

Blood Pressure in Exercise

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Conflicts of Interests

Institutional

- Contribution to clinical trials: Actelion, Medtronic, Edwards, Occlutech, Novartis, Lilly
- Unrestricted grants for investigator initiated trials: Pfizer, GlaxoSmithKline, Abbott, Actelion

Private

- Shareholder: Celgene, Gilead, Vertex, Abbvie, Pfizer, Novartis, Johnson & Johnson, Amgen, Cerner, Lilly, Baxter, Merck, Biogen, ...
- Advisory board reimbursement: Actelion
- Speakers reimbursement: Schiller, Actelion, Abbott, Pfizer, Encysive, AOP Orphan, OMT, GlaxoSmithKline, Medtronic
- Travel expense reimbursement: Pfizer, GlaxoSmithKline, AOP Orphan Pharmaceuticals, Lilly, Actelion, Medtronic, Arrows, Guidant, Fresenius

Measurement

Manual measurement

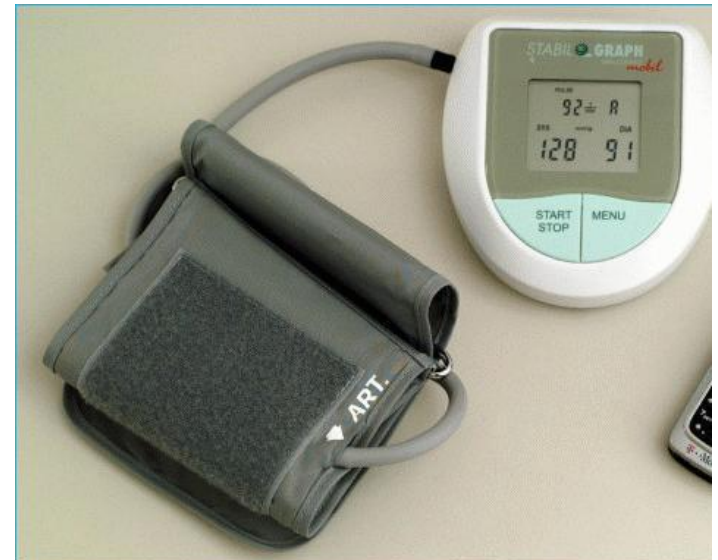
- „gold standard“
- Korotkoff I and IV/V (?)
- easy on ergometer
- takes time
- takes attention
- not on the treadmill



Measurement

Oscillatory measurement

- many artifacts from muscle work and movement



Measurement

Automatic acoustic measurement

- Many artifacts from ergometer or treadmill



Measurement

EKG triggered acoustic measurement

- Evaluated algorithm
- Reliable values on the ergometer and even on the treadmill (?)
- very expensive
- the only reliable alternative for invasive or manual measurements



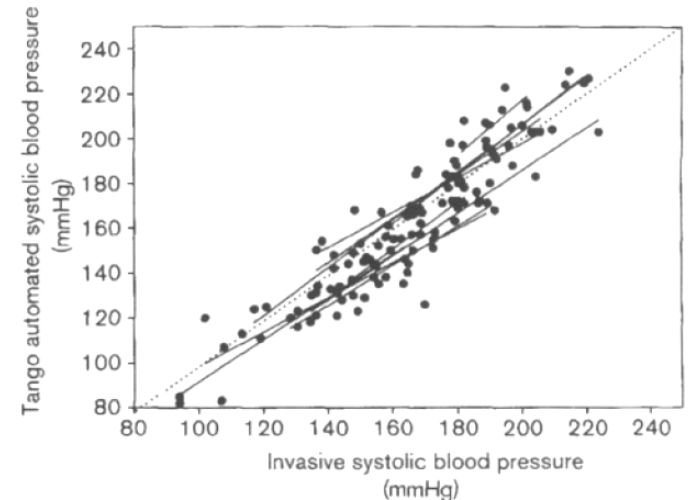
Measurement



Invasive vs. non-invasive BP

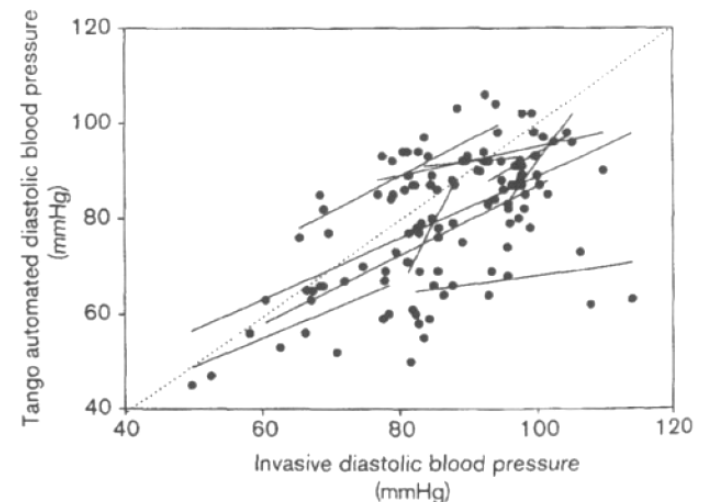
SBP

Variability within
acceptable range
for rough surveillance
($>5\text{mmHg}$ in 48%)



