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Original Article

Association Between Circadian Rhythm with Resting Metabolic Rate in Overweight\Obese Women

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ABSTRACT

Aim: The aim of this study was to investigate the association between circadian rhythm with resting metabolic rate (RMR) in overweight\obese women
Methods: This cross-sectional study included 232 obese and overweight women. Morningness-Eveningness Questionnaire (MEQ) was used to assess the level of circadian rhythm. RMR was measured by indirect calorimetry after a 10-12 hour overnight fasting period by a trained nutritionist. We assessed body composition using multi-frequency bioelectrical impedance analyzer (BIA).
Results: The percentage of overweight and obese women were 48.7% (113) and 51.3% (119), respectively. The number of participants who were morningness, intermediate and eveningness was 28(12.1%), 135(58.2%) and 69(29.7%) respectively. A significant relationship was found between MEQ and RMR.normal (p=0.011). According to linear regression model non-eveningness participants had 81.92 higher RMR compared to eveningness participants (p=0.027).
Conclusion: We found that non-eveningness participants had higher RMR compared to eveningness participants that can have protective effect against obesity, diabetes type2 and other health disorders.

Introduction

The obesity epidemic is one of the most major global health menaces that can lead an increased incidence of several other serious clinical conditions that inflict a heavy economic load on health services. (1-3). In particular, women are more likely to have moderate or severe obesity than men (4).

Circadian rhythms alternate with the 24-hour rhythm created by an endogenously organized system that promotes daily rhythms in behavior, physiology, and metabolism. (5). Circadian rhythms examinate a broad diversity of physiological events, including metabolism, in all organisms. The flexibility to eat, sleep, socialize, and exercise around the clock, which is common in our modern lifestyle, is associated with an increase in metabolic disorders and obesity. (6). The suprachiasmatic nucleus (SCN) in the

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central brain is responsible for maintaining the circadian clock, which is absorbed by the light / dark cycle through retinal optical receptors in the retino-hypothalamic apparatus. SCN is also secreted by the sleep / wake cycle, physical activity, and fasting and nutritional periods. (7, 8). Circadian clocks are found in almost all tissues and cell types, where they control local metabolic activities, including glucose and lipid homeostasis, hormone secretion, immune response, gastrointestinal motility, and digestive processes.(6, 9). whiles these “peripheral clocks”obtain input from the SCN, their phase is sensitive to other external agents including nutrient availability (10). SCN-guided circadian rhythms include nutrition, sleep-wake cycle, glucose metabolism, insulin secretion, and even learning and memory. (11). Morningness–eveningness, which reverberate the sleep–wake template of the circadian rhythm, might also modify metabolic state (12). The favor time of the day for each person to be active or to sleep describes morningness or eveningness. For instance, morning-oriented individuals (morning types/“larks”) sleep early and attain their peak cognitive and physical efficiency in the early daytime hours, while evening-oriented individuals sleep late and function best at later times in the day or the evening. There are also “neither” types who have a moderate circadian rhythm(13). Morningness-Eveningness Questionnaire (MEQ) is the most generally used scale to categorized individuals into different circadian types (14, 15).

The resting metabolic rate (RMR) is the amount of resting energy needed to retain body temperature, repair internal organs, support heart function, maintain ion gradients across cells, and support respiration. RMR accounts for approximately 50% -70% of the total daily energy expenditure in adolescents (16, 17). RMR is affected by age, sex, body weight, pregnancy and hormonal status (18). The chief determinant of RMR is Fat Free Mass that clarify between 60% to 80% of RMR in children and adolescents (16, 19, 20).

Two strong connected systems exist about the circadian system and metabolism relationship; this is a two-way association. In one point of view, circadian system regulates metabolism via linking the SCN to energetic centers in the hypothalamus and brain stem. Conversely, metabolism regulates the circadian system; hormones that regulate metabolism can persuade or unset circadian rhythms (3).

