Johnson Health Tech: EMG Sensor Holder

College of Engineering
UNIVERSITY OF WISCONSIN–MADISON

UW BME Design

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Advisor: Dr. John Puccinelli Client: Staci Quam and Arrington Polman

Department of Biomedical Engineering, Fall 2020

Abstract

JHT uses Delsys Trigno sensors to collect data on a runner's center of mass and step force. To do so, they use the sensor's inertial measurement unit to collect acceleration data and convert it into force using the subject's mass. The current method of attaching the sensors to the back of the shoe with athletic tape often causes the sensor to move and the tape to roll up. This is less than ideal since the sensor movement adds excess noise to the data making it harder to process and the tape rolling up can be uncomfortable for the runner. One chest strap and two different shoe holders were created and tested for stability. In addition to reducing extraneous movement, factors including comfort and ease of use must be considered before selecting the final shoe holder design to continue to improve.

Motivation

- Accelerometers can be used to determine forces and velocities of body segments [1].
- Ground reaction forces and step rate data can be used to assess injury risk [1].
- JHT has no reusable method for attaching the sensors to the heel of users shoes.
- JHT needs sensor holders that are easily applied, stable, reusable, and will not impede on the runners natural gait.
- Better sensor holder will increase the accuracy of the data collected.

Background Research

- The sensor is an electromyography and accelerometry device [2].
- Can output data wirelessly and be processed externally [2].
- Acceleration data can be converted to step rate and force per step.
  - Addition of center of mass data can yield more accurate data for total body movement.
  - Sensors can be placed at other areas of interest.
- Newton's second law can be used to find various forces exerted on the runner [3].
- Forces can be combined with joint angle and loading rate to characterize running technique [4].
- JHT can characterize a runner's gait and determine injury risk across different environments.

Design Specifications

- Must weigh < 0.5 lbs.
- Two sets of sensor holders.
- Cost less than $500.
- Reusable and easily sterilized.
- Does not interfere with the runner or cause injury.

Shoe Sensor Holder:

- Held on the heel.
- Fit shoes sizes 21.6 cm to 28.6 cm [5].
- Withstand up to 4 kN of force [6][8].
- Displacement less than 0.5 cm

Chest Sensor Holder:

- Fit a chest circumference between 80 and 150 cm [6][7].
- Sensor displacement less than 2.0 cm

Acknowledgements

Dr. Puccinelli
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Staci Quam

Design Progression

- The Straps:

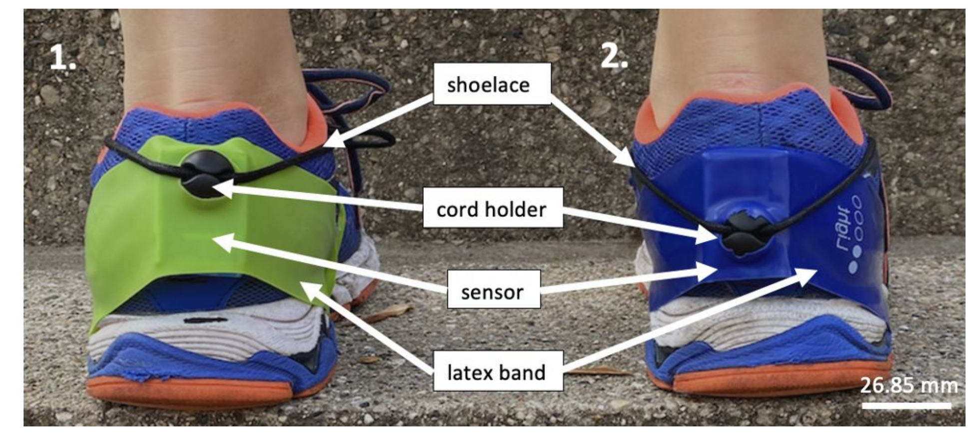

Figure 1: This image shows the progression of the straps design and how placement of the cord holder changed.

- The Clip:

Figure 2: The first model developed to test the feasibility of the Clip design. Pipe cleaners were run directly over the heel of the shoe and under the insole.

Final Design

The Clip

- Shaped so that the portion of the wire in the shoe runs up the side rather than the back.
- **18 gauge copper wire model:** Rubber-coated copper wire runs beneath the insole of the shoe and attaches to a duct tape sensor holder (Figure 3a).
- **16 gauge steel wire model:** Steel wire runs beneath the insole and attaches to a polyester sensor holder (Figure 3b).