DBP

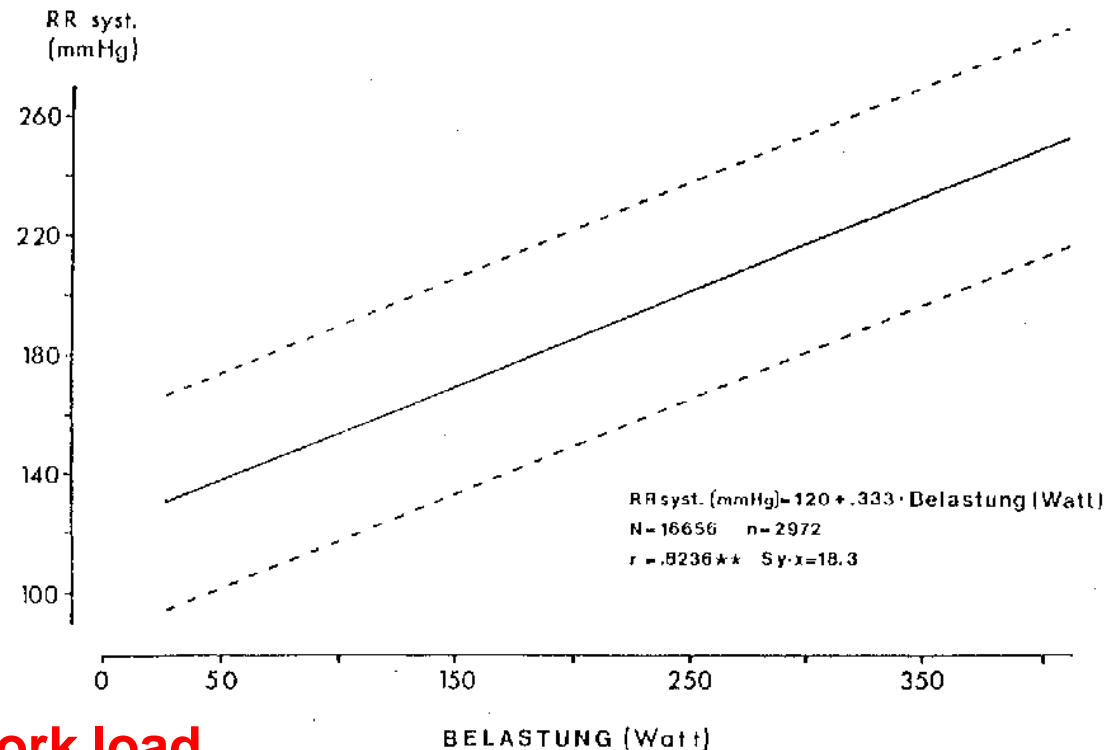
fairly high variability



Reference Values

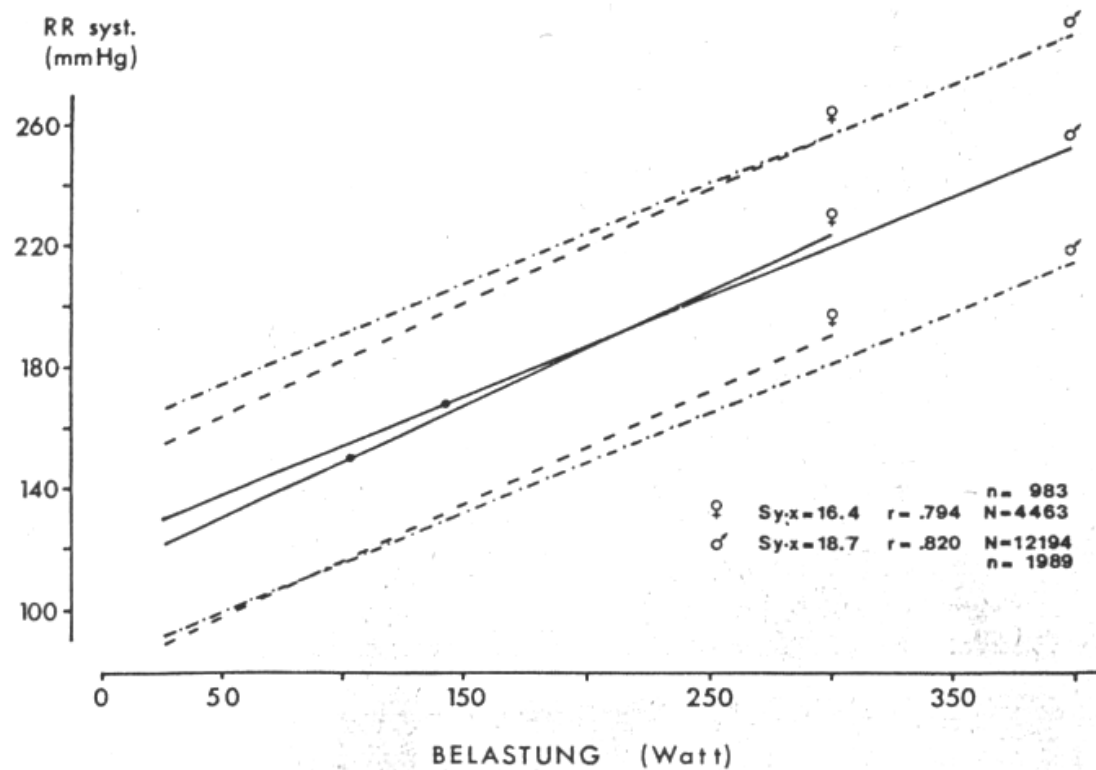
Regression

- 2972 subjects
- 16656 measurements
- $r = 0.824$

