International Journal of Medical and Pharmaceutical Research
Website: https://ijmpr.in/ | Print ISSN: 2958-3675 | Online ISSN: 2958-3683
NLM ID: 9918523075206676
Volume: 4 Issue:3 (May-June 2023); Page No: 958-964

Original Article

IJMPR

A Comparative Study of Heart Rate Variability in Shift Working Security Guards

Vikas Jain[1], Virendra Verma[1], Gaurav Bhatnagar[2], Dr. Aditya Naidu[*2]

[1] Professor, Department of Physiology, Gajra Raja Medical College, Gwalior, Madhya Pradesh
[2] Postgraduate student, Department of Physiology, Gajra Raja Medical College, Gwalior, Madhya Pradesh

ABSTRACT

Background: Shift working inclusive of night shift working can severely compromise the autonomic nervous system. Since there is limited literature available about cardiac autonomic activity in shift workers compared to regular (9 am- 5 pm) workers, the purpose of our study is to assess the impact of shift working on Heart Rate Variability (HRV), by comparing HRV measures of shift workers to regular workers.

Material and Methods: the study was conducted in Department of Physiology, Gajra Raja Medical College, Gwalior. The participants were security guards working in the same gated community with same working hours, but employed in day and night shifts. 30 cases comprised of 30 night shift guards and 30 controls were 30 day shift guards (total subjects being 60). 5 minute ECG samples were obtained for each respective group at shift beginning and shift end via computerized 12 lead ECG equipment and HRV analysis was done in time domain and frequency domain parameters. Comparisons were done done between cases and controls by independent T test within 95% CI.

Results: time domain parameters SDNN and RMSSD exhibited significantly diminished values in night shift workers. Frequency domain analysis showed sympathetic dominance (LF nu, LF/HF ratio) and parasympathetic suppression (HF nu) in night shift workers.

Conclusion: night shift working leads to a sympathetic dominant state in cardiac autonomic function, combined with diminished parasympathetic activity, which is detrimental to cardiovascular health.

Key Words: *Shift worker, Night Shift worker, Heart rate variability, Time domain, Frequency domain, Cardiac autonomic function*

***Corresponding Author**
Dr Aditya Naidu*
Postgraduate student, Department of Physiology, Gajra Raja Medical College, Gwalior, Madhya Pradesh

INTRODUCTION

We all have an internal clock in our brain that regulates human physiology and behavior, and was observed in most parameters studied, such as hormone secretion, sleep propensity and architecture, and subjective and electroencephalographic (EEG)-estimated alertness [1]. This is the same clock that tells us when it is time to go to sleep and also when to wake up. This clock is called Circadian Rhythm. The two things that help set this clock are daylight and night time darkness. Part of the brain responding to this light-dark cycle and thus the primary body clock is the Suprachiasmatic nuclei, cluster of about 10,000 neurons located on either side of the midline above the optic chiasma (approx. 3cms behind the eyes) [2]. Although in modern society artificial lighting makes it possible to have light for the whole 24-hour span, body functions (e.g., hormonal, metabolic, digestive, cardiovascular, mental) are still mainly influenced by the natural light/dark cycle, showing periodic oscillations that have, in general, peaks (acrophases) during the daytime and troughs (nadirs) at night [3]. Peak of sleepiness is from midnight until 7 am. Shift work comprises work schedules that extend beyond the typical ''nine-to-five'' workday, wherein schedules often comprise early work start, compressed work weeks with 12-hour shifts, and night work [1]. About 20% of the working population in the United States, Australia and Europe are engaged in this work pattern [4]. Working night shifts forces us to stay awake and work against our Circadian Rhythm. When the night shift ends and it is daylight, we try to sleep while we are alert. Cognitive function, hormonal regulation and autonomic homeostasis get affected severely. Cognitive function impairment due to shift work may be well assessed by measuring reaction times, while cardiac autonomic homeostasis is reliably assessed using Heart rate variability. Extended working hours and shift or night work are well established risk factors for workplace accidents and several negative health effects, including cardiovascular diseases [5].