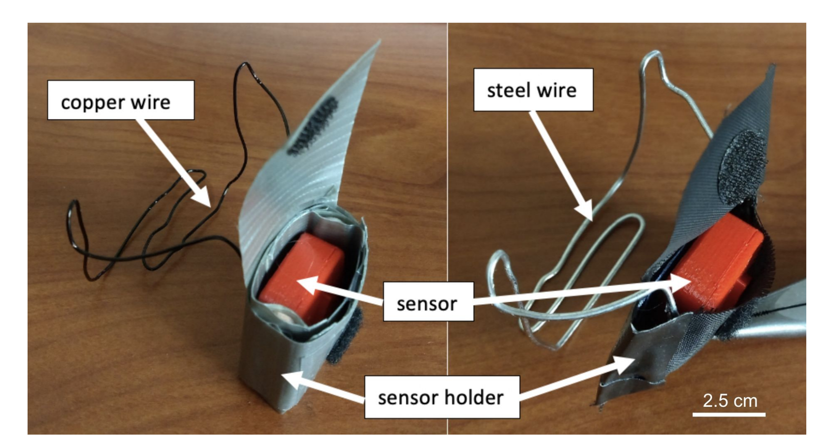

Figure 3a and 3b: These images show the copper wire model (3a) and the steel wire model (3b) out of the shoe. Each consists of one continuous wire for easy transfer between shoes.

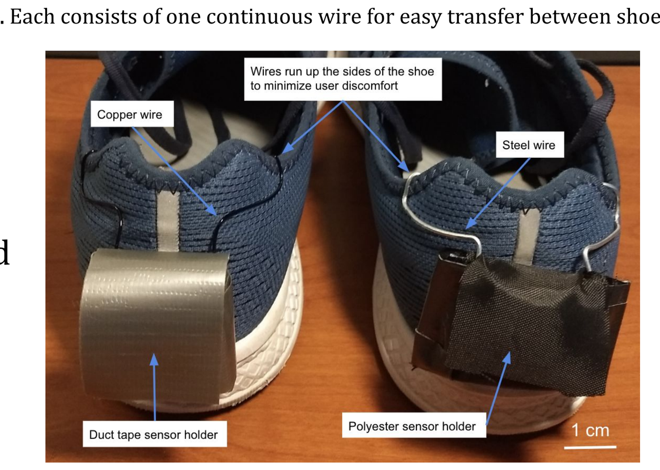

Figure 4: Both Clip designs applied to running shoes. The 18 gauge rubber-coated copper wire on the left, and the 16 gauge steel wire on the right.

The Straps

- Latex band creates downward force on sensor that is opposed by the shoelace in the cord holder to ensure stability of the sensor.

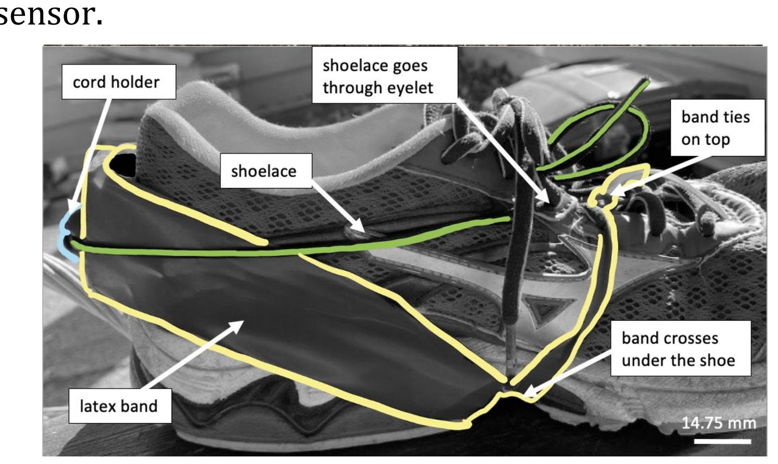

Figure 5: The final design of the straps design consists of a latex band that is crossed under the arch of the foot and tied on top of the laces to ensure a wider range of adjustability.

