Research Paper

Impact of Circadian Rhythm Disturbance and Chronotype on Medical Students' Mental State

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ABSTRACT

Introduction: Shift workers usually undergo circadian misalignment, which appears when the feeding and sleep-wake cycles are desynchronized with the temporal framework organized by the internal biological clock. People differ considerably in their tolerance to shift work depending on their chronotype. This research aimed to obtain information about circadian disorders and chronotype (as a mediating variable) on consequent mental states such as impulsivity, depression, anxiety, stress, addiction potential, and boredom in students of a medical university in northeastern Iran. We studied the mental state of individuals with circadian misalignment and compared it with the healthy control group.

Methods: The study design is a double-blind, randomized, controlled clinical trial. Thirty-five participants were randomly assigned to circadian alignment/misalignment protocols. Subjects completed questionnaires as baseline data (pre-test) and the end of the interventions (post-test). The study instruments were the multidimensional state boredom scale (MSBS), addiction potential scale, depression, anxiety, and stress scale-21, and Barratt impulsiveness-11 (BIS-11). To analyze outcomes, we categorized participants based on chronotype as mediate variable within each group (circadian aligned and misaligned condition).

Results: The mean age of the participants was 21.66 years (range: 18-25 years). One-way analysis of variance to compare research variables in groups based on chronotype (evening, intermediate type, and morning types) showed a significant difference between the three chronotype groups in the total and non-planning impulsivity, as well as active and passive addiction potential ($P<0.001$). The Bonferroni post hoc test was used to compare the mean of variables in the chronotype groups about total and non-planning impulsivity scores, as well as active and passive addiction. The results showed that non-planning ($P<0.01$) and active addiction ($P<0.001$) in people with evening and intermediate types were significantly lower than in people with morning type ($P=0.02$).

Conclusion: Alterations in diurnal profiles of activity, sleep, and feeding time, based on chronotype related to impulsiveness and boredom, and such circadian misalignment were associated with addiction potential.

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Highlights

• Circadian misalignment increases impulsivity, addiction potential, and boredom in medical students.

• Morning-type medical students show higher impulsivity and addiction potential.

• Circadian misalignment negatively affects attention and time perception, impacting cognitive performance in medical students.

• Evening-type medical students are more vulnerable to mental health problems caused by irregular sleep patterns.

• Maintaining a stable sleep-wake cycle is essential for reducing mental health problems in medical students.

Plain Language Summary

The daily activities, such as sleeping, eating, and studying, are regulated by an internal biological clock known as the circadian rhythm. When this rhythm is disrupted (often due to irregular sleep-wake disorder), it can negatively affect mental health. This study examined the effect of circadian rhythm misalignment on impulsivity, stress, anxiety, depression, addiction potential, and boredom in Iranian medical students. We also investigated how chronotype (morning or evening type) influences these effects. The medical students were assigned to two rhythm misalignment and alignment groups. The findings showed that students with circadian misalignment had higher levels of impulsivity and addiction potential, particularly those with a morning chronotype. Evening-type students were more vulnerable to these effects. These results highlight the importance of maintaining a stable sleep/wake schedule for medical students.

1. Introduction

Living organisms exhibit various cyclic physiological changes over the day and night cycle (Kim & Kim, 2019; Patke et al., 2020). In most animals and humans, the sleep-wake rhythm is the most obvious diurnal rhythm (Rivkees, 2007). Misalignment of circadian rhythms may result from a mistimed light-dark cycle and feeding time, or there may even be misalignment between the peripheral and central rhythms (Lewis et al., 2020; West et al., 2017). The medical literature reports that misalignment has intense effects on processes that influence the risk of cardiovascular disease, as well as metabolic and neuropsychiatric conditions (Hower et al., 2018; Moreno et al., 2019; Walker et al, 2020). Sleep disturbance is one of the most immediate and significant consequences of the misalignment of the sleep-wake cycle with the biological night (Ingram, 2020). Circadian variability affects wakefulness, feeding behavior, metabolic function, and mood differently (Parkar et al., 2019; Poggiogalleet al., 2018; Zaki et al., 2018).

People have been divided into chronotype groups since the beginning of the 20th century (Becker et al., 2016). Chronotypes can generally be categorized into three types: Morning types, evening types, and non-types, which differ according to several behavioral, psychological, and biological variables, including usual eating times, appetite, mood, performance, and alertness (Kim & Kim, 2019; Kiveläet al., 2018). Morning types start their activities earlier in the morning, while evening types are more efficient later in the day (Matchock & Mordkoff, 2009). Morning types are tested in the morning, and evening types are tested in the evening. They respond more quickly to tasks that measure their reaction time (Lara et al., 2014). Shift workers usually undergo circadian misalignment, which appears when the feeding and sleep-wake cycles are desynchronized with the temporal framework organized by the internal biological clock. People differ considerably in their tolerance to shift work depending on their chronotype. Several studies have highlighted that evening types are a risk factor for depressive symptoms and the onset of depressive disorder in young people (Lotti et al., 2021). In studies that investigated the relationship between chronotype in university students, detrimental effects of sleep deprivation due to studying included decreased cognitive performance, lower motivation, increased aggression, increased depression, daytime sleepiness, and addictive behaviors (Montaruli et al., 2019; Van den Berg et al., 2018). Nursing and medical studies are also related to making up for sleep deprivation, circadian disruption, and missed weekend sleep on weekends or days off (López-Soto et al., 2019; Sun et al., 2019).

