

Psychosocial Workplace Factors And Physiological Mechanisms Affecting The Cardiovascular System

Session # 3 Hour 1

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Cardiovascular Changes Associated With Exposure to Work Stressors

- ↑ workplace blood pressure (BP)
- Sustained elevations in BP
- ↑ left ventricular mass

Strongest direct evidence

Cardiovascular Changes Likely Associated With Exposure to Work Stressors

- Arteriosclerosis

Adverse metabolic responses (glucose intolerance, adverse lipid profile), ↑ fibrinogen

- Changes in heart rate (HR)

(↑ HR, diminished HR variability, sometimes ↓ HR)

Cardiovascular Changes Possibly Associated With Exposure to Work Stressors

- Myocardial ischemia

Compromised O₂ balance in the myocardium

- Compromise to cardiac electrical stability
- Triggering of acute cardiac events

The Classical Defense Response

- Activated when called upon to actively cope with a challenge or stressor
- Prepares the organism for a physical response: "Fight or Flight"
- Phylogenetically very old

Physiological components of the Defense Response

- Cognitive:
 - Increased Alertness
 - Rapid Assessment of the situation
 - Rapid decision-making

- Metabolic – Energy Mobilization:
 - Increased blood glucose
 - Increased blood lipids
 - Inhibition of anabolism

Physiological components of the Defense Response (contd.)

- Hemodynamic:

- Activation of the cardiovascular system, with blood flow directed to the heart, skeletal muscles and the brain
- Fluid and sodium retention by the kidney to maintain blood volume
- Coagulation promoted to prevent excessive bleeding with potential injury

These responses are mediated by activation of the SP nervous system, activation of sympathoadreno-medullary system (catecholamine), as well as the hypothalamic-pituitary-adrenocortical system (glucocorticoids). These, in turn, act on other hormonal systems.

The Classical Defense Response to Modern-Day Stressors?

- Many of today's stressors are likely to be chronically present rather than acute
- A physical response (fighting or running away) is rarely, if ever, called for

Key Question:

Is active coping possible and does it lead to resolution?

(Recall the Active Quadrant of the JSM)

The Gazelle versus ”Civilized” Humans

- **Auditory warning signal**
= hearing the predator
(*Acute danger*)
 - **Immediate**
neuroendocrine & CV
preparation
 - **Visual imperative signal**
= the predator coming
close
 - **The gazelle’s response**
= ”all-out flight”
 - **Return to physiologic
baseline**
- **Visual signals often**
predominate (*Threat
often implicit, but
continuous*)
 - **Lower grade, chronic**
neuroendocrine & CV
preparation
 - **Minimal flight or fight
response**
 - **Chronic state of**
”visceral –vascular
readiness”

Vigilance Response

- Active coping downplayed—watching and waiting
- Slowed: HR, breathing, metabolism
(energy conserved)
- Blood vessels constrict--↓ blood flow to skeletal muscles
- Provoked by: noxious or symbolically threatening stimuli, defeat, hopelessness
- Neuroanatomically distinct from the Defense Response

Defense and Defeat

- "The ancient 'defense' and 'defeat' reactions, intended for quite different situations, are often activated by the artificial stimuli and symbolic threats inherent in today's hectic and competitive life." (*Folkow 1994*)
- Frequent shifts between defense and defeat
- Activation of Sympathoadrenal medullary and hypothalamic-pituitary-adrenocortical axes

How can Work Stressors lead to ↑BP & Hypertension (1)?

I (a). The Defense Response: Acute CV Reaction

↑ HR, ↑ stroke volume (*the heart beats hard and fast*)

↑ Blood flow to skeletal muscles, heart & brain

↓ Blood flow to kidneys, ↓ Na excretion (↑ blood volume)

Overall effect = Reversible ↑ BP (mainly systolic)

Preparation for Fight or Flight

How can Work Stressors lead to ↑BP & Hypertension (2)?

I (b): The Defense Response & Sustained ↑ BP

(i) Prolonged, repeated defense response without physical activity: No skeletal muscle vasodilatation

(ii) Sustained ↑ sympathetic outflow (+ angiotensin, insulin)
→ thickening of blood vessel walls

(i) & (ii) → **Sustained ↑ BP** (especially diastolic) →

The heart beats against resistance → ↑ heart mass → further
↑ BP & ↑ risk of cardiac events

How can Work Stressors lead to ↑BP & Hypertension (3)?

