

Job stress bio-monitoring methods: heart rate variability (HRV) and the autonomic response

Jesper Kristiansen



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Objectives

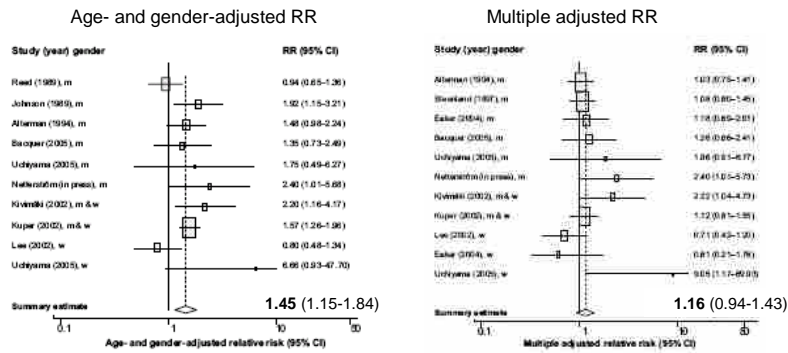
After the presentation you will:

- Know what heart rate variability is and how it is measured.
- Have a basic understanding of the physiology behind HRV.
- Understand how HRV is related to activity in the parasympathetic and sympathetic branches of the autonomic nervous system.
- Know of different ways to apply HRV measurements in research.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Job stress and cardiovascular disease

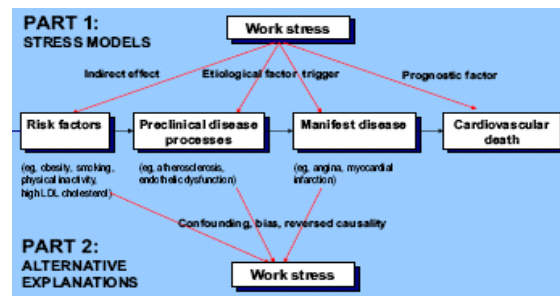


Source: Work stress in the etiology of coronary heart disease - a meta-analysis. Kivimäki et al., Scand J Work Environ Health 2006, 32: 431-42.



NATIONAL RESEARCH CENTRE FOR THE WORKING ENVIRONMENT

Job stress and cardiovascular disease



Source: Work stress in the etiology of coronary heart disease - a meta-analysis. Kivimäki et al., Scand J Work Environ Health 2006, 32: 431-42.



NATIONAL RESEARCH CENTRE FOR THE WORKING ENVIRONMENT

Two primary physiological stress reaction systems

The hypothalamus-pituitary-adrenal (HPA) axis

The autonomic nervous system (ANS)

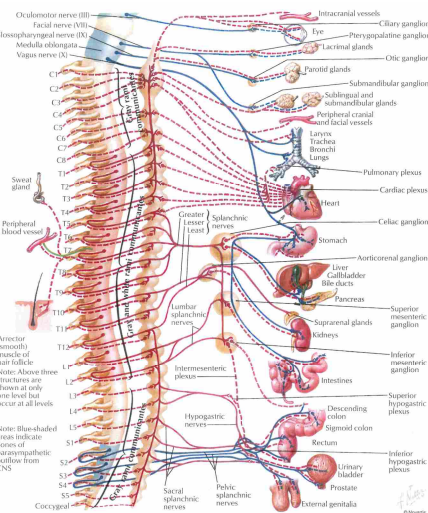
A definition of stress:

Stress is the body's multi-system response to any challenge that overwhelms, or is judged likely to overwhelm, selective homeostatic response mechanisms (TA Day, Prog Neuro-Psychopharm Biol Psych 2005; 29: 1195 – 1200).

HPA and ANS play key roles in mediating this multisystem response!



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT



The autonomic nervous system

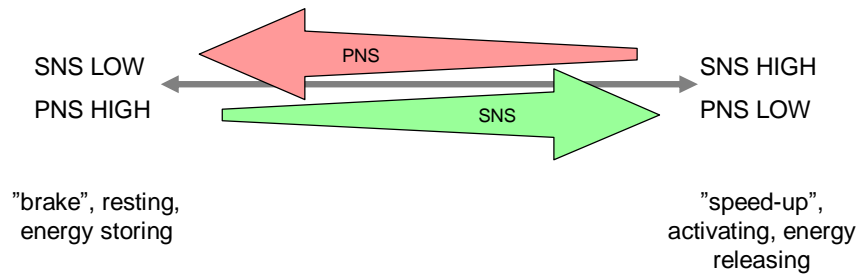
Sympathetic and parasympathetic nervous system (SNS and PNS)



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

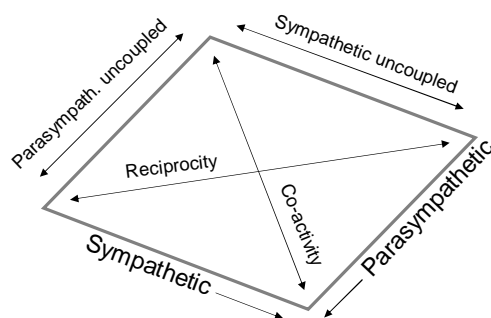
Old view on SNS/PNS

One-dimensional reciprocal response system:



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Autonomic space (Berntson)

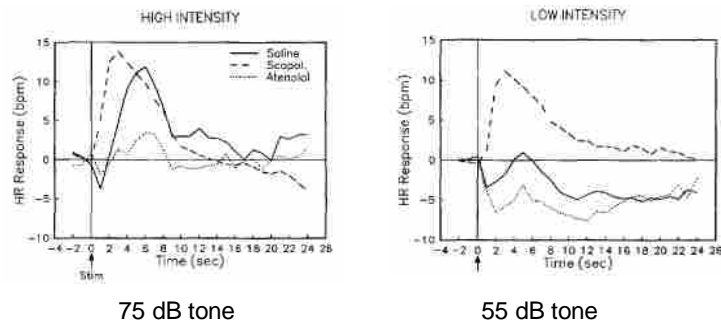


G.G. Berntson et al. Psychol. Rev. 1991; 98: 459-487.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Example: Co-activation of PNS and SNS at low stimulus intensity



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Heart rate variability (HRV)

- Changes in blood pressure, heart rate etc.: Result of the combined changes in PNS and SNS
- HRV: Individual contributions from PNS and SNS can be obtained.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

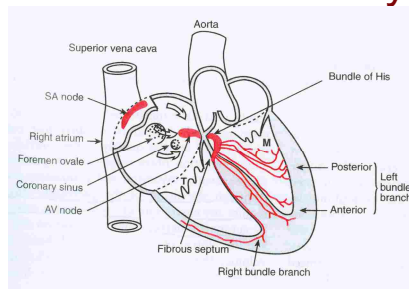
1. HRV basics



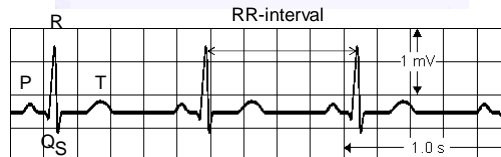
NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

HRV = Heart rate variability

The cardiac conduction system (from: Levick (2003). An Introduction to Cardiovascular Physiology, 4th ed.)



