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Associations of Heart Rate Variability and the Work Ability Index:

A study on finding objective mental health measures for Workers' Health Surveillance Programs

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Abstract
Occupational stress has in a large number of studies been proven to increase and challenge employees' sustained employability. By optimizing workers' health surveillance programs (WHS), predictions of future health can be made and prevention of mental health illness can be facilitated. Current WHS include mainly subjective measures of mental health and stress but validity of these measures is frequently insufficient. The objective of this study was to explore the relation between heart rate variability (HRV) and the work ability index (WAI), and therefore contribute to more effective WHS, and the promotion of sustained employability. The study was designed as cross-sectional, and a linear regression analysis was applied with WAI as the dependent variable and the HRV measurements separately (SDNN, RMSSD, MHRR and normalized coherence) as independent variables. Work ability was measured with the index WAI, short version (WAI-Netzwerk, 2012). HRV was measured with the biofeedback pulse sensor tool emWave Pro (Institute of HeartMath), using the six-breath protocol. The result showed that one of the HRV measures mean heart rate range (the difference between the maximum and minimum heart rate during each breathing cycle) was negatively associated with WAI, when controlled for age B = -.26, 95% CI [-.48, -.05], β = -.38, t = -2.48, p = .016. The data gave unexpected results, and the conclusion cannot be made that HRV is an accurate and objective measure for work ability and sustained employability. Future studies should investigate other constructs associated with sustainable employability and continue to find evidence for HRV as an objective measure of mental health.

Keywords
Heart rate variability, work ability index, sustainable employability, workers' health surveillance programs, mental health, stress

Introduction

Occupational stress has in a large number of studies been proven to increase due to new forms of employment contracts, job insecurity, the ageing workforce, work intensification, high emotional demands at work and a poor work-life balance (Milczarek et al., 2007). Work-related stress is associated with ill health and diseases (Friedman, 1998) and is among the most costly health problem in terms of absenteeism, decreased productivity and performance (Bedell & Kaszkin-Bettag, 2010; Levi, 2000). An aging workforce, especially in western countries, calls for greater focus on decreasing the cost on occupa-tional health, and creating improved conditions for sustained employability (Ilmarinen, 2001; Silverstein, 2008; Sluiter, 2006). Sustainable employability is according to Van der Klink and colleagues (2010) defined as employees having the opportunity to perform work with preservation of health and wellbeing during their working lives, now and in the future. Different from studies in healthy careers, where the focus is on an employee's mental and physical state, sustainable employability addresses a supportive work environment and an employee's attitude and motivation to develop their capabilities and stay healthy in their jobs. Commonly used proxies for sustained employability are *work ability*, *productivity, absenteeism* and *vitality* (Koolhaas, Brouwer, & Groothoff, 2010).

To promote sustained employability, the use of workers' health surveillance (WHS) programs has increased (Aldana et al., 2005). The purpose of a WHS program is to prevent occupational illness and work-related injuries, maintain and promote health in relation to work, and maintain and improve functioning and employability (World Health Organization, 2002). With early detection of health problems and optimal interventions the development of work-related stress can be minimized and future health and performance may be enabled (Pärkkä et al., 2009; Pelletier, 2009). The psychosocial work environment measures (e.g., stress, workload and mental health) of WHS programs are mainly based on questionnaires. Subjective measures can have limited reliability and validity due to the likeliness of overestimating the answers and the risk of bias (Gupta et al., 2014; Van den Berg, Elders, Zwart & Burdorf, 2009). According to previous studies, both subjective and objective aspects are required to measure psychosocial health as they are interrelated (Ezoe & Morimoto, 1994; Järvelin-Pasanen et al., 2013; Pärkkä et al., 2009).

A prevalent subjective research measurement that has been validated in large international studies, and often included in the WHS, is the Work Ability Index (WAI). *Work ability* is characterized by the balance between a worker's individual resources and the demands of the work environment (Ilmarinen, 2001; Tuomi et al., 1998) and has been associated with occupational stress and sustainable employability (Salonen et al., 2003; Silverstein, 2008). The purpose of the WAI, other than measuring the sustained health of workers and an organization's resilience, is to obtain high quality of work, a high quality of wellbeing, and an active and meaningful retirement (Tuomi, Huuhtanen, Nykyri &

Ilmarinen, 2001). The WAI instrument is believed to have economic benefit for the workplace, as well as, prevent early exits (Tuomi et al., 2001). Work ability decreases with aging due to the challenges placed on an aging workforce to adapt to organizational changes (Ilmarinen, 2001; Tuomi, Ilmarinen, Martikainen, Aalto & Klockars, 1997). Also being "older" is proposed to decline the odds for good work ability by 6% per year (van Holland, Soer, Boer, Reneman, Brouwer, 2015). Stress has been proved to be a strong predictor of reduced WAI (Hasselhorn, Muller, Tackenberg, 2005; Pranjic, Males-Bilic, Beganlic & Mustajbegovic, 2006). One of the main criticisms of WAI is that it contains many disparate questions that more or less indirectly measure work ability (e.g., diagnosis of chronic conditions and sick leave) (Ahlström, Grimby-Ekman, Hagberg & Dellve, 2010). This may give too much weight to diagnoses not necessarily related to work ability. Due to the complexity of the construct and in order to simplify the measurements, a single-item question is often used. The proposed advantages of using the WAI single-item is that the results more easily can be interpreted by health practitioners, that the test takes shorter time to conduct and its cost effectiveness (Gupta et al., 2014). Both WAI and WAI single-item will be tested in this study.