II. The Defeat Reaction

- Activation of the hypothalamic-pituitary adrenocortical axis → ↑ glucocorticoids → direct pressor effects + potentiation of sympathetic effects on BP
- Possible relation to the vigilance response → vasoconstriction

Less empirical evidence for all the links in this pathway in relation to workplace stressors

How can Work Stressors lead to ↑ BP & Hypertension (4)?

III. Defense + Defeat (Effort-Distress Model)

--Monotonous, vigilance task →

↑ epinephrine & ↑ cortisol excretion

--Task requiring effort and low control

↑ epinephrine & ↑ cortisol excretion & ↑ BP (diastolic)

Laboratory studies—Note similarity to Job Strain Model

Job strain and Sustained \uparrow BP

- For work stress to contribute to a tonic \uparrow BP, the blood pressure of the exposed individual would have to be \uparrow not only in the presence of a stressor but also during rest.
- Job Strain=Low- or moderate-grade stress, usually present over longer periods of time
- Exposure to job strain is associated with \uparrow BP not only during work, but also at home and, in some studies, during sleep

Summary of Statistically Significant ($p < .05$) Findings from the Work Site BP Study on Job Strain* and Ambulatory BP**

<u>Design</u>	<u>Wave</u>	<u>AmBP</u>	<u>Location</u>	<u>Effect Size (mm Hg)</u>	
<u>Cross- Sectional</u>	1 (n=264)	<u>SBP</u>	<u>work</u>	<u>+6.8</u>	
		DBP	work	+2.8	
		<u>SBP</u>	<u>home</u>	<u>+6.5</u>	
			<u>SBP</u>	<u>sleep</u>	<u>+6.2</u>
	2 (n=195)	SBP	work	+6.4	
		DBP	work	+5.0	
		SBP	home	+6.9	
		DBP	home	+4.9	
		SBP	sleep	+5.0	
<u>Longitudinal</u> Repeated exposure (job strain at both Time 1 and 2)	1 & 2	SBP	work	+11.1	
		DBP	work	+9.1	
		SBP	home	+11.1	
		DBP	home	+7.3	
		SBP	sleep	+10.8	
Change in exposure *** (job strain at T1 to no strain at T2)		SBP	work	-5.3	
		DBP	work	-3.2	
		SBP	home	-4.7	
		DBP	home	-3.3	

Atherogenesis & Stress Mechanisms(1)

Early Stages:

Endothelial damage

- Animal studies of social stress
- Hypertension → ↑ shear stress at branch points

Lipoprotein incorporation into plaque-- ↑ LDL cholesterol

- Animal studies of behavioral stress
- Some human "naturalistic" studies: academic exams
- Effort-Reward imbalance (job strain data not consistent)

Social Status and Coronary Artery Atherosclerosis in Female Monkeys

Initial social Status	Manipulated Social Status	Total Cholesterol/ HDL	Coronary Artery Plaque Area
Dominant	Dominant	7.0	0.03
	Subordinate	9.1	0.19
Subordinate	Dominant	8.0	0.09
	Subordinate	7.9	0.04

 Shively CA, Clarkson TB. *Arterioscler Thromb* 1994.

Atherogenesis & Stress Mechanisms(2)

Later Stages (thrombogenesis) :

↑ *Fibrinogen* (converted to fibrin=major constituent of thrombi, ↑ platelet aggregation, ↑ blood viscosity)

Increased fibrinogen linked to:

- Low socioeconomic status
- Low control over work
- Effort reward imbalance

Platelets and Acute Cardiac Syndromes

Activated platelets appear to play a key role in acute cardiac syndromes

(adhere to damaged endothelium, their cytokines stimulate cell proliferation, recruit further platelets into thrombi)

--Platelet activation in CHD patients associated with hostility & generally increased with emotional stress

--No direct data in relation to work stressors, as yet

Assessment of Atherosclerosis in Epidemiologic Studies: Carotid Ultrasound

- Carotid intima-medial wall thickness and plaque can be measured *non-invasively* with high resolution carotid ultrasound
- Appropriate method for population screening
- ↑ progression carotid atherosclerosis over 4 year in Finnish men with high demands and low economic rewards (Lynch 1997)

Heart Rate Variability (HRV)

- Definition: Beat-to-beat oscillations in the heart rate.
- The major determinant of the fluctuations between consecutive heart beats is the respiratory cycle.
(Respiratory sinus arrhythmia)
- Appears to reflect Parasympathetic outflow

HRV Analysis and Example

Time Domain: Sd of the normal sinus (N-N) intervals in all 5-minute segments, and other methods