The aim of this study is to investigate the association between circadian rhythms with Resting Metabolic Rate in overweight \obese women.

Materials and Methods

Study population: This cross-sectional study of 232 healthy overweight and obese women who were referred to health centers in Tehran (capital of Iran). Participants were randomly chosen by stratified cluster sampling.

Inclusion criteria for entering the study include BMI more than 25, less than 40 and the age range upper than 18 years. Menopause, pregnancy breastfeeding, cardiovascular disease, diabetes, cancer, kidney diseases, thyroid diseases, catching to acute and chronic diseases are exclusion criteria. Eligible participants in this study received written informed consent upon confirmation of entry into the study. In addition, the study protocol was approved by Tehran Unirversitry of Medical Sciences.

RMR: We measured Resting Metabolic Rate (RMR) by means of the indirect calorimetric method (METALYZERR 3B-R3, Cortex Biophysik GmbH, Leipzig, Germany). Participants were asked to be fasting and stay in a resting state for 12 hours prior to the test and to abstain from smoking for at least 4 hours before the onset of the process, although the ideal duration is 12 h, to ensure that the body was in a resting and post-absorptive state. Participants were trained to rest in a supine position for 15 minutes, and then they endure the measurement period of 20 minutes. However, we did not take in account the first 5 minutes of the work and only the last 15 minutes were used to compute RMR.

Morningness–Eveningness Questionnaire (MEQ): The first validated questionnaire expanded to determine Morningness-Eveningness dimensions was developed by Horne & Ostberg in 1976 and was called the Morningness-Eveningness Questionnaire (MEQ)(15). This was used to assess phase preferences in circadian rhythms based on descriptions of participants , recognizing whether individuals are identified as morning variants or night variants as a continuous variable(15). In this study, we used Persian version of the reduced Morningness-Eveningness Questionnaire (21).

Anthropometric measurement: digital scales determined Body weight. Height was evaluated using a stadiometer in the standing position. Body composition was measured using multi-frequency bioelectrical impedance analyzer (BIA): InBody 770 Scanner (Inbody Co., Seoul, Korea). Fat Free Mass (FFM), Waist Circumference (WC) and Waist-to-Hip Ratio (WHR) was measured.

Socio-demographic information: Demographic questions collect data about the characteristics such as age, smoking, lifestyle, marital status, menopause, medical history, drug use, and supplements by responding to the general questionnaire.

Statistical analysis: Data were represented by frequency and percentage in parenthesis for qualitative variables. Numerical data were represented with mean and standard deviation (SD) or standard error (SE) for descriptive or analytical purposes, respectively. The MEQ was categorized in to tertiles, the first category was less than first tertile(<-0.97) which is called morningness, the second category was between the first and second tertiles (-0.96 – 0.94) which is called intermediate and the third category was more than second tertile (≥0.95) that is called eveningness . Analysis of Variance was used to compare the mean of RMR variables in categories of MEQ.

Multiple linear regression analysis was used to find the effect of MEQ on RMR, adjusting for age, BMI, FFM, physical activity (IPAC) and energy intake (kcal) in separate models. MEQ categorized into eveningniss and non-eveningness (morningness or Intermediate) categories for linear regression models. The sample size was estimated for the association of MEQ with RMR, as the main dependent variables of this study. There was no missing data. All statistical tests were two sided and p less than 0.05 was considered as statistically significant.

Results

In this cross-sectional study, all 232 participants were female. The characteristics participants are shown in Table 1. The percent of overweight and obese women were 48.7% (113) and 51.3% (119), respectively.