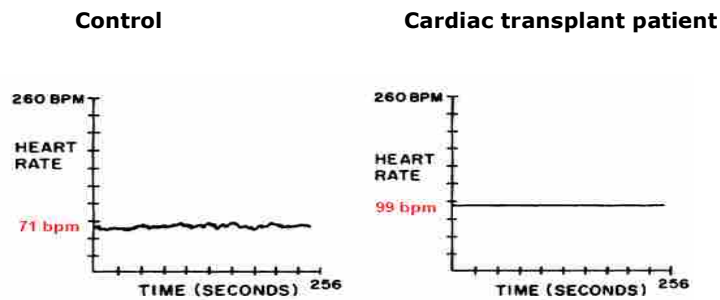
Electrocardiogram (ECG)



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Regulation of HR

Intrinsic heart rate of the denervated heart is almost constant and around 100 bpm.



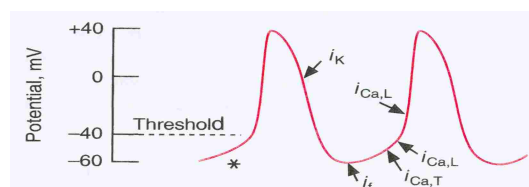
Sands et al (1989). *Circulation* 79: 76-82.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Regulation of HR

The decaying membrane potential of pacemaker cells in the sino-atrial node is the basis for regulation of HR.



i_K : potassium current; i_f : "funny" current (mainly Na^+); $i_{Ca,T}$: Transient Ca^{2+} channel current; $i_{Ca,L}$: Long-lasting Ca^{2+} channel current. * : Pacemaker potential

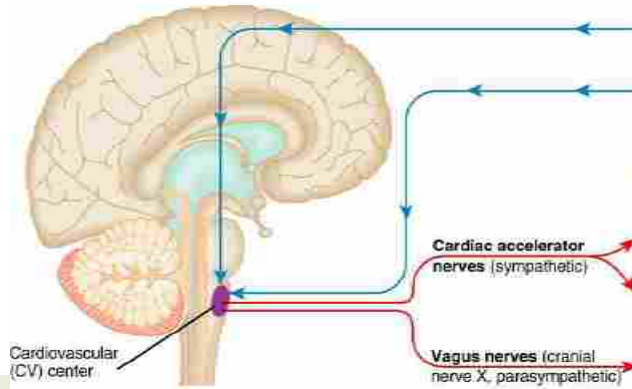


NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Levick (2003). *An Introduction to Cardiovascular Physiology*, 4th ed.

Central control of the heart rate

The cardiovascular center is located in the Medulla oblongata.



Input to cardiovascular center:

From higher brain centers (cerebral cortex, limbic systems, and hypothalamus)

From sensory receptors (baroreceptors, chemoreceptors, proprioceptors)

Output to the heart:

Increased rate of spontaneous depolarizations in SA (AV) node

Increased contractility of atria and ventricles

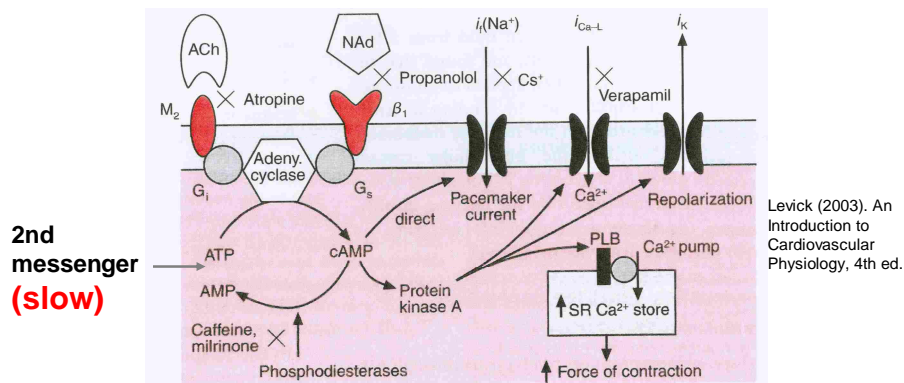
Decreased rate of spontaneous depolarizations in SA (AV) node



NATIONAL RESEARCH CENTRE FOR THE WORKING ENVIRONMENT

ANS regulation of HR

Sympathetic noradrenaline (NAd) binds to β_1 -adrenergic receptors. Parasympathetic acetylcholine (ACh) binds to M2-muscarinic receptors.



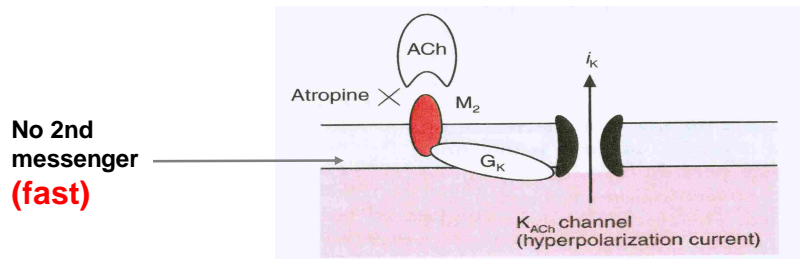
2nd messenger (slow)



NATIONAL RESEARCH CENTRE FOR THE WORKING ENVIRONMENT

ANS regulation of HR

Parasympathetic acetylcholine (ACh) opens K_{ACh} channel – hyperpolarizes the membrane potential.



