

*Article***Social and behavioral rhythms as a marker of well-being indicator in old adults living at home**

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### **Abstract:**

The purpose is to verify in old adults if social and behavioral rhythms (SBRs) are correlated with a positive perception of the quality of life (QoL). Social and behavioral rhythms and related circadian biorhythms are known as central points in the pathophysiology of bipolar disorders. A secondary aim is to see if a similar relationship can be found in Major Depressive Disorder (MDD) in old adults. Sample: 141 people aged  $\geq 65$  years (58,9% Female). Each subject was evaluated using the Social and Behavioral Rhythms Scale (in which higher scores show more dysfunctional SRBs); SF-12 for QoL and a screening tool for depressive symptoms. They underwent a medical evaluation and blood level assays including cholesterol and triglycerides. The medical diagnoses including MDD were taken into account. The Social and Behavioral Rhythms Scale score correlated inversely with SF-12 score ( $p < 0.001$ ) and positively with PHQ9 ( $p < 0.0001$ ). People with MDD had a higher score on social rhythms than controls without ( $p < 0.01$ ). The study highlighted, for the first time, that social and behavioral rhythms have a role in old adults living in the community. Further longitudinal studies with a sufficient number of individuals will be required to confirm these data and clarify causal links of the association.

**Keywords:** Social rhythm; Behavioral rhythm; Well-being; Old adults

## 1. Introduction

Life expectancy has increased worldwide in the last decades and the proportion of older people with a lack of autonomy and disabilities has also increased. This implies significant social and health costs [1]. It is therefore essential that research on the health of older adults must not be limited to the study of pathologies, but also focus on positive well-being and factors that can be used as preventive tools [2, 3]. An element that may affect the quality of life of older adults is the change in circadian biological rhythms and increased vulnerability to factors that influence them. The rhythmicity of metabolic and hormonal processes is controlled by a complex endogenous system of pacemakers in which Melatonin [4, 5] and Cortisol [6, 7] play a central role among the mediators. This system affects, but can also be affected by, external factors such as light/dark-cycles, nutrition and exercise and social activities [8]. In humans, melatonin reaches maximum plasma levels at night around 3 to 4 AM. Its release is regulated by a veritable central circadian rhythm generator as the suprachiasmatic nucleus of the anterior hypothalamus [4]. As is known, melatonin regulates body temperature, sleep and promote sleep onset, and regulates the photosensitive retinal ganglion cells that provide signals to the SCN [4, 5]. Total melatonin secretion declines with age [9, 10]. However, melatonin rhythm is better preserved in healthy older adults [11, 12] in contrast to old people with several neuropathologic illnesses [13-17]. Like melatonin, cortisol rhythms show age-related changes such as a reduction in amplitude with higher secretion at night [6, 7] and delay in the peak in the morning [18].

More alterations of the cortisol rhythm in old humans, as for that of melatonin, were found to be associated with neurodegeneration [19-21]. Organs such as the liver and pancreas are under circadian rhythms in regulating the glucose and lipid metabolism [22]. Age-related weakening of circadian rhythms has been hypothesized as exposing older adults [23] to metabolic diseases. Plasma levels of proinflammatory cytokines fluctuate in accordance with rest/activity rhythms [24]. Evidence suggests that dysfunction in circadian clockwork may influence the link between inflammatory response and diet [25] and that age-related change of rhythms may be related to vulnerability to chronic inflammation and metabolic disorders. Vulnerability to the dysregulation of biological rhythms in older adults has been attributed to reduced responsiveness of the aged master circadian clock to light [26]. Given the increase in light pollution in the modern world and even more so in modern metropolises, this vulnerability exposes the elderly to greater risks [27]. It is also necessary to consider how biological circadian rhythms influence, and may be influenced by, the so-called social and behavioral rhythms.

Older adults show vulnerability to the dysregulation of biological rhythms and, consequently, of biological and social rhythms. Adults above 60 are significantly more likely to "rising from and retiring to bed earlier than younger adults of 20 and 30 years old" [26]. Indeed, older adults experience changes in the architecture of sleep with more awakenings, longer latencies to falling asleep, and shortening of 3 to 4 rapid eye movement stages while asleep [28] with a loss of around 30

minutes of sleep every 10 years from 40 onwards [29]. These changes, if too accentuated, have been shown to be related cognitive decline and risk of falls [30]. Studies on jet lag, have demonstrated a differential impact on older adults compared with young adults, with poorer sleep efficiency, alertness state, and impaired body temperature [31]. The circadian rhythm of body temperature shows a great decrease in amplitude related to age [32]. The dysregulation of the awakening phases and the consequence of an age-dependent jet lag alter the ability to regulate glucose, and therefore the correct rhythm of nutrition [33], which implies a close relationship between the rhythms of sleep and nutrition. Indeed, evidence has found exercise able to reset disruptions in circadian pacemakers [8] and physical activity is closely linked to social relationships and social activities. Therefore, there is strong evidence that social and behavioral rhythms (such as times of awakening and falling asleep, regularity of food and social relationships), are influenced by, and can influence, circadian biorhythms and therefore may have a relationship with vulnerability to metabolic and inflammatory diseases. Up to now, the alterations of social rhythms and biological rhythms in the elderly have been studied mainly in relation to their vulnerability to pathologies or that greater alteration of the bio and/or social rhythms are directly proportional to the risk of pathologies. This has also been seen in mood disorders in which self-esteem and loss of interest in things is central and whose occurrence is closely related to a poor quality of life. In fact, it has been suggested that there is a possible association between induced irregularity of social and behavioral rhythms (due to fortuitous circumstances and/or to basic irregularity, linked to temperamental / personality profiles), and the risk of mood disorder [34-37]. More specifically, some results indicate that bipolar depression is related to disruption of social and behavioral rhythms in the elderly while unipolar depression is not [38]. However, little evidence is known about the relationship between social rhythm and positive mental health, and perception of life satisfaction, specifically in the elderly.

