Title: Influence of Circadian Rhythm Disturbance with Mediating Role of Chronotype on Mental State, Addiction Potential, and Boredom in Medical Students

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Abstract

Background: Shift workers usually underwent 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. The purpose of this research was to obtain information about circadian disorders and chronotype (as a mediating variable) on consequent mental state such as impulsivity, depression, anxiety, stress, addiction potential, and boredom in students of a medical university in northeastern Iran. We study mental state in the group of individuals with circadian misalignment and compared with 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 a baseline data (pre-test) and the end of the Interventions (post-test). The instruments were Multidimensional State Boredom Scale **(**MSBS), Addiction Potential Scale (APS), Depression, Anxiety and Stress Scale-21 (DASS-21), and Barratt Impulsiveness-11 (BIS-11). We categorized participants based on chronotype as mediate variable within each group (circadian aligned & misaligned condition) to analyze outcomes.

Results: The mean age of 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 meaningful difference between the total and non-planning impulsivity, active and passive addiction potential, between the three groups of chronotype ($p<0.001$). The results of Bonferny 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 ($p<0.01$) and active addiction ($p<0.001$) in persons with evening and intermediate types were significantly lower than persons with morning type ($p=0.02$).

Conclusions: 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.

Keywords: Anxiety, Circadian rhythm, Depression, Stress disorders, Substance-related disorders, Chronobiology, Boredom

Introduction

Living organisms exhibit a wide range of cyclic physiological changes over the cycle of day and night (S. Kim & Kim, 2019; Patke, Young, & Axelrod, 2020). From most animals to 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, Oster, Korf, Foster, & Erren, 2020; West et al., 2017). The medical literature reports that misalignment has intense effects on processes that influence the risk of cardiovascular disease, metabolic, and neuropsychiatric conditions (Hower, Harper, & Buford, 2018; Moreno et al., 2019; William H Walker, James C Walton, A Courtney DeVries, & Randy J Nelson, 2020). One of the most immediate and significant consequences of misalignment of the sleep-wake cycle with the biological night is sleep disturbance (Ingram, 2020). Circadian variability affects wakefulness, feeding behavior, metabolic function, and mood in different ways (Parkar, Kalsbeek, & Cheeseman, 2019; Poggiogalle, Jamshed, & Peterson, 2018; Zaki et al., 2018).

Since the beginning of the 20th century, people have been divided into chronotype groups (Becker, Steinberg, & Kluge, 2016). Chronotype can generally be categorized into three types: Morning types, Evening types, and Non-types, which differ according to a number of behavioral, psychological, and biological variables, including usual eating times, appetite, mood, performance, and alertness (S. Kim & Kim, 2019; Kivelä, Papadopoulos, & Antypa, 2018). Morning types tend to start their activities earlier in the morning, while evening types are more efficient later in the day (Matchock & Mordkoff, 2009). Morning types who are tested in the morning and evening types who are tested in the evening respond more quickly to tasks that measure their reaction time (Lara, Madrid, & Correa, 2014). Shift workers usually underwent 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, Pagliai, Colombini, Sofi, & Dinu, 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, Kivelä, & Antypa, 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).

This have been demonstrated that the circadian misalignment effects on important systems in the body. The link between misalignment of circadian rhythms, neurocognitive dysfunction, and substance use disorder may lie in changed function of neural circuits underlying cognitive processing, reward, and impulse control (Brant P Hasler, Soehner, & Clark, 2015; Mattis & Sehgal, 2016; Wallace, 2020). Transgenic animal models show that circadian genes (e.g., Per1, Per2 and Clock) in reward circuits of brain play role in the regulation of appetitive behavior, and both clinical and preclinical researches suggest relation circadian genes to reward function (Rijo-Ferreira & Takahashi, 2019). There is a substantial neuroimaging literature examining the possible links between circadian rhythm shifts and alterations in neural circuitry in the human brain (DePoy, McClung, & Logan, 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, Mallet, Dubertret, Moro, & Guessoum, 2021). It is important for health policy makers to constantly update their information on the health status of health professionals and its changes over time to enable accurate and timely management. In line with this important point and considering that there are few epidemiological studies investigating circadian disorders in medical students, the present research was conducted. The aim of current study was to obtain information about circadian disorders and chronotype (as a mediating variable) on consequent mental state such as impulsivity, depression, anxiety, stress, addiction potential, and boredom in students of a medical university in northeastern Iran.

