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RESEARCH ARTICLE

Association between chronotype, sleep pattern, and eating behaviours in a group of Italian adults

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ABSTRACT

A cross-sectional study was conducted to assess the possible relationship between chronotype, sleeping, and eating patterns in 74 Italian adults (71.6% women). Based on Morningness-Eveningness Questionnaire (MEQ) score, participants were classified as morning ($n = 24$), intermediate ($n = 25$), and evening ($n = 25$) chronotypes. From analysis, no significant differences among chronotypes emerged for sleep habits. As to eating behaviours, the evening subjects showed a significant ($p < 0.05$) shift towards later hours of the day in the consumption of all meals, except dinner. In addition, the evening subjects had a later midpoint of energy intake (EI) of about 35 min and 1 h ($p < 0.001$), respectively, than the intermediate and morning subjects. Analysing the diet quality, morning subjects reported significantly ($p = 0.030$) lower consumption of sweets and sweeteners, and significantly ($p = 0.035$) lower intake of ultra-processed fats and seasonings. Evening subjects showed a significant delay in EI during the day, while morning subjects reported a better-quality diet.

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Introduction

Biological processes are rhythmically regulated in humans. The oscillation of the physiological functions, including the sleep/wake cycle, feeding behaviour, and endocrine function, are marked by the circadian rhythms (Roenneberg and Merrow 2016). The individual manifestation of circadian rhythms has been summarised under the concept of chronotype, which refers to the specific activity-rest preference of an individual over a 24-h period (Adan et al. 2012). Early risers, who are preferentially active in the morning, are said to have a morning chronotype, while late risers with more nocturnal activities are said to have an evening chronotype (Fabbian et al. 2016). People with an intermediate chronotype fall among the early and late risers. The most common method to assess chronotype is the administration of validated questionnaires, such as the Morningness-Eveningness Questionnaire (MEQ) (Horne and Östberg 1976).

A growing body of evidence suggests that chronotype may influence the balance between health and disease. In this regard, a recent meta-analysis found that evening subjects have a higher risk of cardiovascular disease, diabetes, cancer, and depression (Lotti et al. 2021). The reasons, however, are not yet fully known. A possible explanation is a delay in the circadian rhythms of evening subjects of about 2 h compared to morning subjects, which may have a negative impact on several health-related factors, including sleep and eating patterns (Wittmann et al. 2006). Regarding sleep behaviours, recent studies have associated the evening chronotype with a reduction in sleep quality and quantity (Fabbian et al. 2016; Taillard et al. 2021). In fact, it seems that during the week, evening subjects accumulate a significant sleep debt

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due to social commitments that force them to wake up earlier than their preferred time (Montaruli et al. 2021). This mismatch between sleep behaviour and the circadian clock may favour the onset of various metabolic diseases in evening subjects (Knutson et al. 2007; Roenneberg and Merrow 2016).

As to eating patterns, some studies have suggested that evening subjects have worse eating habits, both in terms of mealtimes and diet quality. In particular, evening subjects appear to have higher caloric intake during dinner and a shift in mealtimes towards later hours of the day (Maukonen et al. 2016; Almoosawi et al. 2019). They were also characterised by low consumption of whole grains, fish, vegetables, and fruit and high consumption of unhealthy foods, such as sugary drinks and sweets (Kanerva et al. 2012). However, not all studies found differences among chronotypes, and the tools used in collecting diet data were not always validated (Mazri et al. 2019). Moreover, given the recent interest in this topic, data on the Italian population are very scarce. Since understanding the possible relationship between chronotype, sleep and dietary patterns is essential to guide the development of personalised strategies to prevent chronic diseases and ensure optimal health, further studies are needed. Therefore, the aim of this study was to evaluate the relationship between chronotype, sleeping and eating habits in a sample of Italian adults.