Our hypothesis is that a good adaptation in the regulation of biological rhythms in the elderly is associated with a better state of well-being and therefore a better quality of life. The main purpose of this work is to verify such hypothesis by administering a randomized controlled trial of physical activity in a sample of elderly people living at home to see if their functional social and behavioral rhythms correlate with a positive health measure such as a good perception of the quality of life (QoL). A secondary purpose is to establish whether the regularity of social rhythms correlates with other parameters related to metabolic rhythms and confirm if there is an association between regularity of social and behavioral rhythms and Major Depressive Disorder in old adults.

## 2. Experimental Section

Sample: The study sample included 141 people aged 65 years and older of both genders (83 Females, 58,9%) living at home. They were recruited and preliminarily evaluated for selection to participate in a Randomized Controlled Trial (RCT) on exercise [39]. Inclusion criteria for the preliminary evaluation for eligibility for RCT were having a medical certificate for suitability in non-competitive

moderate-intensity physical activity. Exclusion criteria were BMI>35; unsuitability for moderate physical activity due to medical/physical impairment (mild-moderate chronic diseases such as hypertension or diabetes were admitted). This sample had been preliminarily selected and evaluated to exclude the presence of serious diseases by means of a medical examination and were then set for the randomization.

**Instruments:** Each subject was submitted to a series of instruments as programmed for the RCT design [39]. For the purpose of this study, we took into consideration the measure of: Social and Behavioral rhythms (eating, sleeping, social contacts) measured by the Brief Social Rhythm Scale [40].

The Brief Social Rhythm Scale (BSRS) is a simplified tool derived from more complex tools such as the Social Rhythm Metric (SRM) [41] which had presented excellent psychometric performances but which were too complex for use in large samples or in the context of multidimensional evaluations requiring the use of many tools. BSRS consists of ten items that assess the irregularity with which participants engage in basic daily activities during a week such as the rhythms of sleeping (waking and bedtimes); the regularity in eating (breakfast and dinner) and of social contacts with others (at work, school, and leisure time). Participants must rate the regularity of each activity in their lives on a scale ranging from 1 (very regularly) to 6 (very irregularly). Higher scores thus indicate higher irregularity. In this work, the score is considered as a general sum of the individual items. The tool is administered at a single time point. The BSRS has shown good psychometric properties in terms of internal consistency in transnational studies (40). If the limits for conducting parametric measures for the correlation of the main outcome (BSRS Vs SF-12 score) are met, we will present the linear regression analysis in this measure as a figure with scatterplot.

Health-Related Quality of Life (H-QoL) was measured with the 12-Items Short Form Survey (SF-12) [42]. Depressive Episode and Symptoms were assessed by the Patient Health Questionnaire-9 (PHQ-9) [43]. PHQ9 is a self-administered questionnaire. The PHQ9 score is the sum of the scores of 9 items, each corresponding to one of the key symptoms of the depressive episode DSM criteria. The total PHQ9 score from 0 to 4 indicates minimal symptoms; 5-9 mild minimal symptoms; 10-14, moderate depressive episode; 15-19 moderately severe and 20-27 severe depression. [43].

For the diagnoses of MDD, Cancer, Thyroiditis, Diabetes Type 2 and Hypertension, we adopted the criteria reported in medical assessment adequacy of health conditions for the proposed physical exercise that was part of the trial protocol. We then verified the diagnoses reported by the physical education doctor on the basis of the attached clinical documentation (which, according to the trial protocol, had been requested from each participant). A blinded doctor therefore evaluated the PE doctor's diagnosis and the documentation attached to each participant's dossier and confirmed the diagnoses when in accordance with international standards. Thus, for depressive episodes we have

the current status detected by self-assessment (by PHQ9) and the lifetime one for MDD Lifetime Medical diagnosis.

**Ethical issues:** Each participant received detailed explanations about the aims and procedures of the survey. The study was conducted according to the Declaration of Helsinki and its revisions) [44]. The Independent Ethics Committee of the “Azienda Ospedaliera Universitaria di Cagliari” (Cagliari University Hospital), has approved the study (reference number PG/2018/15546 25 October 2018).

**Statistical analysis:** For measuring the linear correlation between the score at BSRS, verification of the distribution of normality through the Kolmogorov-Smirnov Test of Normality for each parameter considered for correlation was carried out. The correlation between SBRS total score and each parameter considered was conducted by means of both the Pearson and Spearman Correlation Tests, with the intention of using the latter if the data (for each specific parameter involved in the correlation) did not respect the normal distribution. The comparison between subgroups of participants receiving or not receiving a diagnosis (Thyroiditis, Cancer, Diabetes Type 2, Hypertension, Major Depressive Disorder; Depressive Episode) was carried out for each sub-group against a control sample without the same condition selected by randomization after blocks from the overall sample of people without such a condition. For this purpose, for each person with a condition (for example Thyroiditis), a cell was created with all the people without such a condition and the same age (+/- 2 years old) and gender, thus two people (but one for Hypertension, 4 for PHQ $\geq$ 14, MDD in remission without treatment and MDD with antidepressant) were selected by randomization from each cell obtained. The comparison between groups with conditions and matched groups without conditions was carried out by means of the Mann-Whitney Test U.