It has been demonstrated that the circadian misalignment affects essential systems in the body. The link between misalignment of circadian rhythms, neurocognitive dysfunction, and substance use disorder may lie in the changed function of neural circuits underlying cognitive processing, reward, and impulse control (Hasler et al., 2015; Mattis & Sehgal, 2016; Wallace, 2020). Transgenic animal models show that circadian genes (e.g. *Per1*, *Per2*, and *CLOCK*) in reward circuits of the brain play a role in the regulation of appetitive behavior, and both clinical and preclinical research suggests a relationship between circadian genes and reward function (Rijo-Ferreira & Takahashi, 2019). Substantial neuroimaging literature has examined the possible links between circadian rhythm shifts and alterations in neural circuitry in the human brain (DePoy et al., 2017).

Given the increasingly stressful and heavy workload of the COVID-19 pandemic, circadian disorders and resulting complications are expected to increase in some health professionals and students (Marvaldi et al., 2021). It is essential for health policymakers to constantly update their information on the health status of health professionals and its changes over time to enable accurate and timely management. Considering that there are few epidemiological studies investigating circadian disorders in medical students, the present research was conducted to fill the gap in this critical point. The current study aimed to obtain information about circadian disorders and chronotype (as a mediating variable) on resulting mental states such as impulsivity, depression, anxiety, stress, addiction potential, and boredom in students of a medical university in northeastern Iran.

2. Materials and Methods

Study design and procedures

This research is a double-blind, randomized, controlled clinical trial. An overview of the study is provided in Figure 1. After written informed consent was obtained, an assistant randomly assigned subjects to the intervention or control group, and baseline data were obtained. Participants were asked to repeat the examinations at the end of the week.

Study participants

The intervention and control groups, selected from all students of Shahroud University of Medical Sciences, Shahroud City, Iran, were transferred to the experimental site in a specific dormitory for 11 days and housed in unique rooms where the light intensity is specially designed according to luxury, period and light reception time, hours of food intake. The inclusion criteria were male gender, right-handed, aged between 18 and 25 years, and regular sleep and wake rhythm in the last month (8 to 10 hours of sleep per night). The exclusion criteria were a past medical history of psychiatric illness, history of substance use, use of psychotropic drugs, a general medical disorder that endangers the subject's health during the test, a history of brain trauma, metal bodies in the body, including platinum, fragments, or iron fragments, an irregular sleep and wake rhythm in the past month (8 to 10 hours of sleep per night), and a body mass index (BMI) greater than 30.

Randomization and blinding

To ensure the blinding of the investigators, the research coordinator carried out block randomization. Both participants and investigators are blinded to the group protocol. Participants were asked not to disclose details about their condition to their investigator to prevent unblinding. If subjects disclose their treatment, the investigator is immediately replaced by the blinded principal investigator of the project participant.

Study instruments

Reduced morningness-eveningness-questionnaire (rMEQ)

The German version of the rMEQ was applied to collect data. The rMEQ is a brief form of the morningness-eveningness questionnaire designed by Horne and Oestberg (1976). The original version contained 19 items and was rated on a Likert-type scale (Horne & Östberg, 1976). Adan and Almirall (1991) identified a short version of this original form, which was then used in different countries, such as Iran (Adan & Almirall, 1991). rMEQ has adequate psychometric properties, good convergent and construct validity, and test re-test reliability. The scale contains 5 items linked to peak performance, preferred bedtime, time of rising, morning fatigue, and a global self-evaluation item. The Cronbach α was 0.62, and the German version was a reliable and valid measure of chronotype. Participants are classified with scores from high to low into the following types: A total rMEQ score of 18 and above as morning types, between 12 and 17 as intermediate types, and 11 and below as evening types (Adan & Almirall, 1991; Marvaldi et al., 2021).