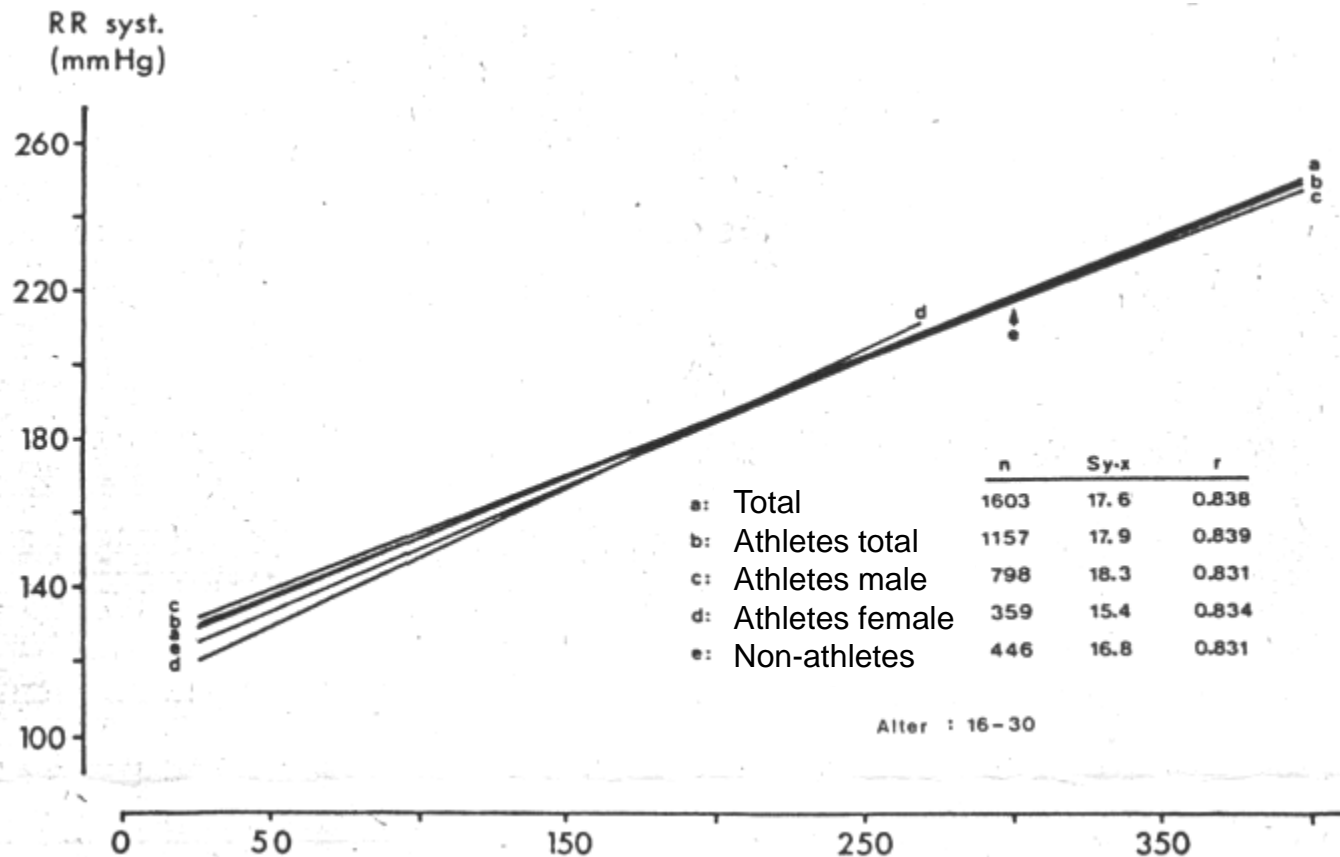


- **$SBP = 120 + 0.333 \cdot \text{work load}$**
- $SD \pm 18 \text{ mmHG}$

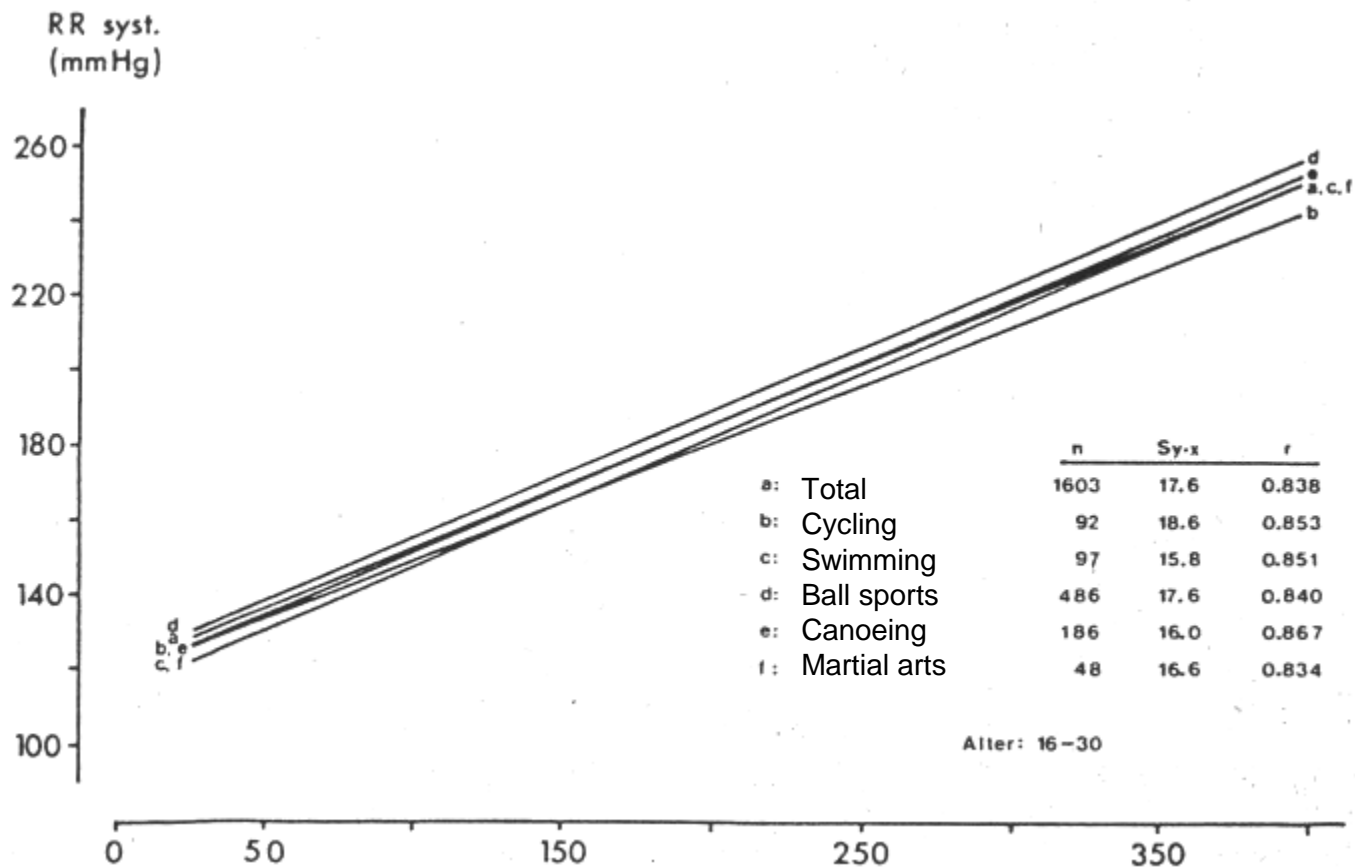
Not depending on sex?