Materials and methods

Participants and study design

A random sample of 95 subjects was recruited from June 2020 to September 2020. Clinically, healthy Italian adults (18–65 years), both genders, resident in Italy were eligible. Subjects were invited to join the study by trained interviewers through telephone conversation. First, the interviewers explained the purpose and the procedures of the study, assessed the compliance with the inclusion criteria, and asked for subjects' consensus to participate. Then, an informed consent form was sent to each person by email. Once the informed consent was completed and re-sent to the investigators, subjects were formally included in this cross-sectional pilot study. Participants were invited to complete questionnaires on socio-demographic characteristics, sleeping patterns, and dietary habits. The obtained information was entered into an electronic datasheet, in which each participant was identified with a unique alphanumeric ID.

The study was conducted according to the guidelines in the Declaration of Helsinki, and it was approved by the Ethics Committee of the University of Florence, Florence, Italy (n. 449/2016, protocol 81120).

Data collection

Socio-demographic and anthropometric parameters

Data on socio-demographic (sex, age, educational level, occupation, and marital status) and anthropometric (weight and height) variables were obtained through a self-administered questionnaire. The body mass index (BMI) was calculated as weight in kilograms divided by the square of the height in metres for each participant, and the ponderal status was defined using the cut-off points for BMI according to WHO standards. In addition, the basal metabolic rate (BMR) was calculated from the standard equation based on sex, age, weight, and height (Harris and Benedict 1918).

Chronotype

Participants' chronotype was determined using the Italian version of the MEQ (Horne and Östberg 1976), a 19-item self-administered tool able to define subjects' diurnal habit preferences for morning or evening through a score ranging between 16 (extreme eveningness) and 86 (extreme morningness). Based on the MEQ score tertiles, participants were divided into three groups defined as evening if the MEQ score was $\leq$52, intermediate if the MEQ score was between 52 and 60, or morning if the MEQ score was $\geq$60.

Sleep pattern

Participants were asked to report their habitual wake-up time in the morning and the time they go to sleep during typical weekdays and weekend days. Sleep duration was then calculated as the difference between bedtime and wake-up time for weekdays and weekend days. The average weighted sleep duration was computed as: (weekday sleep duration $\times$ 5 + weekend day sleep duration $\times$ 2)/7. Sleep quantity was also defined as a dichotomous variable as poor if <7 h per night or good if $\geq$7 h per night, based on the National Sleep Foundation's sleep time duration recommendations (Hirshkowitz et al. 2015). The self-perceived sleep quality was evaluated through the Italian version of the Pittsburgh Sleep Quality Index (PSQI) (Curcio et al. 2013). The PSQI is a self-administered questionnaire scoring between 0 and 21, with higher scores indicating poorer sleep quality. Sleep quality was

Table 1. Demographic and anthropometric characteristics of study participants according to individual chronotype.

	Morning	Intermediate	Evening	*p*-Value*
Sex				0.203
Females	14 (18.9)	19 (25.7)	20 (27.0)	
Males	10 (13.5)	6 (8.1)	5 (6.8)	
Age, years	41 ± 13	35 ± 11	33 ± 8[a]	0.032
Education level				0.627
Pre-graduated	7 (9.5)	7 (9.5)	3 (4.1)	
Graduated	12 (16.2)	13 (17.6)	16 (21.6)	
Post-graduated	5 (6.8)	5 (6.8)	6 (8.1)	
Occupation				0.964
Employed	18 (24.3)	18 (24.3)	18 (24.3)	
Unemployed	6 (8.1)	7 (9.5)	7 (9.5)	
Marital status				0.170
Married/partner	15 (20.3)	10 (13.5)	10 (13.5)	
Unmarried/single	9 (12.2)	15 (20.3)	15 (20.3)	
Weight, kg	64.0 ± 12.7	66.1 ± 12.2	62.5 ± 14.1	0.620
BMI, kg/m^2	22.4 ± 3.3	26.3 ± 3.9	21.8 ± 2.6	0.138
Ponderal status				0.463
Underweight	2 (2.7)	3 (4.1)	2 (2.7)	
Normal weight	18 (24.3)	13 (17.6)	18 (24.3)	
Overweight-obese	4 (5.4)	9 (12.2)	5 (6.8)	

BMI: body mass index.
Categorical variables were expressed as frequencies (percentages), whereas continuous variables as mean ± *SD*.
**p*-Values refer to one-way ANOVA models with Bonferroni *post-hoc* test for continuous variables and to Chi-square tests for categorical variables.
[a]$p < 0.05$ *vs.* morning.

defined as a dichotomous variable as poor if the PSQI score was >5 or good if it was ≤5.

