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

The Problem

- **13.** Invent Yourself: Blood pressure

Study the accuracy of various methods to measure blood pressure.

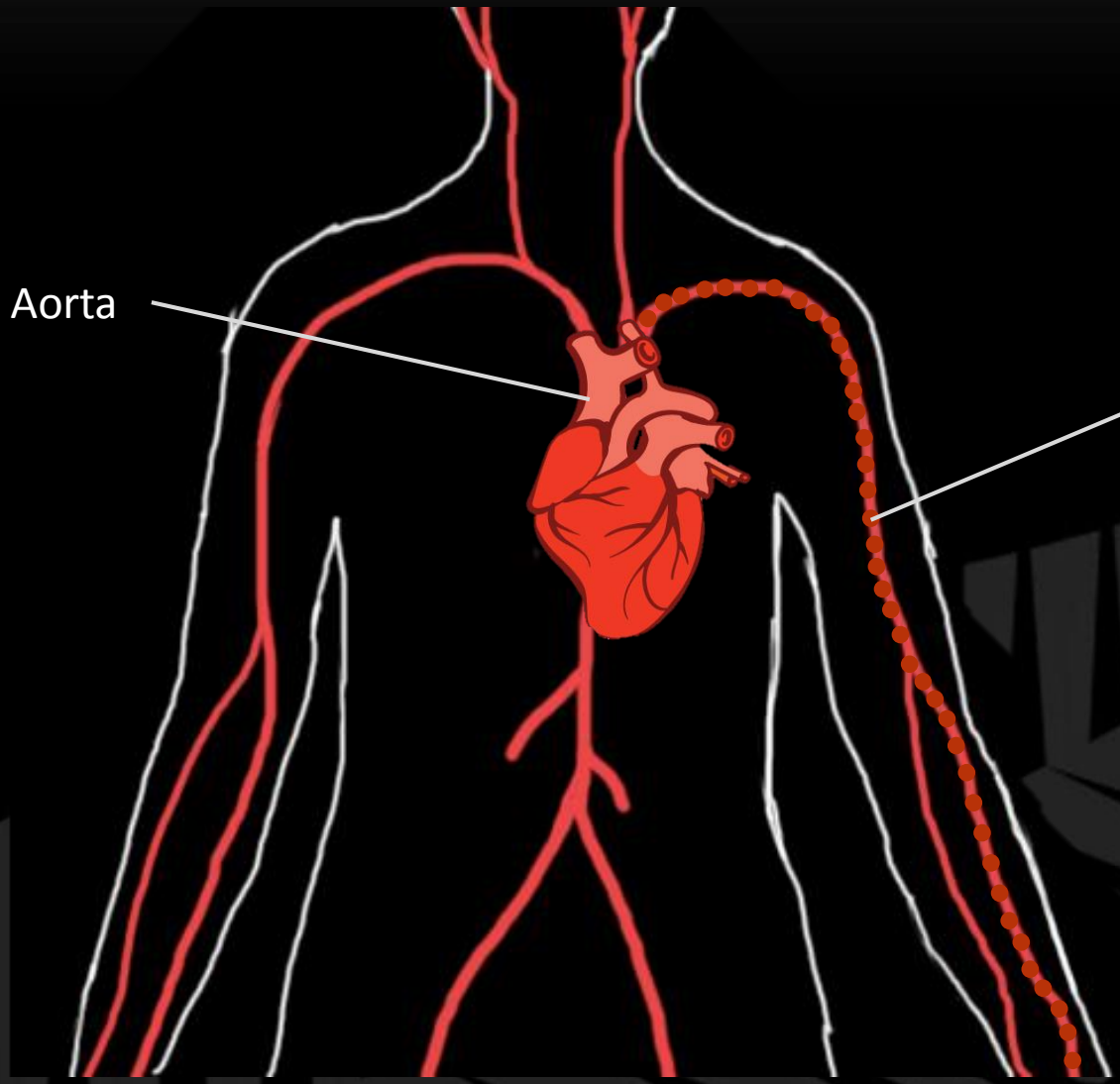
Propose an interesting study involving blood pressure and pulse.

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

Diagnosis	**Hypertension**	**Normal**
Positive	TP (True Positive)	FP (False Positive)
Negative	FN (False Negative)	TN (True Negative)

➢ Methods of Measurement

ABPM
HBPM
} Out of office

Clinic BP } In office

Methods - out of office

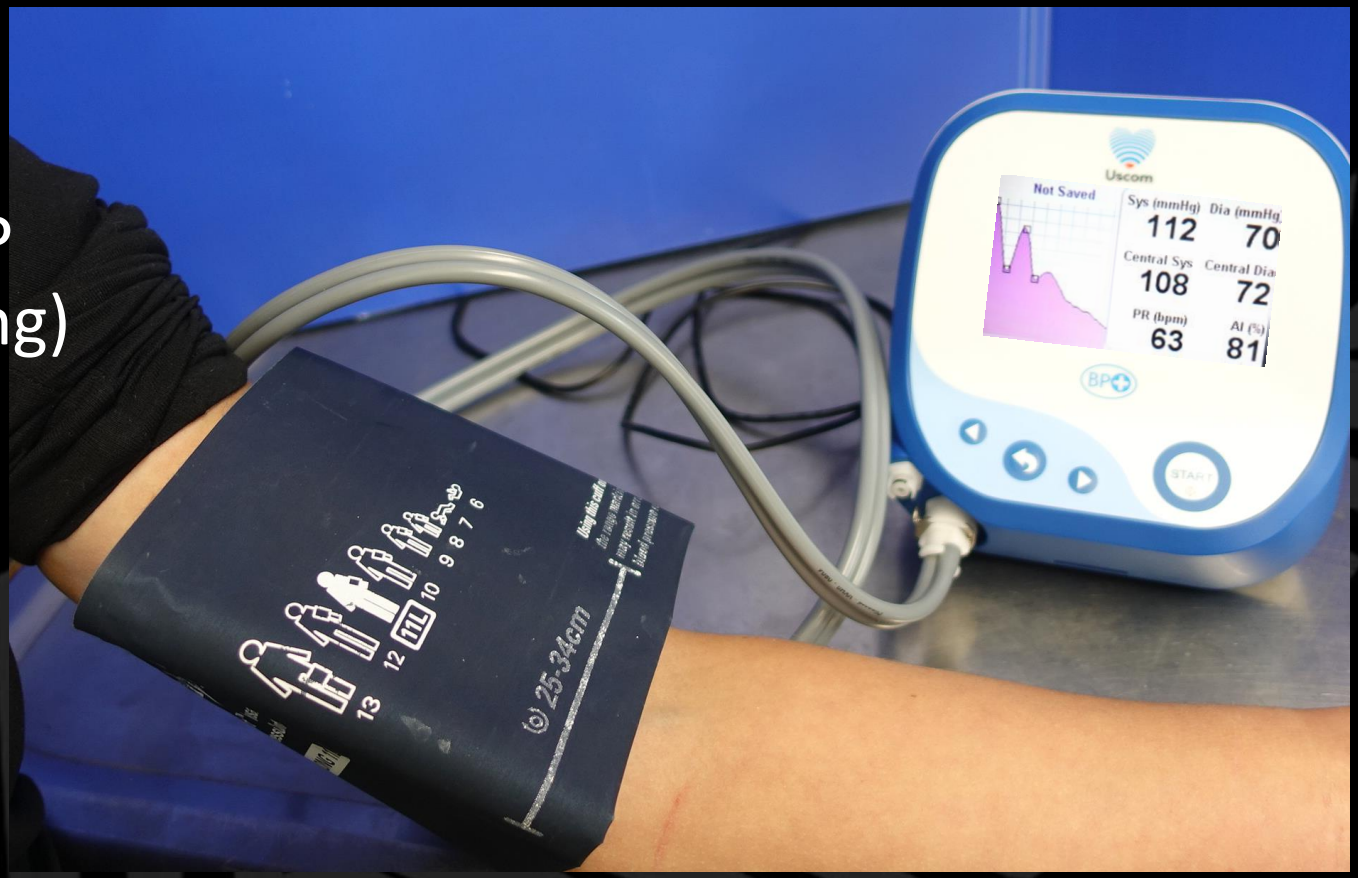
ABPM

(Ambulatory BP Monitoring)

Methods- out of office

HBPM

(Home BP monitoring)