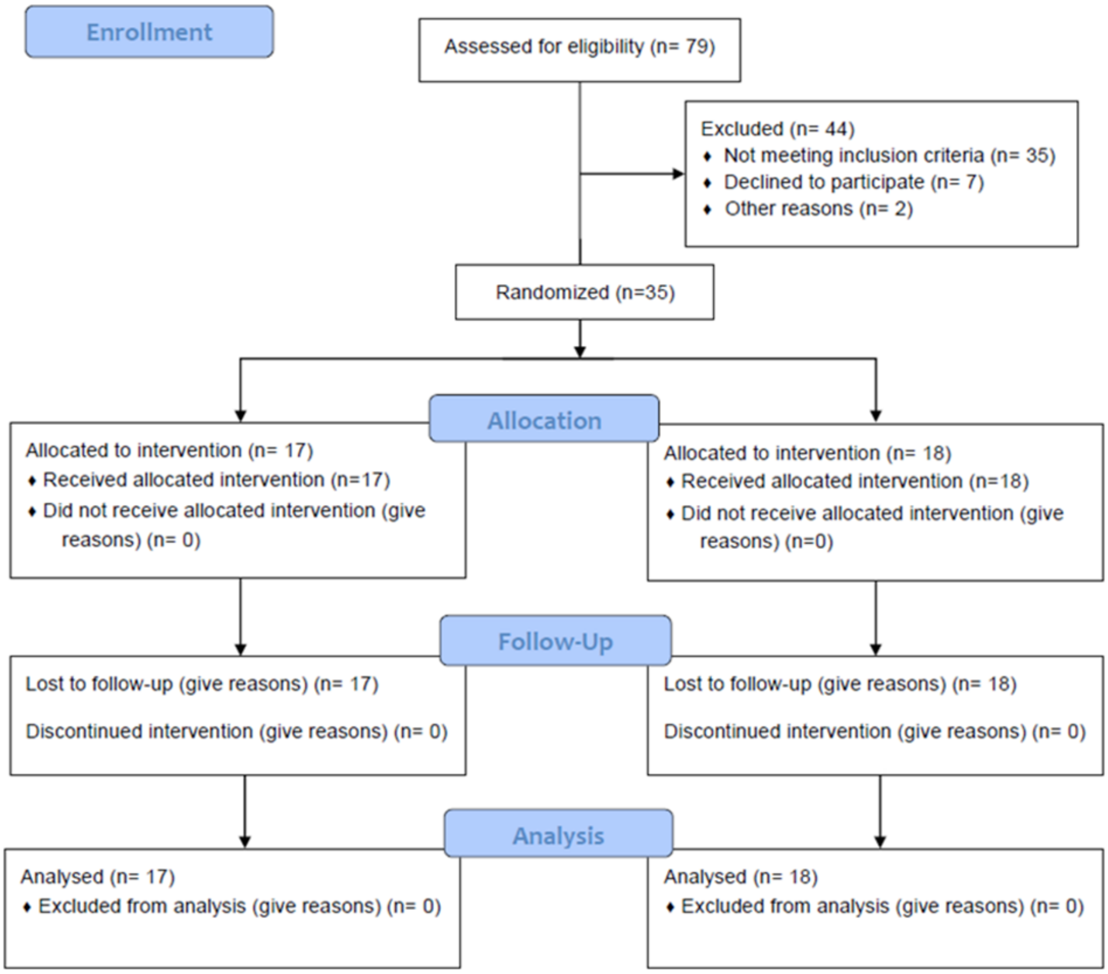

Figure 1. Overview of study procedures

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Multidimensional state boredom scale (MSBS)

Fahlman et al. (2013) developed a MSBS as the first and full-scale measurement of state boredom (Fahlman et al., 2013). In the present study, we applied the Persian version of the MSBS, which was validated on a sample of adults by Mohseni-Ezhiyeh et al. (2017). It has a factor structure similar to the original questionnaire (i.e. 5 factors and 29 items). The Persian version of the MSBS is equivalent to the original version in terms of conceptual and linguistic features. The internal consistency of the Persian version of the MSBS was good. Its Cronbach α is 0.94 for the total score and between 0.80 and 0.89 for the subscale scores (Mohseni-Ezhiyeh & Ghamarani, 2017).

Addiction potential scale (APS)

Weed and Butcher created the APS in 1992 (Weed et al., 1992). In the current study, we used the Persian version of this scale designed by Zargar (2007). This scale contained 2 factors, 36 items, and 5 lie detector items. Most items of the first factor (the active factor) are associated with a tendency to substance use, depression, antisocial behavior, positive attitude to substance use, and sensation seeking. Most items of the second factor (the passive factor) are associated with a lack of depression and assertiveness. The criterion validity test revealed that the mentioned scale can discriminate well between substance users and non-users. The internal validity of this scale was 0.88 (Zargar et al., 2008).

Depression, anxiety, and stress scale-21 (DASS-21)

This study used data from 21 items of the depression, anxiety, and stress scale-42 (DASS-42) (i.e. the DASS-21) developed by Guillemin et al. (1993). Each of the three scales of the DASS-21 contains seven items. The items of the DASS-21 refer to the past week. Each item is scored on a 4-point Likert scale from 0 to 21. The higher the score indicated, the more severe the depression, anxiety, and stress (Asghari et al., 2008; Guillemin et al., 1993).