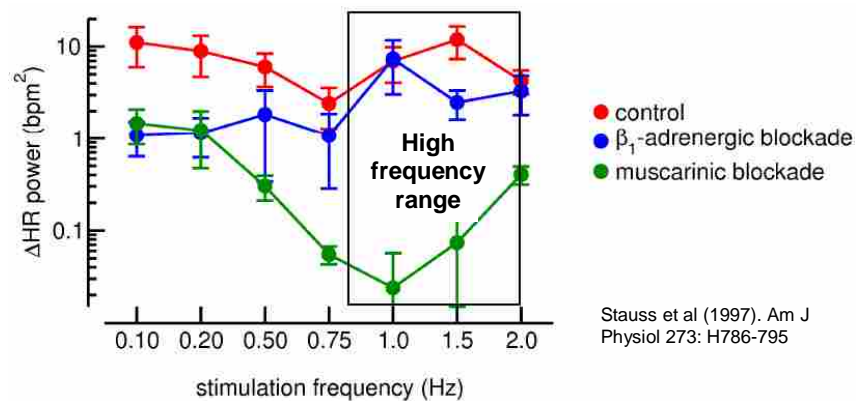
Levick (2003). An Introduction to Cardiovascular Physiology, 4th ed.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

ANS regulation of HR

HR responses to PVN stimulation in rats



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Summary – so far

- Beat-to-beat variability in HR ("instantaneous heart rate) is governed by modulations in SNS and PNS activity.
- Due to the dependency of a 2nd messenger system the modulations of SNS activity has lower maximum frequency than PNS modulations.
- Hence, an analysis of the frequency content of HRV will reveal the contributions from PNS (high frequency modulations of instantaneous HR) and SNS (slow frequency modulations).



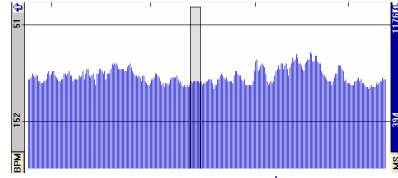
NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

2. Analysis of HRV

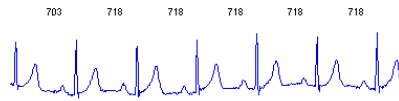


NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

R-R interval variability measures



Tachogram:
R-R intervals



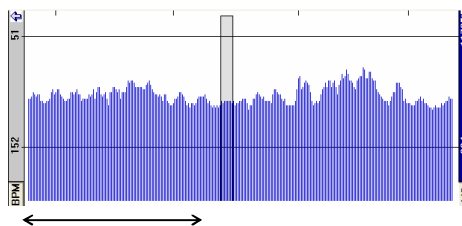
ECG



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

R-R interval variability measures

The tachogram



Segment or "epoch", length depends on the study from few min – >24 hr)

You should not compare HRV calculated for different epoch lengths!



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

R-R interval variability measures

- HRV: The variability of all N-N intervals (e.g., SDNN)
- Other ECG-derived measures:
 - Measures of the power N-N interval variability at different frequencies (e.g., HF power, LF power, RMSSD)
 - Measures describing other aspects of the N-N interval variability (chaotic, randomness etc.) (e.g., ApE)
 - Other measures derived from the ECG (e.g., heart rate turbulence).



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Time domain measures

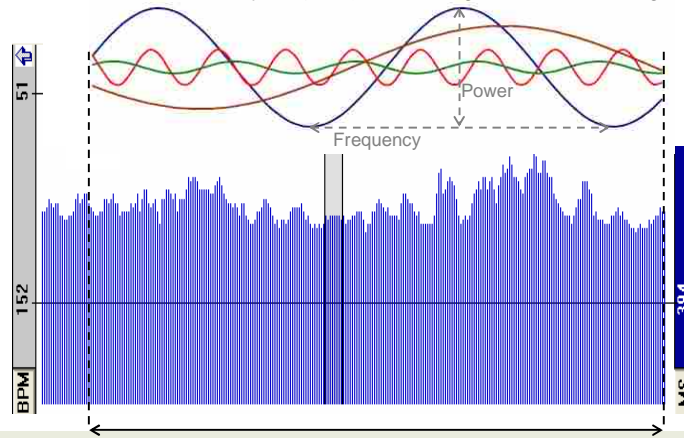
Variable (units)	Definition	Interpretation
SDNN (ms)	Standard deviation of all N-N intervals	Total variability (HRV)
SDANN (ms)	The standard deviation of all 5 min epoch averages of N-N intervals.	Low frequent modulation of HR
SDNN index (ms)	The average of the standard deviations of N-N intervals in all 5 min epochs.	Low frequent modulation of HR
RMSSD (ms)	The square root of the mean of squared differences of successive N-N intervals	High frequent modulation of HR
pNN50 (%)	Percentage of all successive N-N intervals with length larger than 50 ms.	High frequent modulation of HR



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Frequency domain measures

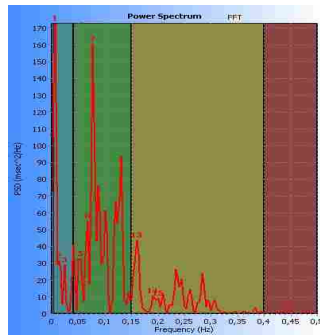
Frequency domain measures extracts frequency information by Fast Fourier Transformation analysis (FFT) or autoregressive modelling



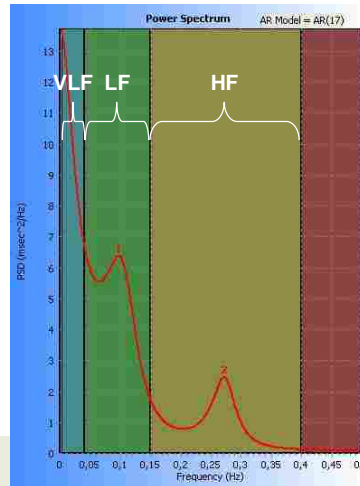
NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

HRV power spectrum

FFT



Autoregressive model



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Frequency domain measures

Variable (units)	Definition	Interpretation
Total power (ms^2)	Total area under the power density function (0.003 – 0.04 Hz)	Total variability (HRV), equal to $(\text{SDNN})^2$
HFP or HF (ms^2)	Area under the power density function in the frequency range 0.15-0.4 Hz	Parasympathetic modulation of HR (respiratory sinus arrhythmia)
LFP og LF (ms^2)	Area under the power density function in the frequency range 0.04-0.15 Hz	Sympathetic modulation of HR with contribution from parasympathetic activity
VLF (ms^2)	Area under the power density function in the frequency range 0.003-0.04 Hz	Modulation of HR by slow blood pressure regulating systems
HF n.u. (normalized units)	HF/(TP-VLF)	Same as HF
LF n.u. (normalized units)	LF/(TP-VLF)	Same as LF
LF/HF	LF/HF	"Autonomic balance", i.e. the balance between sympathetic and parasympathetic activity.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

FFT needs:

- Minimum 10-20 oscillations to determine power, *i.e.*, 60-120 s for HF power, 250-500 s for LF power.
- Stationarity, *i.e.*, no change in mean RR-period, variance, etc.
- Equidistant sampling, *i.e.*, the RR-intervals are sampled at times $t_1 \dots t_i, t_{i+1}, \dots t_n$ etc. separated by the same Δt .



