Correlation between metabolic syndrome disorder and circadian rhythm of physically disabled individuals

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ABSTRACT

Objectives. The aim of this study was to examine the correlation between sleep disorder and metabolic syndrome disorder in physically disabled people. ***Methods.*** The study was conducted among physically disabled persons who were selected from the Education and Rehabilitation Centre of Disabled People in Çorum, a city located in the central north of Turkey. Sleep quality is assessed with Turkish version of Pittsburgh Sleep Quality Index. The metabolic syndrome disorder, weight circumference and blood values of participants are examined by three health personnel from a private hospital in Çorum. ***Results.*** One hundred and three persons (56 M, 47 F) participated in this study. Metabolic syndrome disorder was found in 23 (22.3%) participants. Forty (38.8%) participants had bad sleep quality. The correlation between circadian rhythm and metabolic syndrome disorder was significantly positive (*p*<0.01). It was found that the persons who have a bad sleep quality spend more energy than the persons who have good sleep quality (*p*=0.001). Energy expenditure of the participants with metabolic syndrome disorder is higher than without metabolic syndrome disorder (*p*<0.001) at the time of sleeping. ***Conclusions.*** This study confirms the positive relationship between circadian rhythm irregularity and metabolic syndrome disorder. Also, the study supports the idea that circadian rhythm irregularities cause an increase in daily energy expenditure which leads further metabolic syndrome disorder.

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Keywords: Circadian rhythm, metabolic syndrome disorder, energy expenditure, disabled people

Introduction

Circadian rhythm is one of the most important abilities in adaptation to environment and survival [1]. Under current conditions, circadian rhythm goes through an endogenous biological process of 24 hours. Its oscillation changes according to environmental factors such as light, temperature or food, so it provides a selective advantage in the evolutionary process [2-5]. Especially sleep cycle is the primary process regulated by circadian rhythm [6, 7] and sleep disturbance is accepted as an indicator of circadian rhythm irregularity.

Circadian rhythm has a regulatory impact on the many functions of the body such as body temperature, brain activity, hormone release, energy consumption, energy metabolism which is in relation to hormones, lipids, and cell reproduction [6, 7]. For this reason,

circadian rhythm irregularity is thought to cause many functional disorders in the body. Many studies found that glycogen is affected by circadian rhythm irregularities [8-10]. It has also been showed that sleep disturbance contains within itself a high mortality risk due to obesity, hypertension, diabetes and cardiovascular diseases [11-15]. Following studies revealed a further effect of circadian rhythm on diverse metabolic systems. Because circadian rhythm regulates energy balance and metabolic system of peripheral tissues. It also helps maintenance of metabolic stability by regulating production and activity of metabolic enzymes (e.g. glycogen phosphorylase, lactate dehydrogenase, Acetyl-CoA carboxylase, cytochrome oxidase, malic enzyme, glucose-6-phosphate dehydrogenase) and transport systems of cells. These enzymes and transport systems join to the regulation of amino acids, drug and toxin metabolism, cholesterol metabolism, citric acid cycle, glycogen, and glucose metabolism [4].

Some studies focussed on diverse metabolic disorders, dealt with the correlation between metabolic systems and circadian rhythm. In these studies, one of the most analysed metabolic subjects is glucose metabolism. It is identified that daily 4-hour-sleep is related to decreased glucose clearance and glucose sensitivity [16-18]. In addition to this, findings show that circadian rhythm irregularities trigger the metabolic disorders such as obesity, type 2 diabetes, and cancer [17, 19, 20].