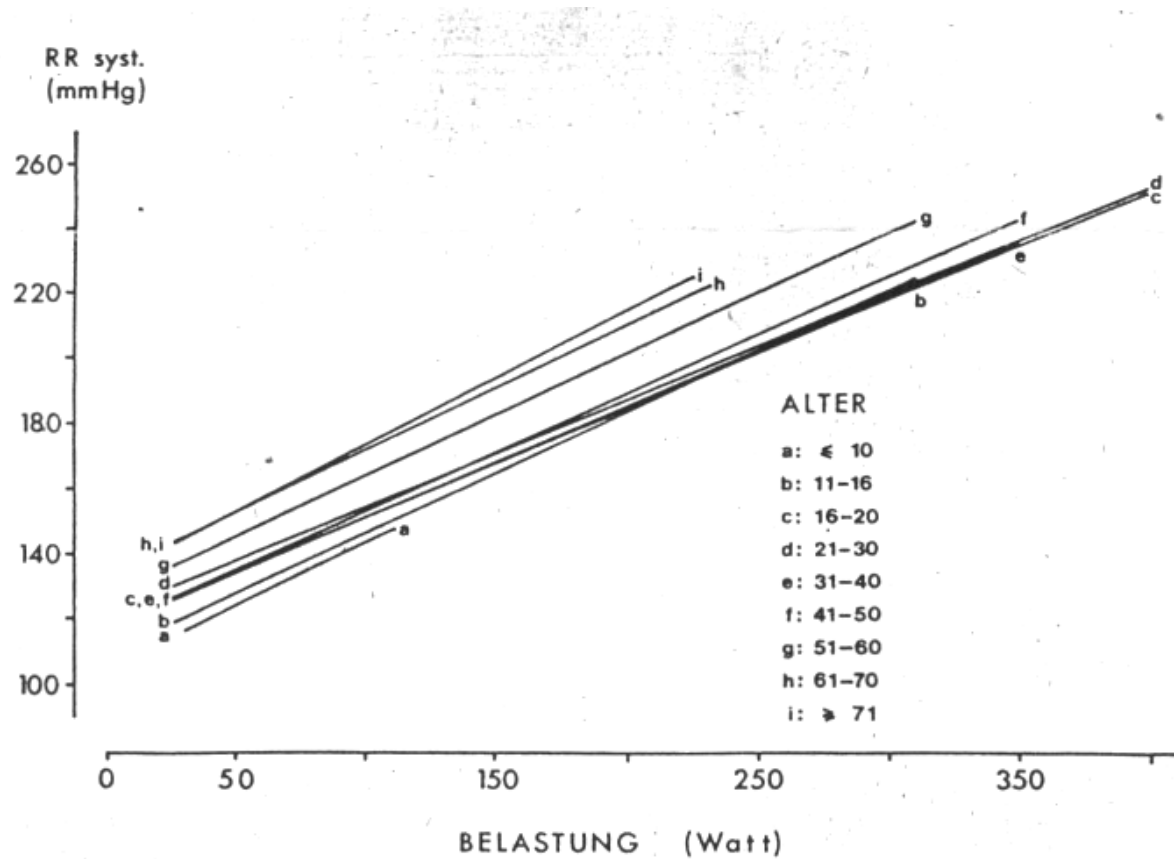
Trained versus non-trained



Type of sport?



Depending on age!

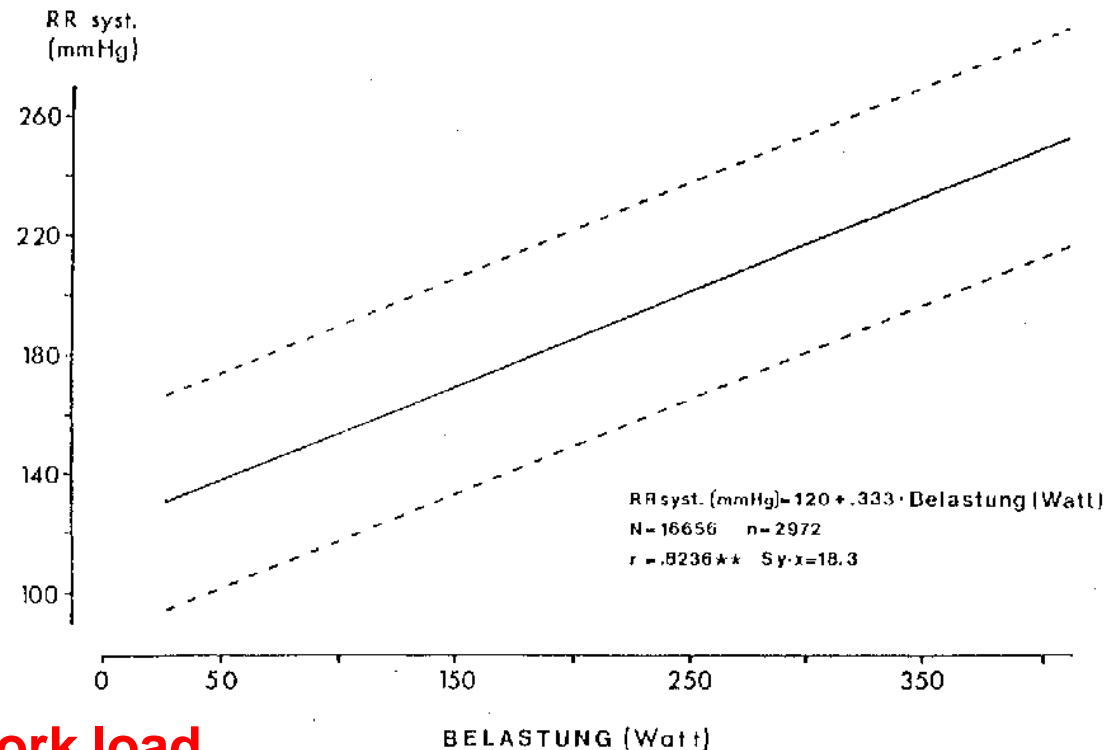


$$\text{SBP} = 111.2 + 0.334 \cdot \text{work load} + 0.310 \cdot \text{age} \pm 17.9 \text{ mmHg}$$