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Time domain vs. frequency domain

- Many measures strongly correlated (e.g., SDNN – total power, RMSSD – HF, RMSSD – pNN50 etc.)
- Difficult to interpret frequency components of HR for long segments (VLF and ULF dominates the power spectrum)
- The estimation of the power spectrum require stationarity of the signal
- Power spectrum analysis: 5 min segments are preferred (down to 2 min possible for HF only!).

Task force (1996). Heart rate variability. Standards of measurement, physiological interpretation and clinical use. Circulation 93: 1043-1065.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

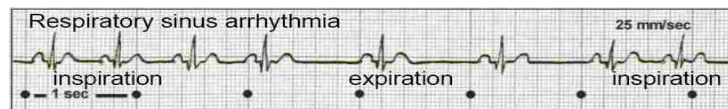
3. Origins of HRV



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Respiratory sinus arrhythmia (RSA)

- Earliest known type of HRV (Hales, 1733)
- Fast heart rate (tachycardia) during inspiration
- Slow heart rate (bradycardia) during expiration.



The frequency of the HF component is entrained to the respiration frequency

S. Hales, *Statical Essays*. I Haemastaticks, Vol. II (Innings & Manby, London 1733)



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Respiratory sinus arrhythmia

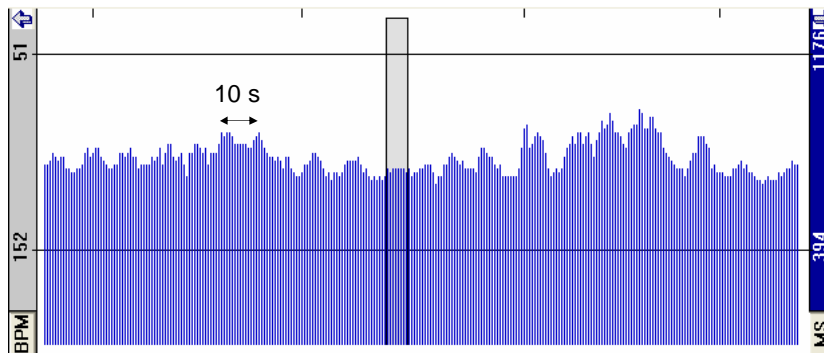
- The exact mechanism causing RSA is not known, but central are:
 - variation of venous return the heart (preload) caused by the "respiratory pump", in combination with
 - reflexes that control HR (Bainbridge reflex and baroreceptor reflexes)
- RSA is therefore an index of the gain of the baroreceptor cardiac vagal reflex responses.

Barnardi et al. (2001). Modulatory effects of respiration. *Auton Neurosci Basic Clin* 90: 47-56



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

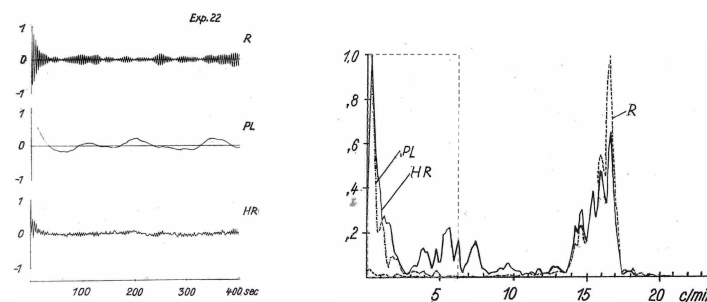
10s fluctuations in HR



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

10s fluctuations in HR

- Discovered much later than RSA (Penaz et al., 1968)



J. Penaz et al. I: *Biokybernetik*, Vol. I (Karl-Marx-Universität, Leipzig 1968), 233-6.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

10s fluctuations in HR

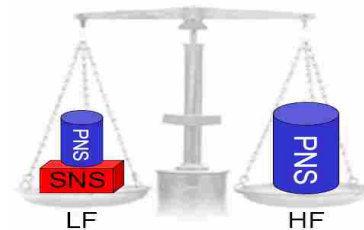
- Oscillations caused by resonance between HR and different blood pressure regulating systems, e.g.:
 - baroreceptor reflex
 - renin-angiotensin system
 - local endothelial NO system
- Afferent nerve signal from these blood pressure regulating systems are integrated in the CNS.
- The HR is result of the balance between efferent nerve traffic from sympathetic and parasympathetic nerves (sympatho-vagal balance).



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Frequency domain measures

- HF spectral power is modulated by parasympathetic activity only
- LF spectral power is modulated by both sympathetic and parasympathetic activity
- LF/HF reflects sympatho-vagal balance.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Summary: HRV measures

- HRV is derived from analysis of (normal) R-R intervals, e.g., recorded from an ECG
- HR oscillates with many frequencies (complex pattern in tachogram) that reflects the influence of different blood pressure systems
- Rapid fluctuations (HF, 0.4 – 0.15 Hz) is caused by vagal activity
- Slow fluctuations (LF, 0.15 – 0.04 Hz) is caused by a mixture of sympathetic and vagal activity.
- Slower fluctuations is caused by even slower regulatory systems (e.g., temperature fluctuations, day-night periodicity).