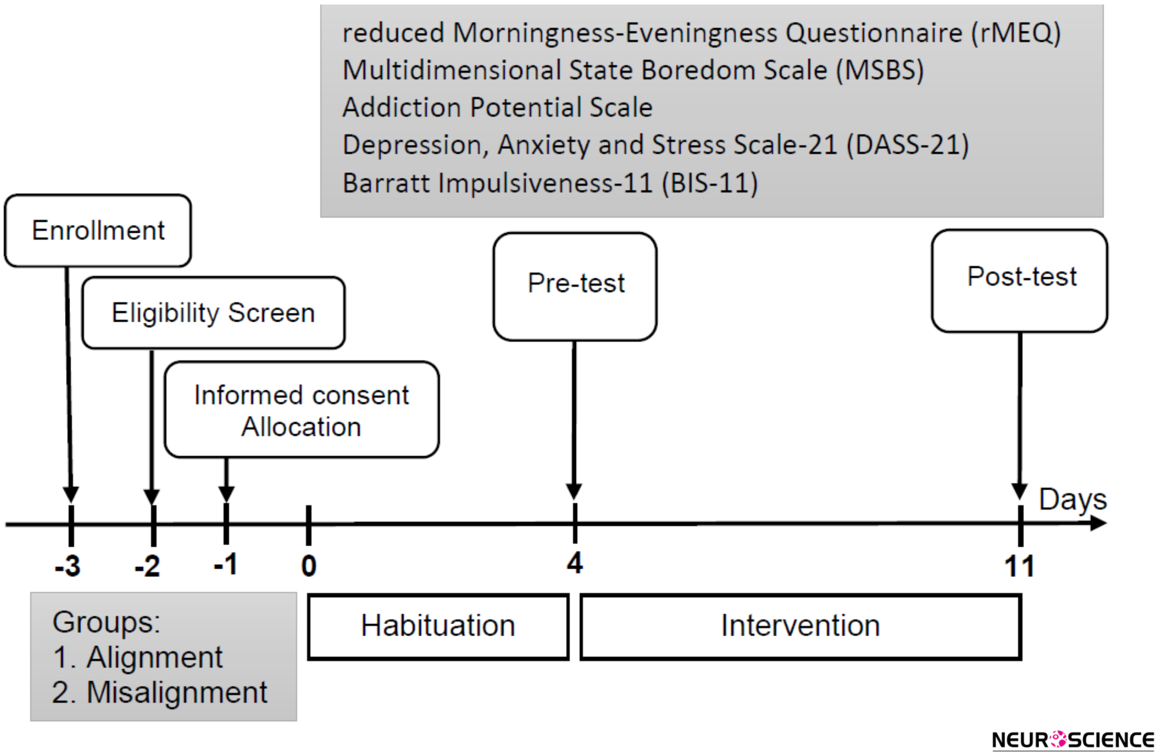

Figure 2. Left box, showing the circadian alignment protocol; right box, showing the circadian misalignment protocol

Barratt impulsiveness-11 (BIS-11)

The BIS-11 (11th version) was developed by Patton et al. (1995). It contains 30 items rated on a 5-point Likert scale. Twelve items are reverse-scored. It also includes three second-order parameters: Attention, motor skills, and non-planning. High scores indicate lower levels of attention, hyperactivity, and lack of planning. Its effectiveness in assessing impulsive dimensions is well established. In Iran, the norm is reduced to 25. In the present study, a 25-question form was used. The internal consistency of Persian BIS-11 is reported to be very acceptable (α=0.81) (Javid et al., 2012; Stanford et al., 2009).

Study intervention

Each participant underwent an 8-day study protocol to measure the effects of circadian misalignment on outcomes (Figure 2). One protocol applied circadian misalignment, and the other presented circadian alignment (Circadian alignment protocol, n=17; circadian misalignment protocol, n=18). On the first day of the 8-day study protocol, the subjects were accepted to the designated dormitory at ~8 AM to perform either the circadian rhythm alignment protocol or the circadian rhythm misalignment protocol (Figure 2). In the circadian alignment protocol, the subjects slept between 11:00 PM and 7:00 AM on days 1-8. In the circadian misalignment protocol, the subjects slept between 11:00 PM and 7:00 AM on days 1-3. On day 4 of the misalignment protocol, the subjects' activation patterns were shifted by 12 hours, and this reversed cycle remained until the protocol's end (day 8). The 12-hour shift on day 4 was made by an 8-hour wake episode and a 4-hour sleep opportunity, and the ratio of sleep opportunity to wake (1:2) remained the same in the adaptation and circadian alignment and misalignment protocols. Figure 2 shows the right conditions during the protocols.