Heart rate variability is the physiological phenomenon of the variation in time interval between consecutive heart beats (R-R interval) in milliseconds [6]. A normal, healthy heart does not tick evenly but instead there is constant variation between heartbeats. Heart rate variability gets affected by any disruption in autonomic homeostasis. Heart rate is regulated by sympathetic and parasympathetic branches of autonomic nervous system. Sympathetic branch increases heart rate and cardiac output and decreases HRV, which is needed during exercise and stress. Parasympathetic branch slows heart rate and increases HRV to restore homeostasis after stress passes [7]. If a person is experiencing stress for long duration, like night shift working, body gets stuck in sympathetically dominant fight state, with low HRV and high stress hormone levels and inflammatory cytokines, even when the person is resting. The fight-or-flight response is elicited by the production of mediators like norepinephrine (NE) and epinephrine (E) from the sympathetic nervous system (SNS) and the adrenal medulla [7]. This is very consuming on the body and can result in various mental and physical health problems. Furthermore it was observed that cardiac autonomic function is mostly influenced by Sleep-wakefulness cycle with very little influence by the internal clock [8], stark contrast to what is seen in other biological variables like body temperature, cortisol etc. Shift workers have higher risk of CVD morbidity and mortality (17%) than non-shift workers, with a 7.1% incremental risk for every five years of shift work exposure after the first five years [9]. Studies of HRV among workers with extended working hours have shown that extended hours of night work, in particular, may lead to decreased HRV [5]. Therefore this study was designed to study the effect of shift working on HRV and consequently cardiac autonomic function and cardiovascular health.

METHODOLOGY

This study was conducted in the post-graduate laboratory of the Department of Physiology, Gajra Raja Medical College, and J.A. group of Hospital, Gwalior (M.P.). Subjects were healthy males between ages of 25-50 years, working as security guards involved in shift work for a period of not less than a year. Security guards who had hypertension or any history of cardiac illness, chronic ailments which may affect sleep pattern or cognitive function, taking any regular medication which may affect sleep pattern or quality, indulging in smoking, alcohol consumption or substance abuse were excluded. Cases were 30 Healthy male subjects of 25 - 50 yrs age, working night shift between 8pm to 8am. Controls were 30 Age matched healthy male subjects working day shift between 8am to 8pm. Following approval from Institutional Research and Ethical Clearance committees, written informed consent was obtained from the subjects. A detailed history and complete clinical examination were done of all the subjects. Subject details including shift work experience, anthropometric measures & vital parameters were taken. ECG recording using computerized ECG machine by RMS (RMS VIESTA 301i) was taken at shift beginning and shift end (once morning and once evening) for each respective group. Recording was done in calm, serene environment with patient lying comfortably in supine position. Heart Rate Variability analysis was done using Kubios HRV, version 2.1 (Department of Applied Physics, University of Eastern Finland, Kuopio, Finland). It included time domain parameters: SDNN, RMSSD & PNN50. SDNN- Standard deviations of the averages of NN intervals in all 5 minutes segments of the entire recording; RMSSD- the square root of the mean of the sum of the squares of differences between adjacent NN intervals; PNN50- % of several instances in which two consecutive NN intervals differ by more than 50 msec. Frequency domain analysis was performed using the non-parametric method of Fast Fourier Transformation. The power frequency spectrum was subsequently quantified into standard frequency–domain measurements as low frequency (LF) component (0.04–0.15 Hz), high frequency (HF) component (0.15–0.4 Hz) in normalized units (nu) & LF-HF ratio.

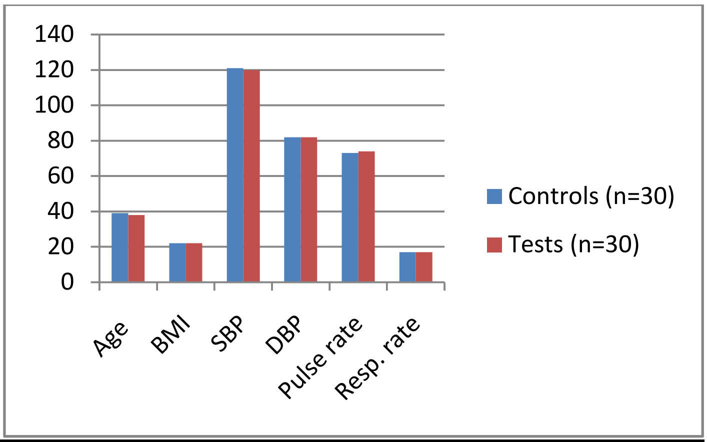
Statistical Analysis: All data were expressed as Mean ± SD. Differences between the study group and controls were examined using independent T test.

