	0.595***	0.362***	0.062
Factor 1 (1UE)	-	0.908***	1	−0.029	−0.035	0.300***	−0.005	−0.017
Cognitive Restraint	0.786	−0.010	−0.029	1	0.996***	0.085*	0.049	0.335***
Factor 2 (2CR)	-	−0.024	−0.035	0.996***	1	0.061	0.023	0.339***
Emotional Eating	0.832	0.595***	0.300***	0.085*	0.061	1	0.913***	0.138***
Factor 3 (3EE)	-	0.362***	−0.005	0.049	0.023	0.913***	1	0.149***
BMI	-	0.062	−0.017	0.335***	0.339***	0.138***	0.149***	1
MEQ	0.833	−0.065	−0.060	0.079	0.086*	−0.023	−0.009	0.008
MEQ 1EM	0.729	−0.017	−0.005	0.024	0.030	−0.017	−0.020	0.034
Factor 1 (1EM)	-	−0.056	−0.040	0.026	0.029	−0.055	−0.044	0.020
MEQ 2 M	0.749	−0.161***	−0.151***	0.123**	0.130**	−0.077	−0.029	0.030
Factor 2 (2 M)	-	−0.196***	−0.177***	0.086*	0.093*	−0.107*	−0.045	0.033
MEQ 3E	0.525	0.084*	0.074	0.008	0.009	0.073	0.043	−0.065
Factor 3 (3E)	-	0.223***	0.199***	0.009	0.009	0.163***	0.090*	−0.053
SWPAQ E	0.770	0.013	0.019	−0.005	−0.012	−0.031	−0.028	−0.054
SWPAQ M	0.787	0.143***	0.139***	−0.124**	−0.136***	0.071	0.043	−0.073
SWPAQ W	0.803	−0.172***	−0.119**	0.009	0.017	−0.181***	−0.147***	0.039
SWPAQ V	0.717	−0.253***	−0.238***	0.024	0.034	−0.180***	−0.103*	0.027
SWPAQ F	0.772	0.051	0.059	−0.032	−0.031	0.023	0.010	−0.066
SWPAQ S	0.735	−0.174***	−0.151***	−0.060	−0.063	−0.124***	−0.081	0.076
MCTQ wSOn	Four	0.085*	0.095*	−0.024	−0.030	0.065	0.031	−0.047
MCTQ wSOff	sleep	0.045	0.014	−0.079	−0.082	0.106*	0.100*	0.011
MCTQ fSOn	times:	0.045	0.053	0.004	0.002	0.046	0.013	0.028
MCTQ fSOff	0.686	0.099*	0.105*	−0.080*	−0.094*	0.080	0.042	−0.070

Alpha: Cronbach's α. TFEQ-R18: Eating habits assessed with the 18-item version of Three-Factor Eating Questionnaire Revised; Factor 1–3 (1UE, 2CR, and 3EE): Scores on the three varimax rotated factors interpreted in terms of the three Scales of TFEQ-R, Uncontrolled Eating (UE), Cognitive Restraint (CR), and Emotional Eating (EE), respectively. Factor 1 – Factor 3 (1EM, 2 M, and 3E): Scores on the three varimax rotated factors of the MEQ interpreted as morning-to-evening preference (1EM), morning (2 M), and evening or night components of the morningness-eveningness (3E), respectively (any of higher scores indicates earliness). Level of significance for Spearman coefficient of correlation: *p < 0.05, **p < 0.01, ***p < 0.001. See other notes to Table 1.

analysis was used to predict from all other assessments Body Mass Index (BMI) and each of three scores on scales or factors of uncontrolled, restrained, and emotional eating behaviors (Table 3). Additionally (see Supplementary materials) a score on each of the chronobiological constructs was predicted from the assessments of uncontrolled, restrained, and emotional eating behaviors and BMI (Table S2), and the gender subsamples were compared using the Student's t-test for independent samples (Table S1). Degrees of freedom for t-tests was corrected (Table S1) when the null hypothesis that the variances for male and female subsamples are equal was rejected (Levene's test).

Results

Confirmation of the three factorial dimensions of the TFEQ-R

The female student subsample was used for analyses (Tables 1–3 and S2), including the checking of factorial structures of the Russian versions of the TFEQ-R and the MEQ.