Frequency Domain (Power spectral analysis):

High frequency component

(0.15 - 0.4 Hz) = Respiratory sinus arrhythmia (RSA)

Low frequency component (0.04 - 0.15 Hz)

RSA:

- P. 433 Friedman 1977

Prognostic Significance of Depressed HRV

Significant independent predictor of:

- Incident coronary heart disease
- Arrhythmia-related death after myocardial infarction

Depressed HRV and Environmental Stressors:

- Heavy mental workload
(A key physiologic indicator in cognitive ergonomics research)
- Can occur with long work hours, shift work
- Recent evidence of association with exposure to job strain or high noise levels (Van Amelsvoort 2000)

Myocardial Ischemia

↑ Myocardial O₂ Demand:

- ↑ HR
- ↑ BP
- ↑ Myocardial contractility
- ↑ Left ventricular mass

↓ O₂ Supply to Myocardium

- ↓ Coronary blood flow
 - Coronary artery disease
 - Coronary artery spasm
 - ↑ blood viscosity
 - ↑ Left ventricular mass (compressed intramyocardial vessels)
- ↓ O₂ content of blood (CO exposure)

Myocardial Ischemia & Mental Stress

- 18 participants with single-vessel coronary artery disease
- Recall of an incident which elicited anger
- Evoked a greater \downarrow in ejection fraction (EF) than exercise
- (\downarrow EF = \downarrow pumping action of the heart ventricle, a consequence of myocardial ischemia)
- -----
- Ironson G et al. Am J Cardiol 1992.