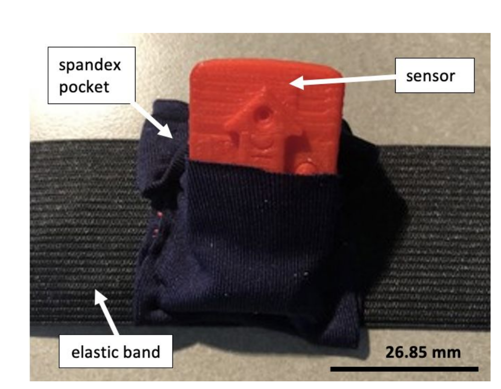

Figure 6: A close up view of the pocket holding the sensor. It is held in place solely by the spandex pocket with the flap overtop.

The Chest Band

- Elastic band gives the strap added stability and reduces the amount of movement around the torso.

Adjustability

- Minimum length 63cm
- Maximum length unstretched 129 cm
- Maximum stretched length ~240 cm

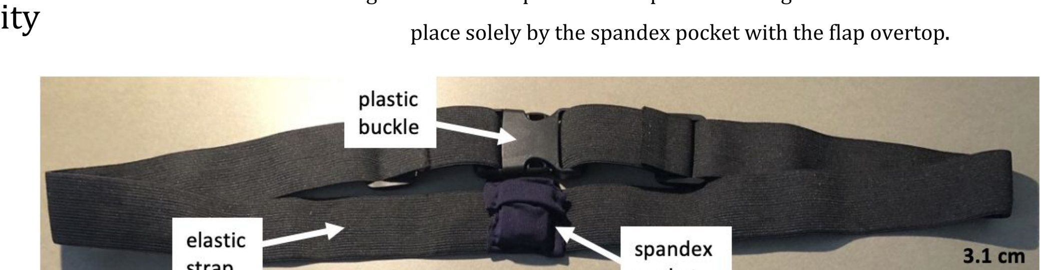

Figure 7: This first prototype of the chest band sensor holder. The center features the pocket for the sensor and the clip would be on the users back.

Testing

Phase One:

Figure 8: Testing set-up to determine which straps design is better

Phase Two:

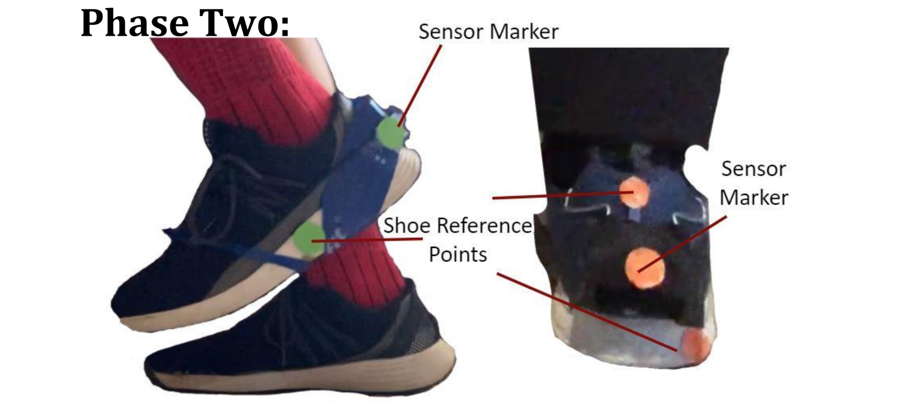

Figure 9: Screenshot of the shoe sensor holders being evaluated via motion capture

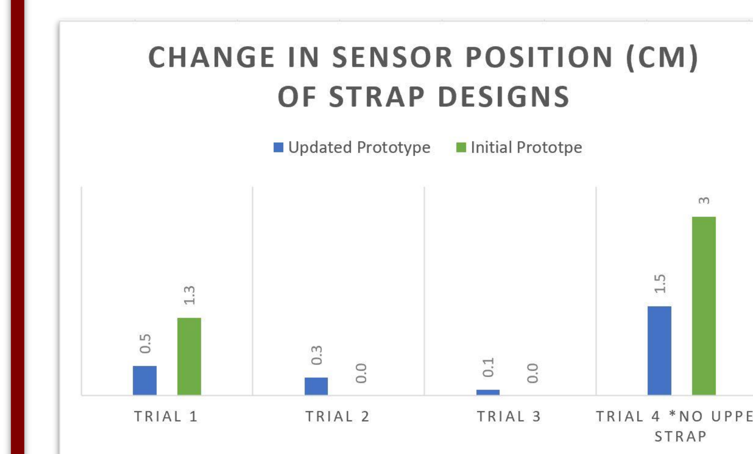

Figure 10: Phase 1 results: change in position of the sensor after one minute of running.