Study outcomes

The outcome of this study is the change from baseline in scales measured by MSBS, APS, DASS-21, and BIS -11 by the end of the intervention.

Statistical analysis

Sample size calculation

The required sample size, according to $Z_{(1-\alpha)}$=1.96, power=0.9, α=0.05, d=0.8, and considering the rate of loss of 10% was calculated 34 (17 people in each group). Sample size was measured using the formula for randomized controlled trial studies as follows:

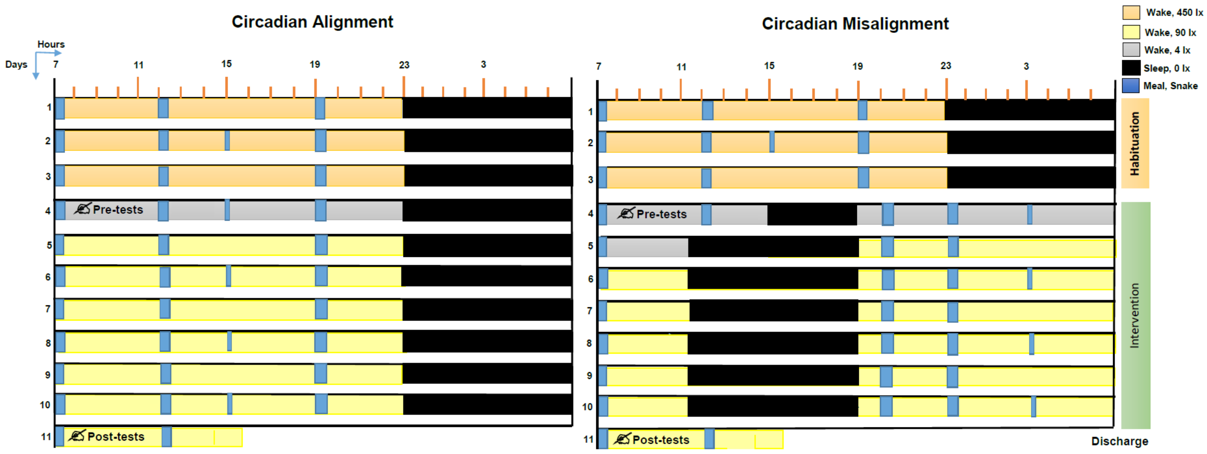

Figure 3. CONSORT

Efficacy analysis

All analyses were conducted in SPSS software, version 25. The two study groups' pre-test and post-test Mean±SD were calculated. In preliminary analyses, we examined the pre-test result in two groups using the independent t-test (equality of means) and Levene's test (equality of variances). We tested primary hypotheses regarding circadian misalignment effects on post-test measures using multivariate analysis of covariance (MANCOVA), Eta squared (η^2), and power. We also categorized participants based on chronotype as a mediate variable within each group (circadian aligned and misaligned condition) to analyze outcomes using a one-way analysis of variance (ANOVA). We provide adjusted P to account for multiple comparisons of primary analyses using a Bonferroni post hoc test. The significance level was set at 0.05.

3. Results

Thirty-five participants were randomly assigned to circadian alignment/misalignment protocols (circadian alignment protocol, n=17; circadian misalignment protocol, n=18).

The mean age was 21.66 years (18-25 years). Thus, complete follow-up was available for 35 subjects. Figure 3 shows a consolidated standards of reporting trials (CONSORT) flowchart for the study. The obtained F value for the pre-test scores showed no significant difference between the groups at the pre-test (P>0.05).

As shown in Table 1, there is a difference between the mean scores of some research variables in the two measurement phases. Box's test of equality of covariance matrices shows that the homogeneity of the variance-covariance matrix is satisfied (Box's M=129.73, F=1.25, df=28, P=0.087). The result of Wilks' lambda test in the post-test showed that the independent variable (circadian misalignment) was effective on at least one of the dependent variables in the intervention group (F=5.88, df=13.8, P=0.009, η^2=0.90, 1-β=0.95). Analysis of covariance was used to evaluate the effect (Table 2).

Table 2 shows that circadian misalignment was effective in motor impulsivity, passive addiction potential, low arousal, inattention, and time perception. Results of the eta-squared coefficient show that the effect of circadian misalignment on motor impulsivity, passive addiction, low arousal, inattention, and time perception was high and that among the variables, the impact on time perception was the largest.

Table 3 presents a one-way ANOVA to compare research variables in groups based on chronotype (evening, intermediate, and morning types). There is a significant difference between the three groups of chronotype regarding total and non-planning impulsivity, as well as active and passive addiction potential. The results of the Bonferroni post hoc test to compare the mean of variables in the chronotype groups about total and non-planning impulsivity scores, active and passive addiction showed that non-planning and active addiction in persons with evening and intermediate types were significantly lower than persons with morning type. The total scores of impulsivity and passive factors of addiction potential in participants with the morning type are significantly higher than in participants with the evening type. Table 4 presents the results of the Bonferroni post hoc test.