Reference Values

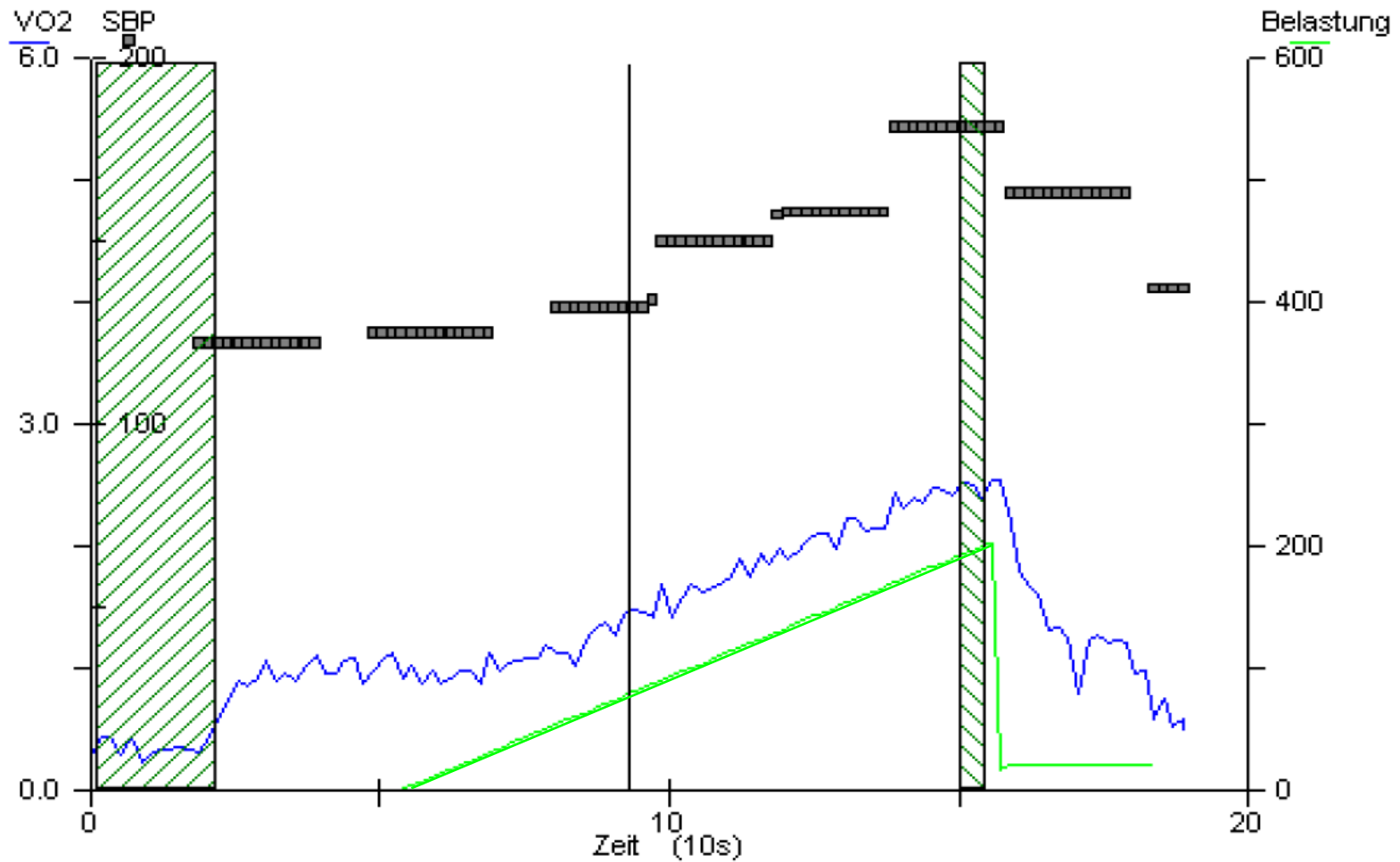
Regression

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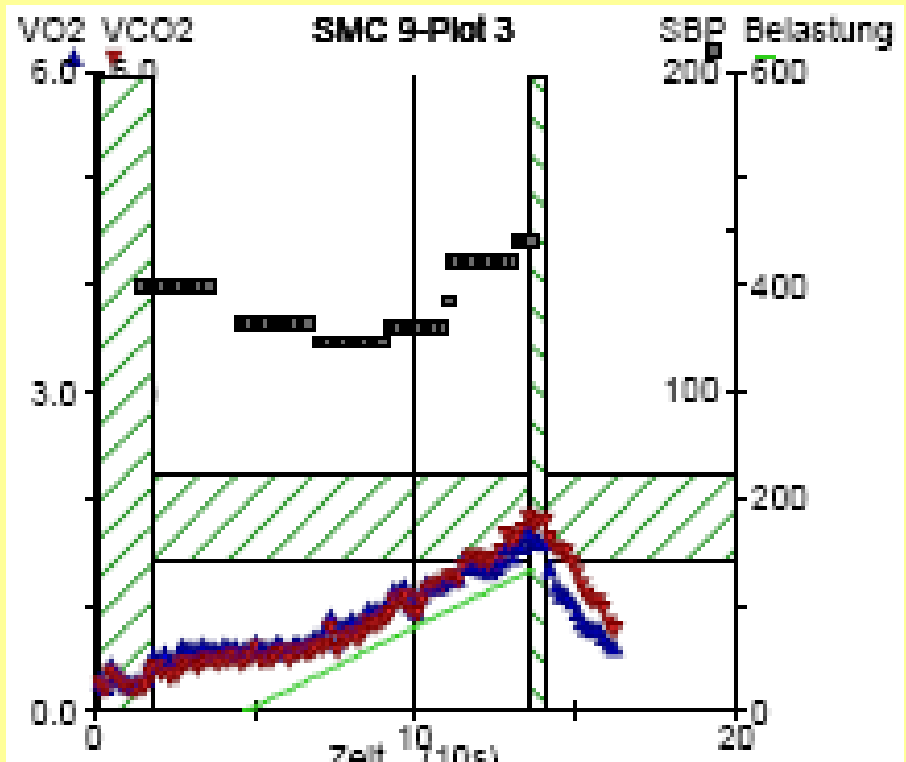
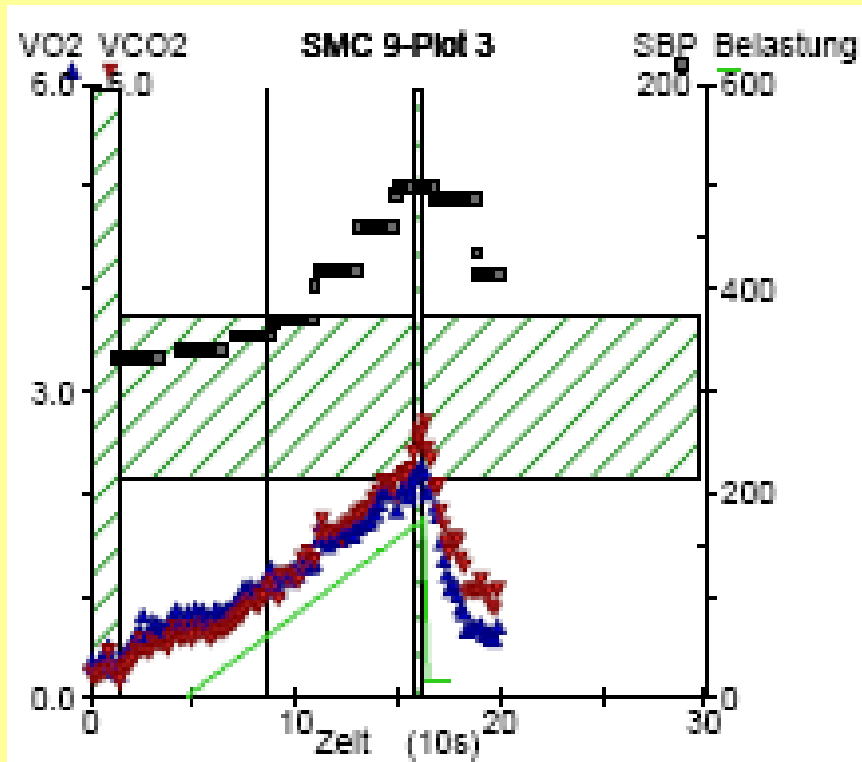