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

4. Factors that influence HRV

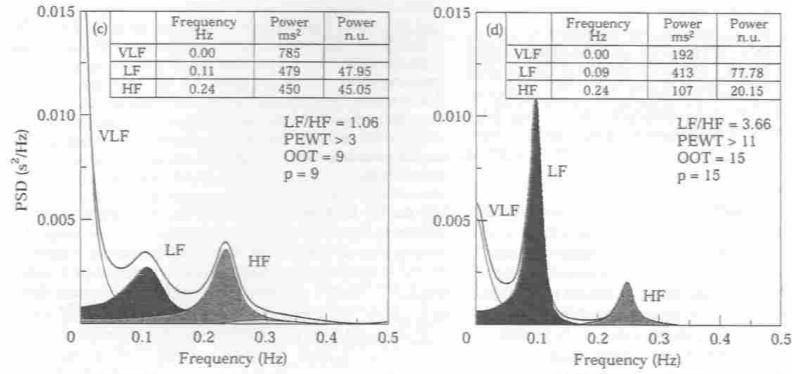


NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Body posture and HRV

Supine rest

After head up tilt



LF/HF = 1.06

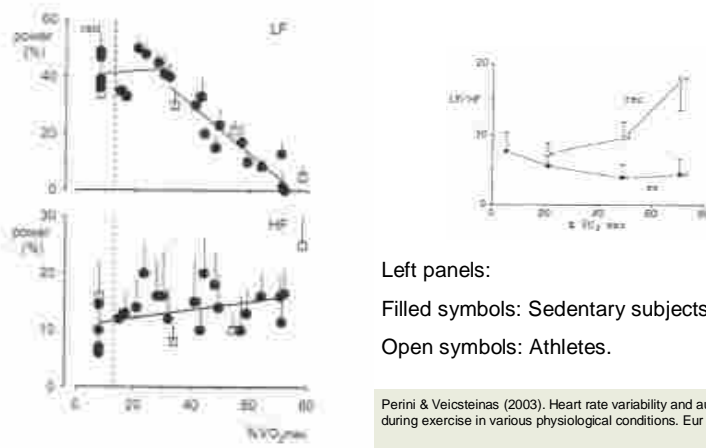
LF/HF = 3.66



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Physical exercise and HRV

"Spectral components do not estimate sympatho-vagal interactions during exercise..." (Perini & Veicsteinas, 2003).



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Physical exercise and HRV

Regulation of HR during exercise depends on:

- Size of the active muscle mass
- Type of exercise (single bout, repeated, static vs. dynamic)
- Intensity of the exercise
- Body position during exercise.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

HRV and gender

Low frequency components of HRV are lower, and high frequency components higher, in women compared men

Crude and adjusted mean values (\pm SD) of LF, HF and total power in men and women.

	Crude			Adjusted for age and heart rate		
	men (n = 149)	women (n = 137)	p value	men (n = 149)	women (n = 137)	p value
LF power, ms ²	5.04 \pm 0.94	4.72 \pm 1.07	<0.01	5.00 \pm 0.92	4.76 \pm 0.92	<0.03
LF as NU, %	67.6 \pm 14.7	58.5 \pm 16.6	<0.0001	67.9 \pm 14.7	58.1 \pm 16.5	<0.0001
HF power, ms ²	4.22 \pm 1.05	4.33 \pm 1.08	0.38	4.17 \pm 0.90	4.39 \pm 0.90	<0.05
HF as NU, %	32.4 \pm 14.7	41.5 \pm 19.6	<0.0001	32.1 \pm 14.6	41.8 \pm 19.6	<0.0001
Total power, ms ²	6.19 \pm 0.83	6.03 \pm 0.89	0.1	6.16 \pm 0.75	6.07 \pm 0.76	0.31

LF power = Area at low frequency (0.04 to <0.15 Hz); HF power = area at high frequency (0.15 to < 0.40); total power = total power spectrum (0.0033 to <0.40 Hz); the values for the areas and total power are naturally log-transformed and expressed in ln ms², NU = normalized units, calculated as the ratio between the power of each component and the total power less the very low component multiplied by 100.

Kuch et al., (2001). Determinants of short-term heart rate variability in the general population. *Cardiol* 95: 131-138.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

HRV and HR, age

LF and HF decrease with HR and age

Regression coefficients (b) and partial R² values of factors related to LF and HF power in forward stepwise regression model

	Men (n = 149)			Women (n = 137)		
	β	partial R ²	p value	β	partial R ²	p value
LF power, ms²						
Heart rate	-0.025	0.08	0.0003	-0.045	0.19	0.0001
BMI	-0.05	0.053	0.003	-	-	-
Age	-0.026	0.026	0.036	-0.032	0.023	0.048
HF power, ms²						
Heart rate	-0.03	0.125	0.0001	-0.07	0.42	0.0001
Age	-0.03	0.038	0.01	-0.029	0.02	0.017
HDL	0.01	0.019	0.07	-	-	-

LF power = Area at low frequency (0.04 to <0.15 Hz); HF power = area at high frequency (0.15 to <0.40); the values for the areas are naturally log-transformed and expressed in ln ms².



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Kuch et al., (2001). Determinants of short-term heart rate variability in the general population. *Cardiol* 95: 131-138.

HRV has a diurnal rhythm

Low frequency components of HRV are lower, and high frequency components higher, at night compared to day

	Day			Night			Day/night difference	
	Mean	Standard deviation	Percentile 05-95	Mean	Standard deviation	Percentile 05-95	Without adjustment for basal HR	With adjustment for basal HR
Heart rate (beats · min ⁻¹)	83.9	10.2	68.2-101.5	65.0	8.6	52.6-80.5	***	/
Time domain HRV								
pNN50 (%)	7.4	7.3	0.3-23.5	17.5	15.5	0.8-49.6	***	ns
rMSSD (ms)	31.5	16.6	13.7-63.4	48.9	29.9	16.6-109.6	***	***
SDANN (ms)	82.9	31.3	44.9-144.7	74.9	33.8	35.9-153.3	***	***
SD (ms)	104.3	33.1	63.1-179.0	110.6	40.1	60.3-196.9	*	***
Freq domain HRV								
tot power (ms ²)	2010	1424	552-4747	2846	2319	607-7247	***	***
LF power (ms ²)	817	572	174-1850	1086	983	191-2881	***	***
ln NU	82.8	8.7	65.6-92.4	74.8	11.9	51.9-89.7	***	***
HF power (ms ²)	187	246	28-619	433	626	37-1368	***	ns
ln NU	17.2	8.7	7.6-34.4	25.2	11.9	10.3-48.1	***	***
LF/HF	6.2	3.5	1.9-12.2	4.0	2.7	1.1-8.7	***	***

For abbreviations see Methods. NU = normalized units. For statistical analysis pNN50, rMSSD, total power, low frequency power, high frequency power, and low frequency/high frequency were transformed to obtain normality, as described in the Methods. Significance of day/night difference: *P<0.05, **P<0.01, ***P<0.005, ns = non-significant.