Table 1. Measurement and deviation of research variables and independent t-test to compare the scores of the two groups in the pre-test

	Variables	Group	Mean±SD		T-test for Equality of Means			Levene's Test for Equality of Variances	
			Pre-test	Post-test	t	df	Sig.	F	Sig.
BIS-11	Non-planning impulsiveness	Intervention	23.33±4.24	24.83±3.94	-0.09	33	0.74	0.10	0.92
		Control	23.47±4.21	24.17±3.89					
	Motor impulsiveness	Intervention	37.05±4.29	36.72±4.34	0.84	33	0.70	0.14	0.40
		Control	35.82±4.3	37.52±4.38					
	Cognitive impulsiveness	Intervention	11.77±1.21	11.61±1.24	-0.52	33	0.61	0.25	0.60
		Control	12±1.27	11.35±1.16					
	Total	Intervention	72.16±7.18	73.16±5.27	0.36	33	0.97	0.001	0.71
		Control	71.29±7.01	73.05±7.88					
DASS-21	Depression	Intervention	3.22±4.95	5.44±6.08	0.62	33	0.05*	3.82	0.53
		Control	2.35±2.93	2.47±3.77					
	Anxiety	Intervention	1.77±2.98	1.66±2.58	0.14	33	0.95	0.001	0.88
		Control	1.64±2.47	1.17±1.59					
	Stress	Intervention	5.44±4.27	7.55±5.06	-0.72	33	0.001*	20.55	0.47
		Control	7.05±8.39	4.58±6.81					
APS	Active factors	Intervention	14.66±11.16	15.44±12.89	-0.85	33	0.94	0.001	0.40
		Control	18±11.96	17.94±13.03					
	Passive factors	Intervention	7.33±4.4	7.33±5.01	0.65	33	0.48	0.50	0.51
		Control	6.35±4.44	6.47±4.19					
MSBS	Disengagement	Intervention	28.77±10.45	53.88±8.34	-0.06	33	0.24	1.38	0.94
		Control	26.76±13.52	28.82±11.59					
	High arousal	Intervention	13.22±6.19	19.77±4.89	0.32	33	0.55	0.35	0.74
		Control	12.17±6.42	12.41±6.01					
	Low arousal	Intervention	12.27±6.95	18.5±5.44	-0.22	33	0.90	0.01	0.82
		Control	11.58±6.04	12±6.38					
	Inattention	Intervention	9.77±4.25	14.66±4.47	-0.36	33	0.01*	7.06	0.71
		Control	10.82±5.92	11.23±4.99					
	Time perception	Intervention	13.61±6.01	27.16±5.39	-.27	33	0.33	0.97	0.78
		Control	16.82±8.09	16.05±7.24					
	Total	Intervention	120.11±7.57	113.66±8.18	-0.28	33	0.83	0.04	0.77
		Control	120.82±7.22	122.94±6.25					

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Abbreviations: APS: Addiction potential scale; BIS-11: Barratt impulsiveness-11; DASS-21: Depression, anxiety, and stress scale-21; df: Degree of freedom; MSBS: Multidimensional state boredom scale; Sig.: Significant.

*Significant.

Table 2. Results of analysis of covariance to investigate the effect of circadian misalignment on the outcomes

	Variables	SS	df	MS	F	Sig.	η^2	Observed Power
BIS-11	Non-planning Impulsiveness	6.97	1	6.97	1.43	0.24	0.06	0.20
	Motor impulsiveness	55.75	1	55.75	5.58	0.02*	0.21	0.61
	Cognitive impulsiveness	1.48	1	1.48	3.49	0.07	0.14	0.42
	Total	15.07	1	15.07	1.75	0.20	1.08	0.24
DASS-21	Depression	0.27	1	0.27	0.06	0.79	1.001	0.05
	Anxiety	45.85	1	45.85	2.90	0.10	1.12	0.36
	Stress	0.22	1	0.22	0.04	0.84	1.001	0.05
APS	Active factors	1.43	1	1.43	0.02	0.87	0.001	0.05
	Passive factors	875.93	1	875.93	35.47	0.001*	0.63	1.00
MSBS	Disengagement	17.97	1	17.97	2.59	0.12	0.11	0.33
	High arousal	14.75	1	14.75	1.91	0.18	0.08	0.26
	Low arousal	46.22	1	46.22	8.68	0.001*	0.30	0.80
	Inattention	80.07	1	80.07	16.73	0.001*	0.45	0.97
	Time Perception	982.62	1	982.62	23.74	0.001*	0.54	0.99
	Total	6.97	1	6.97	1.43	0.24	0.06	0.20

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Abbreviations: APS: Addiction potential scale; BIS-11: Barratt impulsiveness-11; DASS-21: Depression, anxiety, and stress scale-21; df: Degree of freedom; MSBS: Multidimensional state boredom scale; MS: Mean square; Sig.: Significant; SS: Sum of squares.

