Literature Review: Heart Rate Variability as a Biomonitoring of Occupational Stress

Kajian Pustaka: Variabilitas Denyut Jantung sebagai Biomonitoring Stress Kerja

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ABSTRACT

Introduction: Occupational stress is a modern epidemic. In terms of stress assessment, tools such as questionnaires are believed to be more subjective, especially in the assessment of stress in the workplace, while of course an objective assessment of stress also needs to be carried out. Objective examination for occupationalsstress will be very useful in the occupationalhhealth settings, which can early detect stress at work and prevent the long term effects. Therefore, this literature review aims to investigate the role of HRV in determining occupational stress. **Methods:** The searching methods used were PubMed and Google Scholar to find related journals about occupational stress and HRV, published in English. The articlessthatmmet the inclusion criteria were analysed basedoonothesstudy design, study population, occupationalsstressaand HRV assessment based on the Centre of Evidence-based Medicine, the University of Oxford for therapy study. Moreover, sample size varied from 8 to 1788. **Results:** It was found that there are three studies that fit the criteria, which are one systematic review study, one longitudinal study, and one cross-sectional study. The main finding from those articles was that occupational or job stress is found to be associated with lowered HRV value. **Conclusion:** HRV can be recommended for practicing occupational physicians and company doctors to identify the core areas of work-related stress.

Keywords: biomonitoring, heart rate variability, coccupational stress

ABSTRAK

Pendahuluan: *Stress kerja merupakan epidemi modern. Dalam hal penilaian stres kerja, banyak digunakan analisis psikometri pada stressor tempat kerja tanpa pengukuran fisiologis. Pemeriksaan objektif dari stres kerja akan berguna dalam layanan kesehatan kerja sehubungan dengan pencegahan dini efek stres jangka panjang yang merugikan. Tujuan dari tinjauan literatur ini adalah untuk mempelajari penelitian-penelitan sebelumnya mengenai hubungan antara stres kerja dan HRV, untuk mengetahui peran HRV dalam menentukan stres kerja.* ***Metode:*** *PubMed dan Google Scholar adalah mesin pencari yang digunakan untuk menemukan jurnal terkait stres kerja dan HRV yang diterbitkan dalam bahasa Inggris. Artikel yang terpilih dianalis menurut rancangan penelitian, populasi studi, penilaian stres kerja dan HRV berdasarkan Pusat Kedokteran berbasis Bukti Universitas Oxford untuk studi terapi. Besar sampel bervariasi mulai dari 8 hingga 1788.* ***Hasil:*** *Kami mendapatkan tiga artikel yang memenuhi kriteria. Temuan utama dari semua artikel tersebut adalah bahwa stres kerja yang tinggi terkait dengan penurunan HRV.* ***Simpulan:*** *Penilaian HRV dapat direkomendasikan untuk praktek dokter okupasi dan dokter perusahaan untuk menentukan sumber permasalahan dari stress kerja.*

Kata kunci: *biomonitoring, kerja, stress, variabilitas denyut jantung*

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INTRODUCTION

Occupational or job stress is a chronic condition recognized as a risk for a variety of behavioural and psychological disorders/.Thus, epidemiology understanding, alternative preventions, and interventions are highly needed (Quick and Henderson, 2016).

 doi:10.20473/ijosh.v10i2.2021.273-279
Received February 07, 2021, received in revised form April 20, 2021, Accepted May 28, 2021, Published: April 2021

Long-term work stress has been associated with various health problems such as cardiovascular diseases, musculoskeletal disorders, inflammation process, infection disease, obesity, diabetes, and sleep disorders. Meta-analysis study by Steptoe et al. has reported that high job strain elevated the risk of coronary artery disease by 34% (Steptoe and Kivimäki, 2013).

In terms of stress assessment, tools such as questionnaires are believed to be more subjective, especially in the assessment of stress in the workplace, although of course an objective assessment of stress also needs to be carried out. Therefore, Panari et al. recommend to combine methods of subjective and objective measures to assess stress, which will in turn give the researchers or doctors a comprehensive picture of the patient's condition (Panari *et al*., 2012)

HRV is one of the promising biological markers. More and more commercial devices nowadays provide an automatic measurement of heart rate variability, making it easier for researchers and doctors to diagnose or determine patients' condition or research subjects (Speer *et al.*, 2020).