RESULTS

Table of Anthropometric Data

Parameter	Controls (n=30)	Tests (n=30)	P value	Significance
Age	39.03 ± 1.58	38.07 ± 1.67	0.67	NO
BMI	22.76 ± 0.34	22.99 ± 0.40	0.66	NO
SBP	121 ± 0.77	120.7 ± 0.78	0.81	NO
DBP	82.87 ± 0.81	82.93 ± 0.71	0.95	NO
Pulse rate	73.57 ± 1.26	74.27 ± 1.64	0.73	NO
Resp. rate	17.60 ± 0.30	17.80 ± 0.32	0.65	NO

The above table shows comparison between the controls i.e. Day shift guards & Tests i.e. Night shift guards regarding age, BMI, blood pressure, pulse and respiratory rate. The differences with respect to each are not significant.



Above is the graphical representation of comparison between controls and tests concerning anthropometric and vital data. Results imply both groups to be matched in terms of age, BMI & essential vitals (blood pressure, heart rate, respiratory rate)

Comparison between Shift Working experience

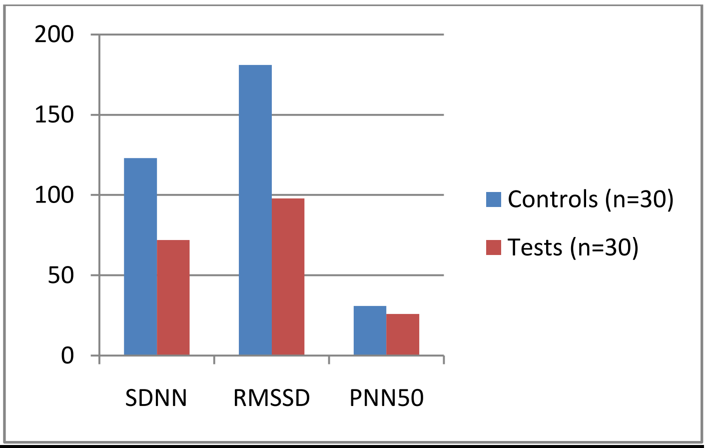
Shift work	Controls (n=30)	Tests (n=30)	P value	Significance
Experience (yrs)	8.8 ± 0.58	8.66 ± 0.66	0.88	NO

Both groups are matched in context of duration/experience of working in the capacity of security guards, and thus eliminates duration of working as a possible confounding factor

Table of Time Domain HRV indices

Parameter	Controls (n=30)	Tests (n=30)	P value	Significance
SDNN	123.3 ± 13.01	72.46 ± 6.16	<0.01	**HIGHLY SIGNIFICANT**
RMSSD	181.4 ± 20.34	98.6 ± 9.29	<0.01	**HIGHLY SIGNIFICANT**
PNN50	31.07 ± 3.19	26.24 ± 2.88	0.26	NO

The above table shows significant differences between Day shift guards and Night shift guards in context of time domain parameters SDNN & RMSSD, with Day shift guards reflecting higher values in both and thus having better HRV outcomes

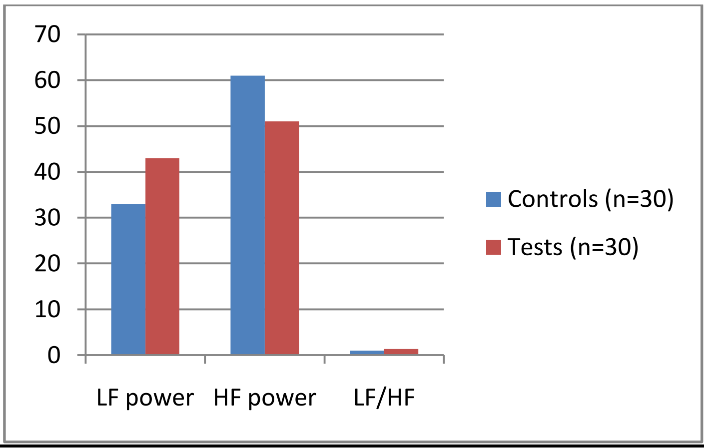


Graphical representation of differences in time domain HRV parameters between control group/day shift guards & test group/night shift guards, The significant differences with respect to SDNN & RMSSD can be clearly observed.

Table of frequency Domain HRV indices

Parameter	Controls (n=30)	Tests (n=30)	P value	Significance
LF power	33.62 ± 2.34	43.92 ± 3.10	0.01	**SIGNIFICANT**
HF power	61.76 ± 2.24	51.92 ± 3.03	0.01	**SIGNIFICANT**
LF/HF	0.99 ± 0.31	1.34 ± 0.22	0.36	NO

Above table depicts the differences between Day shift guards & Night shift guards in context of frequency domain HRV parameters, LF power & HF power. The results imply significantly higher sympathetic activity (LF power) in Night shift guards & conversely significantly lower sympathetic activity in Day shift guards. On the other hand, Night shift guards were found to exhibit significantly lower parasympathetic activity (HF power) in comparison to Day shift guards



Graphical representation of differences between controls/Day shift guards & tests/Night shift guards in context of frequency domain indices of HRV, Significant differences observed in LF power and HF power indices is clearly evident.