It is of interest to investigate how well the WAI corresponds with an objective measure, also reflecting the balance between a worker's individual resources and demands of the work environment. A possible psychophysiological concept related to work ability is the Heart Rate Variability (HRV), which is a widely recognized and validated objective measure reflecting healthy function, self-regulatory capacity, adaptability and resilience of the human body (McCraty, 1996). HRV has in a number of studies proved to be a strong independent predictor of future health (Dekker et al., 2000; McCraty & Shaffer, 2015; Shaffer, McCraty & Zerr, 2014). Reduced HRV has been found in different cardiac pathologies and in patients under stress who are suffering from panic, anxiety or worry (Shaffer et al., 2014); in patients with autonomic dysfunction, including depression and asthma (Agelink, Boz, Ullrich & Andrich, 2002; Kazuma, Otsuka, Matsuoka & Murata, 1997); and in death from several causes (Berntson, Norman, Hawley & Cacioppo, 2008). HRV has also proven to be a more sensitive measure of mental health than blood pressure (Hjortskov et al., 2004; Pärkkä et al., 2009). Based on these findings, HRV has been suggested to evaluate the level of strain at work and recovery after work (Järvelin-Pasanen, 2013).

HRV describes the change in time intervals between contiguous heartbeats, and is "an emergent property of interdependent regulatory systems that operates on different time scales to adapt to environmental and psychological challenges" (McCraty & Shaffer, 2015, p. 46). The adaptability is dependent on the interplay of sympathetic and parasympathetic activity of the autonomic nervous system (ANS) (Schwab et al., 2003). ANS affects how every organ in the body functions and is involved in nearly all physical declines. A weak ANS can also cause death (Sapolsky, 2004). A healthy resilient system with a balanced ANS has in general a high HRV with regular change intervals between heartbeats (Lane et al., 2008). HRV measures are recognized as robust methods with which to evaluate the status of the ANS – the "window" of the real time health in the body – and can be used as a biomarker in the diagnosis of ill health (Russoniello, Zhirnov, Pougatchev & Gribkov, 2013).

HRV decreases under situations of stress (Dekker, 2000) and increases with deepened breathing and rest (Shaffer et al., 2014). It has been found that reduced HRV is related to mortality and disease as it reflects reduced regulatory capacity (Shaffer et al., 2014) as in conditions of stress. Deep breathing triggers the baroreflex, a key mechanism of the autonomic adaptive regulation, to operate at its capability level. The baroreflex plays a key role in producing high amplitude modulation of the heart rate, and when one breathes deeply at around six breaths per minute it has been shown to give an intrinsic resonance response (Vaschillo, Lehrer, Rishe & Konstantinov, 2002). Correlations between HRV parameters and age in a one-minute deep breathing test have been shown to be significantly higher than those in a five minute resting HRV test, thus indicating the greater accuracy of the data generate through deep breathing tests (Russoniello et al., 2013). HRV declines with age, and a well-established explanation shows this is due to lowered parasympathetic activity (Umetani, Singer, McCraty & Atkinson, 1998; Voss, Schroeder, Heitmann, Peters & Perz, 2015). The decline of HRV with aging can lower HRV to levels associated with an increased risk of mortality. It would limit the predictive value of HRV, particularly in the elderly, by making it difficult to distinguish low HRV due to disease from that due to normal aging (Umetami et al., 1998).

A few available studies have tested both objective and subjective measures to get a better prediction of mental health while at work but none were found that explored the relationship between HRV (both one- and five-minute recordings) and WAI, to predict sustained employability. Pärkkä and colleagues (2009) explored the relationship between physiological variables like heart rate, HRV, respiration and blood pressure, and psychological variables like self-assessment of stress, using the Bergen Burnout Indicator (BBI) and the Derogatis Stress Profile (DSP). The study was conducted in real-life settings over a three-month period with 17 white-collar workers primarily employed at universities or in the health care field. The average age was 54.5 years (SD 5.4 years, range 40-62). Participants were enrolled in a rehabilitation program due to stress with measurements taken before, during and after the program. The BBI was filled in prior to the start of the program, and the DSP measured four times during the three-month period. HRV was computed using ambulatory beat-to-beat heartbeat recordings analyzed by the software Firstbeat PRO WAS. The program uses HRV and HR signals to compute *stress* (sympathetic nervous system activity dominates parasympathetic activation) and *relaxation states* (parasympathetic activation dominates sympathetic activation) of the autonomic nervous system. Spearman correlations were computed between the self-assessments and physiological measurements. The results showed moderate but significant overall correlations between physiological and psychological variables. Conflicting correlations was obtained suggesting that stress is an individual reaction with different effects for different people, like for example high blood pressure. Results also showed that HR and HRV variables have stronger correlations with self-reported stress than blood pressure variables. As an objective for future research, the authors propose to find a variable that always indicates stress when it is present.