- **SBP = 120 + 0.333 · work load**
- **SD ± 18 mmHg**

SBP in Panel 1



Normal SBP at Exercise



Exercise Hypertension

BP_{mean} = cardiac output · vascular resistance

$BP_{\text{amplitude}}$ = stroke volume · aortic compliance

Exercise Hypertension

- (congenital) aortic coarctation
- (congenital) mid aortic syndrome
- peripheral vascular disease

- early arteriosclerosis
(early sign of hypertension in future)

Prognostic Value

Circulation
JOURNAL OF THE AMERICAN HEART ASSOCIATION

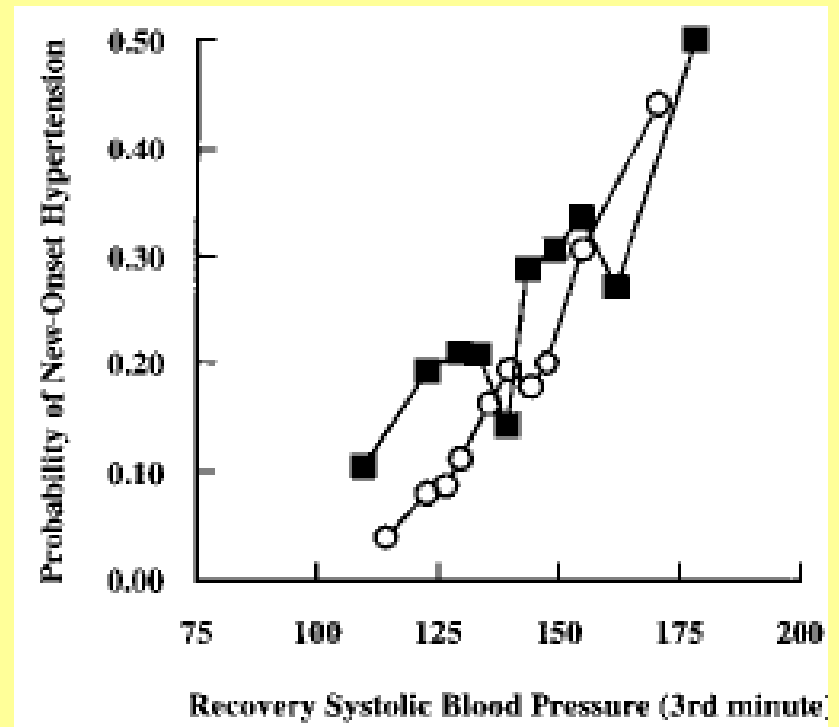
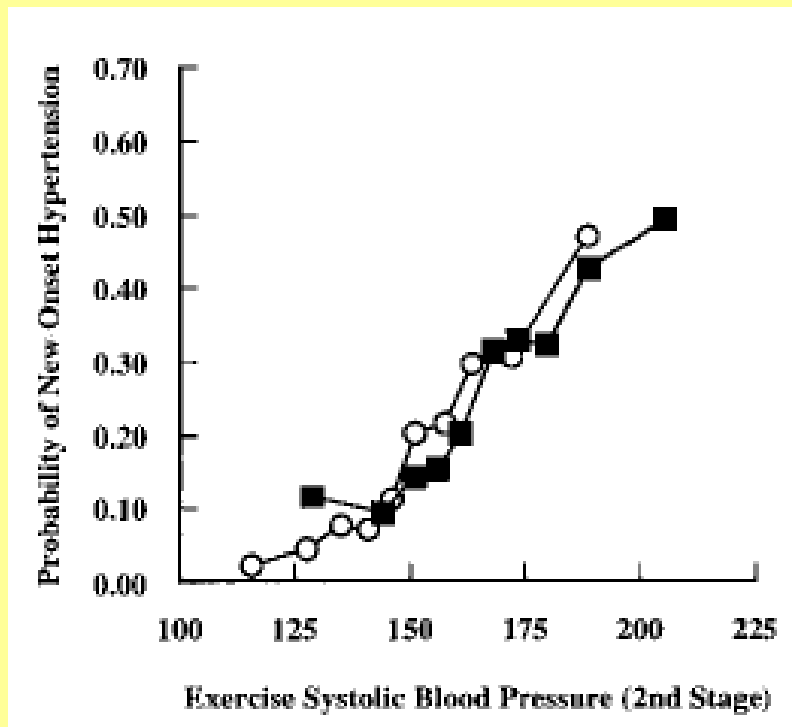


Blood Pressure Response During Treadmill Testing as a Risk Factor for New-Onset Hypertension : The Framingham Heart Study

Jagmeet P. Singh, Martin G. Larson, Teri A. Manolio, Christopher J. O'Donnell, Michael Lauer, Jane C. Evans and Daniel Levy

- n = 2310, 42.1 ± 9.3 years
- normotensive
- treadmill Bruce protocol
- SBP at step 2 (4 km/h, 12%) and 3 min. after exercise
- 8 years Follow-up