*Significant.

4. Discussion

In the present study, we aimed to investigate a one-week circadian misalignment resulting from an inversion of the activation cycle (such as the feeding and sleep-wake), which is typical in shift workers and medical students based on chronotype as a mediating variable, on impulsivity, depression, anxiety, stress, addiction potential, and boredom. The major findings from the present study are as follows. First, there was a significant association between circadian misalignment and motor impulsivity, passive factors of addiction potential, low arousal, inattention, and time perception (subscales of boredom). Second, persons with circadian misalignment and a morning type showed significantly more total and non-planning impulsivity and active and passive addiction potential in comparison with other types. The outcomes of this study have important hints for health care providers. Monitoring and paying attention to the mental health of medical care providers improves the quality of health services in the community.

In accordance with the relevant literature, our results indicate that participants involved in circadian misalignment have psychological conditions compared to a healthy control group with circadian-aligned conditions (Baron & Reid, 2014; Walker et al, 2020). Our findings showed that the problems comprised impulsivity, addiction potential, and boredom. Previous studies have shown that eveningness is a risk factor for impulsivity. Another consistent finding was that having an evening-type and circadian misalignment significantly related to impulsivity and addiction potential (Hwang et al., 2016; Kang et al., 2015; Selvi et al., 2011). In a systematic review, Gillett et al. (2021) reported a significant relationship between circadian rest-activity pattern disturbance (actigraphic variables) and impulsivity and mood disorder in participants aged 12–65. Also, our results, in line with the medical literature, showed circadian misalign-

Table 3. One-way analysis of variance to compare research variables in groups based on chronotype

	Variables	Chronotype	No.	Mean±SD	F	df	Sig.
BIS-11	Non-planning impulsiveness	Evening type	10	20.2±3.76	10.08	2	0.001*
		Intermediate type	9	22.22±3.8			
		Morning type	16	26.06±2.81			
	Motor impulsiveness	Evening type	10	36.2±2.74	0.39	2	0.67
		Intermediate type	9	35.55±4.58			
		Morning type	16	37.12±4.97			
	Cognitive impulsiveness	Evening type	10	11.4±.96	2.58	2	0.09
		Intermediate type	9	11.55±1.33			
		Morning type	16	12.37±1.2			
	Total impulsiveness	Evening type	10	67.8±5.11	5.73	2	0.001*
		Intermediate type	9	69.33±6.89			
		Morning type	16	75.56±6.4			
DASS-21	Depression	Evening type	10	4±4.98	10.14	2	0.55
		Intermediate type	9	2.22±3.07			
		Morning type	16	2.37±4.01			
	Anxiety	Evening type	10	2±2.98	0.07	2	0.92
		Intermediate type	9	1.55±1.94			
		Morning type	16	1.62±3.03			
	Stress	Evening type	10	7.8±6.35	1.19	2	0.31
		Intermediate type	9	7.77±8.68			
		Morning type	16	4.37±5.12			
APS	Active factors	Evening type	10	22.3±10.07	6.90	2	0.001*
		Intermediate type	9	21.66±11.28			
		Morning type	16	9.5±9.01			
	Passive factors	Evening type	10	9.6±4.52	4.17	2	0.02
		Intermediate type	9	7.22±2.04			
		Morning type	16	4.93±4.47			

	Variables	Chronotype	No.	Mean±SD	F	df	Sig.
MSBS	Disengagement	Evening type	10	42±7.39	0.42	2	0.65
		Intermediate type	9	44.33±5			
		Morning type	16	44.12±6.45			
	High arousal	Evening type	10	22±3.29	0.67	2	0.51
		Intermediate type	9	21.33±2.82			
		Morning type	16	22.56±1.75			
	Low arousal	Evening type	10	22.2±2.52	1.30	2	0.28
		Intermediate type	9	23.22±2.38			
		Morning type	16	21.62±2.27			
	Inattention	Evening type	10	13.2±2.57	1.24	2	0.30
		Intermediate type	9	13±3.24			
		Morning type	16	11.56±2.87			
	Time Perception	Evening type	10	19.4±1.64	1.25	2	0.30
		Intermediate type	9	19.44±3.77			
		Morning type	16	21.12±3.5			
	Total	Evening type	10	119.2±6.81	0.31	2	0.73
		Intermediate type	9	116.22±7.94			
		Morning type	16	118.62±10.15			

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Abbreviations: APS: Addiction potential scale; BIS-11: Barratt impulsiveness-11; DASS-21: Depression, anxiety, and stress scale-21; df: Degree of freedom. MSBS: Multidimensional state boredom scale; Sig.: Significant.