Table 1. characteristics of participants

Variable	
Age (years)	
Mean (SD)	36.52 (8.54)
Min – Max	18 - 56
Weight (kg)	
Mean (SD)	79.99 (12.00)
Min – Max	59.00 – 122.40
Height (cm)	
Mean (SD)	160.99 (5.92)
Min – Max	142.00 – 179.00
WC[a] (cm)	
Mean (SD)	98.35 (9.95)
Min – Max	80.10 – 131.30
WHR[b]	
Mean (SD)	0.92 (0.05)
Min – Max	0.81 – 1.08
N (%)	
Overweight	113(48.7%)
Obese	119(51.3%)

[a] waist circumference [b] Waist to Hip Ratio

Table 2 shows the distribution of characteristics across tertiles of MEQ scores. The number of participants who were morningness, intermediate and eveningness was 28(12.1%), 135(58.2%) and 69(29.7%) respectively

Table 2 .Distribution of RMR variables in tertiles of MEQ

	Morningness-Eveningness questionnaire			
	Morningness N=28(12.1%) Mean (SE)	Intermediate N=135(58.2%) Mean (SE)	Eveningness N=69(29.7%) Mean (SE)	p
Variable				
RMR[a] (kcal/day)	1616.39 (69.70)	1581.00 (22.77)	1505.30(26.46)	0.073
RMR.normal	1767.57 (37.78)	1714.57 (11.89)	1673.66 (14.92)	0.011
RMR.per.kg	19.46 (0.57)	19.84 (0.29)	19.40 (0.32)	0.598
RMR.per.BSA	853.32 (23.12)	857.48 (10.59)	827.57 (12.12)	0.218
RMR.CHO	195.17 (14.85)	202.38 (5.77)	195.66 (6.94)	0.736
RMR.FAT	79.53 (5.55)	72.62 (2.26)	67.97 (2.88)	0.129

RMR.PRO	18.17 (0.67)	17.77 (0.25)	16.94 (0.30)	0.081

A significant relationship was found between MEQ with RMR.normal (p=0.011). We did not found any significant relationship between MEQ with other variables (p>0.2).

For linear regression models, MEQ categorized into eveningniss and non-eveningness (morningness or Intermediate) groups. Regression coefficients and 95% CI were reported for five separate linear regression models with RMR as outcome variable (Table 3). In crude model, non eveningness participants had 81.92 higher RMR compared to the eveningness participants (p=0.027), also after adjusting for age this difference was significant (Model 1). When model was adjusted for other confounding variables, relationship was not significant (p>0.20).

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Table 3. Association between MEQ and RMR in overweight and obese women

MEQ (Non eveningness vs. Eveningness)	B (SE)	95% CI	P
Crude	81.92 (36.93)	9.54 – 154.30	0.027
Model 1	76.47 (36.98)	3.98 – 148.96	0.039
Model 2	52.59 (34.92)	-15.85 – 121.02	0.132
Model 3	50.30 (29.64)	-7.79 – 108.39	0.090
Model 4	45.00 (31.72)	-17.17 – 107.17	0.156
Model 5	45.71 (32.20)	-17.39 – 108.82	0.156

Note: Adjusted model to age, BMI, FFM, physical activity (IPACK) and energy intake (kcal) for relationship between MEQ and RMR. Model 1: Adjusted for age. Model 2: Adjusted for age and BMI. Model 3: Adjusted for age, BMI and FFM. Model 4: Adjusted for age, BMI, FFM and physical activity (IPACK). Model 5: Adjusted for age, BMI, FFM, physical activity (IPACK) and energy intake (kcal). Dependent Variable: RMR. *P value < 0.05 is significant

Discussion

To our knowledge, this is the first study to examine the relationship between circadian rhythm and RMR in obese and overweight women. We found that non-eveningness participants had higher RMR compared to eveningness participants.

In a review by McHill and Wright, reports that there is strong evidence from both animal and human models that sleep disorders and circadian inadequacy in weight gain, obesity, and metabolic health are undesirable. Although diet and exercise are recognized as major contributors to poor metabolic health, sleep duration, quality, and circadian rhythm should be considered as contributing factors to metabolic disease.(22). As this review showed circadian rhythm could effect on weight in both animal and human models, it can be in line of the result of our study.