Prognostic Value



Prognostic Value

Hypertension

JOURNAL OF THE AMERICAN HEART ASSOCIATION



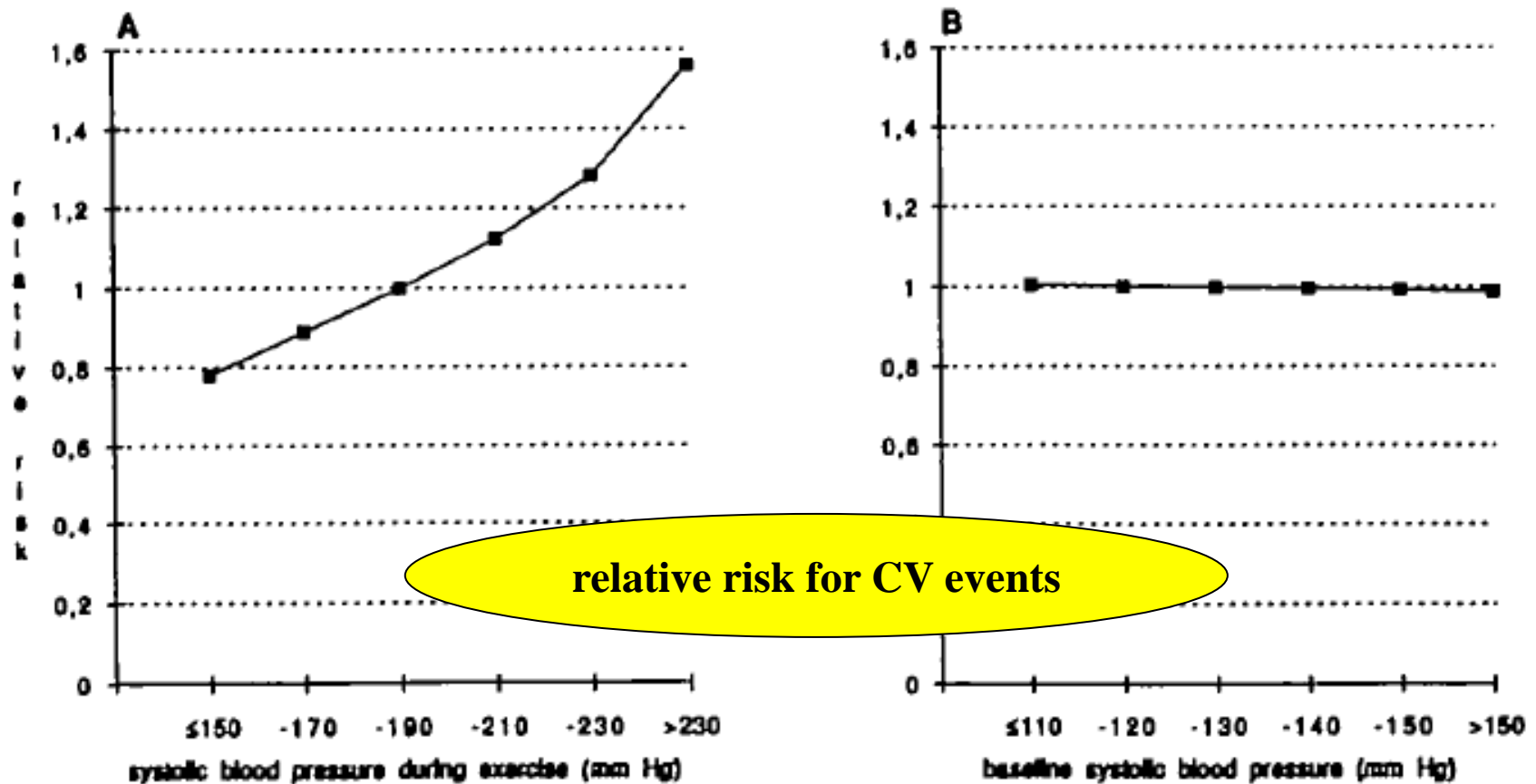
American
Heart
Association®

Prognostic significance of exercise blood pressure and heart rate in middle-aged men

J Filipovsky, P Ducimetiere and ME Safar

- n = 4907, 47.5 ± 1.9 year-old men
- resting BP <180/105 mmHg
- Three steps on the ergometer (82, 164, 191 Watt), BP after 3 min of 164 Watt
- 17 year follow-up
- Outcome: relative risk after correcting for age, height, heart rate, cholesterol, smoking, BMI, physical activity

Prognostic Value



Guidelines

ACC/AHA PRACTICE GUIDELINES—FULL TEXT

ACC/AHA 2002 Guideline Update for Exercise Testing

A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee on Exercise Testing)

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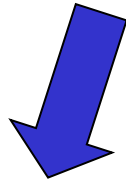
Exercise testing has been used to identify patients with abnormal blood pressure response destined to develop hypertension. Identification of such patients may allow preventive measures that would delay or prevent the onset of this disease.

Exercise Hypotension

$$BP_{\text{mean}} = \text{cardiac output} \cdot \text{vascular resistance}$$

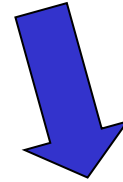
$$BP_{\text{amplitude}} = \text{stroke volume} \cdot \text{aortic compliance}$$