Järvelin-Pasanen and co-workers (2014) measured in their study on 48 female shift-worker nurses (mean age 45 years; SD 10; range 20-59), 24-hour HRV recordings, and

WAI questionnaire data. HRV analysis was used to compare physiological strain related to a conventional shift schedule and new ergonomically improved schedules, as HRV reflects parasympathetic activity of the ANS, and HRV has been observed to decrease in shift workers. The HRV changes are related to the increased risk of lower physiological (e.g. cardiovascular diseases, breast cancer and diabetes) and psychological well being (e.g. fatigue, sleep disorders and occupational accidents), and mental health in shift workers. WAI questionnaire data and HRV recordings were gathered during the conventional shift and again after one year of working in the new ergonomically improved shift schedule. The 24-hour HRV recordings were measured with a Suunto T6 or Suunto Smart Belt HR monitor. WAI was assessed using total WAI score and the WAI single-item question. The result showed that a change from a conventional to an ergonomic shift schedule was associated with beneficial changes in HRV, as well as between the beginning and end of the shift (e.g. RMSSD conventional beginning of shift M = 14.3, SD = 6.7, conventional end of shift M = 16.7, SD = 7.4, ergonomic beginning of shift M = 15.8, SD = 8.5 and end of shift M = 17.3, SD = 7.2). Furthermore, HRV analysis seems to be an accurate tool and it provides an objective assessment of psychophysiological strain at work, but it needs to be complemented with subjective values (like WAI) to interpret the results. In the study they controlled the potential effect of perceived work-related stress or work ability on HRV parameters but there was only a minor effect, meaning that the changes in HRV were attributable to factors other than stress at work.

HRV has been questioned to provide an accurate and reproducible measure of mental health in social, emotional and cognitive experiments, as HRV is affected by respiration and blood pressure (Quintana & Heathers, 2014). A risk mentioned by Quintana and Heathers (2014, p. 1) is that “if the direction of causality between experimental task and the coordinated response within cardiac, circulatory and respiratory variables is poorly understood simple relationships between task and output changes may be obscured”. Often uncontrolled measures like medicine, food and water consumption, a full bladder, and time of day may drastically influence HRV and should be considered in future experiments (Quintana & Heathers, 2014).

To summarize, due to increased mental health risks of the individuals, and the related costs of absenteeism, decreased productivity and performance for the organizations, it is of great interest to optimize the WHS by finding biomedical (objective) measures, which in combination with self-reporting (subjective) tools, better predict work ability and sustained employability. The aim of this study was to examine whether heart rate variability (HRV) is related to work ability, using WAI, and can therefore be a valid biometric stress measure in future WHS programs. The hypothesis was that HRV is positively correlated with WAI.

Method

Participants

A total of 238 blue-collar workers from two locations (A, B) of a Dutch furniture production company were included in the study. The study was part of care as usual in the workplace. All workers of the company were invited to participate. The sample average education level was 2,28 (2 = low, 3 = medium) on a 5-level scale. The majority (88%) of the participants were working a full-time, 40-hour week. The mean employment time was 16,7 years.

Sampling procedure and ethics

The purpose and procedure of the occupational health surveillance was presented in a kick-off meeting on the work floor, which was organized by the health supplier. The employees were asked to participate voluntarily and 134 persons agreed to do so. All employees were explained that a complete subjective and objective set of measures would be required for the study and that they could object to a part of the set or withdraw from the study at any time. Participants received a personal code for the online questionnaire and an appointment for the biometric tests in the workplace. Both the employer and the participants provided informed consent for participation in the study. It was communicated to the participants that all test results will remain confidential and not reach the managers' awareness. Group results will only be presented with groups larger than 15 persons. It is an individual responsibility to follow up on the health advices given after the tests. The Ethics Board at the University Medical Center Groningen in The Netherlands decided that formal approval of the study was not necessary as the workers are normally subjected to care as usual. All procedures were in accordance with the ethical standards of the responsible committee.

Study design and setting

This study had a cross-sectional design. The data were collected during regular occupational health surveillance by an occupational health supplier between March and April 2015. The study was part of the two-year SHIFT study (Sustained Health and Innovative Strategies For Technological Interventions) at Saxion University in The Netherlands (Tech for Future, 2014), with the aim to develop a decision support tool for professionals in the field of occupational health care, and to submit technology-enhanced objective measurements to the protocol.

