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: Celgen, 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 (>5mmHg in 48%)

DBP
fairly high variability

Reference Values

Regression

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

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

SBP in Panel 1
Normal SBP at Exercise
Exercise Hypertension

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

\[ BP_{\text{amplitude}} = \text{stroke volume} \cdot \text{aortic compliance} \]
Exercise Hypertension

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

• early arteriosclerosis
  (early sign of hypertension in future)
Prognostic Value

Prognostic Value


- 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
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
- vasodilation
- acute heart failure
- 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
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 incompliance (early arteriosclerosis).

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

Acute exercise hypotension = acute circulatory failure
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