A metabolic syndrome disorder covers many symptoms of different metabolic disorders and is associated with increased risk of having at least one of those metabolic disorders. People with metabolic syndrome disorder (MetS), for example, catch the disease of type-2 diabetes 5 times easier and of cardiovascular 2 times easier [21]. Common symptoms of MetS are identified as abdominal obesity, glucose intolerance, dyslipidemia, coronary artery disorder, diabetes mellitus and hypertension [22]. Due to the rate of incidence of these symptoms in both MetS and circadian rhythm irregularities, a possible correlation between them is analysed in a study. Results reveal only a possible and bi-directional link [23]. Welsh *et al.* [24] states in his study that disruption of circadian rhythm causes a vicious cycle by leading to MetS which are further causing the maintenance of circadian rhythm irregularities. The aim of this study was to reveal the form of the above-explained relationship, especially in physically disabled people.

Methods

This study approved by the ethical committee of Okan University Institute of Health Sciences (research protocol number: 75, date: March 30, 2016). The study was conducted among physically disabled persons who were selected from the Education and Rehabilitation Centre of Disabled People in Çorum, a city located in the central north of Turkey. Data gathering process began in April 2016 and continued until June 2016. Totally 103 persons (56 M, 47 F) participated in the study. The age of participation varies between 18 to 74. The purpose and procedure of the study were explained in detail to all participants. In the study, participants' sleep patterns are treated as an indicator of circadian rhythm. The Turkish version of Pittsburgh Sleep Quality Index [25] is used to evaluate circadian rhythm of the participants. Each one of the participants and one of its immediate relatives answers the questions of the index. The index is formed to assess sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, sleeping medications and daytime dysfunction factors. Those who score 5 or less from the participants were rated as "good" and then those who score 5 points, or more were rated "bad". Bad sleep indicates a high sleep disturbance at least in the two factors or mild sleep disturbance in the factors more than three.

Metabolic syndrome disorder is identified according to criteria of Adult Treatment Panel III in National Cholesterol Education Program. According to these criteria, people are diagnosed with MetS who show three of five symptoms. The symptoms are sorted as following: a) higher blood pressure (BP) than 130/80 mmHg, b) higher triglyceride level than 150 mg/dl, c) higher blood glucose level than 110 mg/dl, d) lower HDL than 40 mg/dl for men and 50 mg/dl for women, e) higher waist circumference than 102 cm for men and 88 cm for women.

In this context, waist circumference of each participant is measured, and blood sample of each is taken. Eight-twelve hours fasting blood samples were taken as 8 ml with yellow-capped tubes by three health personnel from a private hospital in Çorum. Monitoring of blood pressure and measurement of waist circumference are also done by the same health personnel. Fasting blood glucose, triglyceride, HDL cholesterol and LDL-cholesterol levels are analysed with the Roche integra 800 machine. Blood pressure is measured by Erka D-83646 Bad Tölz.

In the study, participants' daily energy expenditure

is also analysed. For this purpose, the daily nutritional values of the participants are calculated during the study.

Statistical Analysis

The data is analysed through SPSS v.22 statistic programme. Descriptive statistics are presented with a number, percentage, mean and standard deviation values. They are used to evaluate the data. To understand whether data show normal distribution or not, Kolmogorov-Smirnov Z test is applied. In all analyses, 5% significance value is used to evaluate results.

Results

There was metabolic syndrome disorder in 23 (22.3%) participants (Tables 1 and 2). A significant difference between the systolic blood pressure, diastolic artery pressure, fasting blood glucose, HDL cholesterol and triglyceride values of participants with MetS and without MetS was found ($p < 0.01$)

Forty (38.8%) of the participants had bad sleep quality (Table 3). There was no significant difference between male and female participants in terms of sleep quality and MetS ($p > 0.05$). Based on these results, the relationship between sleep quality and MetS analysed with Pearson's Chi-Square Test. There was

a significant correlation between sleep quality and MetS ($p < 0.01$). This ratio is also similar for both male and female participants ($p < 0.05$).