Factor analysis of responses to 18 items of the TFEQ-R yielded three principal components with eigenvalues >1 (5.802, 3.150, 1.229). They explained 56.562% of the total variance, and the three varimax rotated factors accounted for 25.526%, 17.432%, and 13.604% of this variance. The loadings >0.5 were shown by many of the 18 items, # 1, 4, 5, 7–9, 13, 14, and 17 on Factor 1, 2, 11, 12, 15, 16, and 18 on Factor 2, and 3, 6, and 10 on Factor 3. The factors were unmistakably identified and included into further analyses under the names previously suggested in the studies in other tongues (e.g., Lauzon et al. 2004; Karlsson et al. 2000): "Uncontrolled Eating", "Cognitive Restraint" and "Emotional Eating". Nine items of the first varimax rotated factor (each with loading >0.5) contained the questions asking about eating more than usual due to a loss of control over food intake and feelings of hunger (1UE). Six items (each with loading >0.5) of the second factor asked about conscious restriction of food intake for controlling body weight and shape or for promoting weight loss (2CR). The remaining 3 items (each with loading >0.5) of the third factor asked about the proneness to eat in response to negative emotions (3EE). Although some of the items showed dual loading on either 1UE or 3EE, none of the secondary loadings exceeded 0.43.

Consequently, either scores on the three scales (UE, CR, and EE) or the three scores on Factors 1–3 (1UE, 2CR, and 3EE) were used to examine the relationships between the eating behaviors and various chronobiological assessments (Tables 2 and 3, S2). Scores on the UE, CR, and EE scales were calculated in the way utilized by de Lauzon et al. (2004). Cronbach's αs suggested acceptable or good reliability of all of these three TFEQ-R' scales (Table 2).

Subdivision of the MEQ into three subscales

Factor analysis of the responses to the 19 items of the MEQ yielded five principal components with eigenvalues >1 (5.166, 1.647, 1.148, 1.044, 1.011) that explained 52.710%

Table 3. Predicting BMI and each of three eating assessments from other assessments.

	18-item Three-factor eating questionnaire Revised							
Assessments Scales	Uncontrolled Eating		Cognitive Restraint		Emotional Eating	BMI		
F-ratio	66.38***	44.91***	9.06***	6.64***	44.45***	10.15***	7.67***	9.06***
R square	0.416	0.420	0.088	0.097	0.418	0.098	0.110	0.102
Uncontrolled Eating	-	-	−0.020	−0.038	0.610***	−0.015	−0.002	−0.028
Cognitive Restraint	−0.013	−0.024	-	-	0.036	0.257***	0.263***	0.255***
Emotional Eating	0.614***	0.607***	0.064	0.056	-	0.145**	0.144**	0.142**
BMI	−0.010	−0.002	0.260***	0.267***	0.094**	-	-	-
MEQ 1EM	0.061	-	−0.024	-	-	0.052	-	-
MEQ 2 M	−0.152***	-	0.122*	-	-	0.046	-	-
MEQ 3E	0.073	-	−0.013	-	-	−0.104*	-	-
SWPAQ E	-	−0.005	-	0.059	−0.008	-	−0.009	-
SWPAQ M	-	0.053	-	−0.136**	−0.037	-	−0.040	-
SWPAQ W	-	0.043	-	−0.06	−0.098*	-	0.060	-
SWPAQ V	-	−0.098*	-	−0.003	−0.008	-	−0.030	-
SWPAQ F	-	0.025	-	0.022	0.013	-	−0.090*	-
SWPAQ S	-	−0.092*	-	−0.066	0.002	-	0.112*	-
MCTQ wSOn	-	-	-	-	-	-	-	−0.055
MCTQ wSOff	-	-	-	-	-	-	-	−0.002
MCTQ fSOn	-	-	-	-	-	-	-	0.129*
MCTQ fSOff	-	-	-	-	-	-	-	−0.099*

Scores on the three subscales of the MEQ were interpreted as the components of the morningness-eveningness behaviors, the morning-to-evening comparison (1EM), morning time (2 M) and evening or nighttime (3E), respectively (any of higher scores indicates earliness). Non-significant results obtained in the analyses of these three sets of chronobiological assessments as predictors were not included. Level of significance for either F-ratio or Standardized Beta for the predictors: *p < 0.05, **p < 0.01, ***p < 0.001. See other notes to Tables 1 and 2, S1, and S2.

of the total variance. Since it is unlikely that the last two components with very close to an eigenvalue of 1 would not be confirmed by the results of parallel analysis, only three first components were subjected to varimax rotation. The rotated factors accounted for 16.108%, 15.014%, and 10.774% of the total variance. Primary loadings >0.4 were shown by the items #10, 11, 8, 15, and 17–19 on Factor 1, items #1, 3–5, 7, 9, and 13 on Factor 2, and items #2, 6, 8, 12, 14, and 16 on Factor 3. The questions showing the primary loading on Factor 1 asked to compare different times of the day; the questions loaded on Factor 2 asked about morning hours; and the questions of Factor 3 asked about either evening or night hours.