### 3. Results

The distribution of SBRS score in the sample respected the normal distribution according to the Kolmogorov-Smirnov Test of Normality and the same was true for the level of cholesterol in the blood. For all the other measures examined it did not; we therefore referred to the results of Spearman's non-parametric test. However, the results of the two tests (the parametric Pearson and the non-Parametric Spearman) were superimposable.

The score at SBRS of each participant was shown in an inverse linear correlation between the score at SF-12 (measuring H-QoL) of the same individual, which means that the higher the score at BSRS (i.e., more dysfunctional social rhythms) the lower the score at SF-12 (i.e., more worsened was H-QoL). (**Rho**=-0.238,  $p<0.01$ ). The result was confirmed when comparing the SBRS score with the component of the SF-12 that measures psychological well-being (**Rho**=-0.262,  $p<0.01$ ) while no inverse relationship between BSRS and SF-12 for quality of physical life was shown ( $\text{Rho}=0.1542$ ;  $p=0.120$ ). On the contrary, the score for SBRS was in a linear correlation with the score of PHQ9

which measures Depressive Symptoms ( $\rho=0.309$ ;  $p<0.001$ ). The SBRS score correlated positively with blood triglyceride dosage ( $\rho=0.157$ ,  $p=0.06$ ) but did not with blood cholesterol dosage ( $\rho=0.157$ ,  $p=0.06$ ) or with BMI ( $\rho=-0.007$ ,  $p=0.930$ ). The subgroups of people who had cancer or type 2 diabetes or hypertension did not have a higher mean SBRS score than those who did not have the same disorder, people suffering from thyroiditis did have a higher score ( $24.7\pm8.7$  vs.  $19.10\pm5.2$ ,  $Z=-2.860$ ,  $p<0.01$ ).

A Lifetime Major Depressive Disorder medical diagnosis was associated with a higher score at the scale of social rhythms ( $24.8\pm11.9$  vs  $20.8\pm9.5$ ,  $Z=-2.773$ ,  $p=0.0056$ ) as well people with a score at PHQ9 $\geq10$  (identifying a current depressive episode) ( $29.3\pm12.5$  vs  $21.0\pm8.3$ ,  $Z=-4.532$ ,  $P<0.001$ ) and those with Chronic Depression (medical diagnosis of Lifetime MDD) taking antidepressants ( $28.4\pm13.0$  vs  $20.3\pm8.3$ ,  $Z=-6.813$ ,  $P=0.010$ ). People with previous MDD in remission (i.e. with lifetime medical diagnosis of MDD but negative at PHQ9) and currently without treatment showed no difference in social or behavioral rhythms with respect to their respective control group. Since the limits for conducting parametric measures for the correlation of the main outcome (BSRS Vs SF-12) score were met, we then presented the linear regression analysis of this measure in Figure 1 with scatterplot

**Table 1. Correlation between SBRS score and measures of healthy and pathologic measures in 141 old adults living at home**

Condition /Measure	Pearson R P(2tailed)	Spearman Rho P(2tailed)	Kolmogorov-Smirnov Test of Normality K-S test statistic (D)
SBRS	---	----	0.1045 $P=0.081^*$
H-Qol/SF12	-0.360 $p<0.0001$	-0.238 $p=0.0044$	0.1393 $P=0.007^{**}$
Physical QoL/MSF-12	-0.154	-0.120	0.1153

	p=0.0601	p=0.1542	P=0.041**
Psychological QoL/PSF-12	-0.262 P=0.0023	-0.262 <b>p=0.0017</b>	0.1750 P<0.001**
Depressive Symptoms/PHQ9 score	0.396 P<0.0001	0.309 P<0.0001	0.02259 P<0.001**
Total Cholesterol	0.158 P=0.0602	0.157 <b>p=0.06</b>	0.06184 P=0.6351*
Triglycerides	0.256 P<0.001	0.262 <b>p=0.00165</b>	0.13271 P=0.0013**
BMI	-0.0008 P=0.9294	-0.007 p=0.930	0.21715 P<0.001**

\*data do not differ significantly from those normally distributed

\*\*data are not normally distributed.

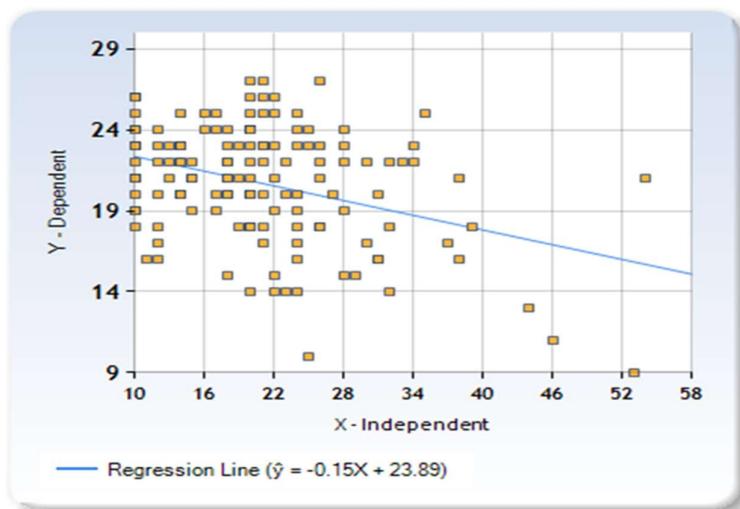
*Table 2. Social Rhythms in specific diagnostics in study sample*