Participants' energy expenditure related to sleep quality and MetS are analysed (Table 4 and Table 5). Energy expenditure of participants who have bad sleep quality and good sleep quality is compared through independent sample t-test. The results show a significant difference between two groups in terms of daily energy expenditure ($p = 0.001$). Daily energy expenditure of participants who have bad sleep quality (mean: 2210 ± 569) is higher than participants who have good sleep quality (mean: 1370 ± 500). Daily energy expenditure of participants with MetS and without MetS was also compared. The results show that participants with MetS have higher daily energy expenditure than participants without MetS (mean: 2160 ± 703) vs. mean: 1562 ± 597; $p < 0.001$) (Table 5).

Discussion

Irregularity in sleep cycle was interpreted as an irregularity in circadian rhythm in this study. Because this interpretation comes from a significant correlation between circadian rhythm disturbance and metabolic syndrome disorder. This finding is also supported by some previous studies. In their study, Hung et al. [26]

Table 1. Distribution of metabolic syndrome criteria (n = 103)

Metabolic Syndrome Criteria	Data
Waist Circumference (cm)	89.86 ± 16.65 (60-129)
Systolic artery pressure (mmHg)	119.51 ± 17 68 (90-170)
Diastolic artery pressure (mmHg)	68.35 ± 12.61 (50-100)
Fasting Blood Glucose (mg/dl)	90.18 ± 25.33 (46-263)
Normal	93 (90.3%)
Low	10 (9.7%)
HDL (mg/dl)	22.1 ± 91.1
Normal	61 (59.2%)
>150	42 (40.8)
Triglyceride (mg/dl)	158.64 ± 105.90 (51.2-661.3)
Normal	64 (62.1%)
High	39 (37.9%)
Metabolic syndrome	
No	80 (77.7%)
Yes	23 (22.3%)

Data are shown mean ± standart deviation (min-max values) or number (percent).

Table 2. Metabolic syndrome criteria of individuals with metabolic syndrome disorder

Participant Number	Sex	Waist Circumference (cm)	Blood Pressure (mmHg)	Glucose (mg/dl)	HDL (mg/dl)	Triglyceride (mg/dl)
1	Female	95	140/80	115	48	115
2	Female	99	110/60	122	51	194
3	Female	100	110/60	108	48	376
4	Female	104	150/80	116	41	144
4	Female	116	110/70	95	35	215
6	Female	92	140/90	89	32	221
7	Female	89	130/60	114	64	176
8	Female	129	130/70	93	30	266
9	Female	102	130/60	93	41	177
10	Female	117	130/70	139	48	131
11	Male	114	120/70	73	30	482
12	Male	117	160/100	85	22	406
13	Male	115	120/80	99	35	211
14	Male	112	140/80	140	38	205
15	Male	117	130/80	97	34	335
16	Male	114	130/70	67	39	157
17	Male	118	140/90	84	37	165
18	Male	107	130/70	76	39	151
19	Male	115	150/80	95	51	245
20	Male	119	170/90	130	43	225
21	Male	120	150/90	93	34	241
22	Male	114	150/90	193	40	190
23	Male	120	160/90	68	36	161

reported a higher risk for people who have bad sleep quality. Jennings *et al.* [27] also stated that bad sleep quality increases the prevalence of MetS [27].

Because of the relationship between circadian rhythm and MetS, the body needs more energy due to lack of sleep. In other words, energy need is found to be related to sleep deprivation. Experimental studies on sleep restriction show a negative correlation between sleep deprivation and appetite-related ghrelin and leptin hormones and between total energy intake and body weight [28-30]. Furthermore, it is stated that this energy requirement is met by increased consumption of total fat, saturated fatty acid, and carbohydrate-rich foods [31]. Accordingly, many studies on circadian rhythm irregularities that cause sleep disorders present that these irregularities also

Table 3. Distribution of sleep quality criteria (n = 103)