Therefore, we used the abbreviated names "Factor (1EM)" and "1EM" (morning-to-evening comparison), "Factor (2 M)" and "2 M" (morning behaviors), and "Factor (3E)" and "3E" (evening or night behaviors), respectively, for scores on Factors 1–3 and for scores on the 7-, 6-, and 6-item subscales representing these three factorial dimensions. Correlations between these scores and other chronobiological assessments supported such interpretation of the three factors. Namely, MEQ 1EM demonstrated equally strong correlations with Morning and Evening Lateness scales (SWPAQ E and M, respectively) and with sleep onset and offset on free days (fSOn and fSOff, respectively), while MEQ 2 M showed stronger correlations with SWPAQ M and fSOff in contrast to MEQ 3E showing stronger relationships with SWPAQ E and fSOn (Table 1).

As it is illustrated in the first column of Table 2, the whole MEQ scale had excellent reliability; however, unsatisfactory reliability was shown by the third subscale (Cronbach's α of 0.525), while the two other subscales showed acceptable or good reliability (Table 2). Overall, a score on any of three subscales positively correlated with the other scores, and a higher score indicated earliness and negatively correlated with lateness scores of another questionnaire and with reports on sleep times (Table 1).

Correlations between eating and chronobiological assessments

Each of the scores on the scales or factors of eating behaviors (six scores in total) were tested on their associations with 17 chronobiological assessments (Table 2). Correlation analysis indicated that each of three aspects of eating behaviors significantly (p = .05/17 = <0.003) correlated with, at least, one of the chronobiological assessments (Table 2). A higher score on Cognitive Restraint (CR) was significantly associated with a lower SWPAQ M score and a higher MEQ 2 M score, the indicators of a better ability to wake in the morning, and a higher morning alertness level. Moreover, a nominal correlation between a higher CR score and an earlier sleep offset on free days was in the same-direction, i.e., cognitive eating restriction was linked to earlier wakeups (Table 2).

When compared to the pattern of significant relationship with the chronobiological assessments shown by CR score, the pattern shown by a score on Uncontrolled Eating (UE) was the opposite. A higher score on the UE factor or scale was significantly associated with a higher SWPAQ M score and a lower MEQ 2 M score, indicating an inability to wake in the morning and a lowered level of morning alertness. Moreover, a higher UE score showed the same directional relationship with a later sleep offset on free days and a later sleep onset on weekdays, i.e., delayed bedtimes preceding earlier risetimes on weekday mornings (Table 2). Additionally, a higher UE score was significantly associated with lower wakeability scores (SWPAQ W and V), a lower Nighttime Sleepability score (SWPAQ S), and a lowered alertness in the evening or nighttime hours (MEQ 3E).

The pattern of correlation of Emotional Eating (EE) did not resemble the pattern shown by CR. Morning behaviors were not found to be significant correlates of EE. However, the pattern shown by EE partly resembled the pattern shown by UE. A higher EE score was significantly associated with lower wakeability scores (SWPAQ W and V), a lower Nighttime Sleepability score (SWPAQ S), and a lowered alertness in the evening or nighttime hours (MEQ 3E). Moreover, the same kind of relationship was revealed by the pattern of correlation of EE score with sleep offset on weekdays (Table 2).

Notably, the opposing other patterns of correlation with either the UE or EE score was demonstrated by scores on MEQ's Factors 2 and 3 (2 M and 3E; Table 2). This suggested that low scores on uncontrolled and emotional eating scales were associated with earliness in the morning behavior and lateness in the evening and night behavior. None of the correlations was significant for MEQ 1EM (morning-to-evening comparison).

BMI contrasted to the scores of the eating behavior scales of the TFEQ-R by not showing significant correlations with any of 17 chronobiological assessments (Table 2).

