13. Blood Pressure

Millie “Grim Geek” Rea
New Zealand
Presentation Outline

- Explanation of Blood Pressure (BP)
- Methods of Measurement
- Inherent Variation
  - exploration of the physiological variables
- Effect on Measurement & Diagnosis
• **13. Invent Yourself: Blood pressure**

Study the accuracy of various methods to measure blood pressure.

Propose an interesting study involving blood pressure and pulse.
My Problem

Blood Pressure is inherently variable. Investigate how this phenomenon affects the reliability of different methods used to diagnose hypertension.
Explanation of Blood Pressure
Aorta

Brachial Artery
Hypertension

High Blood pressure > 130/80 mmHg
Effects of Hypertension

“Elevated BP [Hypertension] is the main risk factor for cardiovascular disease, the number one cause of mortality worldwide.”

-World Health Organisation
Importance of reliability

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Hypertension</th>
<th>Normal</th>
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</thead>
<tbody>
<tr>
<td>Positive</td>
<td>TP (True Positive)</td>
<td>FP (False Positive)</td>
</tr>
<tr>
<td>Negative</td>
<td>FN (False Negative)</td>
<td>TN (True Negative)</td>
</tr>
</tbody>
</table>
Methods of Measurement

ABPM

HBPM

Clinic BP

Out of office

In office
Methods - out of office

ABPM
(Ambulatory BP Monitoring)
Methods- out of office

HBPM
(Home BP monitoring)
Methods - in office

- Clinic BP measurement
Inherent Variation
Inherent Variation

![Graph showing inherent variation in systolic blood pressure over a 24-hour period with peaks and troughs.](image-url)
Model Heart
Set up

One way valve, ‘heart’
Set up

- Air pressure Sensor
- Constant Head Apparatus
- T-Junction
- Fake arm
- One way valve
- Piston
- One way valve
Example graph

Pressure (KPa)

Time (s)
Example graph

Time (s)

Pressure (KPa)
Poiseuille's Law

\[ \Delta BP \propto \frac{F L n}{r^4} \]

- \( F \) = Flow
- \( L \) = vessel length
- \( n \) = blood viscosity
- \( r \) = vessel radius
Components of BP

\[ BP \propto CO \times PR \]

\[ BP = \text{Cardiac Output} \times \text{Peripheral Resistance} \]
Components of BP

\[ BP \propto CO \times PR \]

\[ BP = \text{Cardiac Output} \times \text{Peripheral Resistance} \]
Cardiac Output

Cardiac Output = Stroke Volume $\times$ Heart Rate

$CO = SV \times HR$
Cardiac Output

\[ CO = SV \times HR \]
Increasing Stroke Volume

Begins pumping
Cardiac Output

\[ CO = SV \times HR \]
Increasing Heart Rate

![Graph showing the relationship between pulse pressure (KPa) and heart rate (bpm).]
Poiseuille's Law

\[ \Delta BP \propto \frac{F L n}{r^4} \]

\[ BP \propto PR \]
Peripheral Resistance

Vasodilation
Peripheral Resistance

Vasoconstriction
Components of BP

\[ BP \propto CO \times PR \]

- \( BP \) = Blood Pressure
- \( CO \) = Cardiac Output
- \( PR \) = Peripheral Resistance
Effect of Stress

Cardiac Output

Peripheral Resistance
Effect of Stress

Cardiac Output  \[\uparrow\]  Peripheral Resistance
Effect on Measurement & Diagnosis
Influence of setting
Influence of setting

- Exercise or stress
- Working
- Eating
- Resting
Inherent Variation
ABPM vs Gold standard

- **ABPM**
- **Gold Standard**
- **Average Gold standard**
- **Average ABPM**
ABPM vs Gold standard

Systolic BP (mmHg)

Hour

110
120
130
140
150
160

80
90
100
110
120
130
140
150
160

1
3
5
7
9
11
13
15
17

ABPM

Single Gold Standard
Comparing Methods

Measurements by Different Methods

Systolic BP (mmHg)

Hour
Comparing Methods

Measurements by Different Methods

Systolic BP (mmHg)

Hour

ABPM
HBPM
Clinic
# Statistical Simulation

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<td>642</td>
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<tr>
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<tr>
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<td>1438</td>
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<tr>
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<tbody>
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<td>1438</td>
<td>2000</td>
</tr>
<tr>
<td>total</td>
<td>562</td>
<td>1438</td>
<td>2000</td>
</tr>
<tr>
<td>sensitivity</td>
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<td>0.99</td>
<td></td>
</tr>
<tr>
<td>specificity</td>
<td></td>
<td></td>
<td></td>
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<table>
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<th>HBPM</th>
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<tbody>
<tr>
<td></td>
<td>disease</td>
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<td>total</td>
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<td>sensitivity</td>
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<td>specificity</td>
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</table>
Conclusion

Blood Pressure is inherently variable.