Laermans and Depoortere reported that there is a close interaction between the circadian system and metabolism that let an organism to control metabolic processes and supply information about energy status to its main timekeeping system. Irregularity of the circadian system result in impairing metabolism, thereby lead to disorders such as obesity and diabetes (3).

Christopher Depner et al mentioned that circadian rhythms adjust or control daily physiological template with matter for normal metabolic health. Circadian disruption can lead to obesity and diabetes with irregular eating and amount of food intake, energy imbalance, impaired glucose tolerance, and insulin sensitivity. (23).

Jiandie D. Lin et al demonstrated that circadian clocks are critical in biological processes in organism. Transcriptional co activator PGC-1α is a key factor that complete clock and metabolic pathways. Recent findings indicate that PGC-1α can together regulate both clock and energy metabolism. PGC-1α may serve as an integrator of nutritional signals that synchronizes metabolic functions to clock (24).

Junghyun Noh mentioned that obesity and an imbalanced energy metabolism occur when amount and frequency of food intake during the biological night is increased in humans. There is complex mechanisms by which circadian disruption result in metabolic dysregulation and to specify the potential for improving sleep and circadian rhythms to promote metabolic health(25).

Satchidananda Panda has done a review in this field. Epidemiological data show that chronic circadian rhythm disturbances increase the risk of metabolic diseases. Conversely, time-restricted feeding, which triggers a daily cycle of feeding and fasting without reducing calories, maintains daily rhythms and can reduce metabolic diseases. (26).

Eleonora Poggiogalle et al demonstrated that disruptions in circadian rhythms impair metabolism and influence the pathogenesis of metabolic disease. Evidence indicates that circadian misalignment alters glycemic control, energy balance and weight, increasing the risk of diabetes and obesity. An acute bout of circadian misalignment can increase postprandial glucose levels by 11–21%(27), informing that maintaining circadian rhythm is very important for metabolic health(28).

In this study, we showed that non-eveningness participants had higher RMR compared to eveningness participants that this reduced RMR can leads to weight gain and metabolic diseases in human. Our study was in line with other studies and these findings highlight an integrative role of circadian rhythms in physiology.

This study had some limitations that we will examine. First, the cross-sectional design of the study was one of our limitation. Second, Evaluation of study results only in women. As a suggestion, it is recommended to conduct this study in other type of randomized clinical trials and prospective observational studies and in two separated men/women's groups.

Conclusion

We found that non-eveningness participants had higher RMR compared to eveningness participants that can have protective effect against obesity, diabetes type2 and other health disorders. We need regular circadian rhythm activity to maintain normal body function; otherwise, most of the complex health-related cycles will be disrupted.

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References

1.Kyrou I, Randeva HS, Tsigos C, Kaltsas G, Weickert MO. Clinical problems caused by obesity. Endotext [Internet]: MDText. com, Inc.; 2018.

2.Hurt RT, Kulisek C, Buchanan LA, McClave SA. The obesity epidemic: challenges, health initiatives, and implications for gastroenterologists. Gastroenterology & hepatology. 2010;6(12):780.

3.Laermans J, Depoortere I. Chronobesity: role of the circadian system in the obesity epidemic. Obesity reviews. 2016;17(2):108-25.

4.Jonikas JA, Cook JA, Razzano LA, Steigman PJ, Hamilton MM, Swarbrick MA, et al. Associations between gender and obesity among adults with mental illnesses in a community health screening study. Community mental health journal. 2016;52(4):406-15.

5.Silver R, Kriegsfeld LJ. Circadian rhythms have broad implications for understanding brain and behavior. European Journal of Neuroscience. 2014;39(11):1866-80.

6.Eckel-Mahan K, Sassone-Corsi P. Metabolism and the circadian clock converge. Physiological reviews. 2013;93(1):107-35.

7.Blume C, Garbazza C, Spitschan M. Effects of light on human circadian rhythms, sleep and mood. Somnologie. 2019:1-10.