Raemaker et al. (1998). Heart rate variability and heart rate in health volunteers. *Eur Heart J* 19: 1334-1341.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

5. Examples on research applications of HRV:

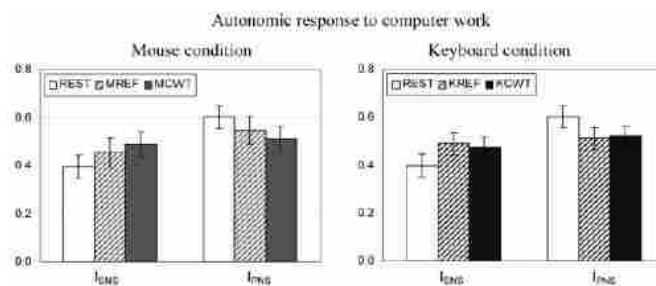
a) Experimental studies of mental load



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

HRV and mental challenge

Increase in LF n.u. and a decrease in HF n.u. during color-word test (CWT) compared to rest condition.



I_{SNS} = LF normalized; I_{PNS} = HF normalized

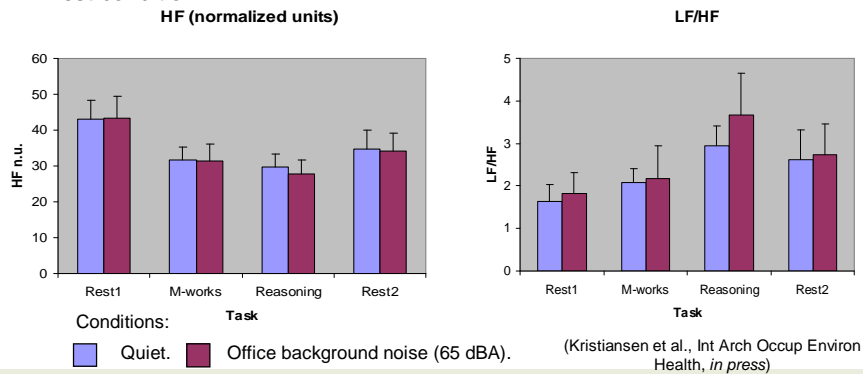
Garde et al. (2002). Effects of mental and physical demands on heart rate variability during computer work. Eur J Appl Physiol 87: 456-461.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

HRV and mental challenge

Decrease in HF n.u. and increase in LF/HF during computerbased drawing task under time pressure (M-works) and logical reasoning task compared to rest condition.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

5. Examples on research applications of HRV:

b) Cardiovascular risk in healthy populations



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

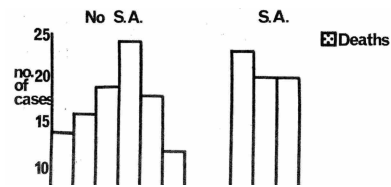
Absence of sinus arrhythmia (SA) associated with increased cardiovascular risk

SINUS ARRHYTHMIA IN ACUTE MYOCARDIAL INFARCTION

M. M. WOLF, M.B., B.S., M.R.A.C.P.,* G. A. VARIGOS, M.B., B.S.,† D. HUNT, M.D., F.R.A.C.P.‡ AND J. G. SLOMAN, F.R.C.P. (EDIN.), F.R.C.P. (LOND.), F.R.A.C.P.§

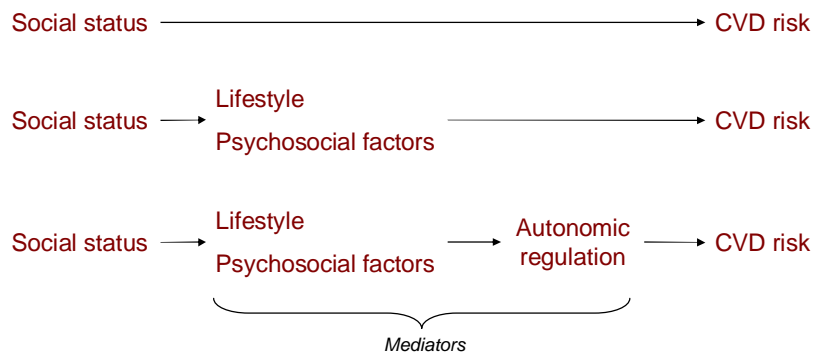
Cardiology Department, The Royal Melbourne Hospital

Med. J. Aust., 1978, 2: 52-53.



NATIONAL RESEARCH CENTRE FOR THE WORKING ENVIRONMENT

Social status and CVD risk



NATIONAL RESEARCH CENTRE FOR THE WORKING ENVIRONMENT

The Whitehall II study

Does Autonomic Function Link Social Position to Coronary Risk? The Whitehall II Study

Harry Hemingway, FRCP; Martin Shipley, MSc; Eric Brunner, PhD; Annie Britton, PhD; Marek Malik; Michael Marmot, FRCP

Circulation 2005; 11: 3071-3077.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

The Whitehall II study

TABLE 2. Behavioral and Psychosocial Factors and Age-Adjusted Means of Heart Rate and HRV

	Participants, n	Heart Rate, bpm	SDNN, ms	LF Power, ms ²	HF Power, ms ²
Behavioral factors					
Current smoker					
No	1991	68.7 (68.2–69.2)	34.5 (33.8–35.1)	332 (319–346)	118 (112–123)
Yes	193	70.6 (69.1–72.2)	31.6 (29.7–33.5)	271 (237–309)	96 (82–112)
<i>P</i>		0.02	0.007	0.004	0.01
Vigorous exercise					
Some	714	66.4 (65.6–67.2)	36.1 (34.9–37.2)	363 (338–389)	131 (121–142)
little / none	1329	70.3 (69.7–70.9)	33.2 (32.4–34.0)	308 (292–324)	108 (102–114)
<i>P</i>		<0.001	<0.001	<0.001	<0.001
High alcohol consumption					
No	1758	68.4 (67.8–68.9)	34.7 (34.0–35.4)	338 (324–353)	121 (116–128)
Yes	391	71.2 (70.1–72.3)	32.0 (30.6–33.4)	278 (253–306)	93 (84–104)
<i>P</i>		<0.001	<0.001	<0.001	<0.001

Values in parentheses are 95% CIs.