Many studies have focused on Heart Rate Variability (HRV) in healthy participants. However, less is known about the association between occupational stress or stress at work and HRV values. Therefore, this literature review aims to find out the role of HRV in determining occupational stress regarding whether or not it can help the occupational health doctors to identify work-related stress.

METHODS

The searching method used Pubmed and Google Scholar to find related journals about Occupational Stress and Heart Rate Variability. The searching method was performed on December 23rd 2020. The words to find were "Occupational Stress", "Work Stress", "Job Stress", "Heart Rate Variability", and "HRV".

The search strategy is shown in a flowchart (Figure 1). The author scanned every ten articles from Pubmed (by titles and abstracts) to exclude unrelated articles on the first phase of the selection. Duplicated articles from Google Scholar were then removed. After the selection, the critical appraisal was done using several aspects based on the Centre of Evidence-based Medicine, the University of Oxford for therapy study.

The sample size in these three studies varied between 8, 85 and 1788. Moreover, the mean age ranged from 31 to 41 years. A total of 10 articles were analysed in the systematic review studies; nine studies were cross-sectional studies, while one was carried out with an observational study design

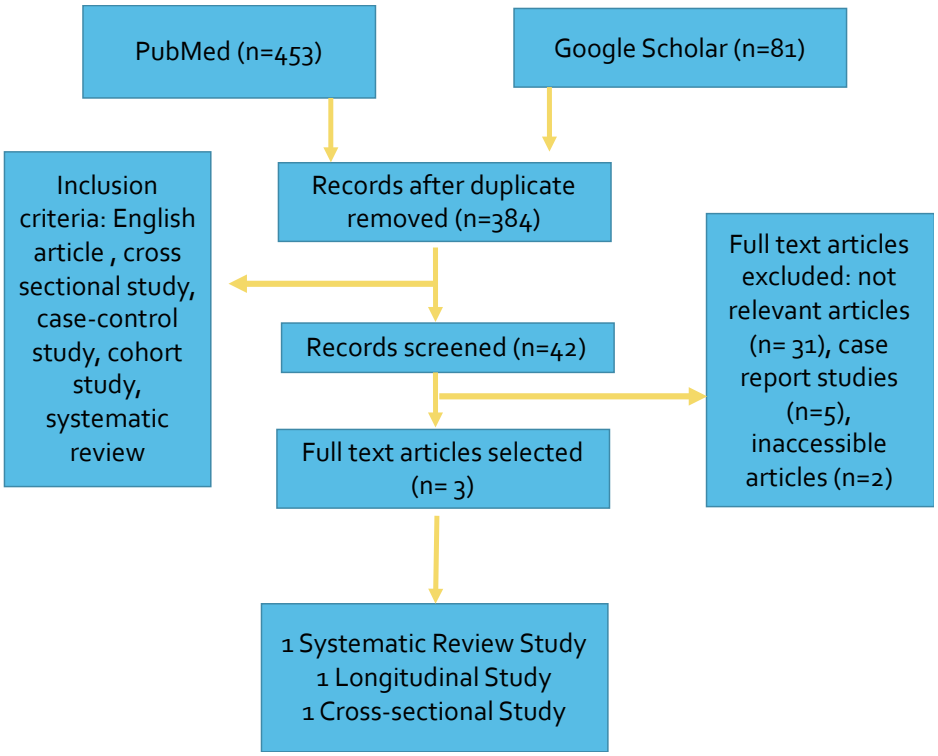

Figure 1. Searching Strategy Flowchart

with one year follow up. In the systematic review studies, the subjects were healthcare workers, factory workers, media workers, workers in consumer goods production, workers in aeroplane manufacturing, and white-collar workers. Meanwhile, eight surgical residents and specialists participated in the longitudinal study, and 85 workers from a company participated in a cross-sectional study.