DISCUSSION

The intrigue of researching team into harmful effects of shift working and how to efficiently study it in scientifically sound manner was the bedrock of our study conceptualisation. At its inception, shortcomings of contemporary studies were earmarked and efforts were made to circumvent the said confounders. With the approval of institutional ethics committee, appropriate subjects fulfilling the inclusion criteria (and dispossessed of the exclusion criteria) were chosen and sampling was done after obtaining due informed consent. The control group were security guards working day shift with shift duration of 12 hours. Test group comprised of security guards working night shift of same duration in the same community. Only males were chosen so as to negate any gender-owing differences in HRV measures, since in females they are known to variate with different phases of the menstrual cycle [10, 11, 12, 13, 14, 15, 16 & 17]. Selecting guards from the same workplace with the same shift duration negated any work related bias from interfering with our measures. Both groups were sampled at shift beginning & at shift end and final measures were considered after averaging the two. In doing so, possibility of any difference in measures owing to subjective fatigue [18, 19, 20 & 21] was eliminated. Since HRV measures are also known to vary with time of the day [22, 23 & 24] i.e. diurnal variation, our method of morning & evening sampling for each respective group eliminated any interference in measures arising from the aforesaid diurnal variations.

Subjects from both group were found to be age & BMI matched, negating any differences in outcomes to be the result of an age difference [25, 26, 27, 28 & 29] or BMI difference [30, 31]. Statistical analysis yielded significant differences between test and control groups in HRV measures. Statistical analysis also ensured there were no significant differences in shift work duration between the test and control groups (shift working duration matched).

In this study we observed a highly significant difference (p=0.0008) in SDNN between day shift guards (123.3 ± 13.01 msec) vs. Night shift guards (72.46 ± 6.16 msec*)*. Similar findings were reported by Wehrens et al. [32], Neufeld et al. [33] and other researchers [34, 35] who had investigated HRV differences amongst shift workers. However, some studies of similar design, for e.g. those done by Amelsvoort et al. [36], lee et al. [37] and other researchers [38, 39, 40 & 41] show no significant difference in SDNN values amongst shift and non-shift workers. As SDNN is a well established indicator of cardiovascular health, our finding of significantly reduced values in night shift guards implies that shift workers suffer from poorer cardiovascular health.

The next parameter of time-domain indices of HRV we investigated is RMSSD, which is considered a reliable indicator of cardiovascular health. We found highly significant group difference in RMSSD (p=0.0005), with much lower values in test group/night shift guards (98.6 ± 9.29 msec*)* compared to control group/day shift guards (181.4 ± 20.34 msec*)*. Similar findings were reported by Shanmugavaradharajan et al. [39] and other researchers [32, 34]. Few other studies of similar design [38, 35 & 41] reported no signicant differences in RMSSD amongst shift workers.

The third and last parameter of time-domain HRV indices we investigated is PNN50. Known to reflect parasympathetic activity, higher PNN50 values reflect increased vagal activity over sympathetic activity in resting conditions. Not much value has been ascribed yet to PNN50 as a diagnostic/screening/prognostic tool in medical science. Although in our results PNN50 was lesser in the test group/night shift guards (26.24 ± 2.88%) compared to control group/day shift guards (31.07 ± 3.19%), the difference was not statistically significant (p=0.26). Therefore we cannot positively conclude that PNN50 measures would be adversely affected in shift workers until further scientific evidence backs up the assumption.