Measurements

Work Ability Index

Work ability was measured by the index WAI, short version (WAI-Netzwerk, 2012). WAI is a standardized questionnaire that reflects the ability to work based on workers' self-perception with reliability indicating a Cronbach's alpha between 0.72 and 0.80 (Tuomi et al., 2001). WAI short contains 7 questions: (i) *subjective estimation of present work ability compared with the lifetime best* (0−10 points); (ii) *subjective work ability in relation to both physical and mental demands of the work* (2−10 points); (iii) *number of diagnosed diseases* (1−7 points); (iv) *subjective estimation of work impairment due to disease* (1−6 points); (v) *sickness absence during past year* (1−5 points); (vi) *own prognosis of work ability after 2 years* (1, 4, or 7 points); and (vii) *psychological resources (enjoyment in daily tasks, activity and life spirit, optimistic attitude about the future)* (1−4 points) (Tuomi et al., 1997). The index was calculated by summing the points of each item and the result scale ranges from 7–49. The scores were divided into three categories: 7−27 *poor*, 28−36 *moderate*, and 37−49 *good,* based on indications from previous WAI studies. The calculated value describes the relation between current condition and demands at work but give no reasons for eventual disorders. The single-item question used in the questionnaire was formulated: *Current work ability compared to highest work ability ever: Assume that our work ability at its best has a value of 10 points. How many points would you give your current work ability? (0 means that you currently cannot work at all).* The correlation between WAI and single-item outcomes on workability has, according to Ahlström and colleagues (2010), showed *r* =.87.

Heart Rate Variability

HRV was measured with the biofeedback pulse sensor tool emWave Pro (Institute of HeartMath). The emWave Pro uses Photoplethysmography (PPG) technology, which is based on the ability of hemoglobin to absorb light. As the amount of hemoglobin passing through the blood vessels changes due to the pulsatile nature of blood transportation, the amount of absorbed light also changes (Russoniello et al., 2013). PPG technology is a reliable and valid method of capturing and quantifying real time HRV data, both resting HRV and deep breathing tests (Russoniello et al., 2013). HRV is measured by various parameters. For our study, SDNN, RMSSD, MHRR and normalized coherence were used. SDNN is the standard deviation of all mean normal-to-normal intervals measured in milliseconds. The measure reflects the ebb and the flow of all the factors that contribute to HRV and the heart's ability to respond to hormonal changes (Mc Craty & Atkinson, 1996; Task force of the European society of Cardiology and the north American association of pacing and electrophysiology (ESC-AAPE), 1996). The RMSSD is the root mean square of successive differences between the normal heartbeats reflecting the short-term variance in heart rate. This value provides an estimate of the parasympathetic regulation of the heart (Mc Craty & Atkinson, 1996; ESC-AAPE, 1996). MHRR is the mean heart rate range, which is the difference between the maximum and minimum heart rate during each breathing cycle. The result is then expressed in beats per minute, as the mean of these heart rate differences for each measured cycle (ESC-AAPE, 1996; Mc

Craty & Atkinson, 1996). Normalized coherence is a frequency domain measure of coherence[1] where power in the coherence peak of the power spectrum density is divided by total power. This measure represents the ratio of coherence relative to total power and ranges from 0 – 100 (Mc Craty & Atkinson, 1996).

One-minute and five-minute protocol

Data was recorded for five minutes of resting breathing and for one minute of forced deep breathing for each participant. Normalized coherence value is most accurate in the five-minute resting breathing protocol, and was used in the analysis. For the other measures of SDNN, RMSSD and MHRR, the one-minute protocol was used.

Personal and work characteristics

Personal characteristics included in the questionnaire were age, gender, level of education. *Work characteristics* were working hours per week and the number of years employed.

Biometric and health measures

Additional biometric measures that were collected in the comprehensive SHIFT study were weight, height, belly circumference, body fat induction tool, systolic and diastolic blood pressure, glucose, total cholesterol, BMI (body mass index), resting state heart rate and VO2 max.

Data collection

The WHS data was collected in three sets: (1) online questionnaire, including WAI, filled in at home at least two days prior to (2) objective measurements (HRV) collected by an occupational physical therapist in the workplace, and (3) a counseling session with a health supplier. The participants were asked not to eat or drink 45 minutes prior to the appointment (which was 60 minutes prior to the HRV measurements), and to avoid heavy physical work during the last hour.