Condition	BSRS Mean±SD in people with the condition as described in first column  N=sample size  F=Number of females  >75Years = number of people	BSRS Mean±SD in people without the condition as described in first column  N=sample size  F=Number of females  >75Years = number of people older than	Z	P

	older than 75	75		
Thyroiditis	24.7±8.7 (N=25) [Female=11 >75Years=5]	19.10±5.2 (N=50) Female=22 >75Y=10]	-2.860	<0.01
Cancer	22.6±9.7 (N=15) [Female=11 >75Years=5]	22.7±5.7 (N=30) Female=22 >75Years=10]	0.602	0.548
Diabetes Type 2	18.0±5.8 (N=12) [Female=4 >75Years=4]	19.7±7.1 (N=24) [Female=4 >75Years=4]	0.922	0.357
Hypertension	20.5±3.9 (N=55) [Female=27 >75Years=15]	21.0±9.9 (N=55) Female=54 >75Years=30]	0.648	0.515
Major Depressive Disorder Lifetime (medical diagnosis)	24.8±11.9 (N=20) [Female=15 >75Years=5]	20.8±9.5 (N=40) [Female=30 >75Years=10]	-2.773	0.0056
Depressive Episode PHQ≥10 (55.5% with medical diagnosis)	29.3±12.5 (N=9)	21.0±8.3 (N=36)	-4.532	0<.001

of MDD)	[Female=8 >75Years=3]	Female=32 >75Years=12]		
Previous MDD in remission without treatment	18.5±7.2 (N=8)  [Female=6 >75Years=2]	20.7±9.2 (N=32)  [Female=24 >75Years=8]	0.311	0.756
Chronic Depression with antidepressants (medical diagnosis)	28.4±13.0 (N=8)  [Female=7 >75Years=1]	20.3±8.3 (N=24)  Female=28  [Female=28 >75Years=4]	-6.813	0.010

**Figure 1. Linear Regression between BSRS Scores and SF-12) Score presented with scatterplot**



Sum of  $X$  (BSRS Score) = 2938

Sum of  $Y$  (SF-12 score) = 2922

Mean  $X$  = 20.8369

Mean  $Y$  = 20.7234

Sum of squares ( $SS_X$ ) = 10533.2482

Sum of products ( $SP$ ) = -1598.3617

Regression Equation =  $\hat{y} = bX + a$

$b = SP/SS_X = -1598.36/10533.25 = -0.15174$

$a = M_Y - bM_X = 20.72 - (-0.15*20.84) = 23.88528$

$\hat{y} = -0.15174X + 23.88528$

#### 4. Discussion

To our knowledge, our study is the first to show that in a sample of elderly adults, social and behavioral rhythms are related to positive well-being, i.e. having a functional and stable rhythm as measured by the SRBS scale (in which lower scores indicate more functional rhythms) is inversely related to the SF-12 score which measures the quality of life, with a higher score indicating a higher perceived QoL.

Such a result (relationship between social rhythms and quality of life) which had instead been found in numerous studies on mood disorders. Especially studied was the link between sleep and quality of life in Bipolar Disorders [36, 37]. Data on Major Depressive Disorder were conflicting [38]. Our study shows that the SRBS score correlates positively with the PHQ9 score, which is an indicator of depressive symptomatology at point prevalence. PHQ9 shows high scores during a depressive episode. A depressive episode (with a high PHQ9 score) can occur in both Major Depressive Disorder and Bipolar Disorder (these are lifetime diagnoses which both involve the presence of depressive episodes), claiming that the correlation SRBS/PHQ9 indicates a link between the presence of Major Depressive Depression and the high score at SRBS may be biased by presence of people with Bipolar Disorders. However, Bipolar Disorder has a lower frequency in the community and, what is more, in older people, than does Major Depressive Disorder, thus the weight of Major Depressive Disorders in the correlation is higher than that of Bipolar Disorder.

However, the association between Major Depressive Disorder and Rhythms is also confirmed by the higher scores at the SRBR scale among all those who have had a specific medical lifetime diagnosis of Major Depressive Disorder compared to those who have not. In conclusion, the results indicate that in the elderly social and behavioral rhythms are strongly altered in Major Depressive Disorder in older adults. The presence of a dysfunctional profile of social and behavioral rhythms is confirmed in those with chronic depression while suffering from a depressive episode in the past is not associated with altered rhythms in people who had recovered from it (i.e. people with MDD diagnosis but negative at PHQ at current evaluation). This element is relevant since it suggests a possible role of

improving circadian rhythms in a recovery path as well as a possible role in prevention, although a cross-sectional study cannot explain the causal sense of this association (i.e. if it is the healing of depression that causes the return to a functional rhythm or if a factor of recovery is the return to a functional rhythm). This aspect will need to be clarified by future longitudinal studies.