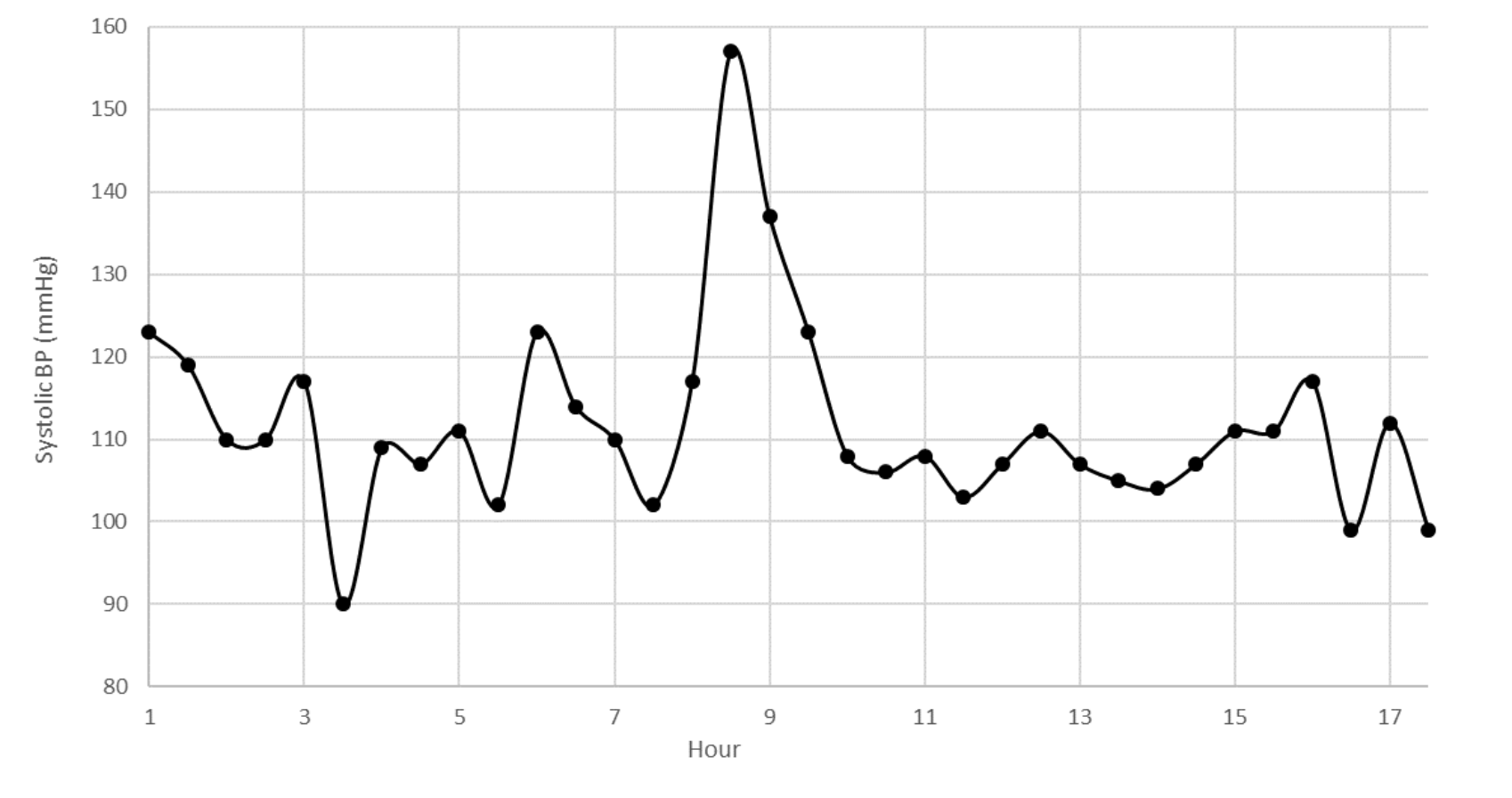


Methods- in office

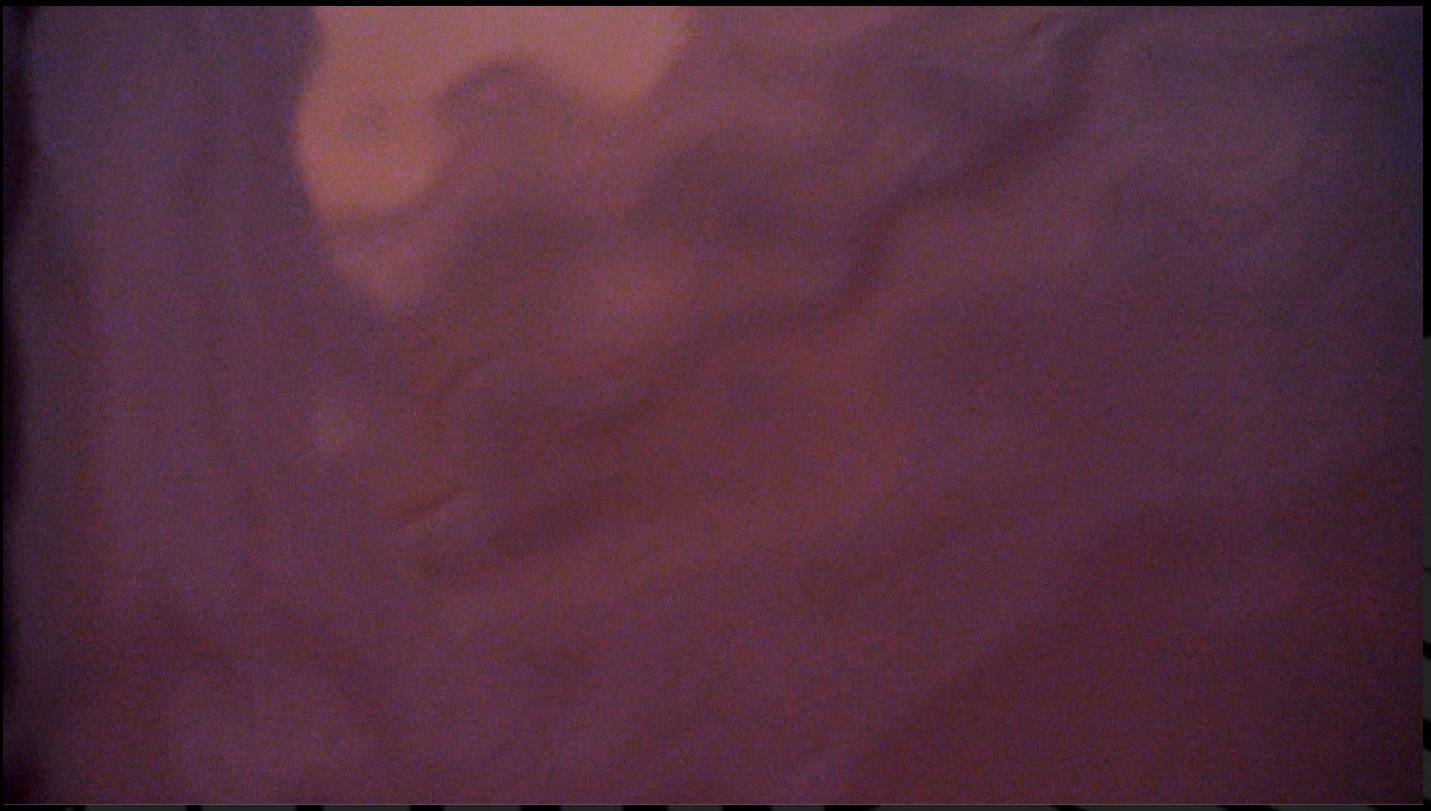
- Clinic BP measurement

- Inherent Variation

Inherent Variation

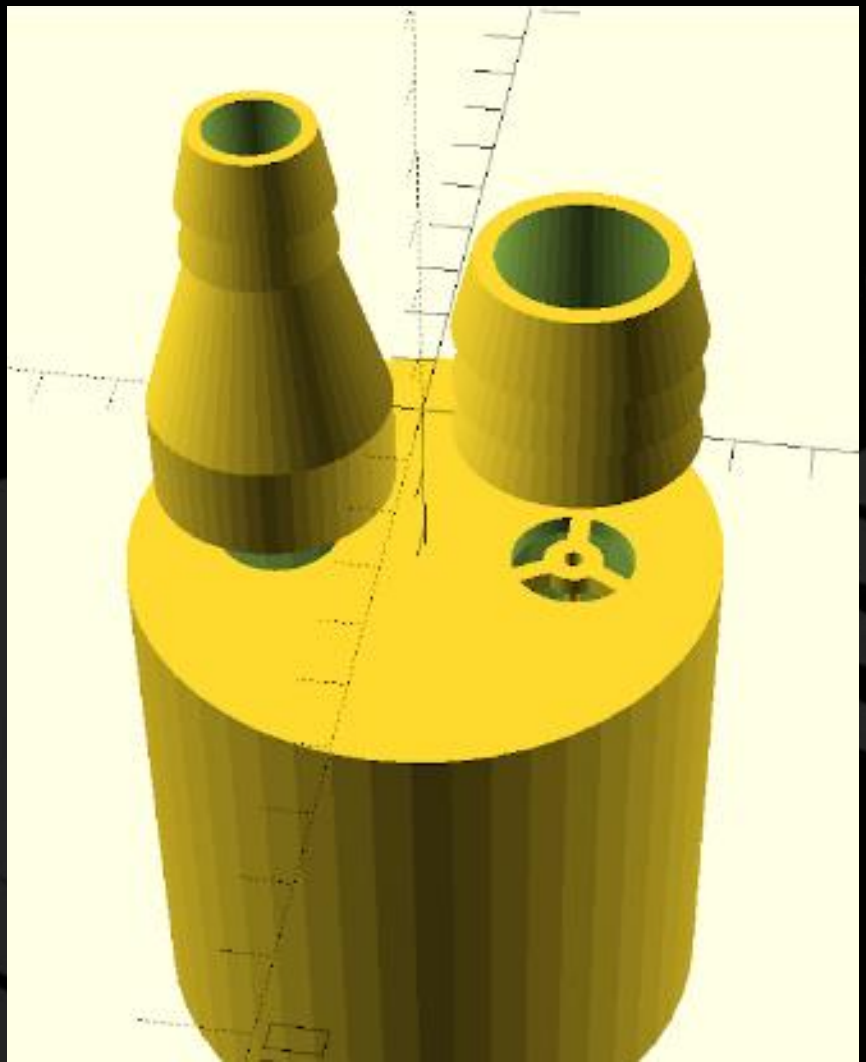


Model Heart

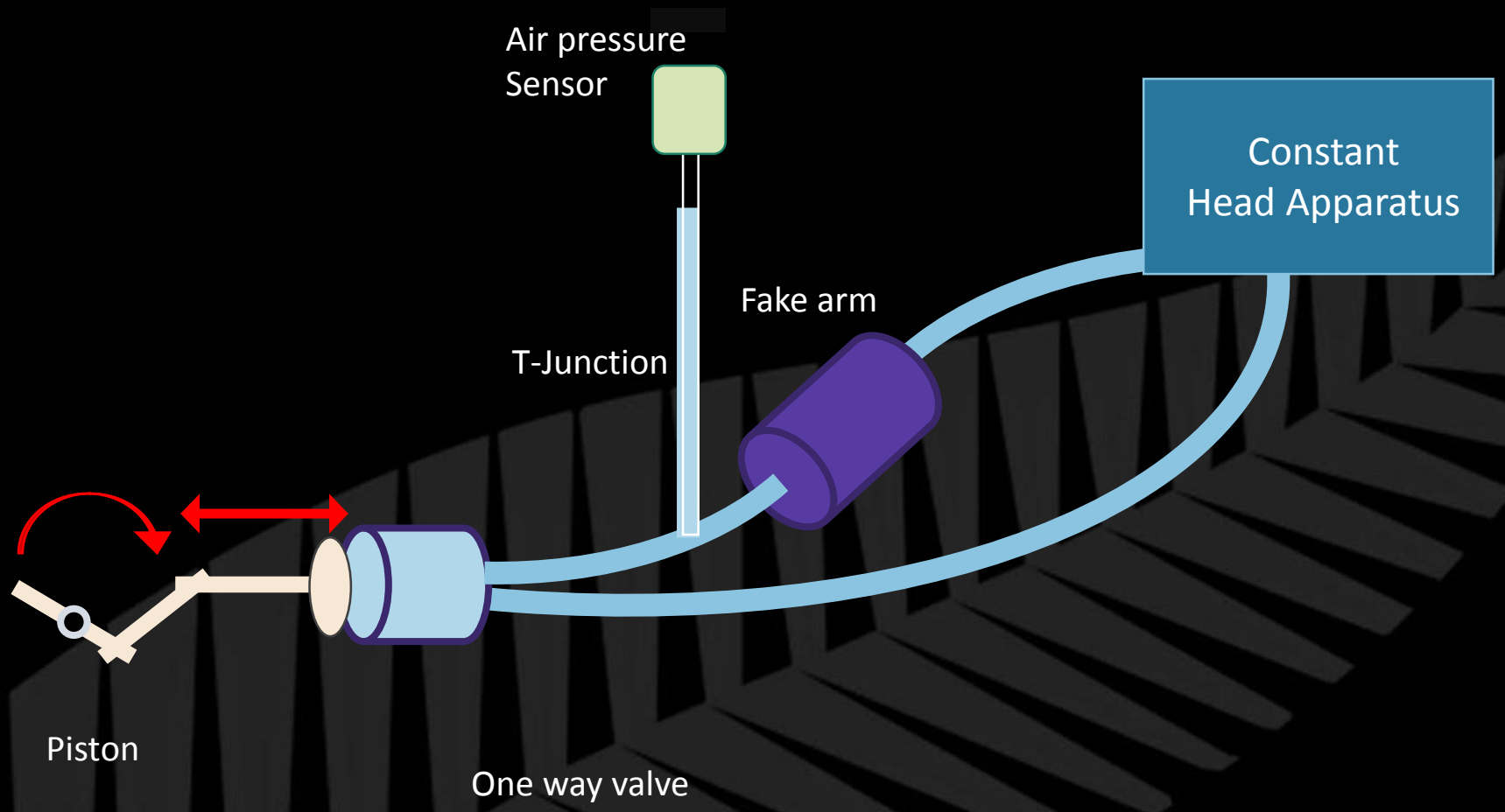


Set up

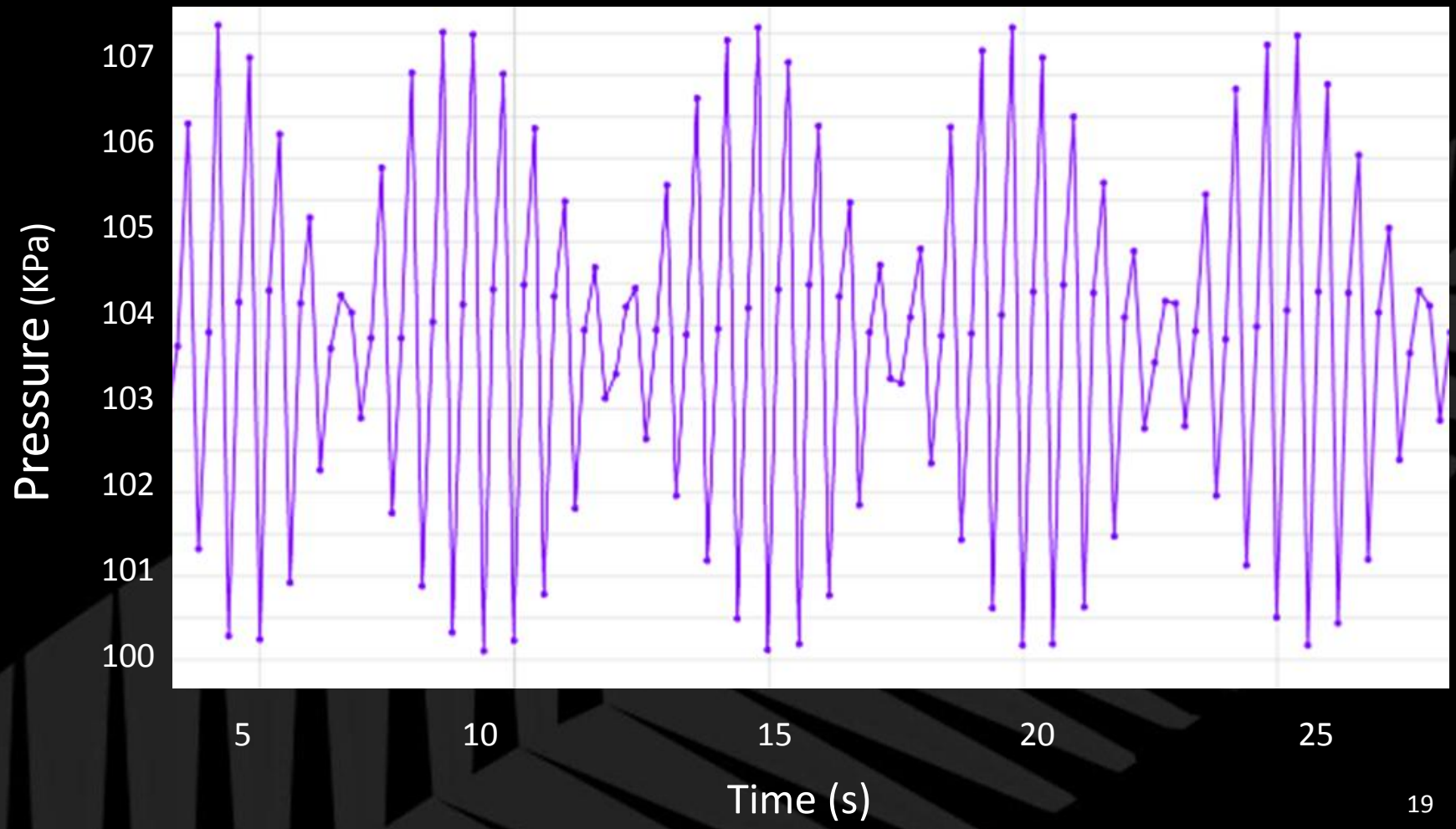
One way valve,
'heart'