Eating behaviours

Participants were asked to report their habitual mealtimes (i.e. for breakfast, lunch, dinner, and snacks) during typical weekdays and weekend days. The eating window was calculated as the interval between the time of the first and the last meal of the day. The midpoint of energy intake (EI) was defined by calculating the midpoint between the time of the first and the last meal of the day. Dietary intakes were investigated through a 7-d standardised weighed dietary record (WDR). Participants were provided with detailed verbal and written instructions both by telephone and email, and then contacted again by trained interviewers to check the correctness of the compilation. They were required to indicate each food/drink consumed together with the relative quantities in grams/millilitres. Data were entered in the Metadieta software application (Me.Te.Da., Rome, Italy) by trained personnel, carefully checked for errors, and then analysed to obtain EI and nutrient intakes (i.e. carbohydrates, fat, and protein). Participants were defined as under-reporters, normal-reporters, or over-reporters by using Goldberg's cut-off values for EI:BMR revised by Black (Goldberg et al. 1991; Black 2000). The habitual consumption of ultra-processed food (UPF) was investigated by asking participants to complete the NOVA Food Frequency Questionnaire (NFFQ) (Dinu et al. 2021), a 94-item tool validated in the Italian adult population. UPF are formulations of ingredients, mostly for industrial use only, derived from a series of industrial processes (Monteiro et al. 2018). When processing NFFQ data, the amount of food consumed was calculated in grams per week and in grams per day, and then classified according to the NOVA food group classification (Monteiro et al. 2018).

Statistical analysis

The statistical analyses were performed using the IBM Statistical Package for Social Science for Macintosh version 27.0 (SPSS 27.0; IBM Corp., Armonk, NY, USA), setting the significant level of $p = 0.05$. Categorical variables were expressed as frequencies (percentages), whereas continuous variables as mean ± standard deviation (*SD*). Analyses were performed excluding misreporters (under- and over-reporters) as defined based on the ratio between the mean EI reported in the WDR and the estimated BMR. Differences in continuous variables among MEQ groups (evening, intermediate, and morning groups) were explored through one-way ANOVA models with the Bonferroni *post hoc* test. Chi-square tests were used to compare categorical variables among MEQ groups. Correlations between MEQ scores and other investigated variables were performed using Pearson correlation coefficients.

Results

Characteristics of study participants

In total, 74 participants had complete and accurate data and were included in the analysis. The mean age was 36 ± 11 years, and most participants ($n = 53$; 71.6%) were females. The mean BMI was 22.6 ± 3.3 kg/m^2 and over half of the sample ($n = 49$; 66.2%) fallen between the normal weight cut-offs. Based on MEQ score tertiles, participants were classified as morning ($n = 24$ subjects), intermediate ($n = 25$), and evening ($n = 25$) chronotypes. Their demographic and anthropometric characteristics were similar, except for age, which was higher for participants in the morning group (Table 1).

Sleep pattern and chronotype

Participants' sleep data according to individual chronotype are presented in Table 2. Significant differences among groups were observed for bedtime

Table 2. Sleeping pattern of study participants according to individual chronotype.