The major influencer of HRV is the Autonomic nervous system, with its Sympathetic & Parasympathetic branches. The PNS improves HRV while the SNS reduces HRV. Hence lower HRV reflects sympathetic over activity & dominance over PNS while the vice versa is true as well. This Qualitative Analysis of HRV is done through Frequency Domain measures. We compare power within the frequency spectral bands, namely LF (low frequency, 0.04-0.15 Hz) and HF (0.15-0.40 Hz). LF band is reflective of sympathetic activity while HF band reflects parasympathetic activity. So the measures of LF and HF power, expressed as ms^2/Hz or n.u. (normalized units) and the ratio of LF power to HF power provides valuable insight into Sympathovagal balance of the individual, and helps in better discerning HRV findings of the said individual. As for LF power, it was found to be significantly higher (p=0.01) in test group (43.92 ± 3.10 nu) compared to control group (33.62 ± 2.34 nu). This clearly demonstrates higher sympathetic activity in night shift workers compared to day workers. Similar findings have been reported by Tobaldini et al. [42] and other researchers [36, 32, 38 & 43]. However, some studies have yielded no such finding, like those of Adams et al. [44] and others [8, 37, 35, 45 & 41]. Study by Furlan et al. [46] upheld the opposite i.e. reduced sympathetic activity during night shift (lower LF). Nonetheless, the statistically significant difference in our study clearly demonstrates sympathetic prevalence in shift workers. Also noteworthy is the significantly (p=0.01) reduced HF power in test group/night shift guards (51.92 ± 3.03 nu) compared to controls/day shift guards (61.76 ± 2.24 nu). Similar findings have been reported by Adams et al. [44] and other researchers [36, 32, 42, 33, 34, 35, 45, 43, 47 & 48]. Few other studies [8, 46, 37, 38 & 41] report no significant difference in HF power/parasympathetic activity amongst shift workers. However, in our case we observed significant differences in both LF power (higher in night shift guards) and HF power (lower in night shift guards) to positively conclude a sympathetic dominant state with reduced parasympathetic activity in night shift workers compared to day workers.

CONCLUSION

Our results have shown cardiovascular compromise in night shift guards, evident through poorer HRV outcomes compared to day shift guards. The compromise was found to worsen with increasing years of engaging in night shift work. Further research into the impact of shift working must be carried out, not just into physiological aspects of health, but also into other aspects of well being. The impact of working out of sync with natural circadian rhythm on workers' psychological and social well being must also be looked into and adequate remedies must be implemented. The modern world demands round the clock goods & services making shift work unavoidable, but its deleterious effects may be lessened by various non-pharmacological & pharmacological measures.

REFERENCES

1. Boivin DB, Boudreau P. (2014). Impacts of shift work on sleep and circadian rhythms. Pathol Biol (Paris). 62(5):292-301. doi: 10.1016/j.patbio.2014.08.001. Epub 2014 Sep 20. PMID: 25246026.
2. Hastings M. (1998). The brain, circadian rhythms, and clock genes. BMJ. 26; 317(7174):1704-7. doi: 10.1136/bmj.317.7174.1704. PMID: 9857134; PMCID: PMC1114487.
3. Costa G. (2015). Sleep deprivation due to shift work. Handb Clin Neurol. 131:437-46. doi: 10.1016/B978-0-444-62627-1.00023-8. PMID: 26563802.
4. Torquati L, Mielke GI, Brown WJ, Burton NW, Kolbe-Alexander TL. (2019). Shift Work and Poor Mental Health: A Meta-Analysis of Longitudinal Studies. Am J Public Health. 109(11):e13-e20. doi: 10.2105/AJPH.2019.305278. Epub 2019 Sep 19. PMID: 31536404; PMCID: PMC6775929
5. Goffeng EM, Nordby KC, Tarvainen MP, Järvelin-Pasanen S, Wagstaff A, Goffeng LO, Bugge M, Skare Ø, Sigstad Lie JA. (2018). Fluctuations in heart rate variability of health care workers during four consecutive extended work shifts and recovery during rest and sleep. Ind Health. 56(2):122-131. doi: 10.2486/indhealth.2017-0100. Epub 2017 Oct 21. PMID: 29057762; PMCID: PMC5889930
6. Shaffer F, Ginsberg JP. (2017). An Overview of Heart Rate Variability Metrics and Norms. Front Public Health. 5:258. doi: 10.3389/fpubh.2017.00258. PMID: 29034226; PMCID: PMC5624990.
7. Cannizzaro E, Cirrincione L, Mazzucco W, Scorciapino A, Catalano C, Ramaci T, Ledda C, Plescia F. (2020). Night-Time Shift Work and Related Stress Responses: A Study on Security Guards. Int J Environ Res Public Health. 17(2):562. doi: 10.3390/ijerph17020562. PMID: 31952337; PMCID: PMC7013811.
8. Ito H, Nozaki M, Maruyama T, Kaji Y, Tsuda Y. (2001). Shift work modifies the circadian patterns of heart rate variability in nurses. Int J Cardiol. 79(2-3):231-6. doi: 10.1016/s0167-5273(01)00439-9. PMID: 11461746.
9. Torquati L, Mielke GI, Brown WJ, Kolbe-Alexander T. (2018). Shift work and the risk of cardiovascular disease. A systematic review and meta-analysis including dose-response relationship. Scand J Work Environ Health. 44(3):229-238. doi: 10.5271/sjweh.3700. Epub 2017 Dec 16. PMID: 29247501.