Table 1. Critical Appraisal of the Articles

Critical Appraisal of the Systematic Review by Sussanna Jarvelin-Pasanen, Sanna Sinikallio and Tarvainen (2018)	
	Validity
Level of Evidence	2a
Representative Populations Group	Yes, the studies examined representative populations group, including workers from varied industries such as health care workers, factory workers, and white-collar workers
Reference Standard Used	Yes, almost all studies reported used the Task Force Guidelines
Independent Comparison and Blinding	The authors independently reviewed the title, abstract, full text of the journals and conducted discussions if there were disagreement
	Importance
Measurement of Outcome	Measurements of outcome varied. The length of the recording of HRV varied from short term (5-10 minutes) to long term (48 hours)
	Applicability
Test methods are described in detail and easy to be replicated	The measurements and analysis of HRV used by the studies are summarized in the tables.
Critical Appraisal of Longitudinal Study by Langelotz et al. (2008)	
	Validity
Level of Evidence	2b
Representative Populations Group	Eight surgeons with a 24-hour surgical shift took part in this study
Reference Standard Used	The researchers measured HRV using guidelines from the Task Force
Independent Comparison and Blinding	There was no independent comparison and blinding in this study
	Importance
Measurement of Outcome	The authors used Visual analogue scale scores to assess occupational stress. Several time domain parameters were used to measure HRV
	Applicability
Test methods are described in detail and easy replicated	Yes, the HRV measurement methods are described thoroughly. Researchers used a portable automatic device to assess HRV at specific times and specific conditions

Advanced Table 1. Critical Appraisal of the Articles

Critical Appraisal of Longitudinal Study by Low and McCraty (2018)	
	Validity
Level of Evidence	4
Representative Populations Group	Workers from large companies who had regular working hours of 40 hours a week, but workers who consumed drugs that could affect heart rate in the 2 hours before the HRV examination were not included in this study
Reference Standard Used	In this study, HRV was calculated using time domain parameters according to the recommendation of the Task Force
Independent Comparison and Blinding	There was no independent comparison and blinding in this study since the survey data were self-reported, and the results depended on the effort and honesty of each participant
	Importance
Measurement of Outcome	A significant negative correlation was found between stress and HRV values
	Applicability
Test methods are described in detail and easy replicated	Yes, the test methods are described in details and easy to be replicated. The subjects filled up the online questionnaires, and then the researcher performed an HRV assessment of the subjects using the emWave Pro Plus

RESULTS

From the online search results, it was found that there were three studies that fit the inclusion and exclusion criteria, namely one systematic review study by Järvelin-Pasanen, Sinikallio, and Tarvainen (2018), one longitudinal study and one cross- by Langelotz *et al.* (2008), sectional study by McCraty, 2018). After a critical appraisal, it was found that those articles were valid (Table 1).

The levels of evidence are important components of evidence-based medicine. Therefore, the author assessed the evidence level of each selected articles based on the Centre for Evidence-Based Medicine (Burns, Rohrich and Chung, 2011).

Table 2. Summary of Main Results of the Studies Regarding the Relationship between Occupational Stress and HRV Values

Authors	Main Results
(Järvelin-Pasanen, Sinikallio, and Tarvainen, 2018)	Lowered HRV was found to be associated with occupational stress
(Langelotz et al., 2008)	Longitudinal study After a 24 hours shift, HRV parameters increased significantly, suggesting increased levels of relaxation
(Low and McCraty, 2018)	Cross-sectional study A negative correlation was found between stress and HRV measurement

The first selected article was from Järvelin-Pasanen, Sinikallio, and Tarvainen (2018), included in level 2a research category with homogeneity of cohort studies. The second selected article was from Langelotz *et al.* (2008), included in level 2b research category which is an individual cohort study, and the last selected article was from Low and McCraty (2018), included in level 4 research category which is a cross-sectional study.

In the first article by Järvelin-Pasanen, Sinikallio, and Tarvainen (2018), the most frequently used tools in determining occupational stress were the 'Effort-Reward Imbalance (ERI) questionnaire and the 'Job Content Questionnaire (JCQ). Meanwhile, the longitudinal study by Langelotz *et al.* (2008) used Visual Analog Scale to assess stress levels, and the cross-sectional study by Low and McCraty (2018) used Perceived Stress Scale (PSS) as an instrument to assess the level of stress.