	Morning	Intermediate	Evening	p-Value*
Bedtime, hh:mm	23:23 ± 01:09	23:37 ± 00:43	00:24 ± 00:51[a,b]	0.001
Wake up time, hh:mm	06:54 ± 00:47	07:36 ± 00:48	08:07 ± 00:49[a]	<0.001
Sleep duration, hh:mm	07:31 ± 00:59	07:58 ± 01:02	07:46 ± 00:50	0.251
Sleep quantity				
Good (≥7 h/night)	21 (28.4)	22 (29.7)	22 (29.7)	0.998
Poor (<7 h/night)	3 (4.1)	3 (4.1)	3 (4.1)	
Sleep quality				0.691
Good (PSQI ≤ 5)	14 (18.9)	16 (21.6)	13 (17.6)	
Poor (PSQI > 5)	10 (13.5)	9 (12.2)	12 (16.2)	

PSQI: Pittsburgh Sleep Quality Index.
Categorical variables were expressed as frequencies (percentages), whereas continuous variables as mean ± *SD*.
**p*-Values refer to one-way ANOVA models with Bonferroni *post-hoc* test for continuous variables and to Chi-square tests for categorical variables. Different letters in the same row indicate statistically significant differences among MEQ score groups.
[a]$p < 0.05$ *vs.* morning.
[b]$p < 0.05$ *vs.* intermediate.

($p = 0.001$) and wake-up time ($p < 0.001$), with evening subjects usually going to bed and waking up later than participants in the morning group. The number of hours slept, however, was similar. Both sleep quantity and quality, assessed through the PSQI, were non-different among morning, intermediate, or evening chronotypes. When correlation analyses were performed between the total MEQ score and the time of going to bed and waking up, a significant inverse correlation was found only with the habitual wake-up time ($r = -0.547$, $p < 0.001$).

Eating behaviours and chronotype

Breakfast, lunch, and dinner were regularly consumed by most of the sample (99% had breakfast and 100% had lunch and dinner), while mid-morning and afternoon snacks were consumed regularly by 39 (53%) and 57 (77%) participants, respectively. The average daily EI was 1691 ± 373 kcal, distributed as follows: 17 ± 5% at breakfast, 5 ± 5% in the mid-morning snack, 37 ± 7% at lunch, 9 ± 5% in the afternoon snack, and 37 ± 2% at dinner. Comparing the chronotypes, we found that evening subjects had their meals later than morning subjects, reaching statistical significance for all meals except dinner (Figure 1). In terms of energy distribution, evening subjects consumed a lower percentage of calories at lunch (33 ± 6% of daily EI) than intermediate (38 ± 6% of EI) and morning (34 ± 6% of EI) subjects. In contrast, the afternoon snack provided them with more calories (11 ± 6% of E) than the intermediate (8 ± 4% of EI) and morning (7 ± 3% of EI) subjects.

The total MEQ score was inversely correlated with habitual breakfast time ($r = -0.545$, $p < 0.001$), mid-morning snack time ($r = -0.440$, $p = 0.004$), and lunch time ($r = -0.295$, $p = 0.011$). A weak inverse correlation was also observed between the total MEQ score and the time between dinner and bedtime ($r = -0.238$, $p = 0.041$). When calculating the midpoint of EI, a good inverse correlation was found with the MEQ score ($r = -0.460$, $p < 0.001$).

Table 3 shows the participants' timing, energy, nutrient, food, and UPF intake according to their chronotype. While the eating window was similar among the three groups, evening subjects had a later midpoint of EI ($p < 0.001$) of about 35 min and 1 h, respectively, than the intermediate and morning subjects. In terms of energy and nutrient intakes, there were no significant differences among the groups. The analysis of food groups revealed a lower consumption of sweets and sweeteners in morning subjects ($p = 0.030$), and no differences for the other food groups, such as fruit, vegetables, cereals, meat and fish, dairy products, eggs, fats, and beverages. Finally, the evaluation of UPF consumption showed significant differences only for UPF fats and seasonings, with significantly lower intakes in morning subjects ($p = 0.035$).