Material and Methods

Study Design and Procedures

The study design is a double-blind, randomized, controlled clinical trial. An overview of study has provided in Figure 1. After written informed consent is obtained, subjects would be randomly assigned to the intervention or control group by a assistant and baseline data will be obtained. At the end of the week, participants were asked to repeat the examinations.

Participants

The intervention and control groups, selected from all students of Shahroud University of Medical Sciences, were transferred to the experimental site in a specific dormitory for eleven days and housed in special rooms where the light intensity is specially designed according to luxury, period and light reception time, hours of food intake. Inclusion criteria were male gender, right-handed, age between 18 and 25 years, and regular sleep and wake rhythm in the last month (8 to 10 hours of sleep per night). 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), a body mass index (BMI) greater than 30.

Randomization and Blinding

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

Instruments

Reduced Morningness-Eveningness-Questionnaire (rMEQ)

The German version of the rMEQ was applied for collecting of data. The rMEQ is a brief form of the Morningness-Eveningness Questionnaire (MEQ) designed by Horne and Oestberg (1976). The original version contained 19 items and rated on a Likert-type scale (Horne & Östberg, 1976). Adan and Almirall (1991) identified a short version this original MEQ, which was then used in different countries, such as Iran (Adan & Almirall, 1991). The rMEQ has adequate psychometric properties and good convergent and construct validity as well as testretest 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's alpha was 0.62, and the German version was found to be 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 with 11 and below as evening types (Adan & Almirall, 1991; Marvaldi et al., 2021).

Multidimensional State Boredom Scale (MSBS)

Fahlman et al (2013) developed MSBS as the first and full-scale measurement of state boredom (Fahlman, Mercer-Lynn, Flora, & Eastwood, 2013). In 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 the factor structure similar to the original questionnaire (i.e., 5 factors and 29 items). The Persian version of the MSBS are equivalent to the original version regarding the conceptual and linguistic features. The internal consistency of the Persian version of the MSBS was good, Cronbach's alpha 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)

The APS was created by Weed and Butcher in 1992 (Weed, Butcher, McKenna, & Ben-Porath, 1992). In the current study, we use 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 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 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, Najarian, & Naami, 2008).

Depression, Anxiety and Stress Scale-21 (DASS-21)

For this study, data from 21 items of the DASS-42 (i.e., the DASS-21), developed by Guillemin et al. (1993), was used. 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 ranging from 0 to 21. The higher the score indicated more severe the depression, anxiety and stress (Asghari, Saed, & Dibajnia, 2008; Guillemin, Bombardier, & Beaton, 1993).

Barratt Impulsiveness-11 (BIS-11)

The BIS -11 (11th version) was developed by Patton et al. (1995)(Patton, Stanford, & Barratt, 1995). It contains 30 items rated on a five-point Likert scale. Twelve items are reverse scored. It also contains 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 ($\alpha = 0.81$)(Javid, Mohammadi, & Rahimi, 2012; Stanford et al., 2009).

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 primary day of the 8-day study protocol, subjects were accepted to the designated dormitory at ∼8 am to perform either the circadian rhythm alignment protocol or the circadian rhythm misalignment protocol (Fig 2). In the protocol of circadian alignment, subjects slept between 11:00 pm and 7:00 am on days 1-8. In the protocol of circadian misalignment, subjects slept between 11:00 pm and 7:00 am on days 1-3. On day 4^{th} of the misalignment protocol, the subjects' activation patterns were shifted by 12 hours, and this reversed cycle was remained until the end of the protocol (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. The right conditions in the course of the protocols are presented in Figure 2.

Outcomes

The outcome of this study is the change from baseline in scales measured by MSBS, Addiction Potential Scale, 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 participants (17 people in each group). Sample size was measured using the formula for randomized controlled trial studies as follows:

$$\frac{2\sigma^2(Z_{1-\alpha}+Z_{1-\beta})^2}{d^2}$$

Efficacy analysis

All analyses were conducted in SPSS 25. The pre-test and post-test means and standard deviations (SD) in two study groups were calculated. In preliminary analyses, we examined the result of the pre-test in two groups using 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 mediate variable within each group (circadian aligned & misaligned condition) to analyze outcomes using one-way analysis of variance (ANOVA). We provide adjusted p values to account for multiple comparisons of primary analyses, using a Bonferny post hoc test. The significance level was set at 0.05.