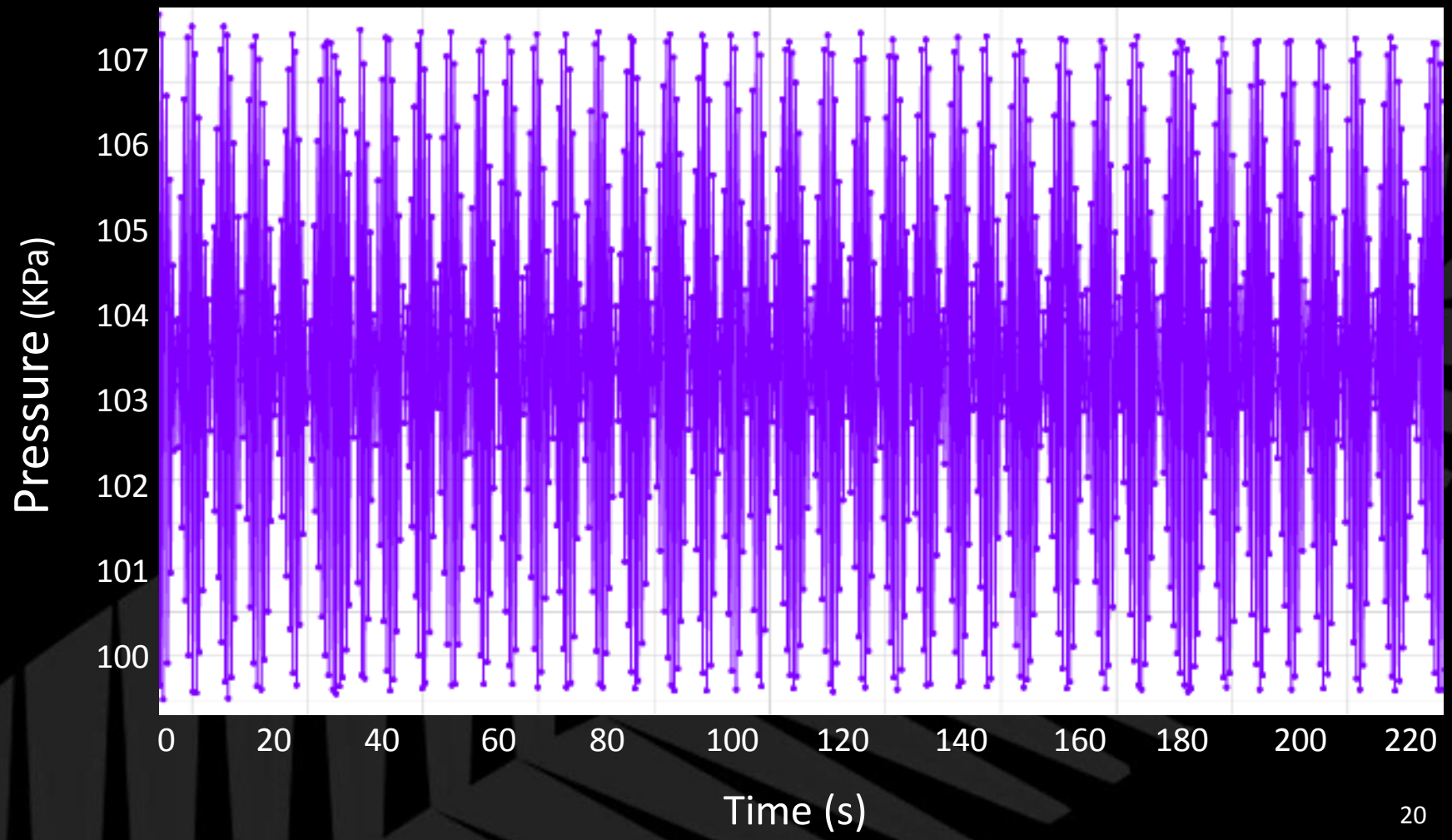
Set up


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

Example graph



Example graph



Poiseuille's Law

$$\Delta BP \propto \frac{\boxed{F}\, L\, n}{\boxed{r^4}}$$

F = Flow

L = vessel length

n = blood viscosity

r = vessel radius

Components of BP

$$BP \propto CO \times PR$$

$$BP = Cardiac\ Output \times Peripheral\ Resistance$$

Components of BP

$$BP \propto \boxed{CO} \times PR$$

$$BP = Cardiac\ Output \times Peripheral\ Resistance$$

Cardiac Output

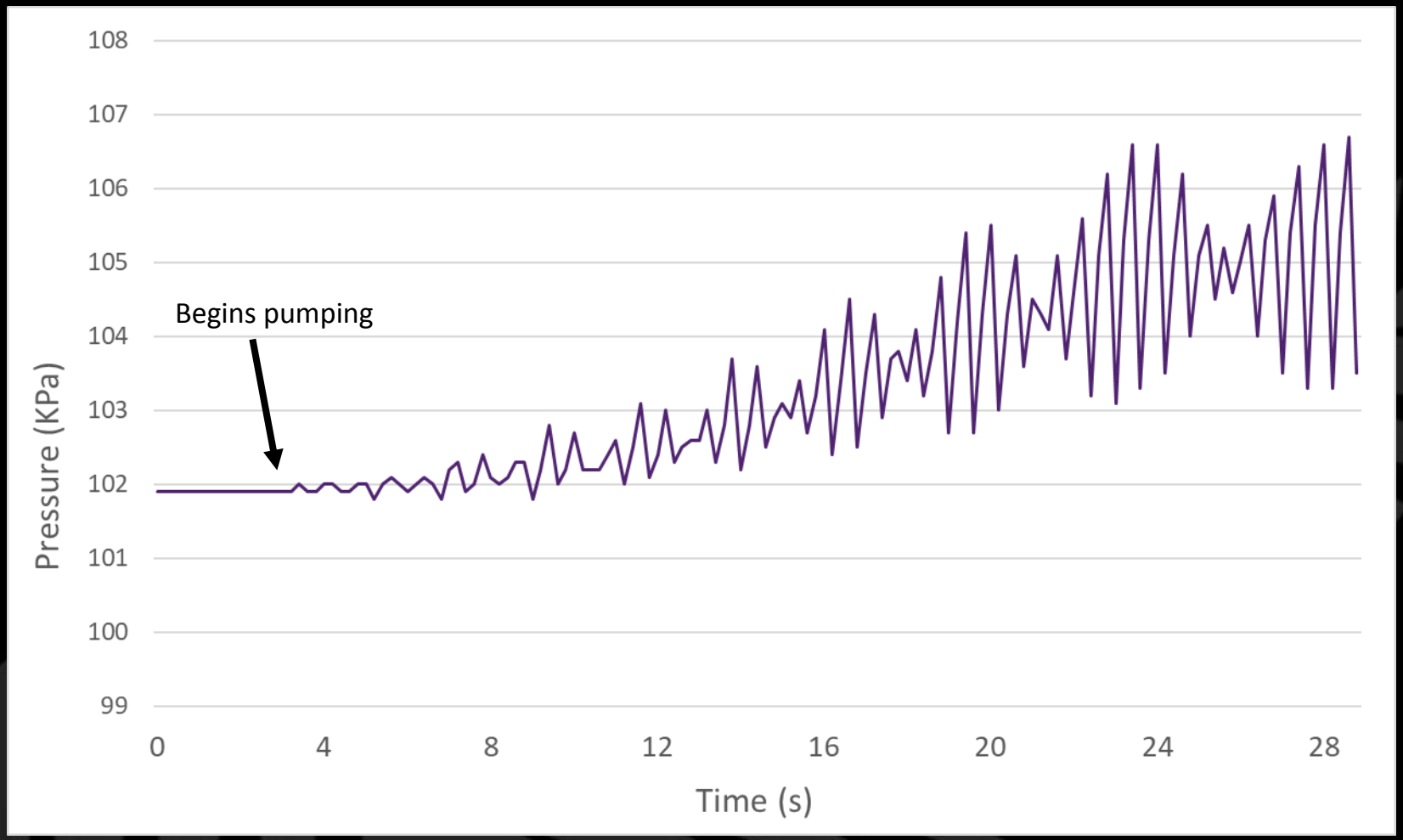
$$Cardiac\ Output = Stroke\ Volume \times Heart\ Rate$$