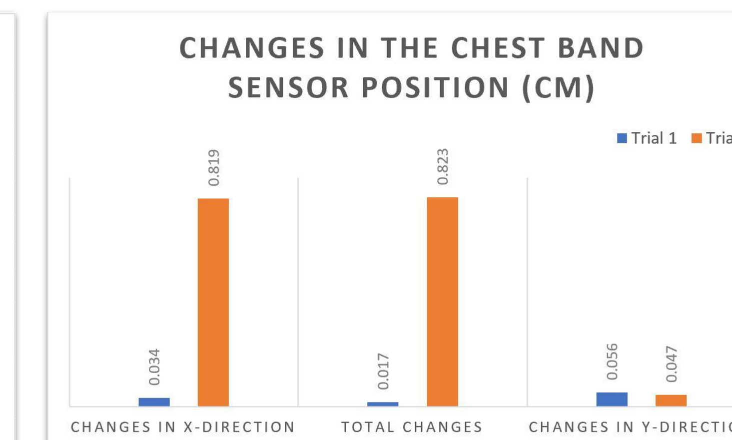

Figure 11: Phase 2 results: change in of the sensor throughout of the trial for the chest sensor holder

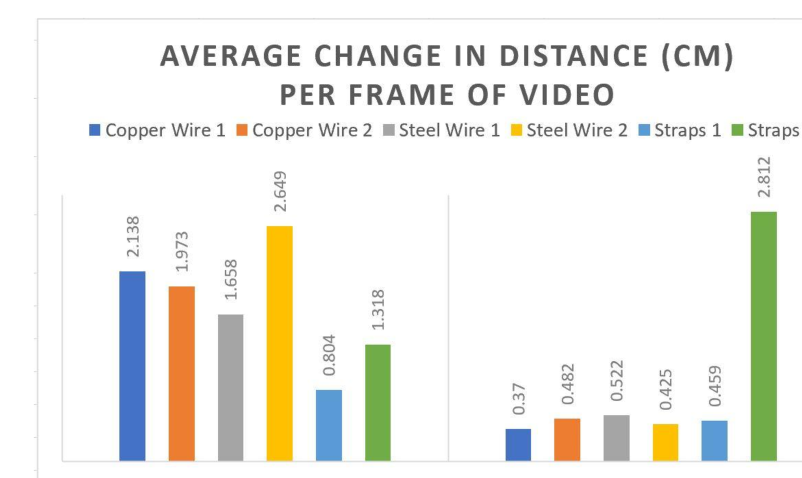

Figure 12: Phase 2 results: average change in distance of the sensor on the shoe per frame for the three final designs in two different perspectives

Table 1: The statistical analysis of the shoe sensor holder phase two results

	p-Value Back	p-Value Side
desired value	**1.0 cm**	**0.2 cm**
Copper 1	0.004	0.342
Copper 2	0.007	0.253
Steel 1	0.028	0.226
Steel 2	7.75×10^{-4}	0.296
Straps 1	0.250	0.270
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Discussion & Future Work

Sources of Error

- Change in foot angle
- Low camera quality
- Kinovea losing the marker

Future Design Modifications

- Add additional support
  - Combine designs
  - Add side wires

Future Testing

- More trials with better cameras
- Trials designed for specific movements
- Filter out the change in X and Y distances that are due to the rotation of the foot
- Test the chest band over different types of clothing

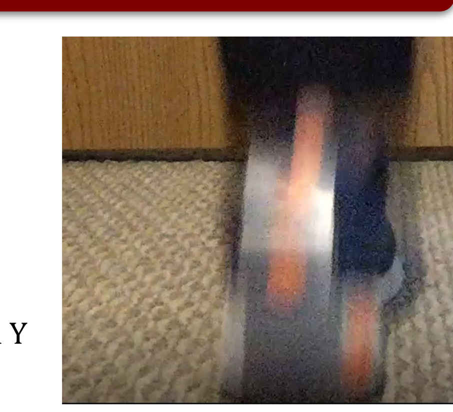

Figure 13: A screenshot of one of the videos used for motion capture. The markers are blurred making it hard for the software to follow and difficult to manually place the tracker.