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 (range: 18-25 years). Thus, complete follow-up was available for 35 subjects. Figure 3 shows a CONSORT flowchart for the study. The obtained F value for the pretest scores showed that there was 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. The result of Box's Test of Equality of Covariance Matrices shows that the condition of homogeneity of 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 ($F = 5.88$, $df = 13.8$, $P = 0.009$, $\eta = 0.90$, $1\text{-}\beta = 0.95$). Analysis of covariance was used to evaluate the effect (Table 2).

Table 2 shows that the circadian misalignment was effective on motor impulsivity, passive addiction potential, low arousal, inattention, and time perception. Results of the ETA 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 effect on time perception was the largest.

Table 3 presented one-way analysis of variance to compare research variables in groups based on chronotype (evening, intermediate type, and morning types). There is a significant difference between the total and non-planning impulsivity, active and passive addiction potential, between the three groups of chronotype. The results of Bonferny 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 score of impulsivity and passive factors of addiction potential in participants with morning type is significantly higher than participants with evening type. The results of Bonferroni post hoc test was shown in Table 4.

Discussion

In the present study, we aimed to investigate that a week circadian misalignment, resulting from an inversion of the activation cycle (such as the feeding and sleep-wake) and 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 obtained from the present study are as follows; (1) 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). (2) Persons with circadian misalignment and a morning type showed significantly more total and non-planning impulsivity, active and passive addiction potential in compared with other types. The outcomes of this study have important hint for the 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 showed participants involved in circadian misalignment showed psychological condition than healthy control group with circadian aligned condition (Baron & Reid, 2014; William H. Walker, James C. Walton, A. Courtney DeVries, & Randy J. Nelson, 2020). Our finding showed that the problems comprised impulsivity, addiction potential and boredom. Previous studies have been shown that eveningness is a risk factor in terms of impulsivity. Another consistent finding was that having an evening-type and circadian misalignment significantly related impulsivity and addiction potential (Hwang, Kang, Gwak, Park, & Lee, 2016; Kang et al., 2015; Selvi et al., 2011). In a systematic review, Gillett et al (2021) reported a meaningful relationship between circadian rest-activity pattern disturbance (actigraphic variables) with both impulsivity and mood disorder in participants aged 12–65 years old (Gillett, Watson, Saunders, & McGowan, 2021). Also, our results in line with the medical literature showed circadian misalignment prospectively related to the potential of substance use (Claudatos, Baker, & Hasler, 2019; Logan et al., 2018). It is understood that impulsiveness prone a person to addiction. Tamura et al reviewed bidirectional relationship between the substance use and circadian system and showed each drug follows a circadian pattern and changes during the development of substance use disorder. Furthermore, expression of clock gene is also altered with progression of addiction in many brain regions associated to reward circuits, addictive behaviors and relapse (Tamura, Oliveira-Silva, Ferreira-Moraes, Marinho, & Guerrero-Vargas, 2021).

Multiple researches 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 the meaningful relationship between the circadian misalignment and boredom. On the other hand, many preclinical and clinical studies have addressed clear link between altered circadian system on depression, anxiety and stress, which was inconsistent with our findings (Blume, Garbazza, & Spitschan, 2019; Difrancesco et al., 2019; J. Kim et al., 2017; Koch, Leinweber, Drengberg, Blaum, & Oster, 2017; Landgraf et al., 2016). Chellappa et al conducted a study in 2020 and found the circadian misalignment due to simulated night shifts significantly reduced mood and well-being levels throughout days of misalignment, as compared to circadian alignment condition in non-shift workers group (Chellappa, Morris, & Scheer, 2020). Several researches have shown a potential causal relationship between disturbed circadian and hypothalamic-pituitary-adrenal (HPA) axis dysregulation (Nader, Chrousos, & Kino, 2010). Also, an animal models (2020) found that the circadian genes *Period 1* and *Period 2* in the nucleus accumbens are involved in the regulation of anxiety-related behavior (Spencer et al., 2013). One possible explanation for inconsistent finding is our small sample size.