$$\boxed{CO} = SV \times HR$$

Cardiac Output

$$CO = \boxed{SV} \times HR$$

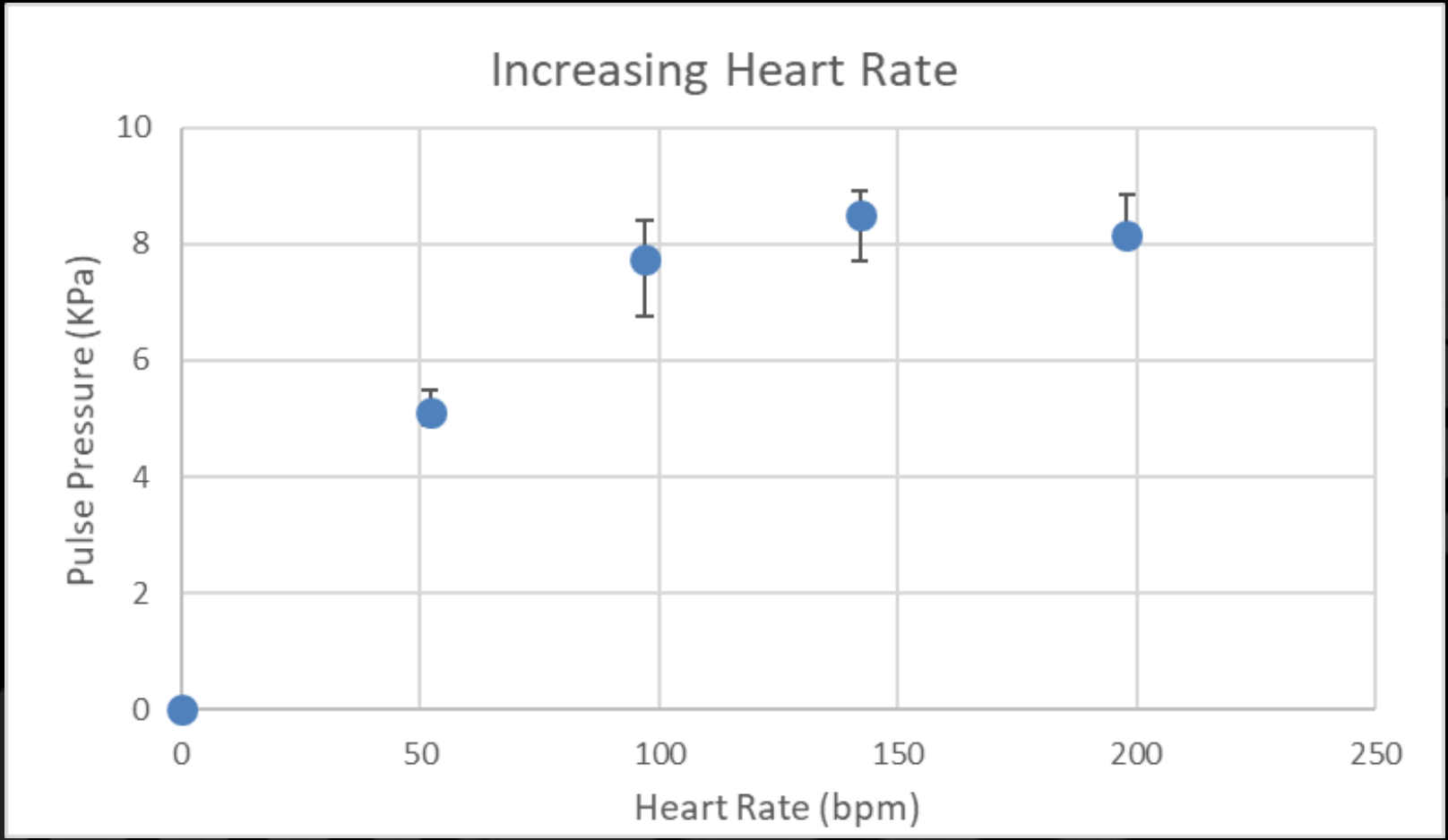
Increasing Stroke Volume



Cardiac Output

$$CO = SV \times \boxed{HR}$$

Increasing Heart Rate

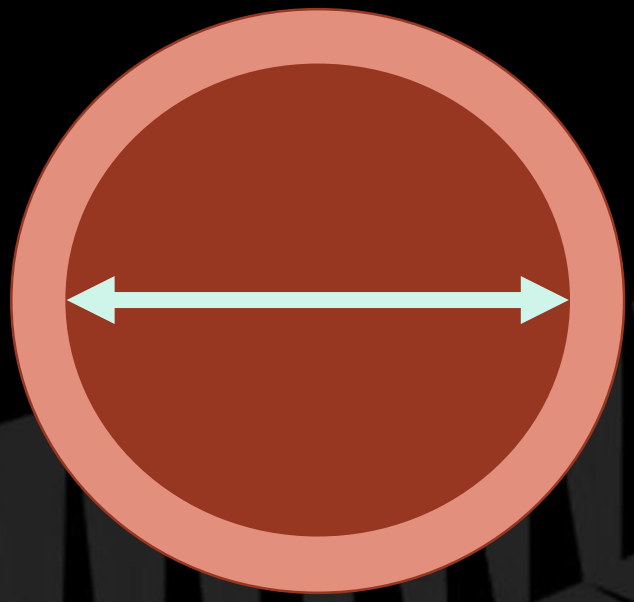


Poiseuille's Law

$$\Delta BP \propto \frac{F\,L\,n}{r^4}$$

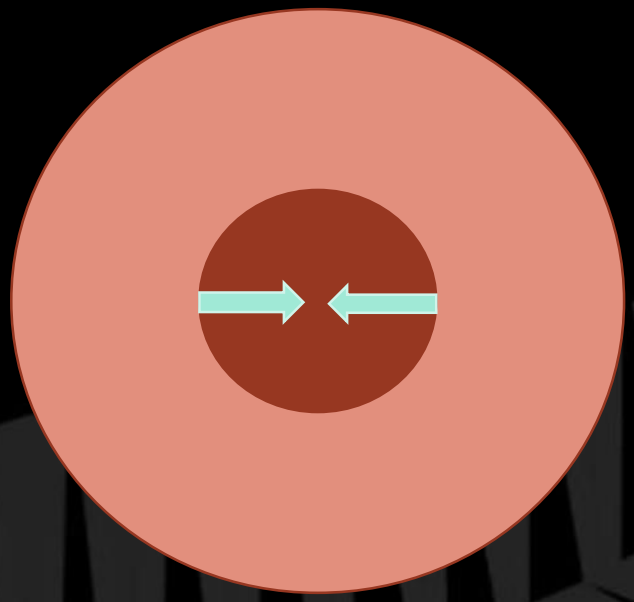
$$BP \propto PR$$

Peripheral Resistance



Vasodilation

Peripheral Resistance



Vasoconstriction

Components of BP

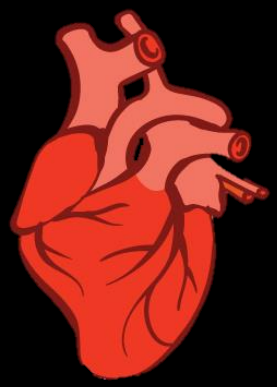
$$BP \propto CO \times PR$$

BP = Blood Pressure

CO=Cardiac Output

PR=Peripheral Resistance

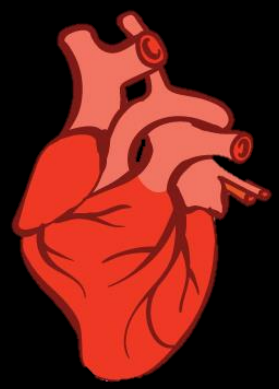
Effect of Stress



Cardiac Output

Peripheral Resistance

Effect of Stress



Cardiac Output ↑

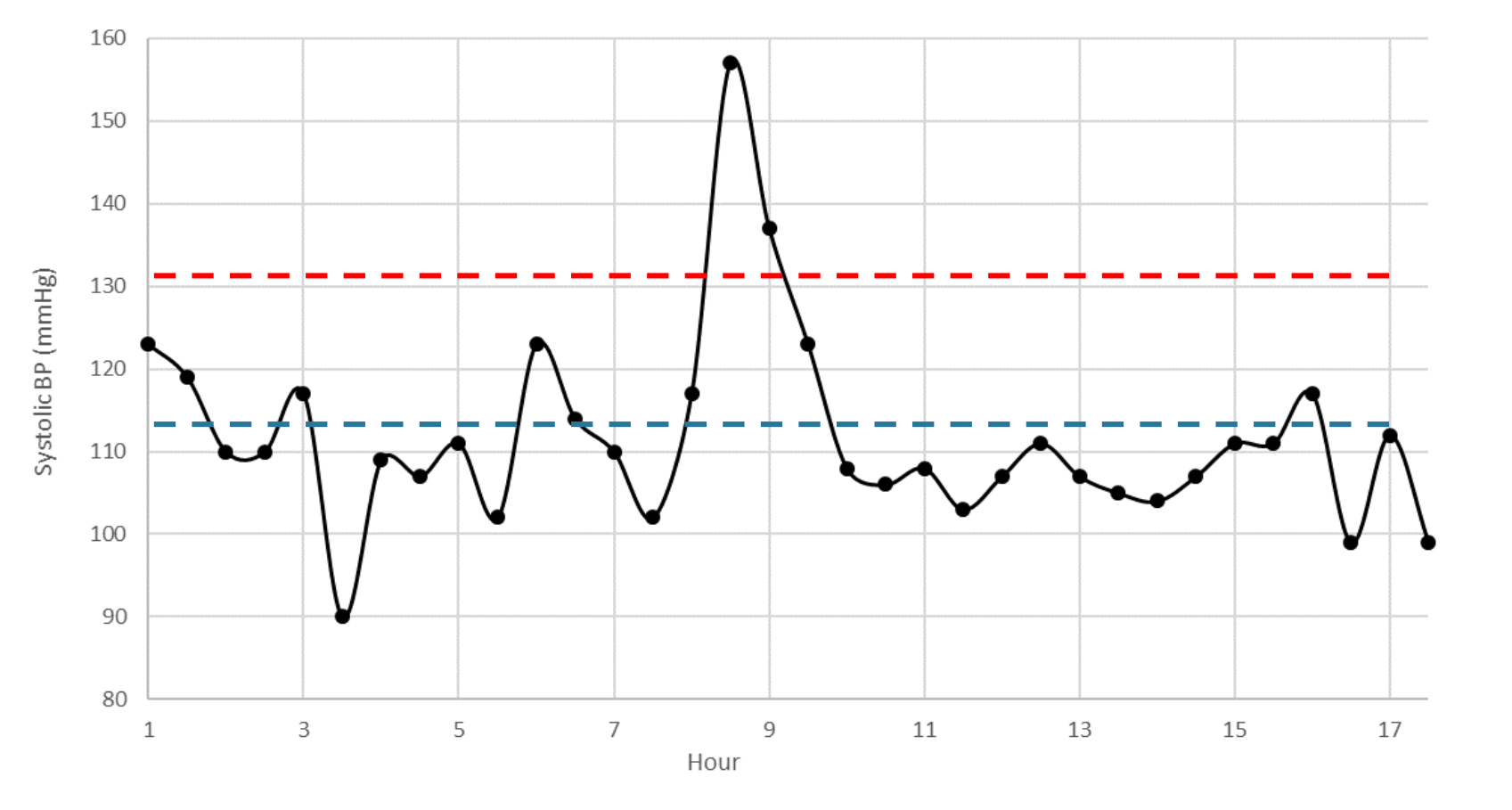
Peripheral Resistance ↑

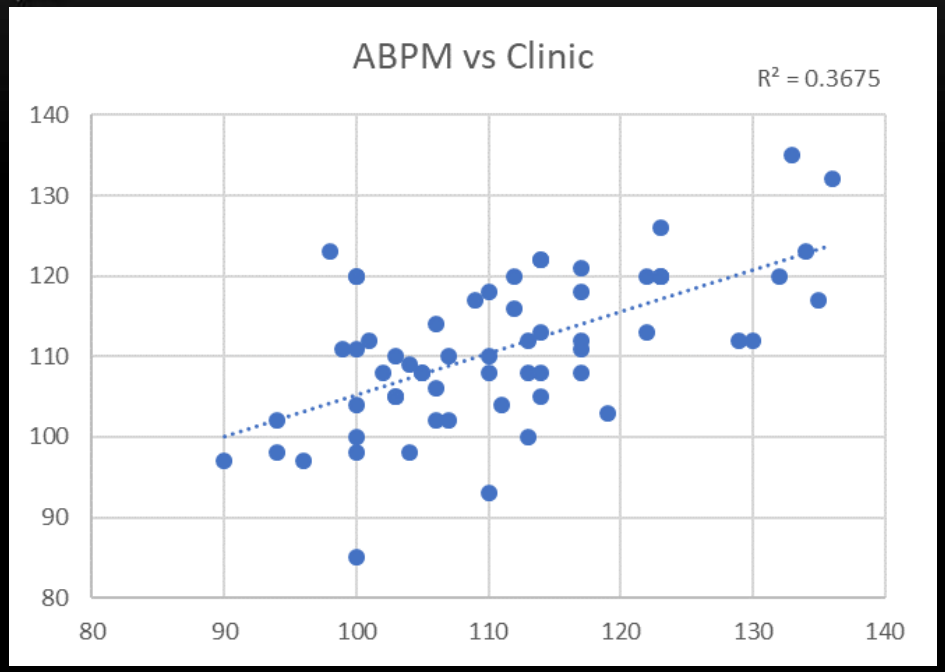
- Effect on Measurement & Diagnosis

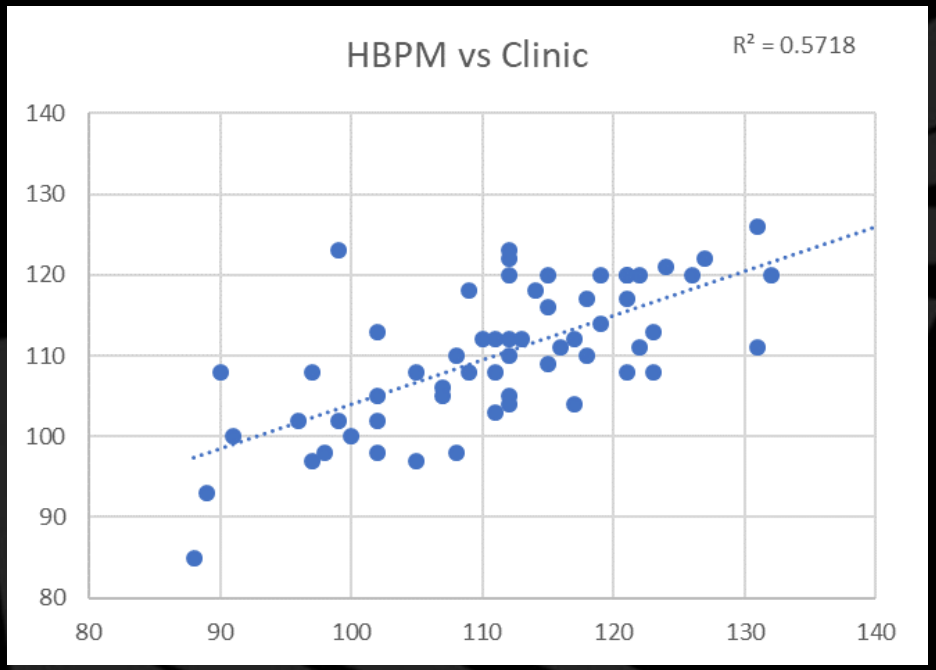
Influence of setting

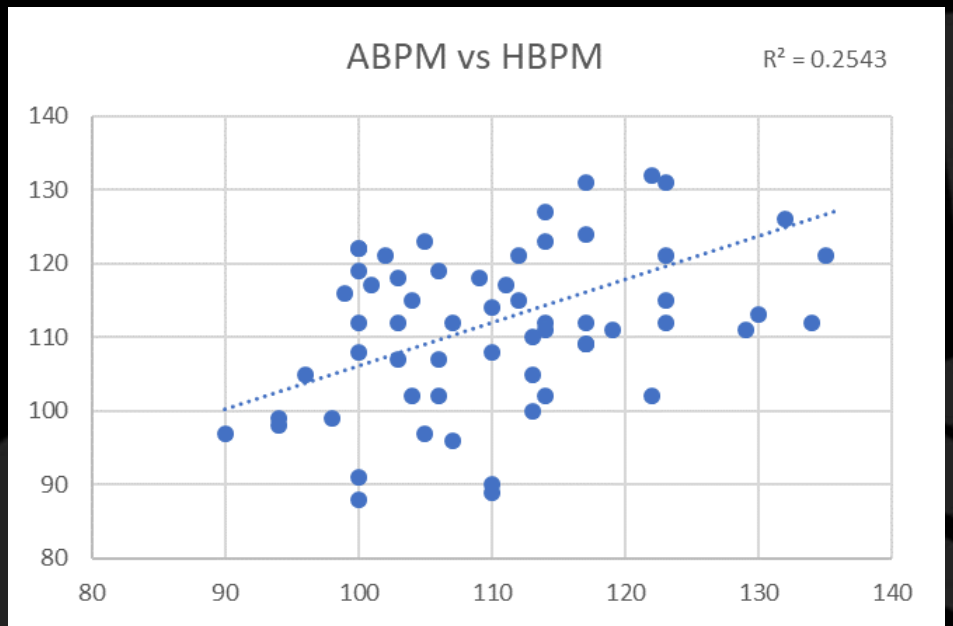
Influence of setting

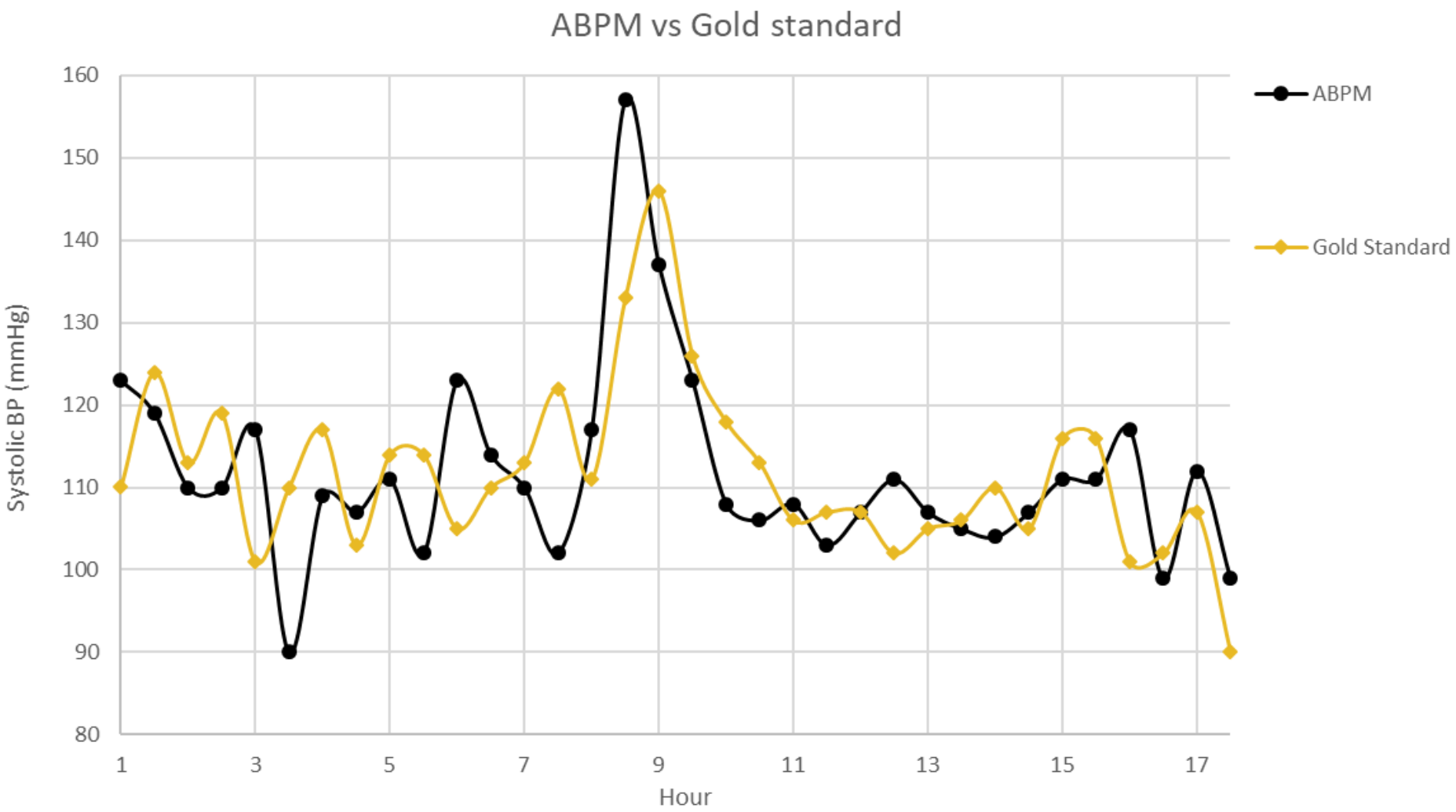
Inherent Variation

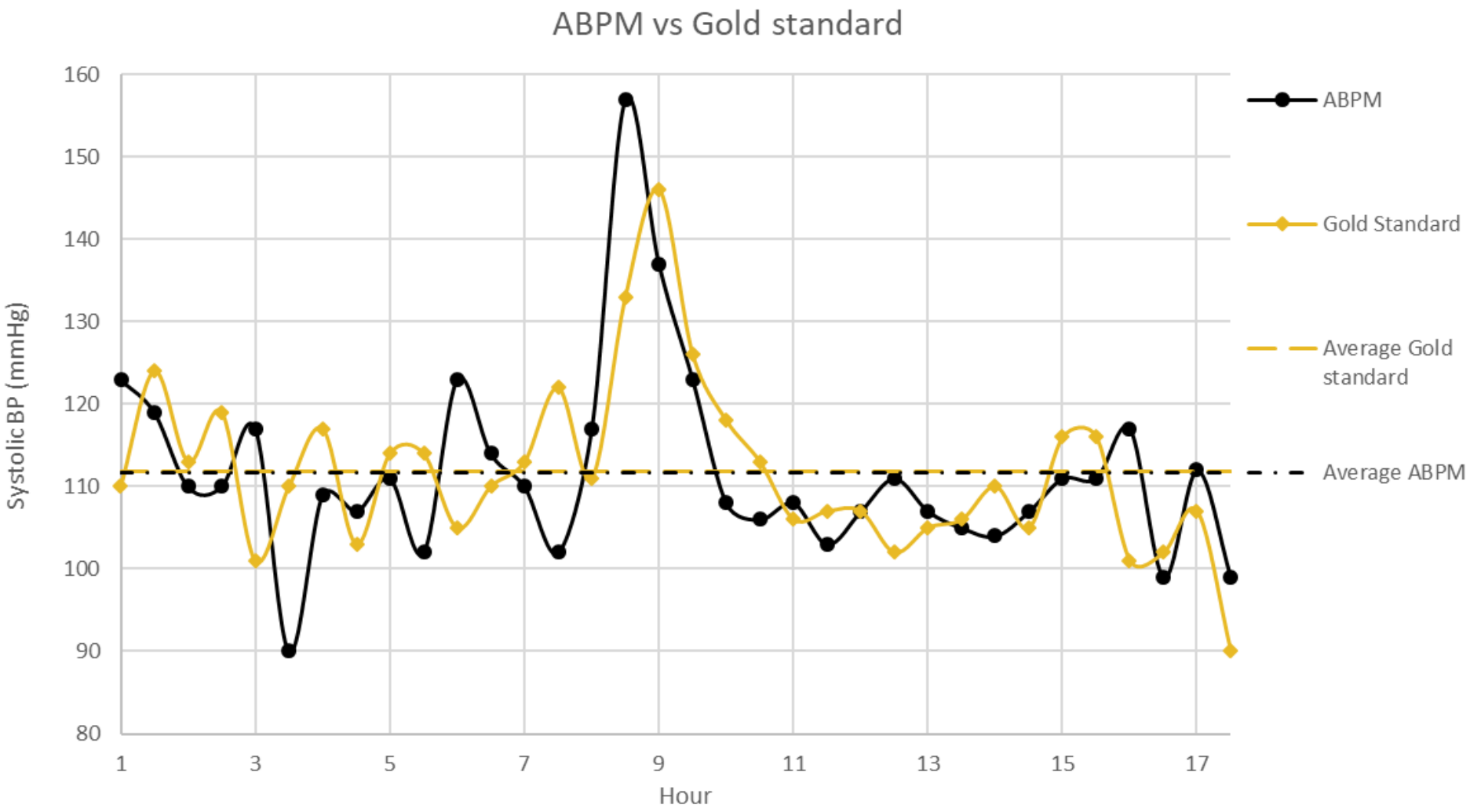


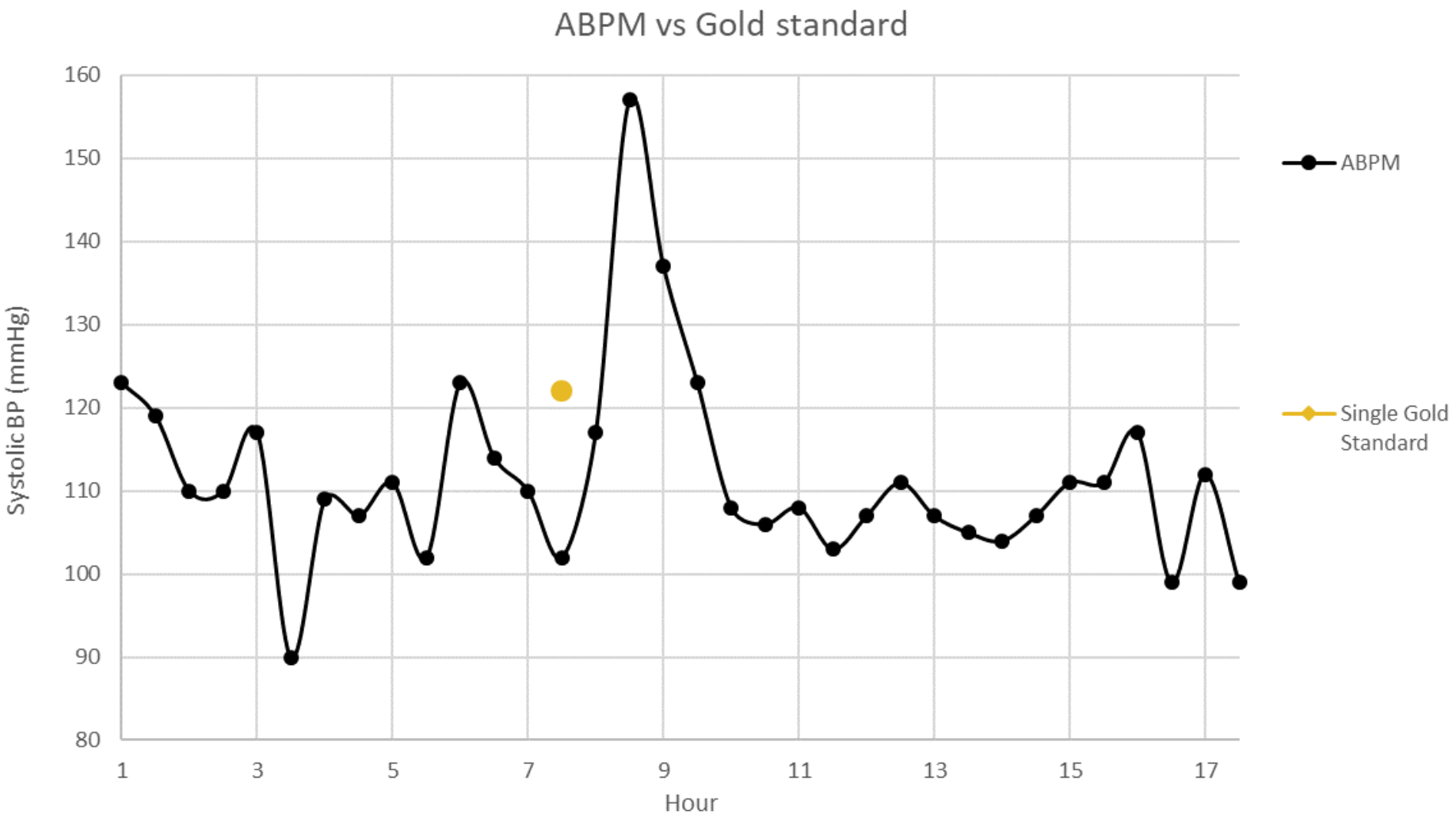

ABPM vs Clinic
R² = 0.3675
140
130
120
110
100
90
80
80
90
100
110
120