Exercise Hypotension



acute pumping failure

acute heart failure



vasodilation

Acute vascular failure

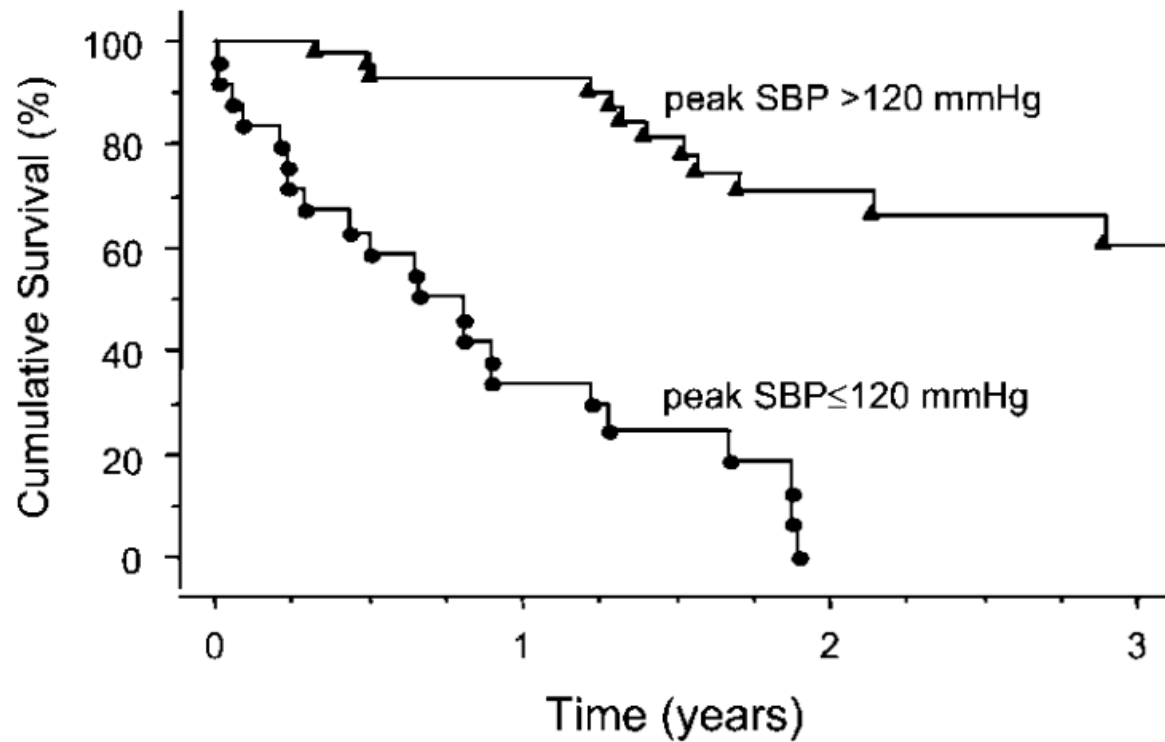


acute circulatory failure

Aortic Stenosis Guidelines

- Exercise testing is contraindicated in symptomatic patients with AS.
- Exercise testing is safe in asymptomatic patients, provided it is performed under the supervision of an experienced physician while monitoring for the presence of symptoms, changes in blood pressure, and/or ECG changes.
- AVR is indicated in asymptomatic patients with severe AS and abnormal exercise test showing symptoms on exercise clearly related to AS (Recommendation I, Level C).
- Aortic valve replacement should be considered in asymptomatic patients with severe AS and abnormal exercise test showing fall in blood pressure below baseline (Recommendation IIa, Level C).

Predicting Survival in PAH



Survival in Heart Failure

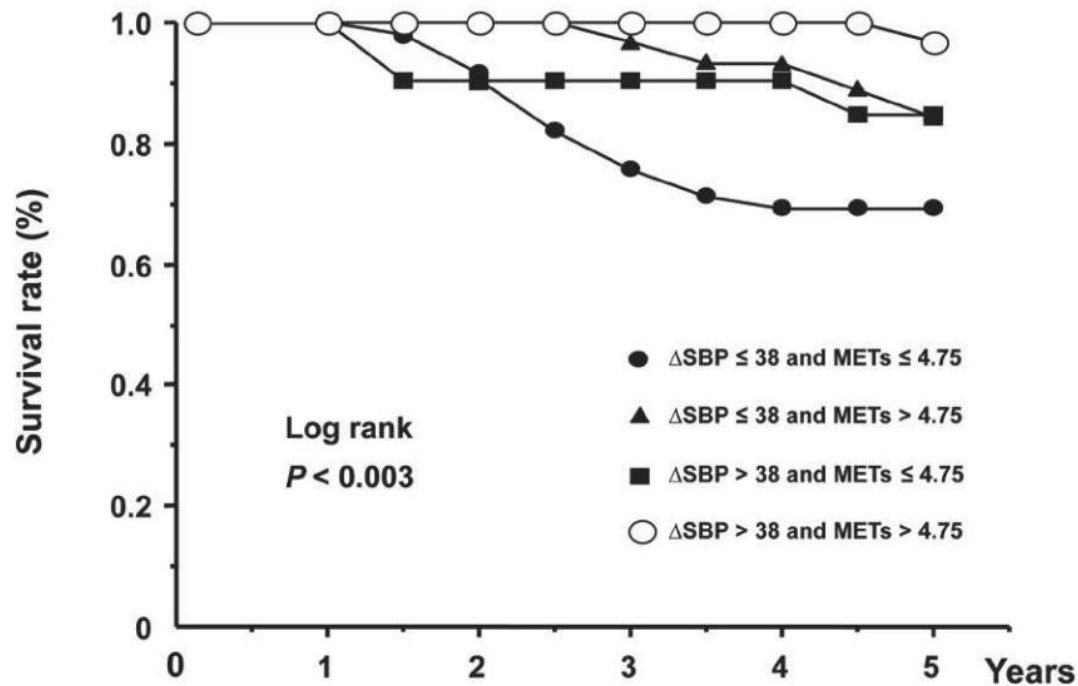


Figure 2. Kaplan-Meier plot relating survival to the combination of an increase in SBP (ΔSBP) with metabolic equivalents (METs).

SBP at Exercise

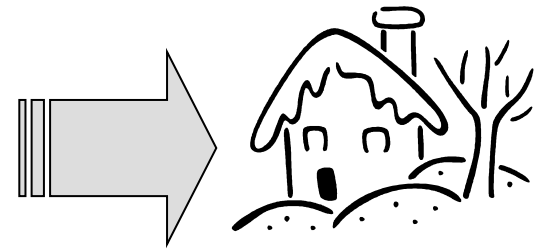
Exercise hypotension

- Heart failure
 - systolic heart failure
 - diastolic heart failure
 - inadequate filling
- Pulmonary hypertension
- Aortic stenosis
- HOCM

Exercise hypertension

- Aortic coarctation
 - decreased compliance
 - restenosis
 - activated RAAS
- Mid-aortic syndrome
- Peripheral artery disease
- Arterial hypertension

Take-Home Message



Exercise BP is difficult to measure

Be careful with diastolic BP interpretation

SBP depends mainly on work load (and age)

Exercise hypertension is a sign of aortic/iliac stenosis or aortic incomppliance (early arteriosclerosis).

Exercise hypotension is a ominous sign in heart failure or PAH patients

Acute exercise hypotension = acute circulatory failure

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