MEASURING EXERCISE BLOOD PRESSURE USING LASER DOPPLER IN KIDS

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Client: Dr. Allen Wilson MD., UW Health Clinics, University of Wisconsin School of Medicine and Public Health
Advisor: Professor Paul D. Thompson Ph.D., University of Wisconsin College of Engineering

Abstract

Dr. Allen Wilson of UW Health Pediatric Cardiology would like a motion-stabilizing device for increased accuracy of a Laser Doppler that indicates when a child's heart is undergoing systolic blood pressure. Other products that measure blood pressure are only done when the patient is at rest, which allows for easier readings of systolic peak pressure. Therefore, Dr. Allen's experimenting with Laser Doppler technology should be considered as novel, and cannot be directly compared with other competing designs. The design team will fabricate a trough to be mounted to the treadmill and a detachable splint that the patient can use while testing to stabilize their hand.

Motivation

- Congenital heart diseases are the most common cause of infant death resulting from birth defects
- 27% of infants who die of a birth defect have a heart defect [1]
- Cost for inpatient surgery to repair heart defects exceeds more than $2.2 billion dollars per year [2]
- Treadmill stress testing can search for signs of arrhythmias, or irregular heart rhythms, to search for symptoms of more severe cases
- Little to no research has been done with detecting types of blood pressure using Laser Doppler technology

Background

Treadmill Stress Testing

- Used to test for arrhythmias (irregular heart rhythms)
- Also tests coronary artery disease
- Typically test lasts approximately 12 minutes
- 3 minute intervals, measure BP
- Intensity of test is gradually increased

Figure 1. Typical treadmill stress testing setup. [3]

Current Methods

- Stethoscope/cuff used to listen and read on adults
- Difficulty hearing cues in children
- Currently uses Piezoelectric pulse transducer with oscilloscope

Laser Doppler Flowmetry (LFD)

- Method used to assess blood flow [3]
- Single-frequency light illuminates tissue
- Frequency distribution of the backscattered light used to estimate blood perfusion

Figure 3. Piezoelectric Pulse Transducer [4]

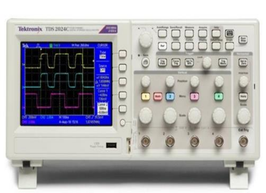

Figure 2. Autotrek oscilloscope used to read blood perusion [5]

Design Criteria

Client Requirements

- Adjustable for ages/hand sizes of 6-12 year olds
- Must provide oscilloscope with steady signal
- Reduce noise for systolic pressure reading
- Must not interfere with stress treadmill testing

Final Design

Considering Human Factors and Ergonomics (HFE)

- Goal of HFE and Psychology is to improve productivity, safety, and comfort [6]
- Design must consider that children have limited cognitive and motor abilities [6]
- Superhero "Willy the Supercow"

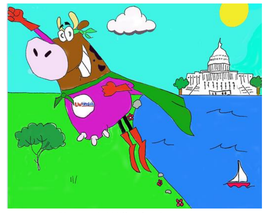

Figure 4. Willy the Supercow

Final Design

- Final design broken up into two parts:
  Hand Trough
  Finger Splint

Hand Trough

- Material: Polyvinyl Chloride, Airtex Heavy Duty Foam, Nylon
- *Dimensions*
- Diameter: 11.150cm
- Length: 17.78cm
- Foam Thickness: 1.27cm

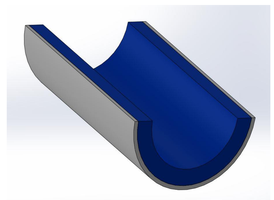

Figure 5. Hand Trough Design

Function: Resting area for blood pressure measurements

Figure 6. Finger Splint Design

Finger Splint

- Material: Aquaplast (Polycaprolactone)

Dimensions

- Depth: 4.230cm
- Length: 10.670cm
- Width: 0.630 cm (index finger portion), 6.35 cm (base component)