Stress-Mediated Mechanisms of Cardiac Electrical Destabilization

- Sympathetic Overdrive

↑ automaticity, ↑ triggered activity, reentry, catecholamine damage

- Other Autonomic Imbalances

PSP versus SP, R versus L sympathetic ganglia

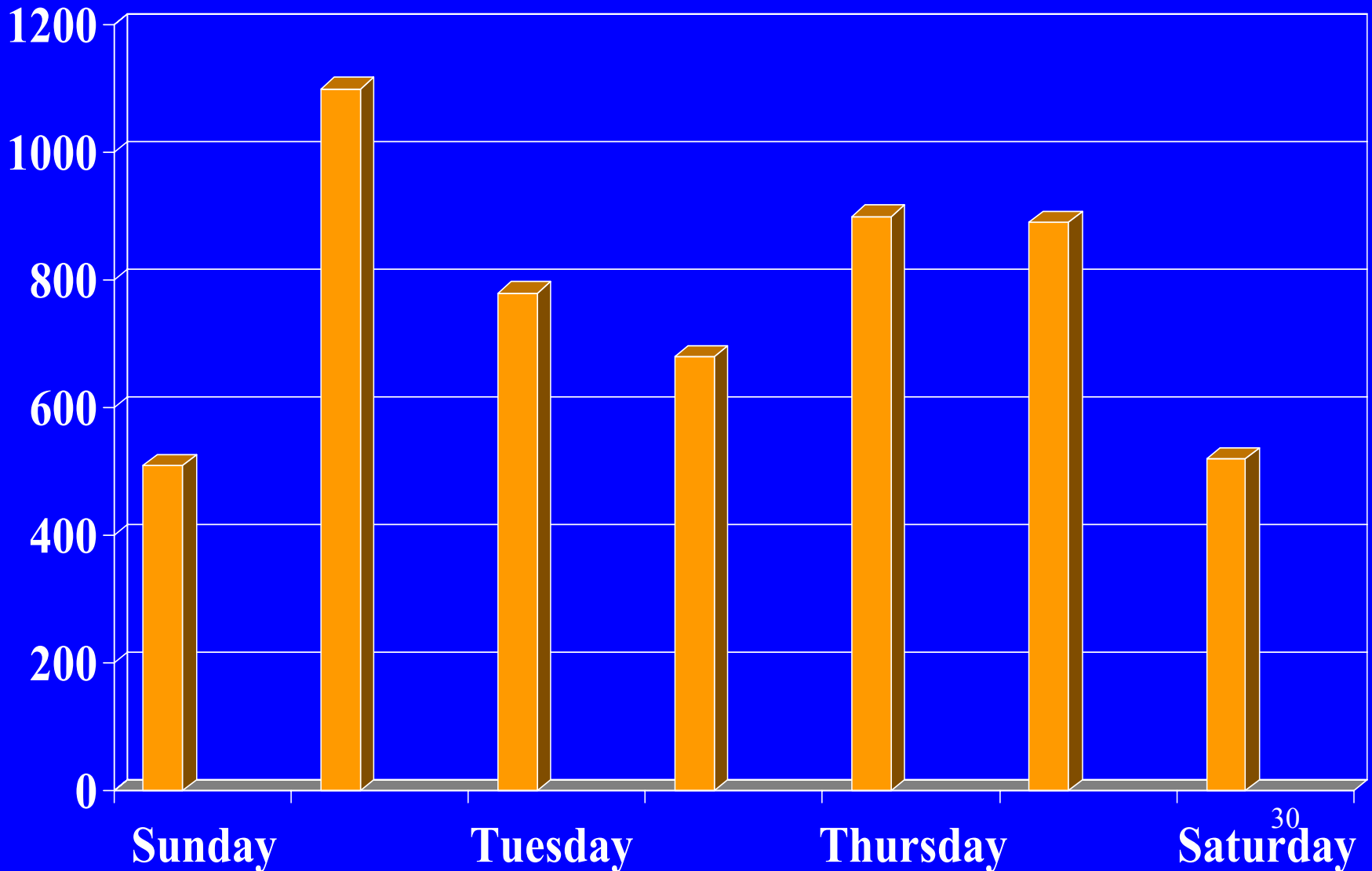
- Increased Left Ventricular Mass

↑ automaticity, ↑ early & late triggering, reentry

- Acute Myocardial Ischemia

Acidosis → ↑ automaticity, slowed conduction → reentry,
Reflex sympathetic overdrive

Septadian Distribution of Life-threatening Arrhythmias (AICD activation) Peters et al. (1996)



Work versus non-work BP

It is estimated that systolic BP is approximately 4-5 mm higher on work days compared to non-work days.

Yet, blood pressure is most commonly measured outside work, in the clinic situation ("Casual Clinic BP")

Occult Workplace Hypertension

Classification of Hypertension using Casual BP versus Ambulatory BP in a Sample of Working Men in New York City*

Casual Diastolic BP taken at the Work Site Clinic	Work Site Diastolic BP Ambulatory		Total (N)
	>85mmHg (N)	<= 85mmHg (N)	
>85mmHg	59	27	86
<= 85mmHg	<u>36</u>	145	181
Total	95	172	267

Clinical Implications of Misclassification

Type I errors: False positives

– (*white coat hypertension*)

Unnecessary treatment

Type II errors: False negatives

–(*Occult workplace hypertension*)

Failure to treat individuals at high risk with
elevated worksite blood pressure

Ambulatory BP monitoring

- Advantages

Naturalistic setting—sampling of "real world" situations

Accuracy: No observer bias, no white coat effect

Large number of readings

Very reliable averages

Enhanced predictive validity

- Disadvantages

Naturalistic setting, uncontrolled circumstances

Lower precision of each individual reading

Logistics--inconvenience

Expense

Ambulatory Monitoring of the Work Environment

- Method of choice
- Allows assessment of
 - the effect of chronic and acute occupational stressors upon BP
 - the additive burden of multiple exposures
- Note that results can be *acutely* affected by physical activity and position, mood, psychological state, non-work related occurrences

AmBP in Male City Bus Drivers

	Drivers (N=15) Split Shift	Significance	Referents (Day shift)(N=20)
<u>Systolic BP</u>			
3:00-7:00	119.9 ± 12.2	**	109.3 ± 5.3
12:00-15:00	134.3 ± 5.2	***	126.7 ± 4.8
<u>Diastolic BP</u>			
3:00 – 7:00	66.4 ± 5.3	**	61.0 ± 5.5
12:00-15:00	89.4 ± 5.2	***	83.9 ± 5.4
<u>Systolic BP</u>			
13:00 – 15:00	133.2 ± 4.8	***	127.1 ± 4.3
20:00 – 24:00	116.6 ± 8.3	**	108.9 ± 8.1
<u>Diastolic BP</u>			
13:00 – 15:00	89.1 ± 5.7	**	83.8 ± 5.1
20:00 – 24:00	73.8 ± 6.0	**	66.7 ± 6.2

Worksite Point Estimates of BP

- Potential alternative to AmBP
- Suitable for workplace surveillance
(more feasible for monitoring large numbers of working people)
- An observer measures the subject's BP with minimum interruption of work.
- A protocol has been developed and is being tested

Assessment of CV function at work

- AmBP and Amb ECG (Holter) monitoring
Integrated assessment of multiple parameters
Potential for detecting trigger mechanisms.