A Holter electrocardiogram (ECG) device was used for recording HRV in seven out of ten studies of systematic review, and the recording length varied from short resting periods (5-10 minutes), 2-12 hours during work period, to one to three full days (24-32 hours) (Järvelin-Pasanen, Sinikallio, and Tarvainen, 2018).

Meanwhile, a longitudinal study by Langelotz *et al.* (2008) monitored HRV using the Polar S810 peripheral pulse rate meter device during a resting period at the beginning of the 24-hour shift, after 12 hours, and at the end of the shift. All participants repeated measurements through out ten 24-hour shifts.

Low and McCraty (2018), on the other hand, used the emWave Pro Plus to monitor the HRV, which is a computer software that collects pulse data. The subject's heart rate information was obtained by attaching a pulse sensor to the subject's fingertips or earlobe, and then the software translated the information into a graphic, which allowed the researcher or author to watch in real time how thoughts and emotions were affecting the subject's heart rhythms. The average duration for each HRV monitor session was 7 minutes in the resting period.

Almost all studies reviewed explicitly reported to have applied the recommendations of the task force by Malik *et al.* (1996) in measuring HRV values. Järvelin-Pasanen, Sinikallio, and Tarvainen (2018) reported thathheighteneddjob stress was found to be associated with lowered HRV values, specificallywwith reduced parasympatheticsactivation.

Meanwhile, based on the results of study conducted by Langelotz *et al.*. (2008), SDNN, RMSSD, and pNN50, which were parameters of the time domain increased significantlyoover224 hours ($p=.003$, $p<.001$, and $p<.001$, respectively), suggesting the increased levelsoofrrelaxation.

Furthermore, Low and McCraty (2018) reported that three negative correlations were found between HRV values and subjective stress: (1) perceived stress and 5-minute mean of interbeat intervals (IBI), $r = -0.217$, $p<0.05$; (2) perceived stress and 5-min SDNN, $r = -0.255$, $p< 0.05$, and (3) perceived stress and Ln 5-min RMSSD, $r = -0.282$, $p< 0.01$. A summary of these three studies' main results regarding the relationshipbetween job stress and HRV values can be seen in the Table 2.

DISCUSSION

HRV is sensitive to changes in the sympathetic nervous system and parasympathetic nervous system (changes in the automatic nervous system) associated with stress (Kim *et al.*, 2018). Based on three journal reviews that have been previously analyzed, the current neurobiological evidence suggests that HRV value is impacted by stress, and lowered HRV is associated with occupational or job stress, specifically with reduced parasympathetic activation. Moreover, there is a decrease in HF power and RMSSD, and an increase in LF/HF ratio. Moreover, the range of subject sizes that vary widely among the studies reviewed could certainly influence the results of this literature review.

It is also noted that if there is any disproportional relationship between workers (resources) and work demand, it will lead to occupational stress. Thus, this literature review shows some diversity in assessing occupational or job stress. As summarized by O'Connor (2016), there are different approaches in job stress assessment. The first approach is the stimulus-based approach, which is the assessment of job stressors. The ERI and the JCQ are the assessment methods that use this approach. The JCQ questionnaire is the most widely used tool to assess occupational stress in the studies reviewed, followed by an ERI questionnaire, Visual Analog Scale Score, and the Perceived Stress Scale. The second approach is the response-based approach, which is the worker's strain assessment. The general reaction to the cause of stress is the approach used by this method. In short, the type of questionnaire used in the studies can influence the determination or diagnosis of occupational or job stress. The research would be more ideal if all subjects use the same tools/questionnaire in assessing occupational stress, so that is why objective assessment such as heart rate variability is important in determining occupational stress.

Almost all the reviewed studies used the guidelines for the measurement, physiological interpretation, and clinical use of HRV recommended by the Task Force; only two out of ten studies from systematic review studies by Järvelin-Pasanen, Sinikallio, and Tarvainen (2018) which were mentioned not to use the Task Force recommendations). Besides, the most frequently method measurement used was time domain methods with wide range of HRV parameters (HR, SDNN, RMSSD). According to *Malik et al.* (1996), some parameters are recommended for time-domain HRV assessment, including the estimate of overall HRV (HRV triangular index, SDNN), the estimate of short-term HRV (RMSSD), and the estimate of long-term HRV (SDANN).