For HRV measurements each participant was recorded individually in a quiet room, in a slightly reclined (10%) seated position. A standard reclining chair was used for testing. The participants received instructions for the test and the emWave Pro was placed on their earlobe. Participants were instructed to remain seated and relaxed and to refrain from making any significant or rapid body movements. Each session started with the five-minute resting HRV test where the participant was asked to breathe normally. Once

[1] A coherent heart rhythm is a harmonic sine-wave-like signal with a narrow, high-amplitude peak in the low frequency (0.04-0.26 Hz) region of the HRV spectrum. Coherence is assessed by identifying the maximum peak (coherence peak) in the 0.04-0.26 Hz range, calculating the integral in a window 0.030 Hz wide, centered on the highest peak in that region, and the calculating the total power of the entire spectrum (Shaffer, McCraty & Zerr, 2014).

the five minutes were up, they were instructed to breath according to the six-breath protocol. This breathing method gives a physiological challenge to assess the maximum HRV range (amplitude) during a one-minute period through deep breathing at the specific rate of five seconds of inhalation and five seconds of exhalation. If achieved, there will be six complete breath cycles over the course of about one minute. The software program uses a breath-pacer to facilitate the regularity of the breathing. The entire minute should be artefact-free, and from these six cycles the minimum and maximum can be determined. Compliance was closely monitored, as insufficient deep breathing or poor synchronization with the breath pacer may result in lower test results. The average duration of each testing session, including the instructions, was seven minutes. The data collectors were experienced health suppliers and occupational physical therapists for HRV. A physician assisted with other biometrics.

Data processing

The WAI results and personal and work characteristics (and biometric values) were compiled in an Excel file by the occupational physical therapist. The HRV results in emWave Pro were visually controlled for incomplete measures caused by technical problems or the inability to complete the test. Test participants with defective values were excluded from the study. The remaining data were transferred into an Excel file in which measures were manually calculated for one and five minutes. The data were thereafter processed by HeartMath Institute of California to get the specific HRV measures.

Statistics

All of the descriptive analyses were performed first. Transformations of the non-normal variables were made. WAI and WAI single-item were transformed by power of 3 and the HRV measures with the natural logarithm (ln). The WAI values of the responders and the non-responders were compared in a t-test. Thereafter, Pearson correlation analyses were made.. Finally, a linear regression analysis was applied with WAI and WAI single-item as dependent variables and the HRV measurements (SDNN, RMSSD, MHRR and normalized coherence) as independent variables, with both initial and normalized data. Age was used as covariate as it is know to have an effect on HRV. The significance level was set at alfa .05. Data were analyzed using SPSS for Mac (version 23.0 SPSS GmbH Software, Munich, Germany).

Results

Participants

The registration for the general occupational health check was in total $N = 134$ (location A $n = 90$ and location B $n = 44$) and the final participation rate $n = 124$. A total of 75 workers volunteered for the HRV measurements, of which 12 were excluded because of non artefact-free cycles or missing one full minute of six deep-breath cycles. This resulted in 63 participants. When processing the data, another 12 participants were excluded due to technical artefacts in the dataset related to the one-minute protocol. This resulted in 51 participants with complete HRV and WAI measurements.

Table 1. Characteristics of participating respondents (n=51) before log transformed data.

	Mean or *n*	*SD*	*Min*	*Max*	*Skewness*	*Kurtosis*
Gender male/female (N)	47/4					
Age	46.16	10.29	19	63	-0.99	0.374
Level of education*	2.53	1.19	0	5	0.26	1.7
Working hours per week	39.59	1.79	32	43	-3.35	12.28
Years employed	16.7	10.85	0	40	0.18	-1.2
SDNN (1 min)	67.84	23.21	28.88	111.47	0.36	-0.87
MHRR (1 min)	15.09	6.99	3.31	34.66	0.74	0.19
RMSSD (1 min)	50.49	21.25	22.24	101.61	0.76	-0.50
Norm. coherence (5 min)	0.35	0.12	0.16	0.68	0.73	0.24
WAI	39.92	4.81	23	47	-1.29	2.35
WAI single item	7.43	1.17	5	10	-0.41	-0.12
WAI-scores						
Good (37-49)	41					
Moderate (28-36)	8					
Poor (7-27)	2					

Note. Level of education (0 = no education, 1 = primary school, 2 = low, 3 = medium, 4 = high school, 5 = university). SDNN = standard deviation of all mean normal-to-normal intervals, RMSSD = root mean square of successive differences between the normal heartbeats, MHRR = mean heart rate range, normalized coherence = frequency domain measure of coherence, WAI = work ability index.

Responders vs. non-responders

When comparing the WAI short and the WAI single-item question scores between the responders (n=51) and the non-responders (n=65) (where data were collected), the independent sample t-test showed no significant differences. In WAI short: $t(114) = -0.86$, $p = .39$, responders $M = 39.92$, $SD = 4.81$ and non-responders $M = 39.02$, $SD = 6.24$. WAI single-item; $t(114) = 0.64$, $p = .53$, responders $M = 7.45$, $SD = 1.19$ and non-responders $M = 7.65$, $SD = 1.92$. A difference was found in age between the responders $M = 46.16$, $SD = 10.32$, and non-responders $M = 50$, $SD = 7.76$, but there were no differences due to gender, $t(114) = -0.72$, $p = .47$. In the biometric values, only a significant difference was found in beats per minute (bpm) in rest $t(95) = 2.68$, $p = .009$, responders M = 68.92, SD = 9.32, and non-responders M = 75.09, SD = 13.15.