Prediction of the three restrained eating assessments and BMI from other assessments

Each of three scores on the eating behavior scales was found to be significantly predicted by other assessments (Table 3). The strongest predictor of CR score was BMI, but CR was not predicted by scores on two other scales of the TFEQ-R. This score was also significantly predicted by chronobiological scores, SWPAQ M and MEQ 2 M, the indicators of ability to wake in the morning and

high level of morning alertness (Table 3). In contrast, scores on UE and EE scales significantly predicted one another, while BMI was among the significant predictors of only one of the scales (EE). The list of predictors of a higher UE score included several chronobiological scores, MEQ 2 M, SWPAQ V and S, the indicators of lowed morning alertness, lowered daytime wakeability, and lowered nighttime sleepability (Table 3). The list of predictors of a higher EE score included inability to wake in inappropriate hours (SWPAQ W), while MEQ and other chronobiological scores were not among the significant predictors (Table 3).

The score on EE scale, and, especially, the score on CR scale significantly predicted BMI. The association pointed at restrained and emotional eating behaviors as the associates of higher BMI. Of the MEQ subscales, the significant predictor of BMI was MEQ 3E score, the indicator of earliness in evening and night activities. The negative ß coefficient suggested that earliness was linked to lower BMI. Of the sleep times, the predictors were a later sleep onset and an earlier sleep offset on free days. The associations suggested that higher BMI might be associated not only with lateness in the evening and night activities, but also with shorter time spent in bed. Of the SWPAQ scales, the predictors of higher BMI were a higher nighttime sleepability and a lower anytime sleepability (SWPAQ's scales S and F, respectively). Thus, the associations of BMI with chronobiological assessments were not revealed by examining the pairwise correlations between BMI and these assessments (Table 2). However, the significant associations emerged after adjustment for other assessments obtained with the same questionnaire, including the contribution of such correlates of BMI as EE and, especially, CR that might suppress the influence of chronobiological traits, states, and abilities in correlational analysis (Table 3).

These results provided by this linear regression analysis aimed at predicting BMI uncontrolled, restrained, and emotional eating behaviors (Table 3) were very similar to the results of additional analysis for predicting scores on each of the chronobiological constructs from the assessments of eating behaviors and BMI (Table S2).

Discussion

In the present cross-sectional questionnaire study of female students at Russian universities, we tried to clarify and extend the previously reported findings on the associations of individual variation in eating restriction behaviors assessed with the TFEQ with individual variation in diurnal preference assessed either with a morningness-eveningness scale (Schubert and Randler 2008; Walker et al. 2015; Aoun et al. 2019) or with its subscales (Konttinen et al. 2014). For the first time, significance of associations with three scales of the TFEQ-R (Karlsson et al. 2000) was examined by applying more than just one chronobiological questionnaire. The administered questionnaires were designed to assess trait-, state-, and ability-like individual chronobiological differences (the MEQ, Horne and Ostberg 1976; the MCTQ, Roenneberg et al. 2003, and the SWPAQ; Putilov 2007, respectively). Overall, the results supported the previously reported positive findings (Schubert and Randler 2008; Konttinen et al. 2014; Walker et al. 2015; Aoun et al. 2019). In line with these findings, the present results on the associations of the three scales of the TFEQ-R with the assessments of trait-, state-, and ability-like chronobiological differences allowed the conclusion that healthy eating behaviors (restrained eating and lack of uncontrolled and emotional eating) seem to be linked to: 1) healthy sleep-wake habits and behaviors 2) several abilities to wake or sleep on demand at certain times of the day. The later link was not previously tested and reported. Moreover, it seems that the present results of analysis of the associations of any of three dimensions of eating behaviors with sleep-wake behaviors were positive because we examined a rather big set of variables representing various chronobiological constructs, including scores on subscales of the originally single MEQ scale, reports on sleep offset and onset times, and scores on Morning and Evening Lateness scales. Therefore, the differential relationships of eating behavior with subconstructs of such chronobiological trait as morningness-eveningness was reliably documented.

In particular, one of the results pointing at the differential relationship of eating behaviors with subconstructs of the morningness-eveningness was provided by applying correlation analysis. Such results suggested that one of MEQ's subscales (MEQ 2 M indicating morning earliness) correlated positively with an eating behavior scale, while one of other subscales (MEQ 3E indicating evening/night earliness) correlated negatively with the same eating behavior scale. Such differential relationship might be a plausible explanation for some of the previously reported inconclusive results, such as the absence of significant associations between the MEQ score and scores on any of the TFEQ-R scales in a sample of female students (Aoun et al. 2019), absence of significant associations between a MEQ score, and a score on EE scale of the TFEQ-R (Walker et al. 2015; Aoun et al. 2019). Moreover, the results of regression analysis suggested that CR and UE are reliably linked to only the morning component of morningness-eveningness continuum assessed as a score on one of