Function: Limits interphalangeal movement

References

[1] Youth and cardiovascular diseases. (2013). Retrieved September 28, 2015.
[2] Congenital heart defect fact sheets. (2012). Retrieved October 1, 2015
[3] Electrocardiograph (ECG,EKG) interpretation. (2009). Retrieved October 3, 2015
[4] http://www.adinstruments.com/products/pulse-transducers
[5] http://www.signaltestinc.com/Tektronix-TDS2024B-Oscilloscope-200-MHz-4-CH-p/tds2024c.htm
[6] Kristi, H. (2004). The Human Interface – New Directions for Designing Interactive Systems
[7] Wensel, R., Opitz, C.F., Anker, S.D., et. Al (2002). Assessment of survival with primary pulmonary hypertension: importance of cardiopulmonary exercise testing. *Circulation,* 106, 319-324.

Testing

Piezoelectric Pulse Transducer vs Laser Doppler Probe

- Compared noise reduction in piezoelectric pulse transducer with laser Doppler Probe using data analytics and visual inspection [7]

Systolic for Piezoelectric vs Laser Doppler

Probe Type	Subject 1	Subject 2	Subject 3	Average
Laser-doppler	3	4	4	**3.67**
Piezoelectric	1	1	2	1.33

Flat Line for Piezoelectric vs Laser Doppler

Probe Type	Subject 1	Subject 2	Subject 3	Average
Laser-doppler	5	4	4	**4.33**
Piezoelectric	1	2	2	1.67

Piezoelectric vs Laser Doppler Noise %

Subject	Subject 1	Subject 2	Subject 3	Average
% Frames Nonzero Laser Doppler	35.08%	32.04%	37.19%	**34.77%**
% Frames Nonzero Piezoelectric	48.31%	54.71%	47.91%	50.31%

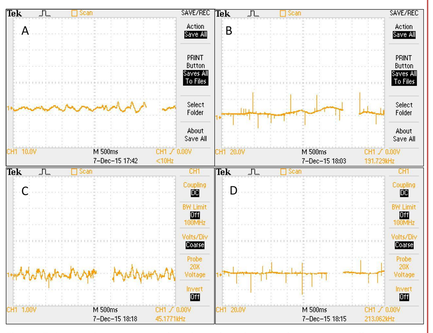

Figure 7. Image A represents the piezoelectric transducer at systolic pressure with a score of 1. Image B represents the laser Doppler at systolic pressure with a score of 4. Image C represents the piezoelectric transducer at flat line with a score of 1. Image D represents the laser Doppler at flat line with a score of 5.

Splint Design vs Trough with Splint Design

- Compared the noise for the splint design to the trough with splint design using visual inspection

Systolic for Splint vs Trough with Splint

Probe Type	Subject 1	Subject 2	Subject 3	Average
Splint	5	4	3	**4**
Trough with Splint	2	3	1	2

Flat Line for Splint vs Trough with Splint

Probe Type	Subject 1	Subject 2	Subject 3	Average
Splint	5	4	4	**4.33**
Trough with Splint	1	2	2	1.67

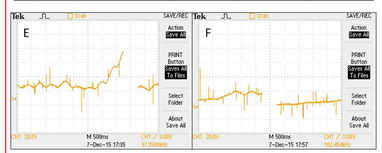

Figure 8. Image E represents the trough with splint at systolic pressure with a score of 1. Image F represents the splint at systolic pressure with a score of 4.

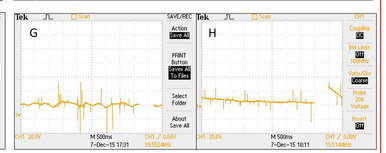

Figure 9. Image G represents the trough with splint at flat line with a score of 1. Image H represents the splint at flat line with a score of 5.

Future Work

- Fabricate splints for a variety of hand sizes
- Look into making the distal phalanx more stable
- Test and analyze data on kids 6-12 yrs old
- Utilize Periflux PSW ExM Analysis Software
- Implement bioinstrumentaion feature
- Apply human factors to create a user-friendly experience

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