Discussion

In this study, we assessed the influence of chronotype on both sleep and dietary habits in a group of Italian adults. The results showed that evening subjects went to bed and woke-up later than morning subjects, but sleep duration and quality did not differ significantly among the chronotype groups. When eating habits were analysed, evening subjects were associated with a significant delay in time eating all meals except dinner, and with differences in energy distribution across the meals. In particular, a significantly lower percentage of calories at lunch and more calories at the afternoon snack emerged in evening subjects, as well as a later midpoint of EI. Regarding diet quality, morning subjects showed significantly lower consumption of

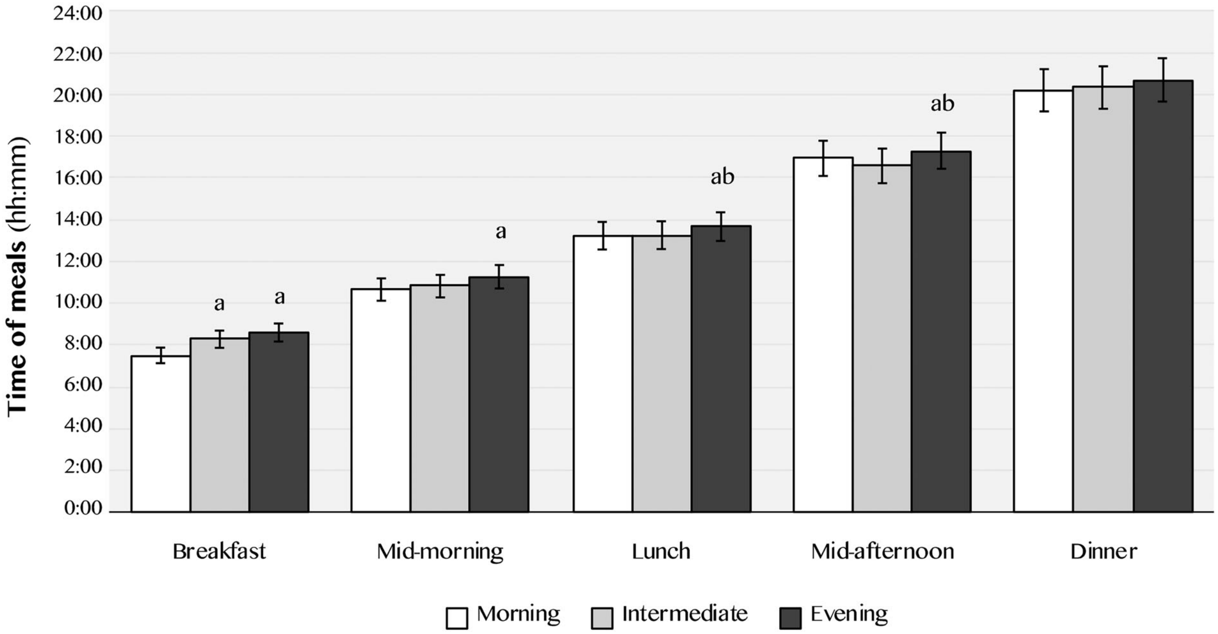

Figure 1. Meal timing by chronotype groups ([a]$p < 0.05$ *vs*. morning; [b]$p < 0.05$ *vs*. intermediate).

Table 3. Eating patterns of study participants according to individual chronotype.