Example:

Acute stressor →

↓ HRV + ↑BP + ↑HR →

Silent myocardial ischemia (↓ST segment) →

Complex ventricular arrhythmias

Laboratory Monitoring

- Controlled environment
- Possibilities for sophisticated physiologic study
(multiple channels-EEG, ECG, BP, digital plethysmography, Oximetry, etc.)

**The paradigm should be
"ecologically relevant"
for the occupational group**

The Occupational Psychosocial Interview

- "Personally relevant mental stress"
- In 10 young male blue collar workers, discussion of stressful workplace events → + 12.4 / +15.1 ↑ in BP
- In a patient who had suffered an acute myocardial infarction → ventricular tachycardia

The Glare Pressor Test

Intermittent Exposure to headlight glare impulses

Elicits Among male Professional Drivers (N=15)

- Desynchronization of the Electroencephalogram (Cortical arousal)**
- Significant \uparrow in diastolic blood pressure,**
- Significant \downarrow in Digital Pulse amplitude (peripheral vasoconstriction)**
- Ventricular arrhythmias in some cases**

No significant physiologic changes found in referents who had no driving experience whatsoever

“These results indicate that drivers show cardiovascular hyperreactivity to the GPT, with strong central arousal as expected during night driving when an on-coming headlight can represent impending danger and the need for accurate and timely responses to avoid a collision”

Work stressors & Untoward CV Changes

Empirical Evidence(1)

- Job strain:
 - ↑ AmBP, ↑ LV mass, adverse HRV profile, ↑ fibrinogen (low control), ↓fibrinolysis (high demands)
- Effort-Reward Imbalance:
 - ↑ AmBP, ↑ BP + adverse lipid profile, ↑ fibrinogen, adverse HRV profile, progression of atherosclerosis

Work stressors & Untoward CV Changes

Empirical Evidence(2)

- Long work hours:

↑ AmBP, adverse HRV profile

- Shift work:

Adverse AmBP & HRV profile, ↑ BP

Work stressors & Untoward CV Changes

Empirical Evidence(3)

- Threat Avoidant Vigilance

Adverse HRV profile, cardiac electrical instability (experimental animal data), ↑ BP (indirect data from human laboratory studies)

Work stressors & Untoward CV Changes

Empirical Evidence(4)

Physical Noxins:

- Noise*: ↑ AmBP, myocardial ischemia
- Heavy lifting*: ↑ BP, cardiac arrhythmias
- Glare*: ↑ BP, cardiac arrhythmias (drivers)
- Cold*: ↑ BP, myocardial ischemia (vasospasm)
- Heat*: ↑ HR, myocardial ischemia
- Vibration*: vasoconstriction

Work stressors & Untoward CV Changes

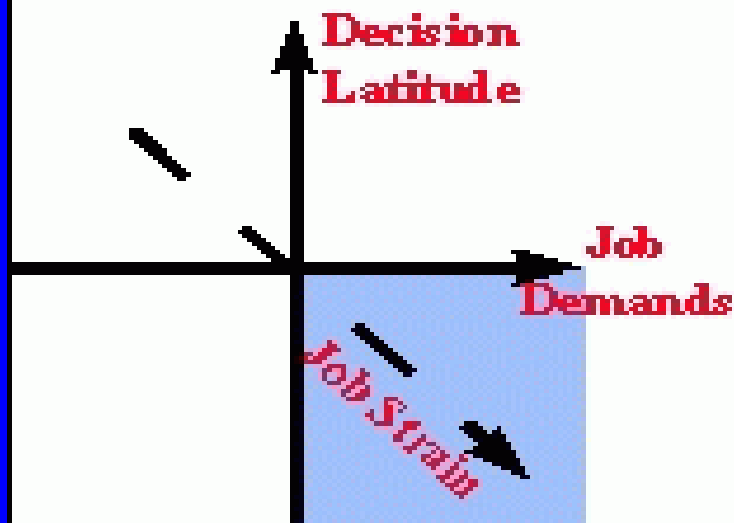
Empirical Evidence(5)

- Chemical Noxins:

- Carbon monoxide*: myocardial ischemia, ↓ cardiac electrical stability
- Lead*: ↑ BP, adverse HRV profile
- Halogenated organic solvents*: ↓ cardiac electrical stability
- Nitrate esters*: sudden cardiac death (acute re-exposure)

Comparison of Karasek and Frankenhaeuser Models

Karasek Model



jeanluc.doc

Frankenhaeuser Model