10. Hulsegge, G., Gupta, N., Proper, K. I., van Lobenstein, N., IJzelenberg, W., Hallman, D. M., Holtermann, A., & van der Beek, A. J. (2018). Shift work is associated with reduced heart rate variability among men but not women. International Journal of Cardiology, 258, 109-114. https://doi.org/10.1016/j.ijcard.2018.01.089
11. Kayacan Y, Makaracı Y, Ozgocer T, Ucar C, Yıldız S. (2021). Cortisol Awakening Response and Heart Rate Variability in the Menstrual Cycle of Sportswomen. Res Q Exerc Sport. 92(4):760-769. doi: 10.1080/02701367.2020.1774486. Epub 2020 Aug 27. PMID: 32853053.
12. Simon SG, Sloan RP, Thayer JF, Jamner LD. (2021). Taking context to heart: Momentary emotions, menstrual cycle phase, and cardiac autonomic regulation. Psychophysiology. 58(4):e13765. doi: 10.1111/psyp.13765. Epub 2021 Jan 16. PMID: 33453074.
13. Sims ST, Ware L, Capodilupo ER. (2021). Patterns of endogenous and exogenous ovarian hormone modulation on recovery metrics across the menstrual cycle. BMJ Open Sport Exerc Med. 7(3):e001047. doi: 10.1136/bmjsem-2021-001047. PMID: 34367655; PMCID: PMC8291316.
14. Brar TK, Singh KD, Kumar A. (2015). Effect of Different Phases of Menstrual Cycle on Heart Rate Variability (HRV). J Clin Diagn Res. 9(10):CC01-4. doi: 10.7860/JCDR/2015/13795.6592. Epub 2015 Oct 1. PMID: 26557512; PMCID: PMC4625231.
15. Armbruster D, Grage T, Kirschbaum C, Strobel A. (2018). Processing emotions: Effects of menstrual cycle phase and premenstrual symptoms on the startle reflex, facial EMG and heart rate. Behav Brain Res. 351:178-187. doi: 10.1016/j.bbr.2018.05.030. Epub 2018 Jun 6. PMID: 29885381.
16. Schmalenberger KM, Eisenlohr-Moul TA, Jarczok MN, Eckstein M, Schneider E, Brenner IG, Duffy K, Schweizer S, Kiesner J, Thayer JF, Ditzen B. (2020). Menstrual Cycle Changes in Vagally-Mediated Heart Rate Variability are associated with Progesterone: Evidence from Two Within-Person Studies. J Clin Med. 9(3):617. doi: 10.3390/jcm9030617. PMID: 32106458; PMCID: PMC7141121.
17. Yazar Ş, Yazıcı M. (2016). Impact of Menstrual Cycle on Cardiac Autonomic Function Assessed by Heart Rate Variability and Heart Rate Recovery. Med Princ Pract. 25(4):374-7. doi: 10.1159/000444322. Epub 2016 Feb 1. PMID: 26828607; PMCID: PMC5588411.
18. Hu S, Lin H, Zhang Q, Wang S, Zeng Q, He S. (2022). Short-Term HRV Detection and Human Fatigue State Analysis Based on Optical Fiber Sensing Technology. Sensors (Basel). 22(18):6940. doi: 10.3390/s22186940. PMID: 36146289; PMCID: PMC9505708.
19. Burlacu A, Brinza C, Brezulianu A, Covic A. (2021). Accurate and early detection of sleepiness, fatigue and stress levels in drivers through Heart Rate Variability parameters: a systematic review. Rev Cardiovasc Med. 22(3):845-852. doi: 10.31083/j.rcm2203090. PMID: 34565082.