References

[1] D. Kiernan, D. A. Hawkins, M. A. Manoukian, M. Mckallip, L. Oelsner, C. F. Caskey, and C. L. Coolbaugh, "Accelerometer-based prediction of running injury in National Collegiate Athletic Association track athletes," Journal of Biomechanics, vol. 73, pp. 201–209, May 2018.
[2] Delsys Incorporated, "Trigno® Wireless Biofeedback System User's Guide," Trigno Wireless Biofeedback System User's Guide, Feb-2020. [Online]. Available: https://delsys.com/downloads/USERSGUIDE/trigno/wireless-biofeedback-system.pdf. [Accessed: 06-Oct-2020].
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[6] "Measure Your Shoe Size." 6 pm. [Online], Available: https://www.6pm.com/measure-your-shoe-size. [Accessed: 6-Oct.-2020]
[7] "SizeUK: Average Measurements for Men & Women," [Online] Humanics, 2020.
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Design Progression: The Straps

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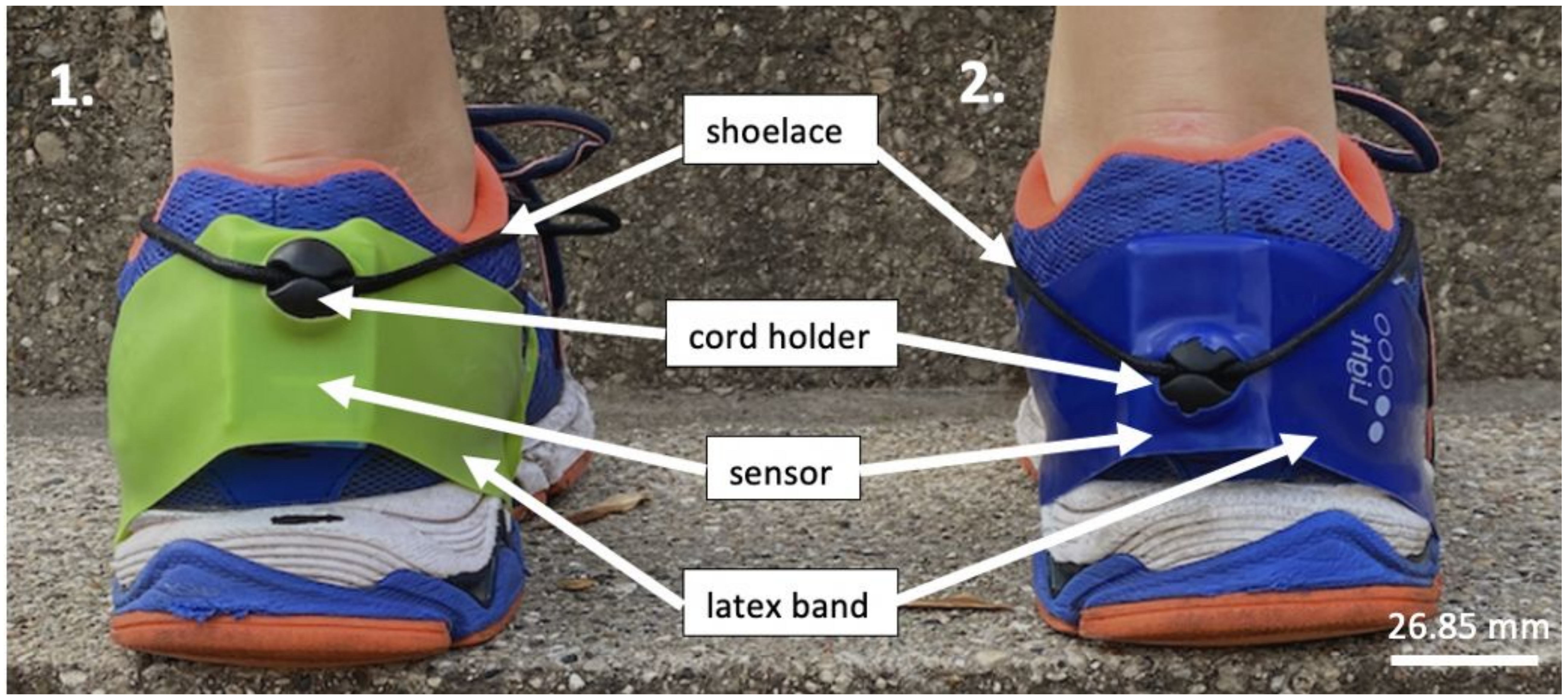


Figure 1a. The back of the two straps prototypes. Demonstrates the difference between the cord holder placement.