HRV and WAI for responders

A significant negative correlation was found between age and the HRV measures; SDNN ($r = -.33$, $p = .02$); MHRR ($r = -.47$ $p < .001$); and RMSSD ($r = -.27$, $p = .05$). Age and normalized coherence were negligible correlated ($r = -.17$, $p = .24$). Neither was age correlated with WAI ($r = .14$, $p = .345$) and WAI single-item ($r = .22$, $p = .124$). WAI and WAI single-item had a strong correlation ($r = .63$, $p < .001$) and likewise were the HRV measurements SDNN, RMSSD and MHRR strongly correlated, except for normalized coherence (see Table 2). The HRV variables were checked for differences between one-minute and five-minute results and all showed a tendency of stronger correlation with age in the five-minute protocol. The internal consistency of WAI was found to be reliable, 28 items; $\alpha = .73$, in line with previous WAI studies.

Table 2. Pearson correlations between HRV variables, WAI, WAI single item question and Age (n=51) (transformed variables)

	WAI	WAI_SI	SDNN	RMSSD	MHRR	Nor. coh.	Age
WAI	-						
WAI_SI	.63**	-					
SDNN	.05	-.05	-				
RMSSD	.11	-.02	.93**	-			
MHRR	.23	-.01	.63**	.61**	-		
Norm. Coh.	.01	-.05	.04	.03	.17	-	
Age	.14	.22	-.33*	-.27**	-.47**	-.17	-

*p < 0.05 (2-tailed)
**p < 0.01 (2-tailed)

An association between WAI and the HRV parameters was not found with the regression analyses. Since literature indicates that age influences work ability and HRV, age was used as a covariate in a linear regression analysis. With WAI as dependent variable and the HRV parameters and age as independent variables, there was a significant negative association between WAI and MHRR (see Table 3). SDNN, RMSSD and normalized coherence had a weak negative effect on WAI but no significance was reached (see Table 3). Interaction effect of age and MHRR were not significant. Also the WAI single-item question was tested with age as a covariate but no significant associations with the HRV measurements were found.

Table 3. Linear regression analysis with WAI and WAI single-item as dependent variables and HRV measures and Age as predictors (n = 51)

Model	R	R^2	F	B	β	p	*95% CI*
WAI							
SDNN (1 min)	.17	.03	(2,48) = 0.72	-.03	-.16	.30	(-.1, .03)
Age				-.06	-.13	.38	(-.20,-.08)
MHRR (1 min)	.35	.12	(2,48) = 3.29	-.26	-.38	.02	(-.48,-.05)
Age				-.12	-.26	.09	(-.27,-.02)
RMSSD (1 min)	.24	.06	(2,48) = 1.53	-.05	-.24	.11	(-.12, .01)
Age				-.07	-.15	.31	(-.21,-.07)
Nor. coh (5 min)	.10	.01	(2,47) = 0.24	-2.34	-.06	.70	(-14.5,- 9.83)
Age				-.04	-.09	.53	(-.18,-.1)
WAI single-item							
SDNN (1 min)	.13	.02	(2,48) = 0.39	.01	.00	.98	(-.02, .02)
Age				-.13	-.01	.41	(-.05, .02)
MHRR (1 min)	.16	.03	(2,48) = 0.61	-.02	-.11	.51	(-.07, .04)
Age				-.02	-.18	.28	(-.06, .02)
RMSSD (1 min)	.13	.02	(2,48) = 0.42	-.002	-.04	.80	(-.02, .01)
Age				-.02	-.14	.36	(-.05, .02)
Nor. coh (5 min)	.13	.02	(2,47) = 0.43	-.45	-.05	.76	(-3.36, 2.46)
Age				-.02	-.13	.37	(-.05, .02)

Note. SDNN = standard deviation of all mean normal-to-normal intervals, RMSSD = root mean square of successive differences between the normal heartbeats, MHRR = mean heart rate range, normalized coherence = frequency domain measure of coherence, WAI = work ability index.

As some data were slightly skewed, WAI: -1.28/0.33 = -3,87, $p < .01$; WAI single-item: -0.43/0.34 = -1.28, *ns;* SDNN: 0.36/0.33 = 1.08, *ns*; MHRR: 0.72/0.33 = 2.16, $p < .05$; RMSSD: 0.73/0.33 = 2.19, $p < .05$; normalized coherence: 0.73/0.34 = 2.17, $p < .05$, a test of normality using $Z = Skewness / Std. Error$ was applied. WAI and WAI single-item were transformed with the power of 3, and the HRV measures were transformed with the natural logarithm. Z-values of 2.58 and 1.96 represents cutoffs for p < .01, and p < .05, respectively. The results yielded very small differences between the previous regression values and the transformed regression values.