	Morning	Intermediate	Evening	*p*-Value*
Food timing				
Eating window, hh:mm	13:04 ± 01:07	12:25 ± 01:04	12:47 ± 01:23	0.174
Midpoint of energy intake, hh:mm	13:50 ± 00:55	14:11 ± 00:29	14:46 ± 00:43[a,b]	<0.001
Energy and nutrient intakes				
Total energy intake, Kcal	1725 ± 409	1690 ± 304	1659 ± 409	0.830
Carbohydrate, %E	48.2 ± 6.1	47.2 ± 5.3	46.1 ± 5.6	0.433
Total fat, %E	33.4 ± 7.6	35.1 ± 5.7	36.3 ± 5.5	0.280
Protein, %E	18.3 ± 3.7	17.6 ± 3.3	17.8 ± 3.8	0.768
Food consumption				
Fruit and nuts (g/d)	253.5 ± 148.6	236.8 ± 148.9	228.2 ± 142.4	0.829
Vegetables and legumes (g/d)	411.8 ± 146.9	351.7 ± 201.1	393.3 ± 157.3	0.452
Cereals and tubers (g/d)	271.0 ± 114.9	324.6 ± 100.3	271.7 ± 79.8	0.100
Meat and fish (g/d)	124.0 ± 85.2	129.9 ± 59.0	109.0 ± 64.3	0.560
Milk, dairies, and eggs (g/d)	224.6 ± 134.8	188.4 ± 86.1	189.0 ± 97.8	0.411
Oils, fats, and seasonings (g/d)	39.6 ± 29.0	46.3 ± 17.8	40.2 ± 22.1	0.536
Sweets and sweeteners (g/d)	67.5 ± 48.5	98.4 ± 44.8[a]	72.9 ± 33.8	0.030
Beverages (g/d)	226.9 ± 162.7	255.1 ± 154.5	234.4 ± 148.4	0.804
UPF intake				
Total UPF (g/d)	151.0 ± 88.8	212.0 ± 129.3	162.6 ± 66.3	0.076
Vegetables and legumes UPF (g/d)	5.5 ± 13.6	12.0 ± 15.9	6.0 ± 12.6	0.196
Cereals and tubers UPF (g/d)	47.7 ± 50.7	51.4 ± 36.1	31.5 ± 19.2	0.145
Meat and fish UPF (g/d)	4.8 ± 6.5	13.6 ± 23.9	9.0 ± 12.9	0.175
Milk and dairy products UPF (g/d)	27.5 ± 41.7	22.8 ± 39.3	27.9 ± 34.4	0.872
Fats and seasonings UPF (g/d)	2.6 ± 4.8	6.8 ± 7.6[a]	3.7 ± 4.0	0.035
Sweets and sweeteners UPF (g/d)	32.0 ± 36.7	49.5 ± 34.6	40.6 ± 19.4	0.151
Beverages UPF (g/d)	17.8 ± 29.1	37.7 ± 70.3	25.2 ± 22.1	0.316
Plant-based dairy and meat substitutes (g/d)	13.1 ± 34.9	18.3 ± 38.4	18.6 ± 40.1	0.851

E: energy; UPF: ultra-processed food.
Categorical variables were expressed as frequencies (percentages), whereas continuous variables as mean ± *SD*.
**p*-Values refer to one-way ANOVA models with Bonferroni *post-hoc* test for continuous variables and to Chi-square tests for categorical variables.
[a]$p < 0.05$ *vs*. morning.
[b]$p < 0.05$ *vs*. intermediate.

sweets and sweeteners, and lower intake of UPF fats and seasonings than the other chronotypes.

This study confirms one of the most reliable pillars of chronobiology, namely that evening subjects wake-up and go to bed later than morning subjects. Surprisingly, no significant differences were observed in sleep duration and quality according to the chronotype. Our results are in line with those of Reutrakul et al., who investigated the relationship between chronotype and sleep pattern, and found that evening subjects had a significant delay in waking-up and going to bed compared to morning subjects (Reutrakul et al.

2013). Similarly, they did not find significant differences in sleep duration among chronotype groups either. In contrast, most studies in the literature report that evening subjects have a shorter duration and worse quality of sleep (Wittmann et al. 2006; Hashemipour et al. 2020; Putilov et al. 2020; Taillard et al. 2021). Interestingly, this evidence has also emerged in some studies conducted on younger population segments, where evening children and adolescents were associated with higher sleep debt (McMahon et al. 2019; Núñez et al. 2019; Esin et al. 2020) and a higher risk of developing mental illness (Tokur-Kesgin and Kocoglu-Tanyer 2021).

Another extremely well-studied aspect in the field of chrono-nutrition, which has also been confirmed by our results, is that the morning chronotype is mainly present in older subjects, whereas young people more frequently report an evening chronotype. Indeed, the chronotype exhibits fluctuations throughout life. Children predominantly show a morning chronotype that changes to eveningness during adolescence and then returns to morningness again around the age of 50 (Almoosawi et al. 2019). These variations are probably due to changes in gonadal hormone secretion and in societal demands (Montaruli et al. 2021).