In terms of the study limitations, first, the sample size was small. Second, neuropsychological variables were measured by self-report rather than behavioral measures 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 it was not impossible for us to recruit female participants due to cultural constraints, it could have led to serious and time-consuming problems in the implementation of 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 with different protocols based on different chronotypes to better control the testing conditions. Our findings add to previous literature by investigating the effectiveness of the circadian system on the neuropsychiatric conditions. The results of this study have important implications for clinical care providers in term of shift work.

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.

Declarations

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Conflict of interest

All authors declare that they have no conflict of interests.

Ethical approval

The study approved by the Ethics Review Committee of Shahroud university of medical science (Registration No. IR.SHMU.REC.1399.170) and has been designed and carried out based on the Declaration of Helsinki and the Ethical Guidelines for Medical and Health research established by ministry of Health and Medical Education and Ministry of Science, Research and Technology, Iran (IRCT NO.: 20210202050223N1). All the participants signed their informed written consent.

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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		Groups	Pre-test (Mean±SD)	Post-test (Mean±SD)	t-test for Equality of Means			Levene's Test for Equality of Variances	
					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±4/30	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	12.00±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	18.00±11/96	17.94±13.03					
	Passive Factors	Intervention	7.33±4.40	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	18.50±5.44	-0.22	33	0.90	0.01	0.82
		Control	11.58±6.04	12.00±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					

* Significant. 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; SD, Standard deviation.

Table 2. Results of analysis of covariance to investigate the effect of circadian misalignment on the outcomes (following variables).

Variable		SS	df	MS	F	Sig.	η	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

* Significant. 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; SD, Standard deviation. SS, sum of squares.

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

variables		Chronotype	n	Mean±SD	F	df	Sig.
BIS-11	Non-planning Impulsiveness	Evening type	10	20.20±3.76	10.08	2	0.001*
		Intermediate type	9	22.22±3.80			
		Morning type	16	26.06±2.81			
	Motor Impulsiveness	Evening type	10	36.20±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	11.40±.96	2.58	2	0.09
		Intermediate type	9	11.55±1.33			
		Morning type	16	12.37±1.20			
	Total Impulsiveness	Evening type	10	67.80±5.11	5.73	2	0.001*
		Intermediate type	9	69.33±6.89			
		Morning type	16	75.56±6.40			
DASS-21	Depression	Evening type	10	4.00±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	2.00±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	7.80±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	22.30±10.07			
		Intermediate type	9	21.66±11.28	6.90	2	**0.**001*
		Morning type	16	9.50±9.01			
	Passive Factors	Evening type	10	9.60±4.52			
		Intermediate type	9	7.22±2.04	4.17	2	0.02
		Morning type	16	4.93±4.47			
MSBS	Disengagement	Evening type	10	42.00±7.39			
		Intermediate type	9	44.33±5.00	0.42	2	0.65
		Morning type	16	44.12±6.45			
	High Arousal	Evening type	10	22.00±3.29			
		Intermediate type	9	21.33±2.82	0.67	2	0.51
		Morning type	16	22.56±1.75			
	Low Arousal	Evening type	10	22.20±2.52			
		Intermediate type	9	23.22±2.38	1.30	2	0.28
		Morning type	16	21.62±2.27			
	Inattention	Evening type	10	13.20±2.57			
		Intermediate type	9	13.00±3.24	1.24	2	0.30
		Morning type	16	11.56±2.87			
	Time Perception	Evening type	10	19.40±1.64			
		Intermediate type	9	19.44±3.77	1.25	2	0.30
		Morning type	16	21.12±3.50			
	Total	Evening type	10	119.20±6.81			
		Intermediate type	9	116.22±7.94	0.31	2	0.73
		Morning type	16	118.62±10.15			

* Significant. 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; SD, Standard deviation.

Table 4. The results of Bonferny 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