Returning to the main result of the study, which is the demonstrated relationship between social rhythms and quality of life in old adults, it is necessary to underline that our results concern only the correlation of the overall score at SBRS with the measure of the quality of life. This is an important result but very difficult to interpret. It is therefore a preliminary picture that suggests the need for future research to better understand the details of the interaction of the specific components (sleep, eating, having social contacts) and to clarify the role of the biological clocks of rhythm. Although we made it clear in the introduction that all aspects of social rhythms are interconnected, by far the aspect most studied so far has been the sleep-wake rhythm as well as the biological markers of this rhythm. For example, incorrect eating habits, such as irregularity in dietary rhythms, may conceivably be related to the kind of food intake, thus may have consequences on the lipid metabolism.

It is well known that dysregulation of light-shadow rhythms can directly influence sex hormones as the block of melatonin at night, due to loss of sleep and excess of light, may influence estradiol/progesterone balance in favor of estradiol [45]. Exposition to light pollution can in fact induce the risk of breast cancer and prostate cancer [46] as well as mood disorders [27]. But it is also known that circadian modifications of melatonin can cause changes in the metabolism of lipids [47]. The consequences on metabolic dysfunctions and obesity of the de-synchronization of biological rhythms due to the effect of artificial light have been hypothesized [48] and are currently studied particularly by Arab researchers concerning the coping mechanism in Ramadan [49]. However, the impact of light disruption on obesity has not yet been clarified and this study, despite having highlighted a relationship between social and behavioral rhythms and blood lipid parameters, has revealed no relationship with BMI.

The blocking of melatonin can affect insulin resistance and carbohydrate metabolism [50] and it has recently been reported that exposure to excess light may induce metabolic syndromes [51]. In our study, however, no direct relationship between altered social rhythms and type II diabetes and BMI was found. But the study did highlight that having dysfunctional rhythms can be related to the lipid metabolism because it has been seen that the scores on the SRBS correlate inversely with the plasma levels of triglycerides. This suggests an influence of social rhythms on some (but not all) aspects related to metabolism, but the sample was not large enough to encompass an analysis of specific aspects of social rhythms that could possibly affect everyone as previous underlined.

From this point of view, it is interesting that our study has verified a close relationship between the alteration of social patterns (which are closely related to biological rhythms) and thyroiditis. Even in

this case, however, the causal link of the association needs to be clarified. Thyroiditis is a chronic disorder and hormonal dysfunction may alter the control of food and sleep. Longitudinal studies with adequate power and sample size will therefore be needed to investigate this link.

The study found no relationship between altered social rhythms and cancer or hypertension. In the first case, it must be remembered that this is a sample of people who, although they may have medium-mild severity disorders, must have tested positive for a medical examination for sports activities. Therefore, they were people in a healthy condition who in the past and at present had overcome a neoplastic pathology. It is reasonable to assume in this case that the regulation of biological rhythms can even accentuate in the improvement. In the same way, it is possible to hypothesize that a self-regulation mechanism may also have occurred in arterial hypertension.

## 5. Conclusions

The study highlights, for the first time, that the rhythm of social relationships and habits such as sleep and nutrition have a role in well-being in old adults. The dysregulation of individual rhythms was found related to disorders such as depression, but also to biological parameters related to dysmetabolism. Further longitudinal studies with a sufficient number of individuals will be needed to confirm these data and clarify the causal link of the association between QoL and SBR.

## Author Contributions

MGC, GC, EP, GO: Conceptualization, Methodology, Software; MGC, GC, EP, RZ, OC, CIAG, MVM: Data curation, Writing, Original draft preparation; MGC, GC, EP, RZ, OC, GC, CIAG, MVM, LM, RD, MP, EC, MPP, GK, SL, FV, AL, MM, MRP, LA, AC, AS, GO, AC, SC, SM, DF, GMM, MM, GF: Visualization, Investigation; MGC, AP, LM, GO, PC, MM: Formal analysis; MGC: Supervision; MGC, GC, EP, MP, GM: Software, Validation; MGC, GC, EP, GK, GO: Writing, Reviewing and Editing; MCG : Funding acquisition; MCG, GC, EP: Project administration.

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## Conflicts of Interest

The authors declare no conflict of interest.