Regarding eating behaviours, a significant delay in the consumption of all meals was observed in evening subjects, except for dinner. This result is in line with previous investigations, such as a Finnish study of 1854 participants, which found that the peak EI of evening subjects was about 1 h later than the peak EI of morning subjects (Maukonen et al. 2017). Similarly, the scoping review by Mazri et al. analysed the eating patterns of the three chronotypes, showing that evening subjects were mostly related to unhealthy dietary behaviours, particularly due to delayed meals (Mazri et al. 2019). Eating meals late in the day may decrease resting-energy expenditure and glucose tolerance but may also blunt the daily cortisol rhythm and thermal effect of food (Bandín et al. 2015). These metabolic alterations may predispose evening subjects to a higher risk of obesity and other chronic diseases (Vera et al. 2018).

We also found that evening subjects differed from other chronotypes in terms of energy distribution across main meals and snacks. Specifically, a significantly lower percentage of calories at lunch and more calories at the afternoon snack were observed in the evening subjects. The same results were found in a Spanish study that showed a higher EI at breakfast and lunch in morning subjects compared to evening ones, who instead reported a higher percentage of total EI at the afternoon snack (Muñoz et al. 2017). Nevertheless, other studies found no differences in energy distribution among all daily meals between morning and evening subjects (Nimitphong et al. 2018; Yazdinezhad et al. 2019). Thus, the pattern of energy distribution between meals and snacks according to the chronotype is still inconsistent, and future studies are needed to obtain more certain evidence (Phoi et al. 2022).

Finally, diet quality was analysed and, for the first time in the literature, the consumption of UPF was considered according to chronotype. From our results, morning subjects were associated with a better-quality diet due to a significantly lower consumption of sweets and sweeteners, and a significantly lower intake of UPF fats and seasonings than the other chronotypes. These results are in agreement with most studies published so far, which show that as the MEQ score increases (towards morningness), the consumption of sweets and sugary drinks decreases (Kanerva et al. 2012; Mota et al. 2016; Zhang et al. 2017). With regard to fat intake, however, the situation is still not entirely clear. In fact, some studies did not observe a significant difference in fat intake according to chronotype (Lucassen et al. 2013; Mota et al. 2016; Maukonen et al. 2017; Muñoz et al. 2017), while others reported that morning subjects were characterised by significantly lower added fat intake than evening subjects (Sato-Mito et al. 2011; Kanerva et al. 2012; Toktas et al. 2018).

This study has some limitations that need to be discussed. First, the cross-sectional design of the study does not allow to prove causality, so longitudinal or interventional studies are required to better elucidate the relationship between chronotype, sleeping, and eating patterns. Second, chronotype and sleep habits were defined using questionnaires, albeit validated ones. Future studies should consider using other methods, such as the dim light melatonin onset for chronotype and the armband actigraphy for sleep pattern, which, although more expensive, are more accurate. Third, the study sample was limited in numerical size and predominantly represented by females, so the results cannot be generalised to the general population. This limitation, however, is partly offset by the very accurate method of data collection. In fact, food intake was assessed through a 7-d WDRs, which is considered the gold standard for diet assessment (Ortega et al. 2015). This allowed us to obtain reliable data and to perform the analysis very accurately, excluding misreporters. Furthermore, this is the first study to use a validated questionnaire specifically designed to assess the consumption of UPF in Italian adults.

Conclusion

In conclusion, this is the first study exploring the association between chronotype, sleep pattern, and eating habits in Italian adults. Although our results found no significant differences among chronotypes in terms of sleep quantity and quality, they associated evening subjects with a significant delay in waking-up and going to bed. The same delay emerged in meal consumption and EI of some meals, leading to negative health implications. Finally, a better-quality diet was observed in morning subjects due to a lower consumption of sweets and UPF fats. More knowledge in this area could help develop personalised strategies to reduce the risk of obesity and related chronic diseases.

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