8.Paul KN, Saafir TB, Tosini G. The role of retinal photoreceptors in the regulation of circadian rhythms. Reviews in endocrine and metabolic disorders. 2009;10(4):271-8.

9.Marcheva B, Ramsey KM, Peek CB, Affinati A, Maury E, Bass J. Circadian clocks and metabolism. Circadian clocks: Springer; 2013. p. 127-55.

10.Banks S, Coates AM, Dorian J. The Impact of Altered Timing of Eating, Sleep and Work Patterns on Human Health: MDPI AG-Multidisciplinary Digital Publishing Institute; 2018.

11.Hastings M, Maywood E, Reddy A. Two decades of circadian time. Journal of neuroendocrinology. 2008;20(6):812-9.

12.Iwasaki M, Hirose T, Mita T, Sato F, Ito C, Yamamoto R, et al. Morningness–eveningness questionnaire score correlates with glycated hemoglobin in middle-aged male workers with type 2 diabetes mellitus. Journal of Diabetes Investigation. 2013;4(4):376-81.

13.Randler C, Freyth-Weber K, Rahafar A, Jurado AF, Kriegs JO. Morningness-eveningness in a large sample of German adolescents and adults. Heliyon. 2016;2(11):e00200.

14.Zacharia T, James J, Prakash H, Mohan RT, Rajashekhar B. Development and standardization of Morningness-Eveningness Questionnaire (MEQ) in the Indian language Kannada. The International Tinnitus Journal. 2014;19(1):36-40.

15.Horne JA, Östberg O. A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. International journal of chronobiology. 1976.

16.Blundell JE, Caudwell P, Gibbons C, Hopkins M, Naslund E, King N, et al. Role of resting metabolic rate and energy expenditure in hunger and appetite control: a new formulation. Disease models & mechanisms. 2012;5(5):608-13.

17.Shaw E, Leung GK, Jong J, Coates AM, Davis R, Blair M, et al. The Impact of Time of Day on Energy Expenditure: Implications for Long-Term Energy Balance. Nutrients. 2019;11(10):2383.

18.Lessan N, Ali T. Energy metabolism and intermittent fasting: the Ramadan perspective. Nutrients. 2019;11(5):1192.

19.Nelson KM, Weinsier RL, Long CL, Schutz Y. Prediction of resting energy expenditure from fat-free mass and fat mass. The American journal of clinical nutrition. 1992;56(5):848-56.

20.Müller M, Bosy-Westphal A, Later W, Haas V, Heller M. Functional body composition: insights into the regulation of energy metabolism and some clinical applications. European journal of clinical nutrition. 2009;63(9):1045-56.

21.Rahafar A, Meysam SJ, Sadeghpour A, Heidari Z, Kasaeian A. Psychometric properties of the Persian version of the reduced Morningness-Eveningness Questionnaire: Further evidence. Sleep and Biological Rhythms. 2015;13(2):112-6.

22.McHill A, Wright Jr K. Role of sleep and circadian disruption on energy expenditure and in metabolic predisposition to human obesity and metabolic disease. Obesity reviews. 2017;18:15-24.

23.Depner CM, Stothard ER, Wright KP. Metabolic consequences of sleep and circadian disorders. Current diabetes reports. 2014;14(7):507.

24.Lin JD, Liu C, Li S. Integration of energy metabolism and the mammalian clock. Cell Cycle. 2008;7(4):453-7.

25.Noh J. The effect of circadian and sleep disruptions on obesity risk. Journal of obesity & metabolic syndrome. 2018;27(2):78.

26.Panda S. Circadian physiology of metabolism. Science. 2016;354(6315):1008-15.

27.Scheer FA, Hilton MF, Mantzoros CS, Shea SA. Adverse metabolic and cardiovascular consequences of circadian misalignment. Proceedings of the National Academy of Sciences. 2009;106(11):4453-8.

28.Poggiogalle E, Jamshed H, Peterson CM. Circadian regulation of glucose, lipid, and energy metabolism in humans. Metabolism. 2018;84:11-27.