Following the time domain methods, the second most widely used method in measuring HRV in the studies reviewed was the frequency domain methods, with the high frequency (HF) and low-frequency (LF) components and the comparison of the two (LF/HF) noted as the most frequently used HRV parameters. Furthermore, respiratory sinus arrhythmia (RSA), or the physiological effect of breathing which is parasympathetic activation, is reflected by the strength of the high-frequency components of HRV.

Based on the results of Langelotz *et al.* (2008) study, it is concluded that after 24 hours shift the HRV value increased significantly, suggesting that the surgeons were in a relaxation stage after the end of working shift, as opposed to the condition during working hours where the HRV values tended to decrease, indicating that the surgeon was under stress.

Low and McCraty (2018) stated that there were three significant negative relationships between PSS (short-term stress) and HRV; In the perceived stress and 5-min IBI, $r = -0.217$, $P < 0.05$; perceived stress and 5-min SDNN, $r = -0.255$, $P < 0.05$; and perceived stress and Ln 5-min RMSSD, $r = -0.282$, $P < 0.01$, H0 would be rejected. This indicates that short-term perceived job stress was significantly correlated with overall HRV.

It should be noted that only one study was performed with an observational study design (Langelotz *et al.*, 2008). By contrast, one out of ten studies analysed in a systematic review study by Järvelin-Pasanen, Sinikallio, and Tarvainen (2018) was a longitudinal study (Borchini *et al.*, 2018). Since longitudinal studies' main advantage is the ability to recognize a pattern of variables over time, this would indeed be the recommended approach in the HRV study of work stress to learn causal relationships. Besides, the deployment of HRV methods and job stress assessments makes a comparison of studies difficult. In based stead of the big picture, a fragmented puzzle emerges. Therefore, more integrated assessment methods and observational study arrangements are highly needed.

Jobbágy *et al.* (2017) reported in their article on HRV-based stress level assessment using very short recordings that HRV was applicable for estimating changes in an individual's actual stress level. Very short duration of HRV recordings (1-2 minutes-long) could be helpful. However, based on the article from Hernández-Gaytan *et al.* (2013), it was not possible to evaluate the duration of exposure and the cumulative effect of stress at work on the HRV if the assessment was done in a short duration.

Castaldo *et al.* (2015) further investigated the associations between HRV and acute mental stress, using short duration HRV measurement excerpts (0.5 – 10 minutes). From this article, it is known that during stress, the fluctuation of HRV at high frequencies depressed significantly. These results might change if the stress measurement wasa carried out after a stress event, as demonstrated in thearticle

from Tharion, Parthasarathy and Neelakantan (2009) and might be consistent with the phases of the stress as described in the journal review from Bracha (2004).

When compared with short duration HRV measurements, long duration of HRV measurements can provide an overview of the worker's overall condition, including HRV values while working, resting at home and sleeping (Sammito *et al.*, 2015).

As the main results of systematic review reported by The AF *et al.* (2020), long-term measurements of HRV (24 hours and longer) showed to be a better objective assessment of stress at workplace since it was able to pinpoint stressors during every task of work.

However, it should be noted that measuring HRV while working involves unidentified cofounding factors that are difficult to fully control, which in turn can affect the interpretation of the measurement results, for example the effect of workers' physical activities as reported by Hautala *et al.*(2010). Therefore, the effects of the confounding factors need to be reduced using subjective methods such as questionnaires. Despite these challenges, the workload and recovery information obtained by HRV will be helpful in early identification and stress prevention, for example, in occupational health care settings.

CONCLUSION

Lowered HRV value is associated with occupational or job stress. Thus, analysis of HRV value can be used as an informative biological marker for objective value of stressors at a workplace. The information regarding work load and physical activities from workers is needed to identify early signs of occupational or job stress and would be helpful to prevent occupational or job stress. The length of time measuring or recording HRV depends on what information needs to be obtained, with short-term measurements as well as long-term measurements having their respective advantages and disadvantages. In short, HRV can be recommended for occupational physicians and company doctors to identify the core areas of work-related stress.

ACKNOWLEDGEMENTS

This literature review was made possible by the assistance of several parties. In particular, the author would like to express great gratitude to the professionals who have participated to the progress and accomplishment of this literature review.

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