20. Chen S, Xu K, Zheng X, Li J, Fan B, Yao X, Li Z. (2020). Linear and nonlinear analyses of normal and fatigue heart rate variability signals for miners in high-altitude and cold areas. Comput Methods Programs Biomed. 196:105667. doi: 10.1016/j.cmpb.2020.105667. Epub 2020 Jul 16. PMID: 32712570.
21. Schmitt L, Regnard J, Desmarets M, Mauny F, Mourot L, Fouillot JP, Coulmy N, Millet G. (2013) Fatigue shifts and scatters heart rate variability in elite endurance athletes. PLoS One. 8(8):e71588. doi: 10.1371/journal.pone.0071588. PMID: 23951198; PMCID: PMC3741143.
22. Singh I, Rabkin SW. (2021). Circadian variation of the QT interval and heart rate variability and their interrelationship. J Electrocardiol. 65:18-27. doi: 10.1016/j.jelectrocard.2021.01.004. Epub 2021 Jan 10. PMID: 33465743.
23. Hashimoto K, Kasamaki Y, Soma M, Takase B. (2019). Diurnal variation of frequency domain T-wave alternans on 24-hour ambulatory electrocardiogram in subjects without heart disease: Significant effect of autonomic nervous activity of the heart. Ann Noninvasive Electrocardiol. 24(3):e12620. doi: 10.1111/anec.12620. Epub 2018 Nov 7. PMID: 30403436; PMCID: PMC6931700.
24. Armstrong RG, Kenny GP, Green G, Seely AJ. (2011). Diurnal variation in heart rate variability before and after maximal exercise testing. Chronobiol Int. 28(4):344-51. doi: 10.3109/07420528.2011.559674. PMID: 21539426.
25. Pal R, Singh SN, Chatterjee A, Saha M. (2014). Age-related changes in cardiovascular system, autonomic functions, and levels of BDNF of healthy active males: role of yogic practice. Age (Dordr). 36(4):9683. doi: 10.1007/s11357-014-9683-7. Epub 2014 Jul 11. PMID: 25012275; PMCID: PMC4150910.
26. Geovanini GR, Vasques ER, de Oliveira Alvim R, Mill JG, Andreão RV, Vasques BK, Pereira AC, Krieger JE. (2020). Age and Sex Differences in Heart Rate Variability and Vagal Specific Patterns - Baependi Heart Study. Glob Heart. 15(1):71. doi: 10.5334/gh.873. PMID: 33150136; PMCID: PMC7583712.
27. Abhishekh HA, Nisarga P, Kisan R, Meghana A, Chandran S, Trichur Raju, Sathyaprabha TN. (2013). Influence of age and gender on autonomic regulation of heart. J Clin Monit Comput. 27(3):259-64. doi: 10.1007/s10877-012-9424-3. Epub 2013 Jan 8. PMID: 23297094.
28. Kumral D, Schaare HL, Beyer F, Reinelt J, Uhlig M, Liem F, Lampe L, Babayan A, Reiter A, Erbey M, Roebbig J, Loeffler M, Schroeter ML, Husser D, Witte AV, Villringer A, Gaebler M. (2019). The age-dependent relationship between resting heart rate variability and functional brain connectivity. Neuroimage. 185:521-533. doi: 10.1016/j.neuroimage.2018.10.027. Epub 2018 Oct 10. PMID: 30312808.
29. Grässler B, Dordevic M, Darius S, Vogelmann L, Herold F, Langhans C, Halfpaap N, Böckelmann I, Müller NG, Hökelmann A. (2021). Age-Related Differences in Cardiac Autonomic Control at Resting State and in Response to Mental Stress. Diagnostics (Basel). 11(12):2218. doi: 10.3390/diagnostics11122218. PMID: 34943455; PMCID: PMC8700263.