130
140

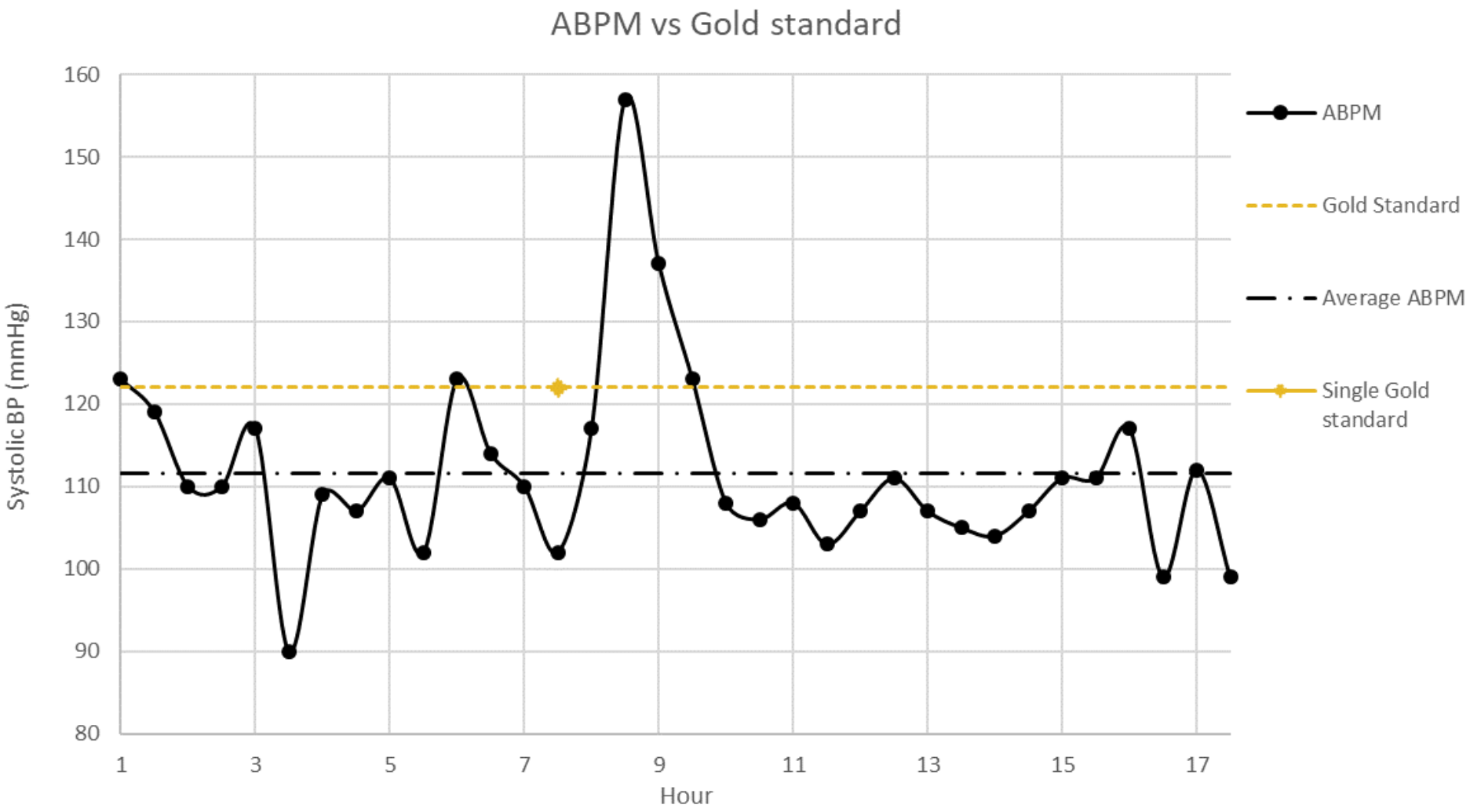

HBPM vs Clinic
R² = 0.5718
140
130
120
110
100
90
80
80
90
100
110
120
130
140


ABPM vs HBPM
R² = 0.2543
140
130
120
110
100
90
80
80
90
100
110
120
130
140

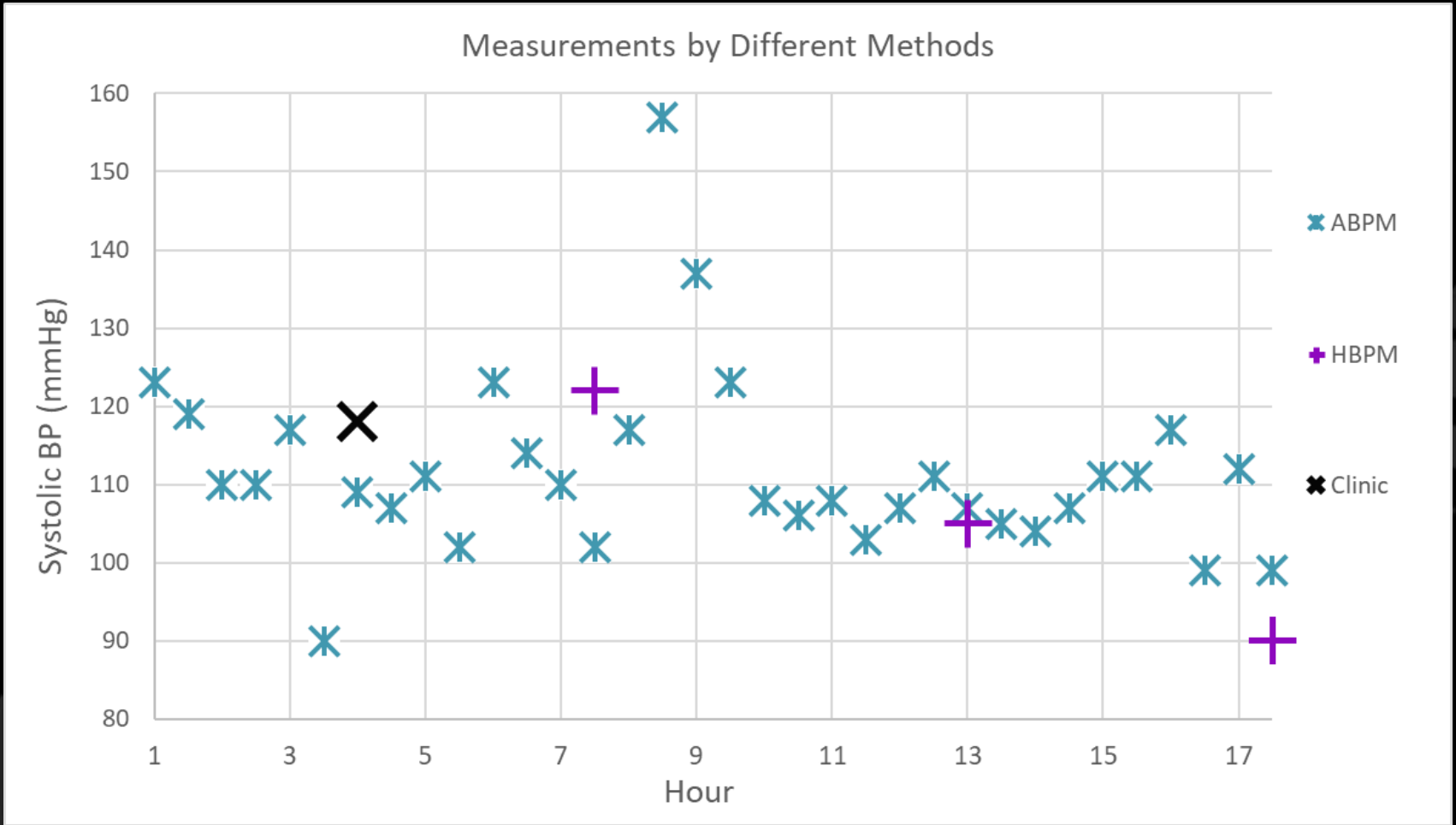

ABPM vs Gold standard
160
150
140
130
120
110
100
90
80
Systolic BP (mmHg)
1
3
5
7
9
11
13
15
17
Hour
ABPM
Gold Standard


ABPM vs Gold standard
Systolic BP (mmHg)
160
150
140
130
120
110
100
90
80
1
3
5
7
9
11
13
15
17
Hour
ABPM
Gold Standard
Average Gold standard
Average ABPM

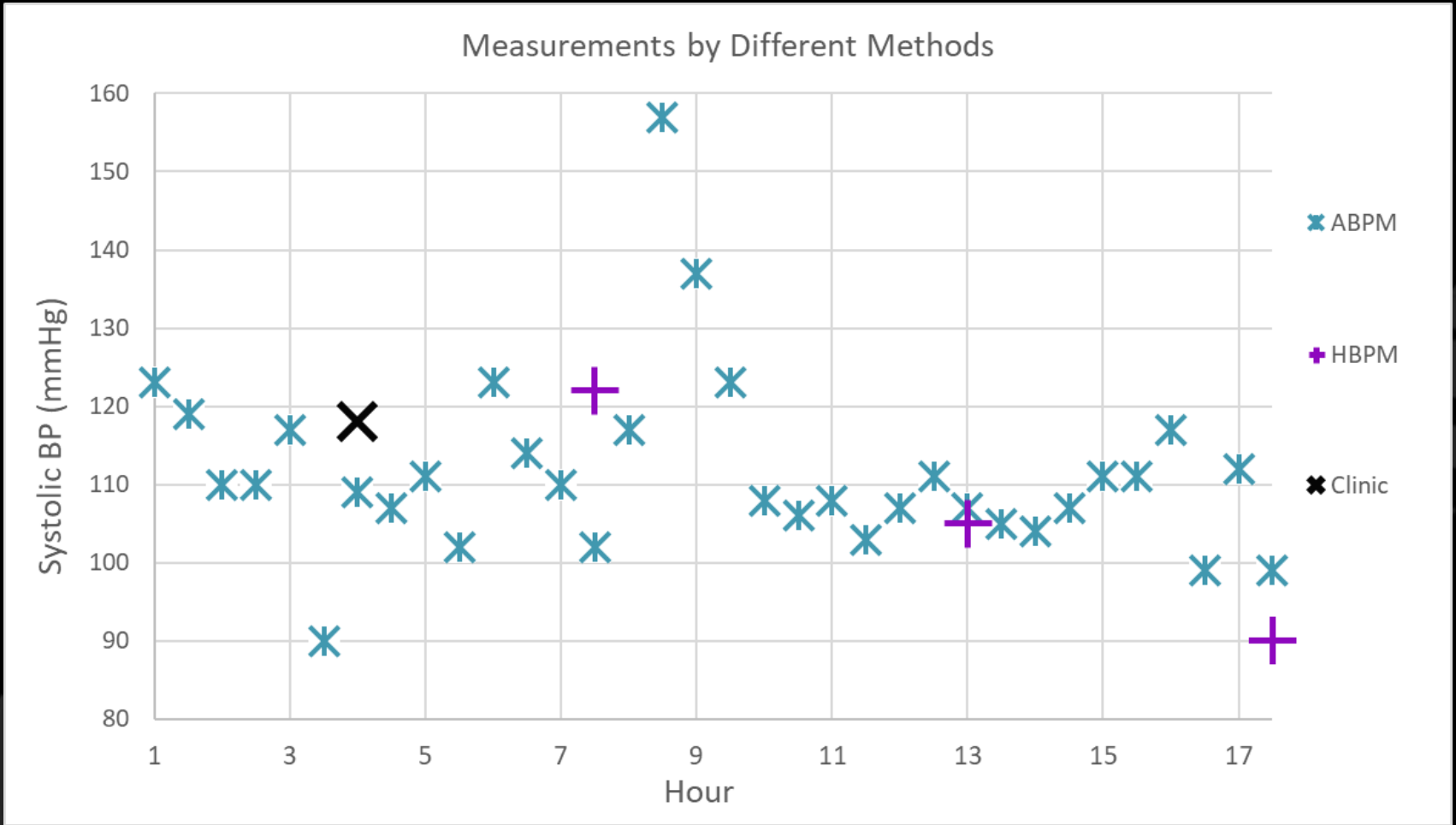

ABPM vs Gold standard
Systolic BP (mmHg)
160
150
140
130
120
110
100
90
80
1
3
5
7
9
11
13
15
17
Hour
ABPM
Single Gold Standard


ABPM vs Gold standard
Systolic BP (mmHg)
160
150
140
130
120
110
100
90
80
1
3
5
7
9
11
13
15
17
Hour
ABPM
Gold Standard
Average ABPM
Single Gold standard

Comparing Methods



Comparing Methods



Statistical simulation

Clinical				ABPM				HBPM			
	disease	no disease	total		disease	no disease	total		disease	no disease	total
diagnosed	413	229	642	diagnosed	508	15	523	diagnosed	441	222	663
not diagnosed	149	1209	1358	not diagnosed	54	1423	1477	not diagnosed	111	1226	1337
total	562	1438	2000	total	562	1438	2000	total	552	1448	2000