## References

1. Kirilov, I.; Atzeni, M.; Perra, A.; Moro, D.; Carta, M. G. Active Aging and Elderly's Quality of Life: Comparing the Impact on Literature of Projects Funded by the European Union and USA. *Clinical practice and epidemiology in mental health: CP & EMH* **2018**, 14, 1-5, doi:10.2174/1745017901814010001.
2. Cossu, G.; Loi, E.; Carta, M. G.; Bramanti, A. The Physical Body Experiences Questionnaire Simplified for Active Aging (PBE-QAG). *Clinical practice and epidemiology in mental health: CP & EMH* **2018**, 14, 70-77, doi:10.2174/1745017901814010070.
3. Oliveira de Carvalho, A.; Filho, A.; Murillo-Rodriguez, E.; Rocha, N. B.; Carta, M. G.; Machado, S. Physical Exercise For Parkinson's Disease: Clinical And Experimental Evidence. *Clinical practice and epidemiology in mental health: CP & EMH* **2018**, 14, 89-98, doi:10.2174/1745017901814010089.
4. Arendt, J. Melatonin and human rhythms. *Chronobiol Int* **2006**, 23(1-2), 21-37, doi:10.1080/0742052050046436.
5. Pack, W.; Hill, D.D.; Wong, K.Y. Melatonin modulates M4-type ganglion-cell photoreceptors. *Neuroscience* **2015**, 303, 178-188, doi:10.1016/j.neuroscience.2015.06.046.
6. Touitou, Y.; Sulon, J.; Bogdan, A.; Touitou, C.; Reinberg, A.; Beck, H.; Sodoyez, J.C.; Demey-Ponsart, E.; Van Cauwenberge, H. Adrenal circadian system in young and elderly human subjects: a comparative study. *J Endocrinol* **1982**, 93(2), 201-210, doi:10.1677/joe.0.0930201.
7. Van Cauter, E.; Leproult, R.; Kupfer, D.J. Effects of gender and age on the levels and circadian rhythmicity of plasma cortisol. *J Clin Endocrinol Metab* **1996**, 81(7), 2468-73, doi:10.1210/jcem.81.7.8675562.
8. Haupt, S.; Eckstein, M.L.; Wolf, A.; Zimmer, R.T.; Wachsmuth, N.B.; Moser, O. Eat, Train, Sleep-Retreat? Hormonal Interactions of Intermittent Fasting, Exercise and Circadian Rhythm. *Biomolecules* **2021**, 11(4), 516, doi:10.3390/biom11040516.
9. Kennaway, D.J.; Lushington, K.; Dawson, D.; Lack, L.; van den Heuvel, C.; Rogers, N. Urinary 6-sulfatoxymelatonin excretion and aging: new results and a critical review of the literature. *J Pineal Res* **1999**, 27(4), 210-220, doi:10.1111/j.1600-079x.1999.tb00617.x.
10. Zhao, Z.Y.; Xie, Y.; Fu, Y.R.; Bogdan, A.; Touitou, Y. Aging and the circadian rhythm of melatonin: a cross-sectional study of Chinese subjects 30-110 yr of age. *Chronobiol Int* **2002**, 19(6), 1171-1182, doi:10.1081/cbi-120015958.

11. Zeitzer, J.M.; Daniels, J.E.; Duffy, J.F.; Klerman, E.B.; Shanahan, T.L.; Dijk, D.J.; Czeisler, C.A. Do plasma melatonin concentrations decline with age? *Am J Med* **1999**, *107*(5), 432-436, doi:10.1016/s0002-9343(99)00266-1.
12. Kin, N.M.; Nair, N.P.; Schwartz, G.; Thavundayil, J.X.; Annable, L. Secretion of melatonin in healthy elderly subjects: a longitudinal study. *Ann N Y Acad Sci* **2004**, *1019*, 326-329, doi:10.1196/annals.1297.055.
13. Wu, Y.H.; Zhou, J.N.; Van Heerikhuize, J.; Jockers, R.; Swaab, D.F. Decreased MT1 melatonin receptor expression in the suprachiasmatic nucleus in aging and Alzheimer's disease. *Neurobiol Aging* **2007**, *28*(8), 1239-1247, doi:10.1016/j.neurobiolaging.2006.06.002.
14. Videnovic, A.; Noble, C.; Reid, K.J.; Peng, J.; Turek, F.W.; Marconi, A.; Rademaker, A.W.; Simuni, T.; Zadikoff, C.; Zee, P.C. Circadian melatonin rhythm and excessive daytime sleepiness in Parkinson disease. *JAMA Neurol* **2014**, *71*(4), 463-469, doi:10.1001/jamaneurol.2013.6239.
15. Wu, Y.H.; Feenstra, M.G.; Zhou, J.N.; Liu, R.Y.; Toranõ, J.S.; Van Kan, H.J.; Fischer, D.F.; Ravid, R.; Swaab, D.F. Molecular changes underlying reduced pineal melatonin levels in Alzheimer disease: alterations in preclinical and clinical stages. *J Clin Endocrinol Metab* **2003**, *88*(12), 5898-5906, doi:10.1210/jc.2003-030833.
16. Videnovic, A.; Lazar, A.S.; Barker, R.A.; Overeem, S. 'The clocks that time us'--circadian rhythms in neurodegenerative disorders. *Nat Rev Neurol* **2014**, *10*(12), 683-93, doi:10.1038/nrneurol.2014.206.
17. Videnovic, A.; Zee, P.C. Consequences of Circadian Disruption on Neurologic Health. *Sleep Med Clin* **2015**, *10*(4), doi:10.1016/j.jsmc.2015.08.004.
18. Sherman, B.; Wysham, C.; Pfohl, B. Age-related changes in the circadian rhythm of plasma cortisol in man. *J Clin Endocrinol Metab* **1985**, *61*(3), 439-443, doi:10.1210/jcem-61-3-439.
19. Breen, D.P.; Vuono, R.; Nawarathna, U.; Fisher, K.; Shneerson, J.M.; Reddy, A.B.; Barker, R.A. Sleep and circadian rhythm regulation in early Parkinson disease. *JAMA Neurol* **2014**, *71*(5), 589-595, doi:10.1001/jamaneurol.2014.65.
20. Hartmann, A.; Veldhuis, J.D.; Deuschle, M.; Standhardt, H.; Heuser, I. Twenty-four hour cortisol release profiles in patients with Alzheimer's and Parkinson's disease compared to normal controls: ultradian secretory pulsatility and diurnal variation. *Neurobiol Aging* **1997**, *18*(3), 285-289, doi:10.1016/s0197-4580(97)80309-0.