Investigate how this phenomena affects the reliability of different methods used to diagnose hypertension.
## Conclusion - Methods

<table>
<thead>
<tr>
<th>Location</th>
<th>ABPM</th>
<th>HBPM</th>
<th>Clinic BP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Out of office</td>
<td>Out of office</td>
<td>Out of office</td>
<td>In office</td>
</tr>
</tbody>
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## Conclusion-Methods

<table>
<thead>
<tr>
<th></th>
<th>ABPM</th>
<th>HBPM</th>
<th>Clinic BP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of measures</td>
<td>many</td>
<td>some</td>
<td>one</td>
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</tbody>
</table>
Inherent Variation

\[ BP \propto CO \times PR \]
White Coat Hypertension
# Conclusion-Methods

<table>
<thead>
<tr>
<th></th>
<th>ABPM</th>
<th>HBPM</th>
<th>Clinic BP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reliability:</td>
<td>Reliable</td>
<td>Reliable</td>
<td>Less reliable</td>
</tr>
</tbody>
</table>
Acknowledgements

• Otis Rea
• Sophie Mance
• Katy Bell
• Murray Chisolm
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• Fiona Wilson
• Moira Wilson
• David Rea
• & Everyone who let me take their blood pressure
Bibliography

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- http://sci-hub.tw/10.1016/0002-8703(89)90761-8 - mathematical model
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3087253/ - palpatory
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4638406/ - role of abpm
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2941726/ - eguchi et al.
- http://hyper.ahajournals.org/content/hypertensionaha/60/2/512.full.pdf - 24 hr variation
- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3639494/#R27
13. Blood Pressure

Millie "Grim Geek" Rea, New Zealand
“Study the accuracy of various methods to measure blood pressure.”

- I investigated the accuracy of ABPM, HBPM, and Clinical measurement for a diagnosis of hypertension

“Propose an interesting study involving blood pressure and pulse.”

- I created a model heart with pulse and pressure
Extra Slides
Components of BP

\[ \Delta \text{Pressure} = \text{Flow} \times \text{Resistance} \]

\[ = C.O. \times PR \]
Causes of Hypertension

\[ \text{BP} = \boxed{CO} \times PR \]
Causes of Hypertension

\[ BP = C.O. \times PR \]
Statistical Simulation

![Graph showing probability distribution of systolic BP measurements for different devices.](image)
Windkessel model

Figure 4.13

The top panel shows the Windkessel model of the circulatory tree. The heart is represented as a variable current source, the distensible arteries as a compliant chamber, and the peripheral vessels as a resistor. The bottom panel shows the equivalent electrical circuit. Note that this is not the only possible “lumped parameter” circuit representation of the circulation; see for example [8]. More sophisticated models include three or four elements; see for example [15] and [16].
• Age
• Sleep
• Setting
• Disease
• Medication
• Respiration
• Body position
• Physical activity
• Emotional stimuli
• Nutritional factors
• Genetic predisposition

• Heart Rate
• Volume of the blood
• Viscosity of the blood
• Compliance / elasticity
• Blood vessel length
• Vessel diameter

\[ CO \uparrow \text{ OR } \downarrow \]
\[ PR \uparrow \text{ OR } \downarrow \]
Measurement Techniques

![Graph showing pressure over time](image-url)
Amplification Phenomena

Blood Flow, Blood Pressure, and Resistance
Regulation

- Regulation & homeostasis
- Baroreflexes
- Autonomic Nervous system
  - Sympathetics
  - Parasympathetics

Baroreceptor

Homeostasis: Blood pressure in normal range
Methods

• ABPM
• HBPM
• Clinic BP

Out of office

In office
Bland and Altman analysis
Blood pressure Diagnosis Chart

- Hypotensive
- Elevated
- Normal
- Stage 1
- Stage 2
- Hypertensive Crisis