Discussion

The aim of this study was to examine the relationship between the WAI and different HRV measures, and to investigate the contribution of HRV toward the achievement of more efficient WHS programs. The regression analysis showed that there was a significant negative association between WAI and one of the four HRV measures: Mean Heart Rate Range (MHRR), which is the difference between the maximum and minimum heart rate during each cycle of breath. The association was found when age was included as a covariate. An association between WAI and the other HRV parameters could not be found. Neither could an association be established between the WAI single-item question and HRV. The HRV measures were negatively correlated with age, in line with previous research results, as HRV declines with age (Voss et al., 2015). In line with the findings of previous studies, WAI and WAI single-item had tendencies of negative correlation with age, as work ability decreases with aging (Ilmarinen, 2001). Here, the correlation was weaker than in previous studies and it was not significant. Contradicting the results of Russoniello and colleagues (2013) which suggested that correlations between HRV and age in one-minute deep breathing tests are significantly higher than in five-minute resting tests, this study showed that the correlations between HRV and age in five-minute protocols were stronger than in one-minute.

Both WAI and HRV are described as predictors of future health and indicators of stress at work (McCraty & Shaffer, 2015; Tuomi et al., 2001). The two measures have been examined in numerous studies, which have respectively proven their high reliability and validity. In this study it was hypothesized that WAI and HRV would have a positive correlation, and that HRV could be used as a predictor of work ability and sustained employability. Instead, the findings showed a weak negative correlation between WAI and HRV, which didn't support the hypothesis. Since a negative correlation was found, the result may be interpreted as having had complications with the data or that other factors interfered.

HRV is known as the “window” of the ANS, which regulates all the sympathetic and parasympathetic activity in the body (McCraty & Shaffer, 2015). HRV is sensitive to environmental, psychological and physiological changes, and studies show that e.g.

medicinal intake, food and water consumption, a full bladder, and the time of the day the test was taken may influence the HRV result (Quintana & Heathers, 2014). These data are included in the SHIFT study but were not included in this study. Uncontrolled psychological or physiological factors mentioned above may have continuous impact on HRV and should therefor have been controlled for.

Another physical factor is deep breathing capacity and one's flexibility to shift on demand from normal relaxed breathing to deep "forced" breathing, following the pace of the metronome. Deep breathing gives a possibility to assess the maximum HRV range possible during one minute. This is perhaps a new challenge for the participant as it could be the first time he/she consciously focuses on the breathing and as a result may have difficulty to perform the task. The test leaders of this study were aware that insufficiently deep breathing could produce lower test results, and they reported that many subjects were uncomfortable with the shift from the five-minute to the one-minute protocol, which could have impacted their breathing. The consequence may have been that the participants weren't able to reach their maximum capacity of deep breathing during the test period. For example, if participants have high WAI scores but don't manage to generate good HRV results there will be a negative correlation between WAI and HRV.

An uncontrolled psychological factor is the stress a participant can experience during the moments of being monitored and "examined" by an "authority". The stress or desire to perform well during a health assessment at work is a well-known phenomenon. In addition to that, employees have a tendency to feel vulnerable when admitting their poor health at work (Nauta & Slauten, 2004). As a result, the stress level could potentially be increased during the measurements. While taking the HRV test, participants were not asked if they were feeling stressed. The WAI was assessed two days prior to the HRV test, in a home setting, and was therefore conducted under different environmental, psychological, and physiological conditions. Possibly this can explain why the correlation was negative, or more likely there should be no correlation at all.

Jönsson and Hansson-Sandsten (2008) made discoveries on HR and Respiratory Sinus Arrhythmia (RSA), which suggested that a negative emotion could positively impact HRV. RSA and HRV relate to one another, as RSA is HRV "in synchrony with respiration by which the R-R interval on an ECG is shortened during inspiration and prolonged during expiration" (Yasuma & Hayano, 2004, p. 683). RSA is also associated with behavioral flexibility, attention and emotion regulation (Jönsson & Hansson-Sandsten, 2008). Others have found that while exposed to an image that creates a negative/positive (valence) or high/low (arousal) emotion, both negative and positive emotion increased RSA (Frazier, Strauss & Steinhauer, 2004). This was explained by the fact that ANS increased focus and alertness when under a negative emotion (stress), which in the moment leads to an increased parasympathetic activity and increased RSA/HRV. That would mean that there is a reverse relationship between emotional valence and RSA during emotional perception. Furthermore, generated neutral emotions lower RSA more than both positive and negative, and the correlation is therefore not linear. This reaction is accurate for participants with "normal health" as the ANS under "high stress" is incapable of raising alertness (Lane et al., 2008) and the RSA/HRV will consequently go down with negative (stress) exposure. Results from Mc Craty, Atkinson and Tomasino (2001) confirms the findings above as they also demonstrate that stress tolerance varies among individuals, and those with highly resilient ANS can perform at higher level for longer periods without generating homeostatic disorders (e.g. HRV decline). An addition to the RSA results was the fact that greater cardiac reactivity in response to emotional stimuli was shown in males rather than females (Jönsson & Sonnby-Borgström, 2003). In the actual study, men were in a large majority. It is relevant to investigate whether participants who had lower WAI results in the study (for that reason) felt stressed by the HRV test (and in particular about making the shift from normal breathing to deepened breathing), and to explore whether that emotion could momentarily increase the HRV, which would explain the negative correlations in the data.