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

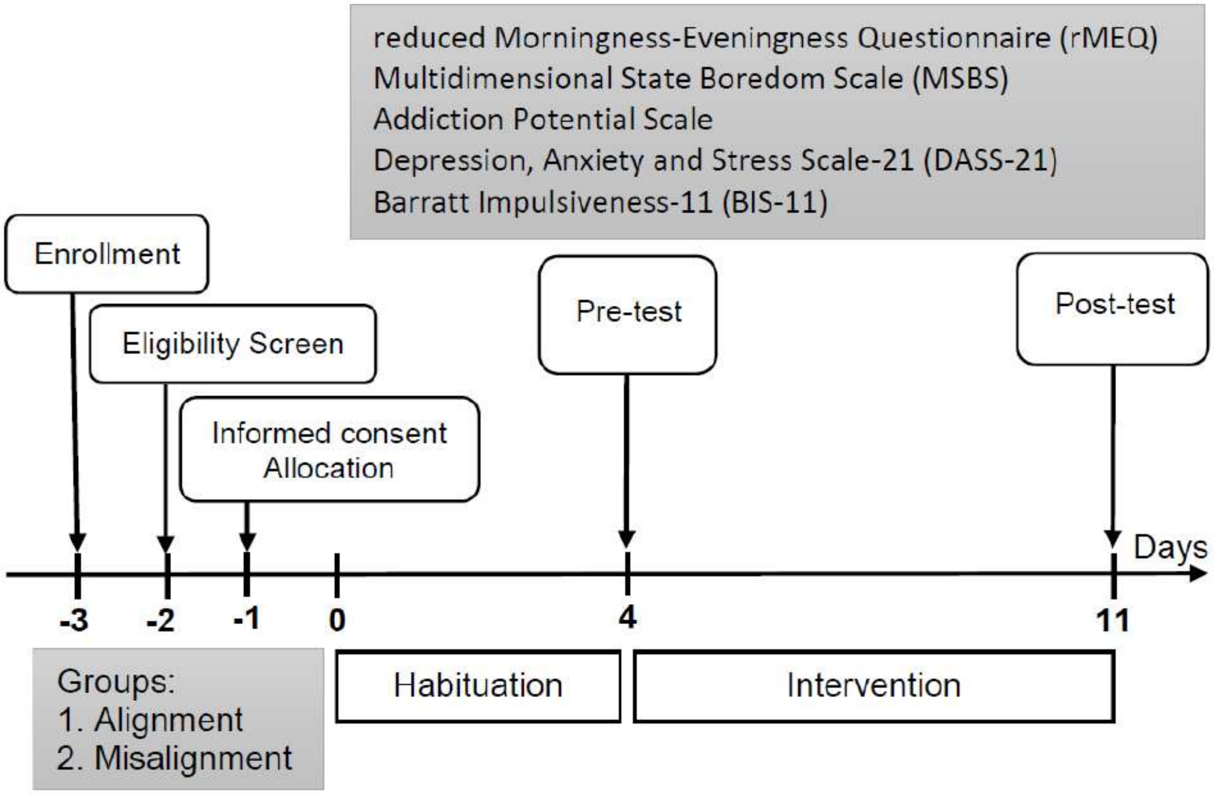

Figure 1. Overview of study procedures.

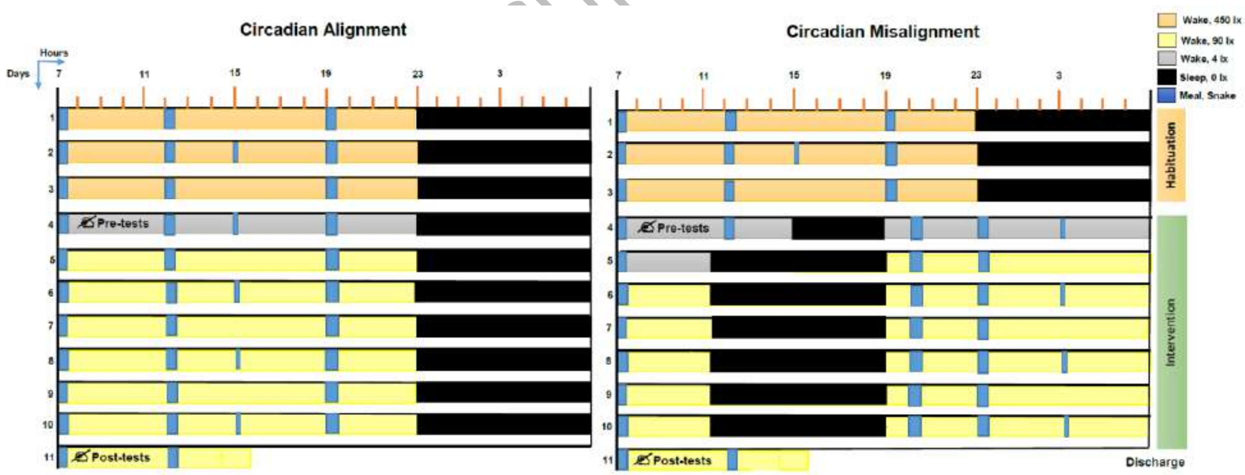

Figure 2. Left box shows circadian alignment protocol and right box shows circadian misalignment protocol.