21. Hatfield, C.F.; Herbert, J.; van Someren, E.J.; Hodges, J.R.; Hastings, M.H. Disrupted daily activity/rest cycles in relation to daily cortisol rhythms of home-dwelling patients with early Alzheimer's dementia. *Brain* **2004**, *127*(Pt 5), 1061-1074, doi:10.1093/brain/awh129.

22. Huang, W.; Ramsey, K.M.; Marcheva, B.; Bass, J. Circadian rhythms, sleep, and metabolism. *J Clin Invest* **2011**, *121*(6), 2133-2141, doi:10.1172/JCI46043.

23. Sohail, S.; Yu, L.; Bennett, D.A.; Buchman A.S.; Lim, A.S. Irregular 24-hour activity rhythms and the metabolic syndrome in older adults. *Chronobiol Int* **2015**, *32*(6), 802-813, doi:10.3109/07420528.2015.1041597.

24. Scheiermann, C.; Kunisaki, Y.; Frenette, P.S. Circadian control of the immune system. *Nat Rev Immunol* **2013**, *13*(3), 190-198, doi:10.1038/nri3386.

25. Nguyen, K.D.; Fentress, S.J.; Qiu, Y.; Yun K.; Cox, J.S.; Chawla, A. Circadian gene Bmall regulates diurnal oscillations of Ly6C(hi) inflammatory monocytes. *Science* **2013**, *341*(6153), 1483-1488, doi:10.1126/science.1240636.

26. Wyatt, J.K.; Ritz-De Cecco, A.; Czeisler, C.A.; Dijk, D.J. Circadian temperature and melatonin rhythms, sleep, and neurobehavioral function in humans living on a 20-h day. *Am J Physiol* **1999**, *277*(4 pt 2), R1152-R1163, doi:10.1152/ajpregu.1999.277.4.r1152.

27. Carta, M.G.; Preti, A.; Akiskal, H.S. Coping with the New Era: Noise and Light Pollution, Hyperactivity and Steroid Hormones. Towards an Evolutionary View of Bipolar Disorders. *Clinical practice and epidemiology in mental health: CP & EMH* **2018**, *14*, 33-36, doi:10.2174/1745017901814010033.

28. Zhdanova, I.V.; Masuda, K.; Quasarano-Kourkoulis, C.; Rosene, D.L.; Killiany, R.J.; Wang, S. Aging of intrinsic circadian rhythms and sleep in a diurnal nonhuman primate, *Macaca mulatta*. *J Biol Rhythms* **2011**, *26*(2), 149-159. doi:10.1177/0748730410395849.

29. Van Cauter, E.; Leproult, R.; Plat, L. Age-related changes in slow wave sleep and REM sleep and relationship with growth hormone and cortisol levels in healthy men. *JAMA* **2000**, *284*(7), 861-868, doi:10.1001/jama.284.7.861.

30. Stone, K.L.; Blackwell, T.L.; Ancoli-Israel, S.; Cauley, J.A.; Redline, S.; Marshall, L.M.; Ensrud, K.E. Osteoporotic Fractures in Men Study Group. Sleep disturbances and risk of falls in older community-dwelling men: the outcomes of Sleep Disorders in Older Men (MrOS Sleep) Study. *J Am Geriatr Soc* **2014**, *62*(2), 299-305, doi:10.1111/jgs.12649.

31. Monk, T.H.; Buysse, D.J.; Carrier, J.; Kupfer, D.J. Inducing jet-lag in older people: directional asymmetry. *J Sleep Res* **2000**, *9*(2), 101-116, doi:10.1046/j.1365-2869.2000.00184.x.

32. Dijk, D.J.; Duffy, J.F.; Czeisler, C.A. Contribution of circadian physiology and sleep homeostasis to age-related changes in human sleep. *Chronobiol Int* **2000**, *17*(3), 285-311, doi:10.1081/cbi-100101049.

33. Davidson, A.J.; Sellix, M.T.; Daniel, J.; Yamazaki, S.; Menaker, M.; Block, G.D. Chronic jet-lag increases mortality in aged mice. *Curr Biol* **2006**, *16*(21), R914-R916, doi:10.1016/j.cub.2006.09.058.

34. Stafford, M.; Ben-Shlomo, Y.; Cooper, C.; Gale, C.; Gardner, M. P.; Geoffroy, M. C.; Power, C.; Kuh, D.; Cooper, R. Diurnal cortisol and mental well-being in middle and older age: evidence from four cohort studies. *BMJ open* **2017**, *7*(10), e016085, doi:10.1136/bmjopen-2017-016085.

35. Gay, C. Environnement social et rythmes sociaux [Social environment and social rhythms]. *Encephale* **2009**, *35* Suppl 2:S72-5, doi:10.1016/S0013-7006(09)75538-1.

36. Moro, M. F.; Colom, F.; Floris, F.; Pintus, E.; Pintus, M.; Contini, F.; Carta, M.G. Validity and Reliability of the Italian Version of the Functioning Assessment Short Test (FAST) in Bipolar Disorder. *Clinical practice and epidemiology in mental health: CP & EMH* **2012**, *8*, 67-73, doi:10.2174/1745017901208010067.

37. Carta, M.G.; Ouali, U.; Perra, A.; Ben Cheikh, Ahmed, A.; Boe, L.; Aissa, A.; Lorrai, S.; Cossu, G.; Aresti, A.; Preti, A.; Nacef, F. Living With Bipolar Disorder in the Time of Covid-19: Biorhythms During the Severe Lockdown in Cagliari, Italy, and the Moderate Lockdown in Tunis, Tunisia. *Front Psychiatry* **2021**, *24*(12), 634765, doi:10.3389/fpsyg.2021.634765.