the three MEQ's subscales (MEQ 2 M). The significant result on this score was confirmed by two other significant results, on morning lateness assessed as a score on the SWPAQ M scale and on sleep offset on free days assessed by the MCTQ. All these associations suggested that morning earliness predicted a higher score on the CR scale and a lower score on the UE scale. In contrast, a score on the EE scale was found to be related to evening/night component of morningness-eveningness assessed as a score on MEQ 3E subscale. We also found that an EE score was most reliably associated with a score on SWPAQ W scale (Anytime Wakeability) that is a positive correlate of both morning earliness and evening lateness (Putilov et al. 2017). These associations suggest that evening earliness and low wakeability predicted a higher score on the EE scale. The result was additionally supported by a significant relationship between an EE score and sleep offset on weekdays. The differential relationships of morning and evening components of morningness-eveningness with the TFEQ's scales seem to be also a plausible explanation of the lack of significant associations of eating behavior with the 1st (the largest) factor of the MEQ (MEQ 1EM), interpreted as a morning-to-evening comparison. Since a score on 1EM subscale is equally linked to morning and evening lateness and alertness, it fails to reveal the positive associations of healthy eating behaviors with high levels of both morning and evening alertness. In summary, by using scores on three subscales or on three factors of the MEQ, we found the differential relationships for morning and evening components of morningness-eveningness and confirmed these relationships using the additional assessments of the morning and evening components of morningness-eveningness obtained by applying either the SWPAQ or MCTQ.

The causes of the relationship between individual differences in the sleep-wake and eating behaviors remain unexplored. These behaviors might share common biological bases. Moreover, their inter-relationship might be mediated by various biological and psychological factors. Konttinen et al. (2014) found that the association of EE with morning alertness (a subscale of the MEQ scale) was partly mediated by depressive symptoms. Recently, Guenther and Stolarski (2021) reported that future-positive and present-fatalistic time perspectives may be considered as mediators of the association between chronotype and eating habits. Future-positive time perspective inclines to considering consequences of one's own behavior, but in a generally positive way when individuals with elevated levels of this temporal orientation perceive future as an opportunity rather than a threat. However, this mediation effect explained only about one third of the chronotype–healthy eating association (Guenther and Stolarski 2021). Therefore, more studies are required to provide deeper insight into such associations.

The major limitation of the present study is in the absence of additional data allowing the comparison of subjective assessments with objective measures of eating behaviors and circadian rhythmicity. The limitations of the present research also include a rather narrow age range of the student participants and the absence of any information on their health that would be used for more strict inclusion criteria. The profound change in the sleep-wake patterns and BMI across ages does not allow the generalization of our positive findings on the chronobiological correlates of eating behaviors to the whole lifespan. Moreover, an additional assessment of psychological and psychiatric states and traits is required to separate the contribution of these traits and states to eating behaviors from the ones reported here concerning the chronotypological characteristics of the female university students. Longitudinal studies with participants that are randomly sampled from the whole population are needed to confirm and extend the present results by the additional results on the objective and repeated measurements of eating behaviors and chronobiological characteristics of these participants. Further research of both healthy and unhealthy individuals is also required to assess the possible interactions between cognitive abilities, personality, psychopathology, chronobiology, and eating behaviors.

Conclusions

The present results confirm the significance of relationship between individual variation in the domains of chronobiology and restricted eating behaviors. They extend the previously published findings suggesting differential relationships of these behaviors with morning and evening components of morning-evening preference. They also provid further evidence for a link between healthy eating behaviors and healthy sleep-wake behaviors, habits, and adaptabilities. Further studies are required to identify potential mediators and mechanisms underpinning the links between sleep-wake and eating behaviors.

Conflicts of Interest

No potential conflict of interest was reported by the authors.

Data availability statement

The dataset is available on reasonable request to the first author.

Ethics approvals

The study was performed in accordance with the ethical standards of this journal (Portaluppi et al., 2010). It was approved by the bioethics commission of the Institute of Life Science of the North Caucasus Federal University, Stavropol (Research project #2019-001, protocol #1 from 20.09.2019). Written consent was obtained as a response "Yes" to the first question of this survey provided by each of the study participants.

Author contributions

Authors ROB and EVB designed the study and wrote the protocol. Authors ROB, ELT and EVB collected the dataset and made its preliminary analysis; Authors ROB, AAP and EVB conducted literature searches and provided summaries of previous research studies, AAP conducted the statistical analysis. Author AAP wrote the first draft of the manuscript, and all authors reviewed and commented on subsequent drafts of the manuscript.

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