	562	1438	2000		562	1438	2000		552	1448	2000
	0.73	**0.84**			**0.90**	**0.99**			**0.80**	**0.85**	
	sensitivity	**specificity**			**sensitivity**	**specificity**			**sensitivity**	**specificity**	

Conclusion

Blood Pressure is inherently variable.

Investigate how this phenomena affects the reliability of different methods used to diagnose hypertension.

Conclusion-Methods

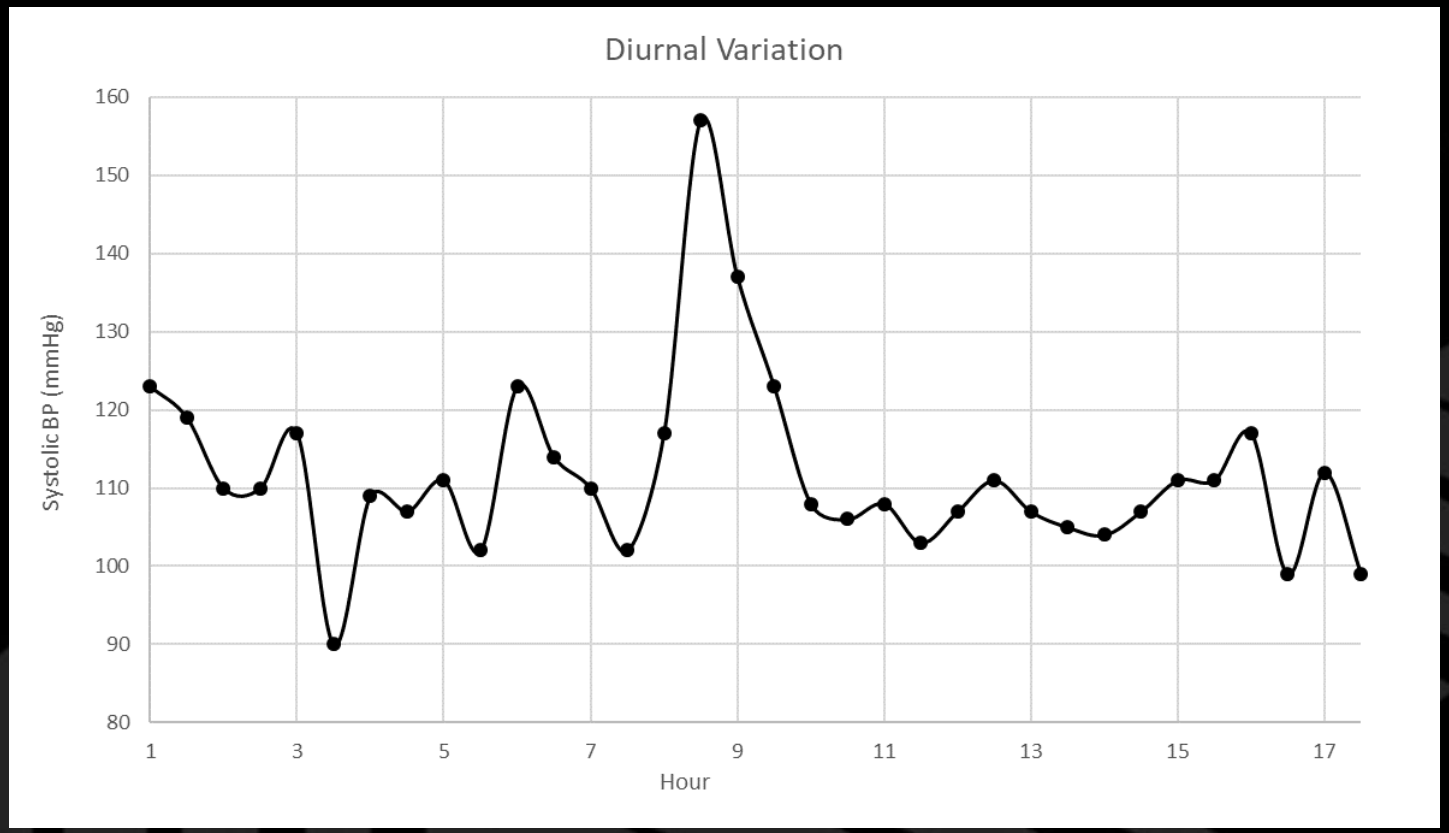
	ABPM	HBPM	Clinic BP
Location	Out of office	Out of office	In office

Conclusion-Methods

	ABPM	HBPM	Clinic BP
Number of measurements	many	some	one

Inherent Variation

$$BP \propto CO \times PR$$



White Coat Hypertension

Conclusion-Methods

	ABPM	HBPM	Clinic BP
Reliability:	Reliable	Reliable	Less reliable

Acknowledgements

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

Bibliography

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- https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3630744/ - importance of CBP & pressure changes, PP amplification
- http://sci-hub.tw/10.1016/0002-8703(89)90761-8 -mathematical model
- http://sci-hub.tw/10.1016/j.jacc.2017.05.064 -cuff everything
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- 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."