30. Grandemange M, Costet N, Doyen M, Monfort C, Michineau L, Saade MB, Multigner L, Cordier S, Pladys P, Rouget F. (2019). Blood Pressure, Heart Rate Variability, and Adiposity in Caribbean Pre-pubertal Children. Front Pediatr. 7:269. doi: 10.3389/fped.2019.00269. PMID: 31355164; PMCID: PMC6635797.
31. Altini M, Plews D. (2021). What Is behind Changes in Resting Heart Rate and Heart Rate Variability? A Large-Scale Analysis of Longitudinal Measurements Acquired in Free-Living. Sensors (Basel). 21(23):7932. doi: 10.3390/s21237932. PMID: 34883936; PMCID: PMC8659706.
32. Wehrens SM, Hampton SM, Skene DJ. (2012). Heart rate variability and endothelial function after sleep deprivation and recovery sleep among male shift and non-shift workers. Scand J Work Environ Health. 38(2):171-81. doi: 10.5271/sjweh.3197. Epub 2011 Sep 27. PMID: 21953310.
33. Neufeld EV, Carney JJ, Dolezal BA, Boland DM, Cooper CB. (2017). Exploratory Study of Heart Rate Variability and Sleep among Emergency Medical Services Shift Workers. Prehosp Emerg Care. 21(1):18-23. doi: 10.1080/10903127.2016.1194928. Epub 2016 Aug 3. PMID: 27487176.
34. Wang ML, Lin PL, Huang CH, Huang HH. (2018). Decreased Parasympathetic Activity of Heart Rate Variability During Anticipation of Night Duty in Anesthesiology Residents. Anesth Analg. 126(3):1013-1018. doi: 10.1213/ANE.0000000000002439. PMID: 29200073.
35. Muzeyyen Arslan, Menizibeya O Welcome, Senol Dane, (2019). The Effect of Sleep Deprivation on Heart Rate Variability in Shift Nurses, *J Res Med Dent Sci*. 7(5):45-52.
36. Van Amelsvoort LG, Schouten EG, Maan AC, Swenne CA, Kok FJ. (2001). Changes in frequency of premature complexes and heart rate variability related to shift work. Occup Environ Med. 58(10):678-81. doi: 10.1136/oem.58.10.678. PMID: 11555690; PMCID: PMC1740055.
37. Lee S, Kim H, Kim DH, Yum M, Son M. (2015). Heart rate variability in male shift workers in automobile manufacturing factories in South Korea. Int Arch Occup Environ Health. 88(7):895-902. doi: 10.1007/s00420-014-1016-8. Epub 2015 Jan 14. Erratum in: Int Arch Occup Environ Health. 2015 Oct;88(7):903. PMID: 25585818.
38. Hsu HC, Lee HF, Lin MH. (2021). Exploring the Association between Sleep Quality and Heart Rate Variability among Female Nurses. Int J Environ Res Public Health. 18(11):5551. doi: 10.3390/ijerph18115551. PMID: 34067371; PMCID: PMC8196961.
39. Shanmugavaradharajan, V., Yogisparan, P., & Vasu, D. (2022). Cardiac Autonomic Changes in Shift Workers as Assessed by Time-Domain Measures of Short-Term Heart Rate Variability. Egyptian Academic Journal of Biological Sciences. C, Physiology and Molecular Biology, 14(1), 257-264. doi: 10.21608/eajbsc.2022.228237
40. Lecca LI, Setzu D, Del Rio A, et al. (2019). Indexes of cardiac autonomic profile detected with short term Holter ECG in health care shift workers: a cross sectional study. La Medicina del Lavoro. 110(6):437-445. DOI: 10.23749/mdl.v110i6.8048. PMID: 31846448; PMCID: PMC7809936.
41. Torrance, T. (2018). Sleep, Shiftwork Adaptation, Autonomic Dysfunction, And Metabolic Syndrome. (Doctoral dissertation). Retrieved from https://scholarcommons.sc.edu/etd/4852
42. Tobaldini E, Cogliati C, Fiorelli EM, Nunziata V, Wu MA, Prado M, Bevilacqua M, Trabattoni D, Porta A, Montano N. (2013). One night on-call: sleep deprivation affects cardiac autonomic control and inflammation in physicians. Eur J Intern Med. 24(7):664-70. doi: 10.1016/j.ejim.2013.03.011. Epub 2013 Apr 17. PMID: 23601527.
43. Sunkari Davana. (2019). A Comparative Study of Sleep Quality and Heart Rate Variability Index in Shifts and Non-Shift Working Population of Bengaluru. International Journal of Physiology, 7(4), 54–57. https://doi.org/10.37506/ijop.v7i4.57
44. Adams SL, Roxe DM, Weiss J, Zhang F, Rosenthal JE. (1998). Ambulatory blood pressure and Holter monitoring of emergency physicians before, during, and after a night shift. Acad Emerg Med. 5(9):871-7. doi: 10.1111/j.1553-2712.1998.tb02816.x. PMID: 9754499.
45. Varga, J., Kardos, K., Nagy, I., & Szirtes, L. (2022). Study of the physiological effects of shift work using the HRV analysis method. Medical Research Archives, 10(4). doi:10.18103/mra.v10i4.2764
46. Furlan R, Barbic F, Piazza S, Tinelli M, Seghizzi P, Malliani A. (2000). Modifications of cardiac autonomic profile associated with a shift schedule of work. Circulation. 102(16):1912-6. doi: 10.1161/01.cir.102.16.1912. PMID: 11034938.
47. Jensen MA, Hansen ÅM, Nabe-Nielsen K, Garde AH, Kristiansen J. (2022). Heart rate variability during sleep after two, four and seven consecutive night shifts and recovery days: A cross-over intervention study. International Archives of Occupational and Environmental Health. 95(7):1443-1451. doi: 10.1007/s00420-022-01873-5
48. Lu G, Xia J, Li Z, and Lei T. (2021). Differences between Night and Day Porters in Heart Rate Variability as A Measure of Cardiovascular Health. Am J Biomed Sci & Res. 14(5). AJBSR.MS.ID.002036. DOI: 10.34297/AJBSR.2021.14.002036.