*Job control was estimated only in those 1461 participants still working.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

The Whitehall II study

TABLE 2. Behavioral and Psychosocial Factors and Age-Adjusted Means of Heart Rate and HRV (continued from previous slide)

	Participants, n	Heart Rate, bpm	SDNN, ms	LF Power, ms ²	HF Power, ms ²
Behavioral factors					
Poor diet					
No	1610	68.3 (67.7–68.8)	34.6 (33.9–35.4)	336 (321–351)	120 (113–126)
Yes	488	70.9 (69.9–71.9)	33.0 (31.7–34.3)	300 (276–326)	105 (96–116)
<i>P</i>		<0.001	0.03	0.02	0.02
Psychosocial factors					
Depression					
No	1424	68.6 (68.1–69.3)	34.5 (33.8–35.3)	335 (319–351)	119 (112–125)
Yes	701	69.2 (68.4–70.1)	33.6 (32.6–34.7)	313 (292–335)	112 (103–122)
<i>P</i>		0.3	0.18	0.12	0.27
Low social networks					
No	1482	68.5 (67.9–69.1)	34.5 (33.7–35.2)	332 (317–348)	120 (113–127)
Yes	584	69.5 (68.6–70.4)	33.4 (32.3–34.6)	307 (284–331)	107 (98–117)
<i>P</i>		0.07	0.15	0.09	0.03
Low job control*					
No	1190	68.1 (67.5–68.7)	36.3 (35.5–37.2)	379 (360–399)	133 (125–141)
Yes	271	70.8 (69.6–72.1)	33.7 (32.0–35.4)	319 (286–355)	114 (101–130)
<i>P</i>		<0.001	0.006	0.004	0.03

Values in parentheses are 95% CIs.

*Job control was estimated only in those 1461 participants still working.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

The Whitehall II study

Notes on the HRV measurements:

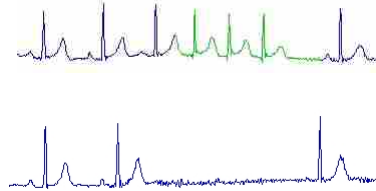
- HRV recordings performed on 2344 men at the screening clinic.
- 5-min recordings sampled at 500 Hz.
- Ectopic beats detected and removed by a mathematical algorithm (automatic).



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Effect of ectopic beats, pauses, artifacts etc.

Examples of common non-sinus rhythms

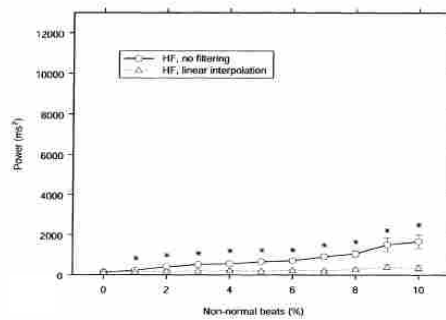


It is necessary to remove such non-sinus beats (pauses) when estimating the spectral power components of HRV!



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Effect of ectopic beats, pauses, artifacts etc.



Group	Definition	n, segments
NN0	0% = non-normal	17319
NN1	0% < non-normal ≤ 1%	5723
NN2	1% < non-normal ≤ 2%	1770
NN3	2% < non-normal ≤ 3%	717
NN4	3% < non-normal ≤ 4%	390
NN5	4% < non-normal ≤ 5%	212
NN6	5% < non-normal ≤ 6%	121
NN7	6% < non-normal ≤ 7%	117
NN8	7% < non-normal ≤ 8%	70
NN9	8% < non-normal ≤ 9%	62
NN10	9% < non-normal ≤ 10%	53

Storck et al., Clin Physiol 2001; 21: 15-21.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

5. Examples on research applications of HRV:

c) Cardiovascular risk in healthy working populations



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Work stress and CVD risk

Effects of Work Stress on Ambulatory Blood Pressure, Heart Rate, and Heart Rate Variability

Tangir G.M., Vrijlkotte, Lorentz J.P., van Doornen, Eco J.C. de Geus

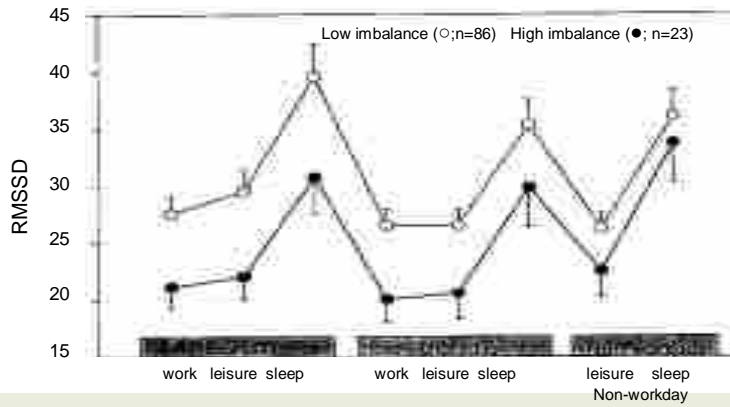
Hypertension 2000; **35**: 880-886.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

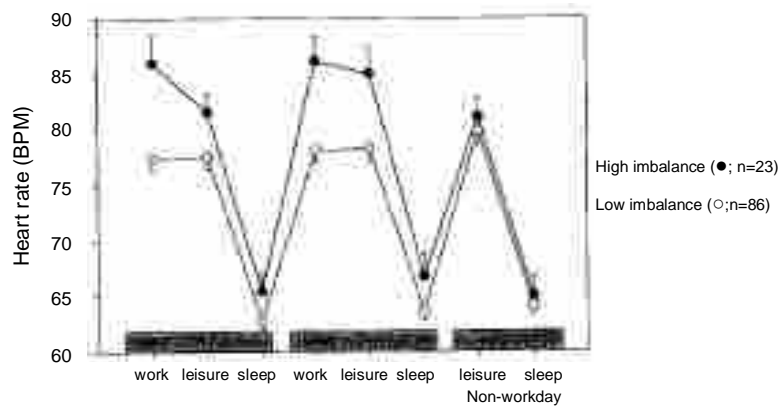
Work stress and HRV

Low RMSSD in white-collar workers with high effort-reward imbalance compared to workers with low imbalance – difference continues on non-workday .