WAI has been questioned as containing items not related to work ability. It also refers to both past and future situations (Ahlström, Grimby-Ekman, Hagberg & Dellve, 2010). Based on the sensitivity that HRV has shown, and its dependency on momentary ANS activity, it might be difficult to significantly correlate HRV with a wide or diffuse construct like WAI.

A relevant question is whether the chosen HRV measures for the study—SDNN, RMSSD, HMRR and normalized coherence—are the optimal measures with which to capture HRV. A deeper analysis of the specific characteristics of the HRV variables will not be included in this study. Normalized coherence showed weak results compared to the other HRV measures throughout this study which should be taken into consideration. Also SDNN, RMSSD and HMRR yielded weak findings, which impacted the validity of the study.

Tentatively another variable that could have impacted the results is the context of the study, including the messages that have been communicated to the employees, the culture of the company, (non) communication from management/test leaders, current projects, organizational changes, and recent issues or conflicts. For example, if an employee experiences a potential threat to his/her job, one strategy could be to "appear" healthier in order to stay competitive, and therefore answer with high scores in WAI. Possibly the context of the tests did impact the scores.

Another potential impact on the correlation between the variables could have been the selected time period. Previous studies suggest that one's current situation impacts how he/she interprets the state of their health three months prior. For example, the answer to the question, *Considering the last three months: Have you been able to enjoy your regular daily activities?* could possibly be impacted by a current emotion (in an at-home environment) and eventually increase the result of WAI.

Other constructs related to sustained employability should be evaluated further. Brouwers, Engels, Heerkens and van der Beek (2015) discuss, in the context of sustainable employability, that the health and well-being of an employee is determined not only by the job context but also by personal characteristics (e.g. traits, needs, competences, and ambitions), motivation for work, and resilience which strengthens the argument that WAI results could be "manipulated" depending on the context. Other proxies for sustained employability—productivity, absenteeism and vitality—could potentially have stronger associations with HRV.

Strengths and limitations

According to an article search, this was the first study conducted on the relationship between HRV and WAI using HRV as a potential objective measurement for sustained employability. The sample size (n = 51) of HRV measures was relatively large compared to other studies but it may have been too small for this study design.

Selection bias could have occurred as participants were allowed to refuse to take part in the HRV measurements, which could not be controlled as HRV data is missing for the non-responders. It is suggested that participants in research studies are healthier than non-participants as it is more in their interest to have their results reported (Conrad, 1987). From the initial sample of 238 workers only 51 (21%) participated in the HRV measurements. Through a non-responsez, differences in WAI short and WAI single-item questions between non-responders and responders were controlled, but no significant differences were found between the two groups. Neither were there significant differences in the biomedical measures, with the exception of heart rate at rest.

A limitation was the low variance of the WAI scores, and therefore not enough participants on each level of the scale to compare with HRV results to find evidence according to Jönsson and Hansson-Sandsten (2008). The fact that 41 out of 51 participants (80%) had *good* scores (M = 39.92) could have been an effect of response bias as the result was not in line with previous research.

As the actual study was field research, there would be a risk of inclusion bias if participants were prohibited to smoke, drink coffee and eat before the test. (They were only instructed not to eat 45 minutes before the test). This could have resulted in more health-restrictive participants in the study. This total study controlled for age, physical activity, level of alcohol consumption, time of the day, medication, and food intake. There was a risk that confounders not taken into consideration may have affected the results.

Implications for further research and for practice

To summarize, the recommendations for future HRV studies using the six-breath protocol, is to control for effects on the heartbeat when shifting from five minutes of resting to one minute of deep breathing. A suggestion is to give the participant a transition time between the two protocols (already applied in the SHIFT study as a result of this study), and to continue to validate one-minute and five-minute protocol as five-minute had stronger correlations in this study. In future HRV tests, a question about the participants current stress level should be added. Also, should the capacity to measure increased HRV under negative valence (stress) be taken into consideration, as the emotional impulse could generate reverse correlations. Preferably, all uncontrolled physical variables (e.g. food, water, bladder, time, etc.) should be controlled.

Conclusions

The results of this study show that one of the HRV measures MHRR was negatively associated with WAI when age was controlled. Due to potential program failure or bias, the data gave unexpected results and a conclusion cannot be made that HRV is an accurate objective measure for work ability and sustained employability. Future studies should continue to find evidence for HRV as an objective measure of mental health.

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