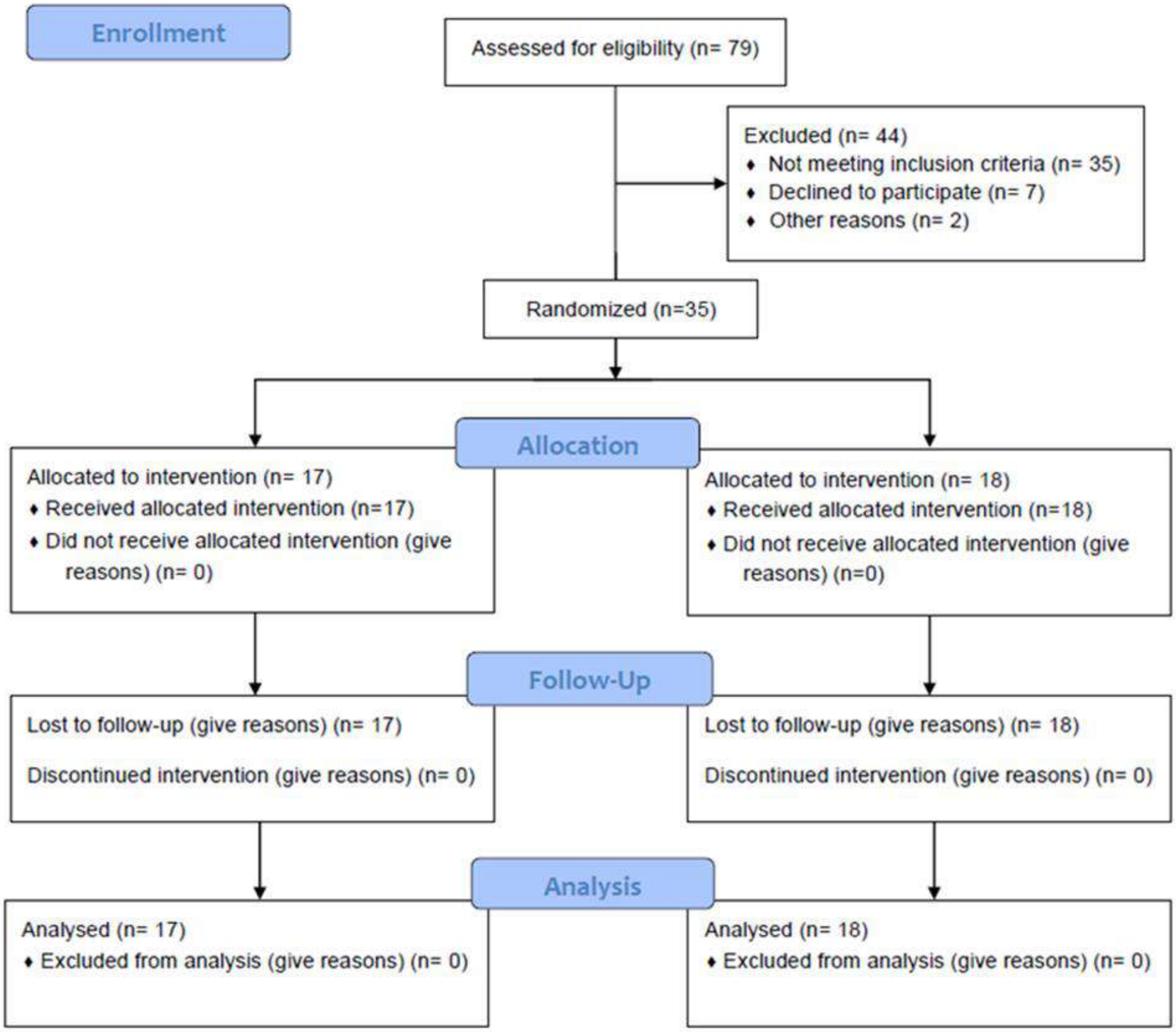

Figure 3. CONSORT flow diagram.