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Work stress and HRV



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Work stress and HRV

Notes on the HRV measurements:

- Ambulatory ECG recordings performed on 109 men.
- RMSSD used to assess vagal tone at work, leisure time, and sleep.
- Diary information used to code for body posture and activity.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Work stress and autonomic regulation

Job Strain and Autonomic Indices of Cardiovascular Disease Risk

Sean M. Collins, PT, ScD, CCS,^{1*} Robert A. Karasek, MD,² and Kevin Costas, MPH²

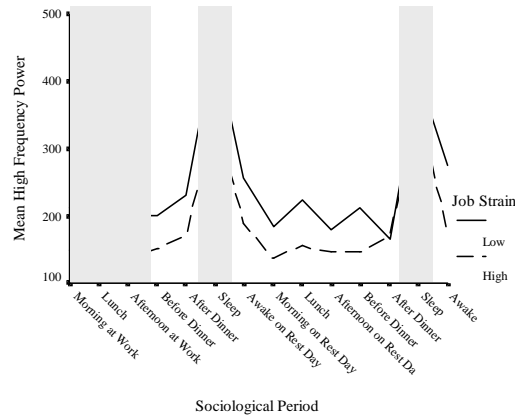
Am J Ind Med 2005; **48**: 182-193.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Work stress and autonomic regulation

HF higher in subjects with low job strain



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

HRV and work-related stress

Sympathetic indices (incl. LF/HF) increase with strain at work but not with overall strain.

TABLE II. Model II Statistics for Sympathetic Variables

Variable	Statistics for sympathetic variables			
	Parameter	Estimate	SE	Sig.
Model I				
QTVI	High strain	0.082	0.105	0.439
	Education	0.004	0.031	0.872
	Age	0.013	0.008	0.129
Lo/hi ratio	High strain	0.205	0.649	0.753
	Education	-0.113	0.209	0.513
	Age	0.139	0.051	0.008
Residual heart rate	High strain	7.46	8.28	0.370
	Education	0.423	2.17	0.812
	Age	0.507	0.639	0.430
Model II				
QTVI	High strain-work	0.278	0.088	0.002
	Education	0.005	0.029	0.866
	Age	0.012	0.008	0.250
Lo/hi ratio	High strain-work	1.58	0.602	0.009
	Education	-0.099	0.179	0.581
	Age	0.142	0.057	0.008
Residual heart rate	High strain-work	68.23	11.69	0.001
	Education	0.415	2.07	0.841
	Age	0.495	0.599	0.410

Repeated measure mixed models procedure using an autoregressive covariance matrix (N = 34).



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

HRV and work-related stress

Notes on the HRV measurements:

- Ambulatory 48-hours ECG recordings performed on 36 men.
- Ectopic beats and artifacts removed by manual screening.
- Spectral components of HRV calculated for 5-min ECG segments (for whole 48-hr recording)
- Diary information used to control for body posture and exertion.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

5. Examples on research applications of HRV:

d) Intervention to reduce stress at work



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Stress reduction (intervention)

Stress Management at the Worksite Reversal of Symptoms Profile and Cardiovascular Dysregulation

Daniela Lucini, Silvano Riva, Paolo Pizzinelli, Maurizio Pagani

Hypertension 2007; **49**: 291-297.

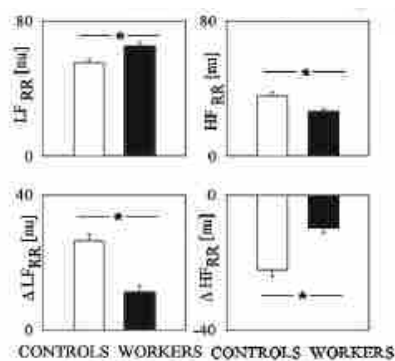


NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Stress reduction (intervention)

White-collar workers in company during downsizing (n=91) and controls (n=79).

Average values for LF and HF at rest and standing induced changes.



Average value (and SEM) of LF_{RR} (left top) and HF_{RR} (right top) at rest and of standing-induced changes of low (ΔLF_{RR}, left bottom) and high (ΔHF_{RR}, right bottom) frequency in control subjects (□) as compared with workers (■). nu indicates normalized units. *P<0.001.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Stress reduction (intervention)

White-collar workers in company during downsizing (n=51). Effect of a stress-management program (SMP, n=26) versus sham program (SP=25).

TABLE 5. Descriptive Statistics of Resting Values of RR Interval Variability in SPM and SP Groups

Group	RR, ms	VAR _{RR} , ms ²	LF		HF		LF/HF*	Respiratory Frequency, Hz	SAP, mm Hg†	DAP, mm Hg
			ms ²	nu [‡]	ms ²	nu [‡]				
SMP										
Before	924±36	2480±369	869±151	93.8±3.0	398±83	30.1±3.4	4.7±1.5	0.26±0.02	121.7±4.1	78.5±2.2
After	947±26	2177±235	592±99	49.3±3.1†	484±78	38.9±3.0†	1.8±0.4†	0.23±0.01	114.1±3.3†	76.7±2.1
SP										
Before	879±36	2871±948	799±237	61.6±3.3	387±135	28.3±3.1	3.4±0.6	0.26±0.01	118.3±3.8	77.0±2.4
After	899±29	2238±289	767±153	58.9±4.0	324±77	33.9±4.7	4.0±0.8	0.28±0.01	125.3±4.2	78.0±2.7

RR indicates RR interval; VAR_{RR}, RR variances; LF, low-frequency component; HF, high-frequency component; LF/HF, ratio between low- and high-frequency components; SAP, systolic arterial pressure; DAP, diastolic arterial pressure; nu, normalized units.

*Significant interaction.

†Significant differences at $P < 0.001$.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Stress reduction (intervention)

Notes on the HRV measurements:

- 5-10 min ECG recordings performed on 170 men at the worksite (workers) or at home or at the clinic (controls).
- Standing induced changes in HRV used to assess autonomic reactivity.
- Spectral components of HRV calculated for 5-min ECG segments.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Summary - I

- HRV can be applied in both laboratory and field studies.
- Ambulatory measurements and measurements performed in work places or at home are feasible.
- HRV can be measured in the awake state or in the sleep.
- HRV have been applied succesfully in studies of psychosocial factors, including workplace stress.
- HRV (or certain HRV metrics) are generally accepted as associated with CVD risk.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Summary - II

- Time domain metrics can be used for long-term recordings, frequency domain metrics for short term recordings.
- Time domain metrics more robust to the influence of ectopic beats, pauses, artifacts, etc., but are more difficult to interpret physiologically.
- Frequency domain HRV metrics can be interpreted physiologically, but ECG needs careful screening before analysis.



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Summary - III

- HRV (and derived metrics) are extremely sensitive to
 - Body posture
 - Mental activity
- HRV (and derived metrics) also depends on
 - Age, BMI, sex, physical fitness, and other lifestyle factors
- It is advisable to address the effects of these variables in the study design



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT

Thank you for your
attention!



NATIONAL RESEARCH CENTRE
FOR THE WORKING ENVIRONMENT