*Significant.

ment prospectively related to the potential of substance use (Claudatos et al., 2019; Logan et al., 2018). It is understood that impulsiveness makes a person prone to addiction. Tamura et al. reviewed the bidirectional relationship between substance use and the circadian system. They showed each drug follows a circadian pattern and changes during the development of substance use disorder. Furthermore, the expression of the *CLOCK* gene is also altered with the progression of addiction in many brain regions associated with reward circuits, addictive behaviors, and relapse (Tamura et al., 2021).

Multiple types of the research reported emotions, affect, mood, motivation, especially achievement emotions (e.g. boredom and anger), have been addressed in relation to chronotype (Fabbian et al., 2016; Itzek-Greulich, Randler, & Vollmer, 2016; Kadzikowska-Wrzosek, 2020). However, no study examined the effect of circadian misalignment on boredom. The present study showed a significant relationship between circadian misalignment and boredom. On the other hand, many preclinical and clinical studies have addressed a clear link between altered circadian system on depression, anxiety and stress, which was inconsistent with our findings (Blume et al., 2019; Difrancesco et al., 2019; Kim et al., 2017; Koch et al., 2017; Landgraf et al., 2016). Chellappa et al. conducted a study in 2020. They found circadian misalignment due to simulated night shifts significantly reduced mood and well-being levels throughout days of misalignment compared to circadian alignment conditions in the non-shift workers' group (Chellappa et al., 2020). Several research studies have shown a potential causal relationship between disturbed circadian and hypothalamic-pituitary-adrenal axis dysregulation (Nader,

Table 4. The results of the Bonferroni post hoc test

Variables	Group (I)	Group (J)	Mean Difference (I-J)	SE	Sig.	CI (95%)
Non-planning impulsiveness	Evening type	Intermediate type	-2.02	1.54	0.60	-5.93, 1.88
		Morning type	-5.86	1.35	0.001*	-9.28, -2.44
Total impulsiveness	Evening type	Intermediate type	-1.53	2.85	1.00	-8.73, 5.66
		Morning type	-7.76	2.50	0.01*	-14.08, -1.44
Active factors	Evening type	Intermediate type	0.63	4.55	0.001*	-10.88, 12.15
		Morning type	12.80	3.99	0.001*	2.69, 22.90
Passive factors	Evening type	Intermediate type	2.37	1.85	0.62	-2.30, 7.05
		Morning type	4.66	1.62	0.02*	0.56, 8.76

Abbreviations: CI: Confidence interval; Sig.: Significant; SE: Standard error.

*Significant.

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Chrousos, & Kino, 2010). Also, animal models show that the circadian genes *Per1* and *Peir2* in the nucleus accumbens regulate anxiety-related behavior (Spencer et al., 2013). One possible explanation for inconsistent findings is our small sample size.

First, the sample size was small in terms of the study limitations. Second, neuropsychological variables were measured by self-report rather than behavioral and physiological measures via actigraphy. Third, the intervention protocol in this study was the same in all three groups: Morning types, intermediate types, and evening types. On the other hand, in this study, the researchers could not find a valid protocol that could be used separately for each of these three groups. Fourth, although we could recruit female participants due to cultural constraints, it could have led to serious and time-consuming problems in implementing this project. Future researchers are recommended to repeat the present study with female participants because there are significant differences in chronotype according to gender. It is also recommended that the study be conducted using different protocols based on different chronotypes to control the testing conditions better. Our findings add to previous literature by investigating the effectiveness of the circadian system on neuropsychiatric conditions. The results of this study have important implications for clinical care providers in terms of shift work.

5. Conclusion

Alterations in diurnal profiles of activity, sleep, and feeding time, based on chronotype related to impulsiveness and boredom, and such circadian misalignment is associated with addiction potential.

Ethical Considerations

Compliance with ethical guidelines

The study was approved by the Ethics Review Committee of Shahroud University of Medical Sciences, Shahroud, Iran (Code: IR.SHMU.REC.1399.170). The study was designed and carried out based on the Declaration of Helsinki and the Ethical Guidelines for Medical and Health Research established by the Iranian Registry of Clinical Trials (IRCT), Tehran, Iran (Code: 20210202050223N1). All the participants signed their informed written consent.

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Authors' contributions

Conceptualization: Mohammad Niroumand Sarvandani; Methodology: Raheleh Rafaiee, Hamed Ghazvini and Behzad Garmabi; Formal analysis and software: Masoud Asadi; Investigation: Mohammad Niroumand Sarvandani, and Hamed Ghazvini; Writing the original draft: Raheleh Rafaiee, and Mohammad Niroumand Sarvandani; Review and editing: Hamid Kalalian Moghaddam; Funding acquisition, resources, and supervision: Hamid Kalalian Moghaddam; Final approval: All authors.

Conflict of interest

All authors declared no conflict of interest.

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