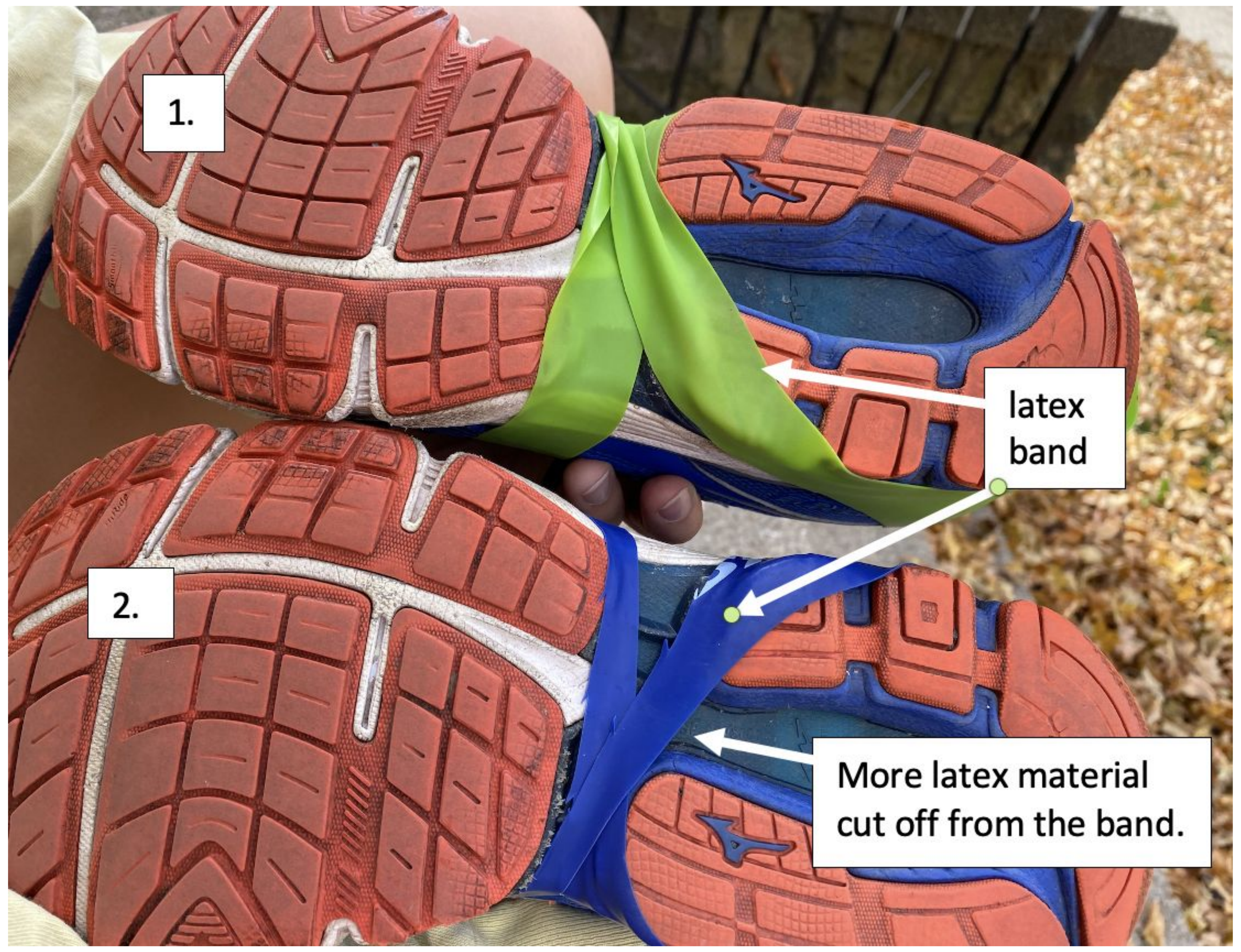


Figure 1b. The latex bands cross under the arch of the shoe.