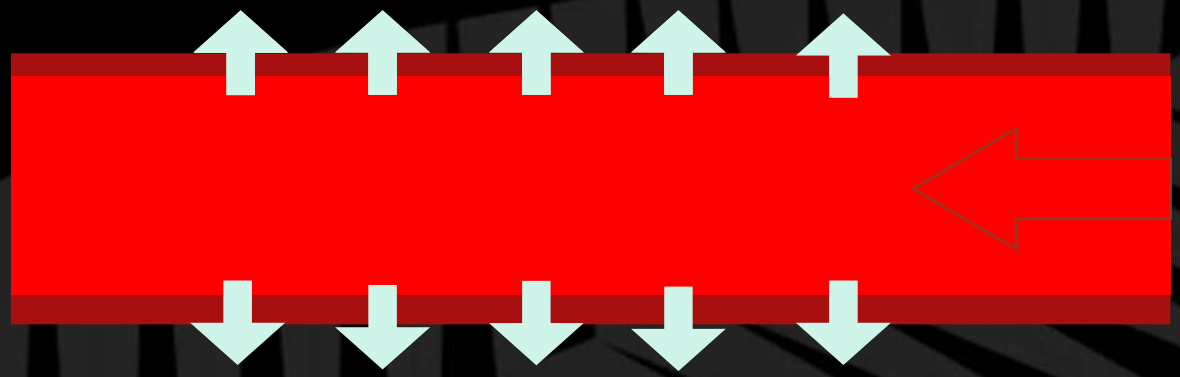
- I created a model heart with pulse and pressure

Extra Slides

Components of BP

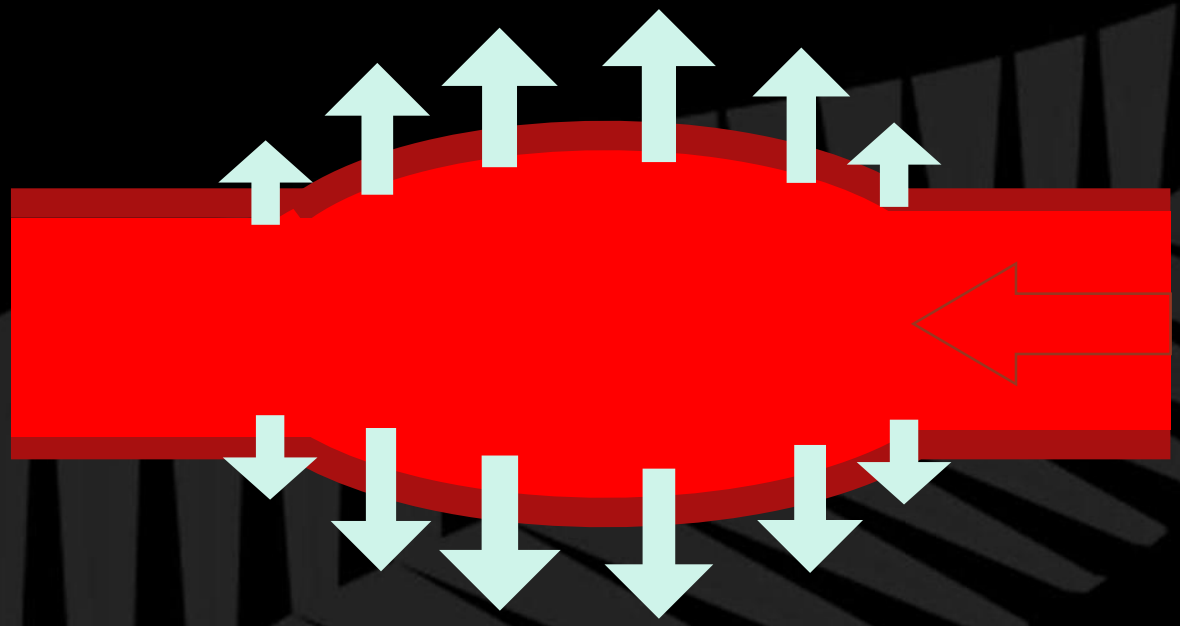
$$\Delta Pressure = Flow \times Resistance$$

$$= C.O. \times PR$$



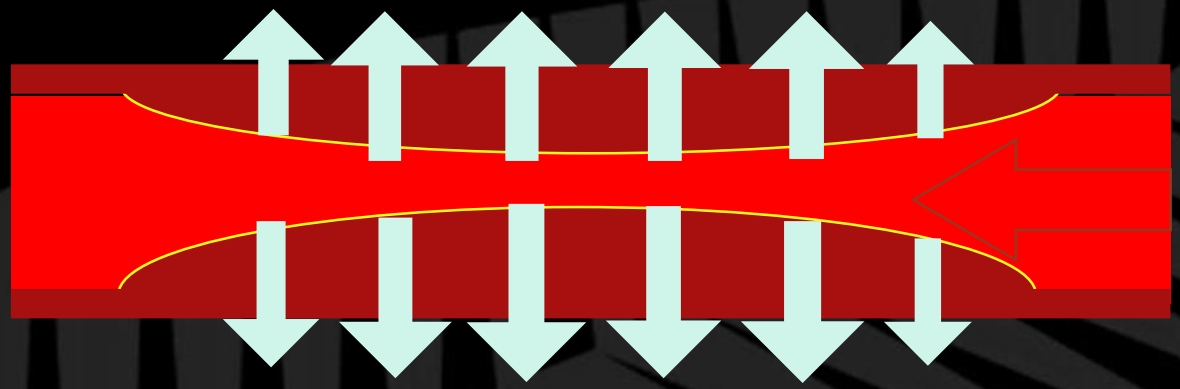
Causes of Hypertension

$$\mathrm{BP} = \boxed{CO} \times PR$$

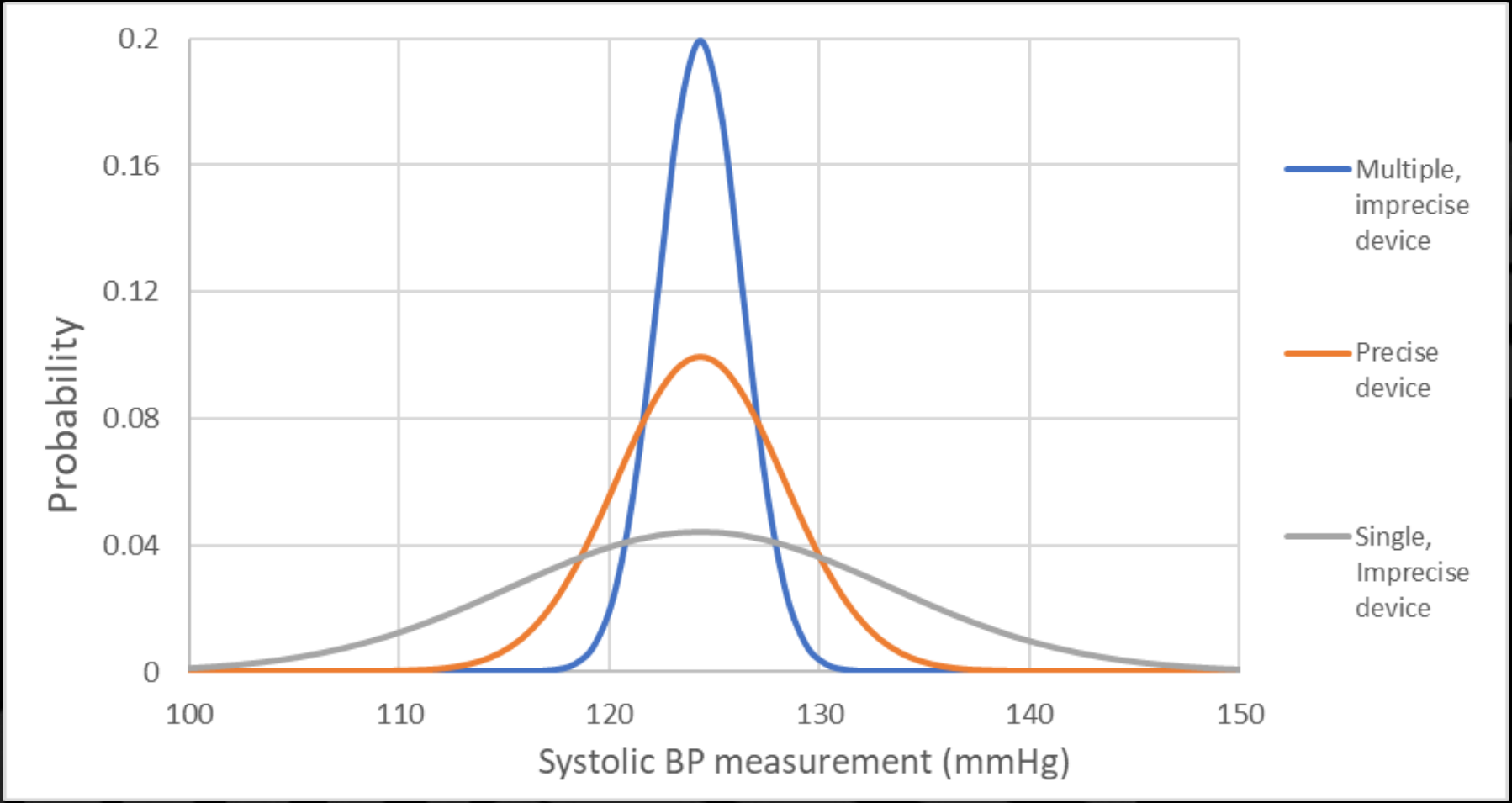


Causes of Hypertension

$$\mathrm{BP} = C.O. \times \boxed{PR}$$



Statistical Simulation



Windkessel model

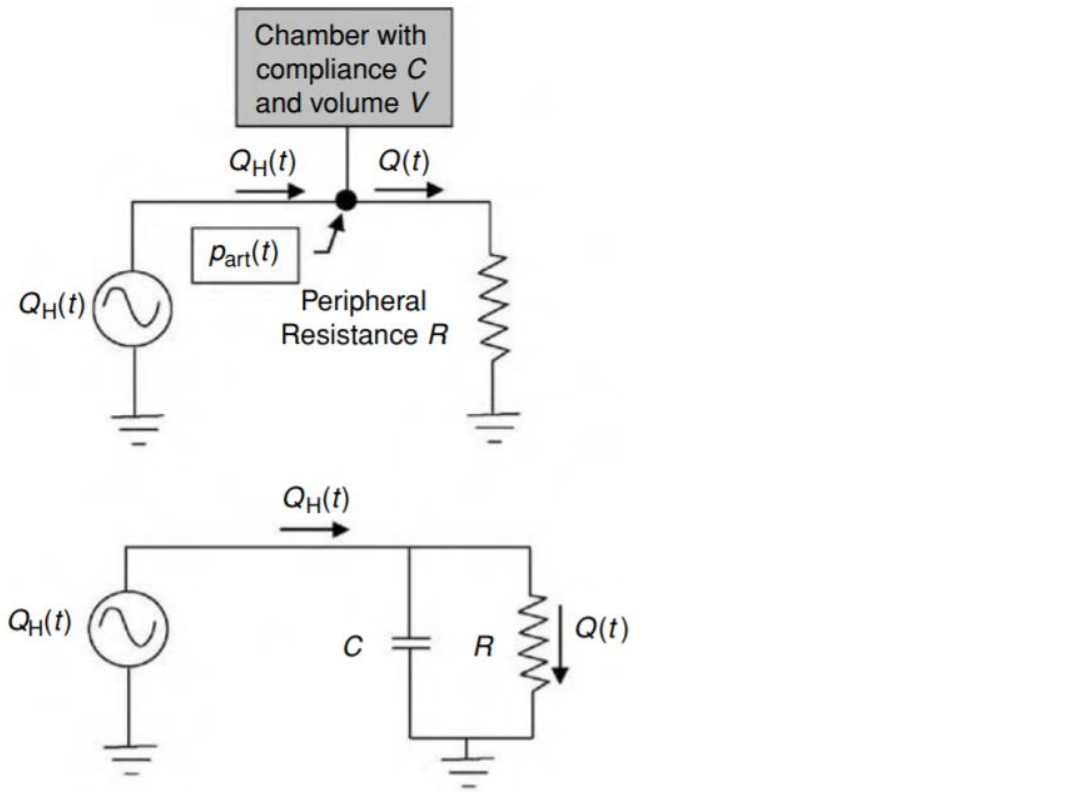


Figure 4.13

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].

https://enggbiochem.files.wordpress.com/2014/08/biomechanics-from-cells-to-organisms.pdf