38. Lieverse, R.; de Vries, R.; Hoogendoorn, A.W.; Smit, J.H.; Hoogendoorn, W.J. Social support and social rhythm regularity in elderly patients with major depressive disorder. *The American journal of geriatric psychiatry: official journal of the American Association for Geriatric Psychiatry* **2013**, *21*(11), 1144-1153, doi:10.1016/j.jagp.2013.01.052.

39. Carta, M. G.; Active Aging Study Group, Active Ageing and Health Identifier: NCT03858114. *Clinical Trial.Gov* **2020**, <https://clinicaltrials.gov/ct2/show/NCT03858114>.

40. Margraf, J.; Lavallee, K.; Zhang, X.; Schneider, S. Social Rhythm and Mental Health: A Cross-Cultural Comparison. *PloS one* **2016**, *11*(3), e0150312, doi:10.1371/journal.pone.0150312.

41. Monk, T.H.; Flaherty, J.F.; Frank, E.; Hoskinson, K.; Kupfer, D.J. The Social Rhythm Metric. An instrument to quantify the daily rhythms of life. *J Nerv Ment Dis* **1990**, *178*(2), 120-126. doi:10.1097/00005053-199002000-00007.

42. Carta, M.G.; Aguglia, E.; Caraci, F.; Dell'Osso, L.; Di Sciascio, G.; Drago, F.; Del Giudice, E.; Faravelli, C.; Hardoy, M.C.; Lecca, M.E.; Moro, M.F.; Calò, S.; Casacchia, M.; Angermeyer, M.; Balestrieri, M. Quality of life and urban/rural living: preliminary results of a community survey in Italy. *Clinical practice and epidemiology in mental health: CP & EMH* **2012**, *8*, 169-174, doi:10.2174/1745017901208010169.

43. Spitzer, R.L.; Kroenke, K.; Williams, J.B. Validation and utility of a self-report version of PRIME-MD: the PHQ primary care study. Primary Care Evaluation of Mental Disorders. Patient Health Questionnaire. *JAMA* **1999**, *282*(18), 1737-1744, doi:10.1001/jama.282.18.1737.

44. World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. *JAMA* **2013**, *310*(20): 2191-2194, doi:10.1001/jama.2013.281053.

45. Chuffa, L.G.; Seiva, F.R.; Fávaro, W.J.; Amorim, J.P.; Teixeira, G.R.; Mendes, L.O.; Fioruci-Fontanelli, B.A.; Pinheiro, P.F.; Martinez, M.; Martinez, F.E. Melatonin and ethanol intake exert opposite effects on circulating estradiol and progesterone and differentially regulate sex steroid receptors in the ovaries, oviducts, and uteri of adult rats. *Reproductive toxicology (Elmsford, N.Y.)* **2013**, *39*, 40-49, doi:10.1016/j.reprotox.2013.04.001.

46. Cho, Y.; Ryu, S.H.; Lee, B.R.; Kim, K.H.; Lee, E.; Choi, J. Effects of artificial light at night on human health: A literature review of observational and experimental studies applied to exposure assessment. *Chronobiology international* **2015**, *32*(9), 1294-1310, doi:10.3109/07420528.2015.1073.

47. Wu, S.; Ye, M.; Li, Z.; Bu, S.; Zhang, Y. Long-term supplementation of dehydroepiandrosterone improved depressive-like behaviors by increasing BDNF expression in the hippocampus in ovariectomized rats. *Helijon* **2020**, *6*(10), e05180, doi:10.1016/j.heliyon.2020.e05180.

48. Wyse, C.A.; Biello, S.M.; Gill, J.M. The bright-nights and dim-days of the urban photoperiod: implications for circadian rhythmicity, metabolism and obesity. *Annals of medicine* **2014**, *46*(5), 253-263, doi:10.3109/07853890.2014.913422.

49. Al-Rawi, N.; Madkour, M.; Jahrami, H.; Salahat, D.; Alhasan, F.; BaHammam, A.; Al-Islam Faris, M. Effect of diurnal intermittent fasting during Ramadan on ghrelin, leptin, melatonin, and

cortisol levels among overweight and obese subjects: A prospective observational study. *PloS one* **2020**, 15(8), e0237922, [doi:10.1371/journal.pone.0237922](https://doi.org/10.1371/journal.pone.0237922).

50. Oosterman, J.E.; Wopereis, S.; Kalsbeek, A. The Circadian Clock, Shift Work, and Tissue-Specific Insulin Resistance. *Endocrinology* **2020**, 161(12), bqaa180, [doi:10.1210/endocr/bqaa180](https://doi.org/10.1210/endocr/bqaa180).

51. Benedito-Silva, A.A.; Evans, S.; Viana Mendes, J.; Castro, J.; Gonçalves, B.; Ruiz, F.S.; Beijamini, F.; Evangelista, F.S.; Vallada, H.; Krieger, J. E.; von Schantz, M.; Pereira, A.C.; Pedrazzoli, M. Association between light exposure and metabolic syndrome in a rural Brazilian town. *PloS one* **2020**, 15(9), e0238772, [doi:10.1371/journal.pone.0238772](https://doi.org/10.1371/journal.pone.0238772).