Sleep Quality Criteria	PSQI score			
	0	1	2	3
PSQI - Sleep Quality	26 (25.2%)	66 (64.1%)	6 (5.8%)	5 (4.9%)
PSQI - Sleep Latency	43 (41.7%)	21 (20.4%)	33 (32.0%)	6 (5.8%)
PSQI - Sleep Duration	71 (68.9%)	13 (12.6%)	17 (16.5%)	2 (1.9%)
PSQI - Habitual Sleep Efficiency	70 (68.0%)	18 (17.5%)	7 (6.8%)	8 (7.8%)
PSQI - Sleep Disturbances	14 (13.6%)	83 (80.6%)	6 (5.8%)	0 (0%)
PSQI - Use of Sleeping Medications	49 (47.6%)	48 (46.6%)	1 (1.0%)	5 (4.9%)
PSQI- Daytime Dysfunction	44 (42.7%)	55 (53.4%)	3 (2.9%)	1 (1.0%)
PSQI total score				
Mean	5.15 ± 2.99			
Range	0-13			
Sleep Quality				
Good	63 (61.2%)			
Bad	40 (38.8%)			

Data are shown as mean ± standard deviation or number (percent). PSQI = Pittsburgh Sleep Quality Index

Table 4. Carbohydrate, protein and fat requirements for sleep quality (n = 103)

| | | | Sleep Quality | | | | |
| | | Good | | | Bad | | |
		Min-Max	Median	Mean±SD	Min-Max	Median	Mean±SD
Male (n = 56)	Carbohydrate %	26-58	43.5	44.13 ± 6.39	37-59	50.5	48.94 ± 5.02
	Protein %	10-25	19	18.84 ± 3.13	15-21	18	17.56 ± 1.65
	Fat %	27-49	36.5	36.95 ± 5.10	25-43	34	33.72 ± 4.56
Female (n = 47)	Carbohydrate %	31-53	43	42.72 ± 6.85	32-55	49	46.64 ± 6.87
	Protein %	15-27	17	18.32 ± 3.34	14-23	18.5	18.18 ± 2.28
	Fat %	32-49	39	39.24 ± 4.98	28-47	34	35.59 ± 6.07
Total	Carbohydrate %	26-58	43	43.57 ± 6.56	32-59	50	47.68 ± 6.15
	Protein %	10-27	18	18.63 ± 3.20	14-23	18	17.90 ± 2.02
	Fat %	27-49	38	37.86 ± 5.14	25-47	34	34.75 ± 5.46

Table 5. Evaluation of daily energy expenditure according to sleep quality and MetS (n = 103)

Feature		n	Min-Max	Median	Mean±SD	t	p
Sleep Quality	Good	63	483-2964	1329	1370 ± 500	-7,880	0.001
	Bad	40	563-2963	2264	2210 ± 569		
Metabolic Syndrome	No	80	482-2964	1499	1562 ± 597	-4,062	< 0.001
	Yes	23	1088-2961	2296	2160 ± 703		

t = Independent t-test. MetS = metabolic syndrome disorder, n = number of participant

have consequences for night eating syndrome [7, 32-34]. These interlinked disorders further increase the risk of metabolic disorders such as obesity and cardiovascular diseases. As a result, there is a causal correlation between increased energy requirement and sleep disturbance. Thus, daily energy consumption of participants is also researched in our study. The study proves that both bad sleep quality and MetS are causally correlated with energy consumption. The daily energy consumption of participants who have bad sleep quality and MetS is higher than the participants who have good sleep quality and no MetS. These findings support the previous assumption and indicate a chain of reaction due to irregularities of circadian rhythm.

Conclusions

The results of this study contribute to better understanding the relationship between circadian rhythm and metabolic syndrome disorder. Many parameters of this relationship need to be studied especially in terms of causal relation. Because, energy consumption is resulted from disturbance of metabolic balance and lead to circadian rhythm irregularities. A more comprehensive study seems necessary to understand the nature of this causal relationship.

Conflict of interest

The author disclosed no conflict of interest during the preparation or publication of this manuscript.

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