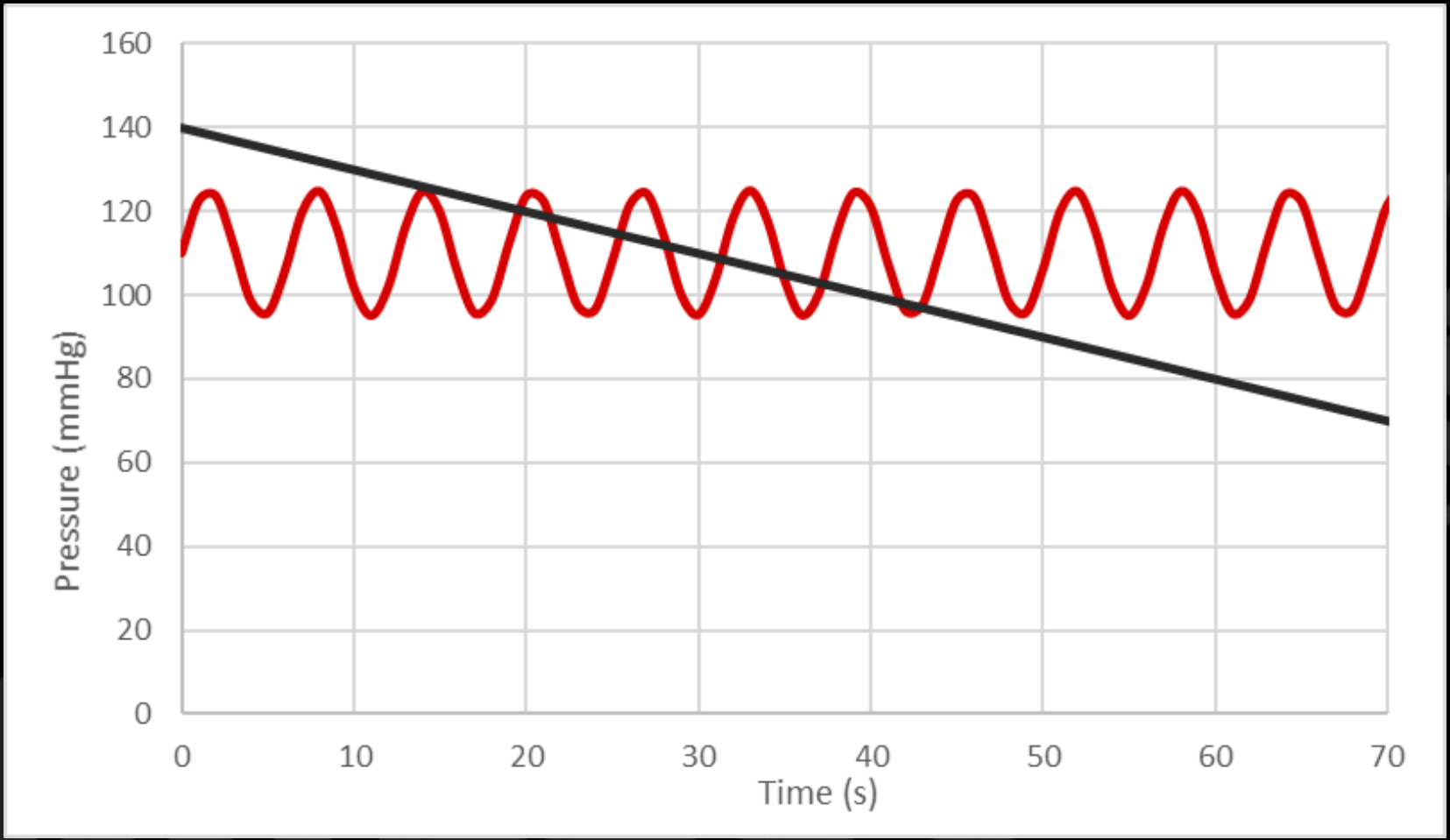
- Age
- Sleep
- Setting
- Disease
- Medication
- Respiration
- Body position
- Physical activity
- Emotional stimuli
- Nutritional factors
- Genetic predisposition

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

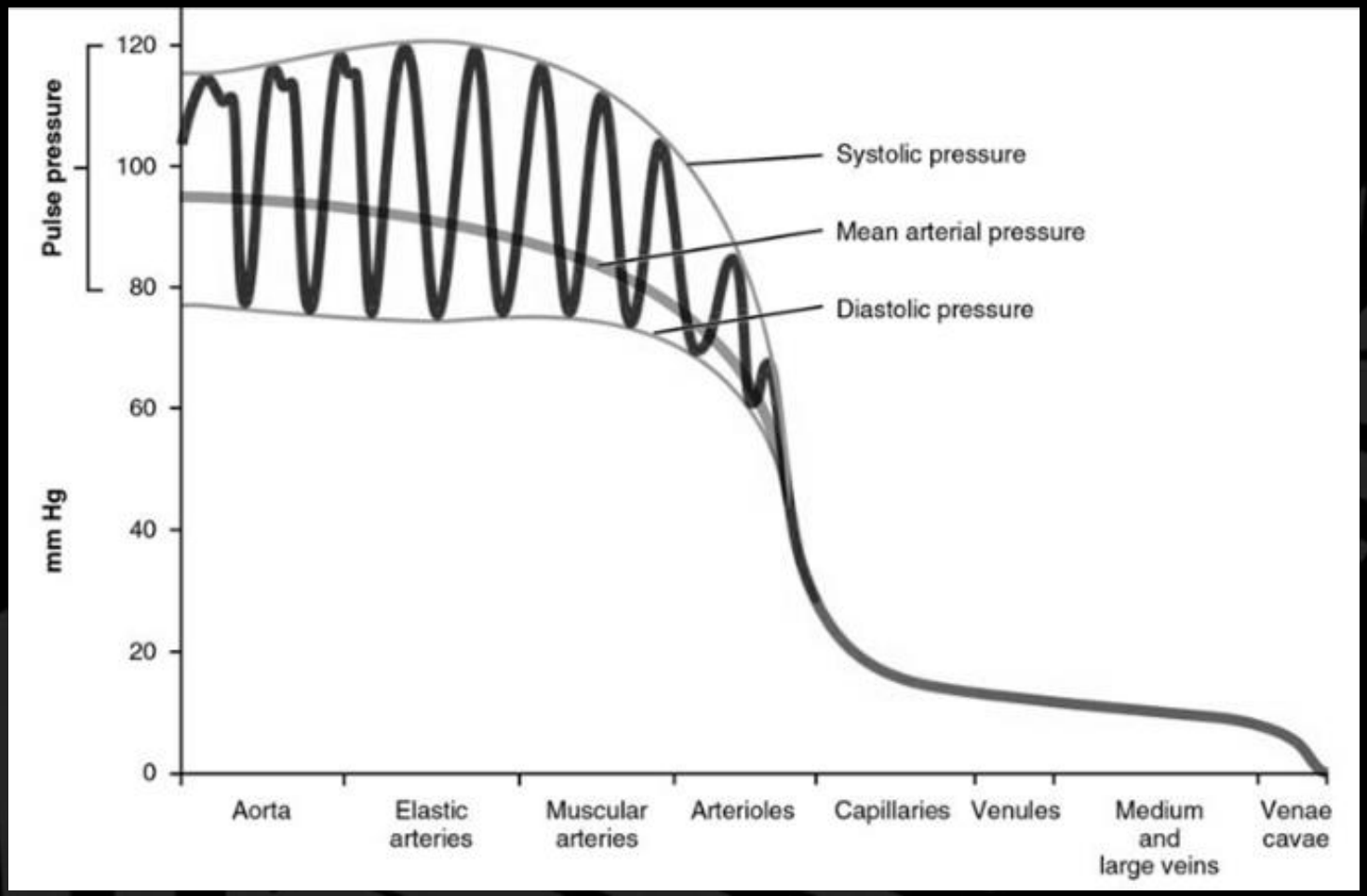
CO ↑ OR ↓

PR ↑ OR ↓

Measurement Techniques

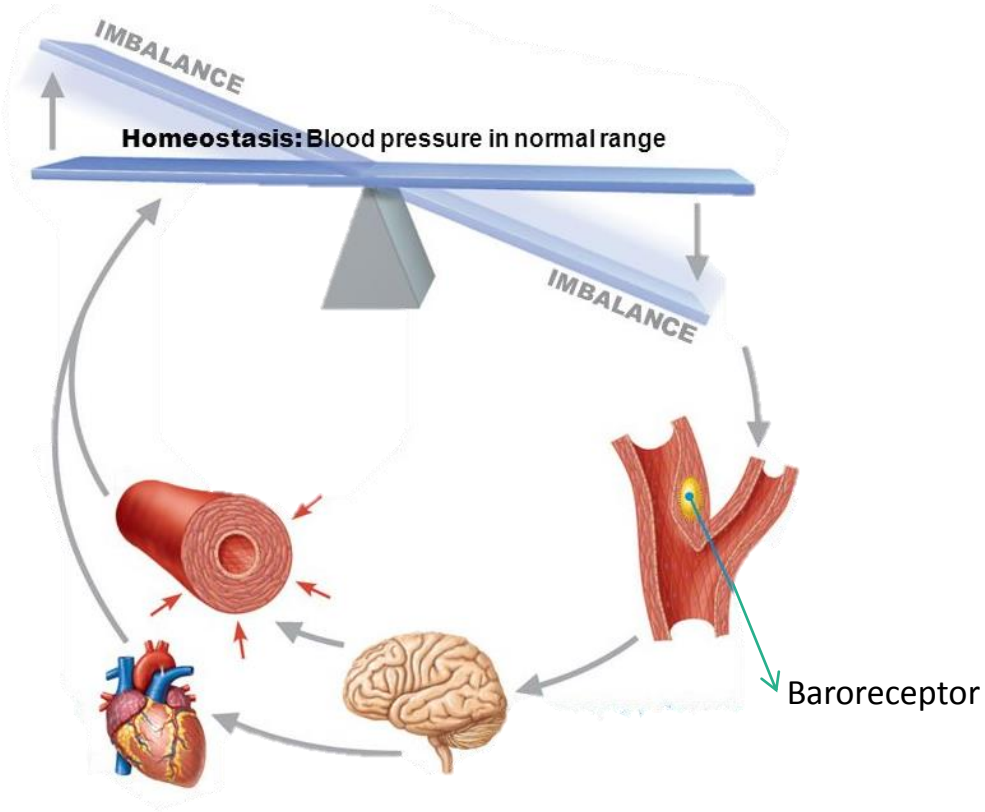


Amplification Phenomena



Blood Flow, Blood Pressure, and Resistance

Regulation



- Regulation & homeostasis

↓

- Baroreflexes

↓

- Autonomic Nervous system

↓

- Sympathetics
- Parasympathetics

Methods

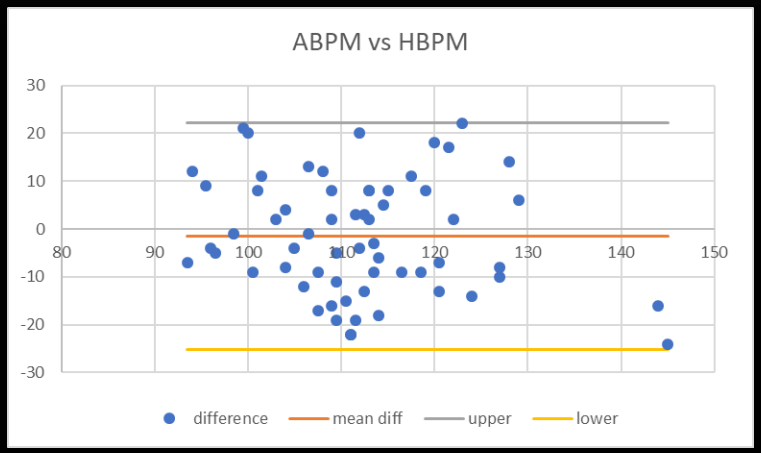
- ABPM
- HBPM

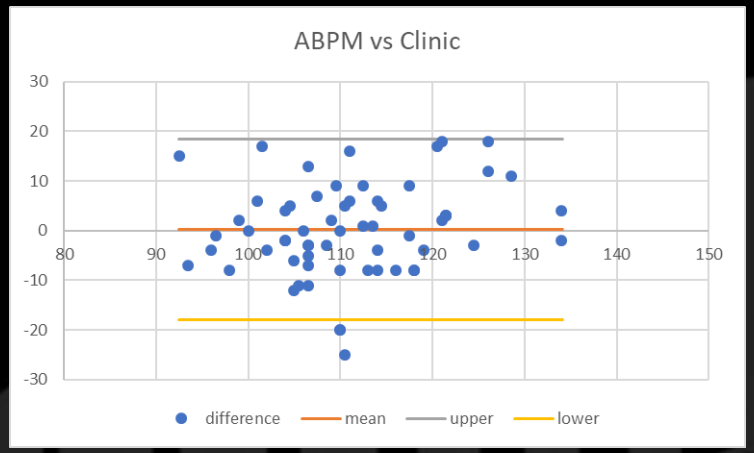
} Out of office

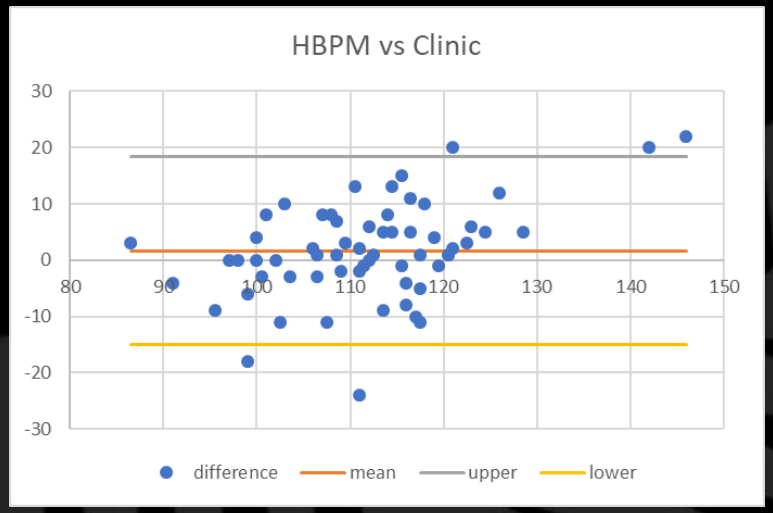
- Clinic BP

} In office

Bland and Altman analysis







Blood pressure Dagnosis Chart