Figure 1c. The force created by the shoelace in first prototype has a downward angle and an upward angle in the final design.

Design Progression: The Clip

Figure 2a. The first model developed to test the feasibility of the Clip design. Pipe cleaners were run directly over the heel of the shoe and under the insole.

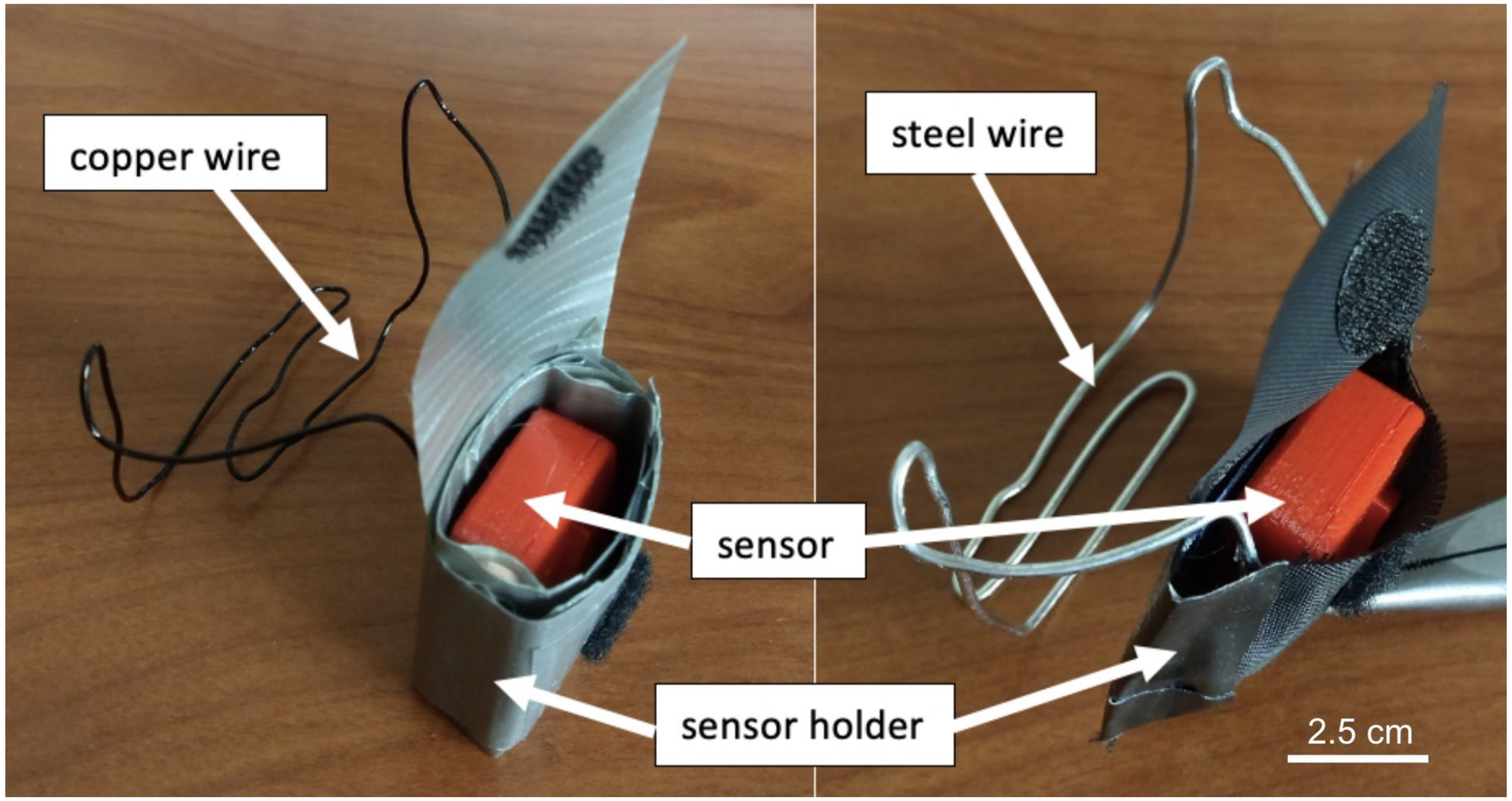
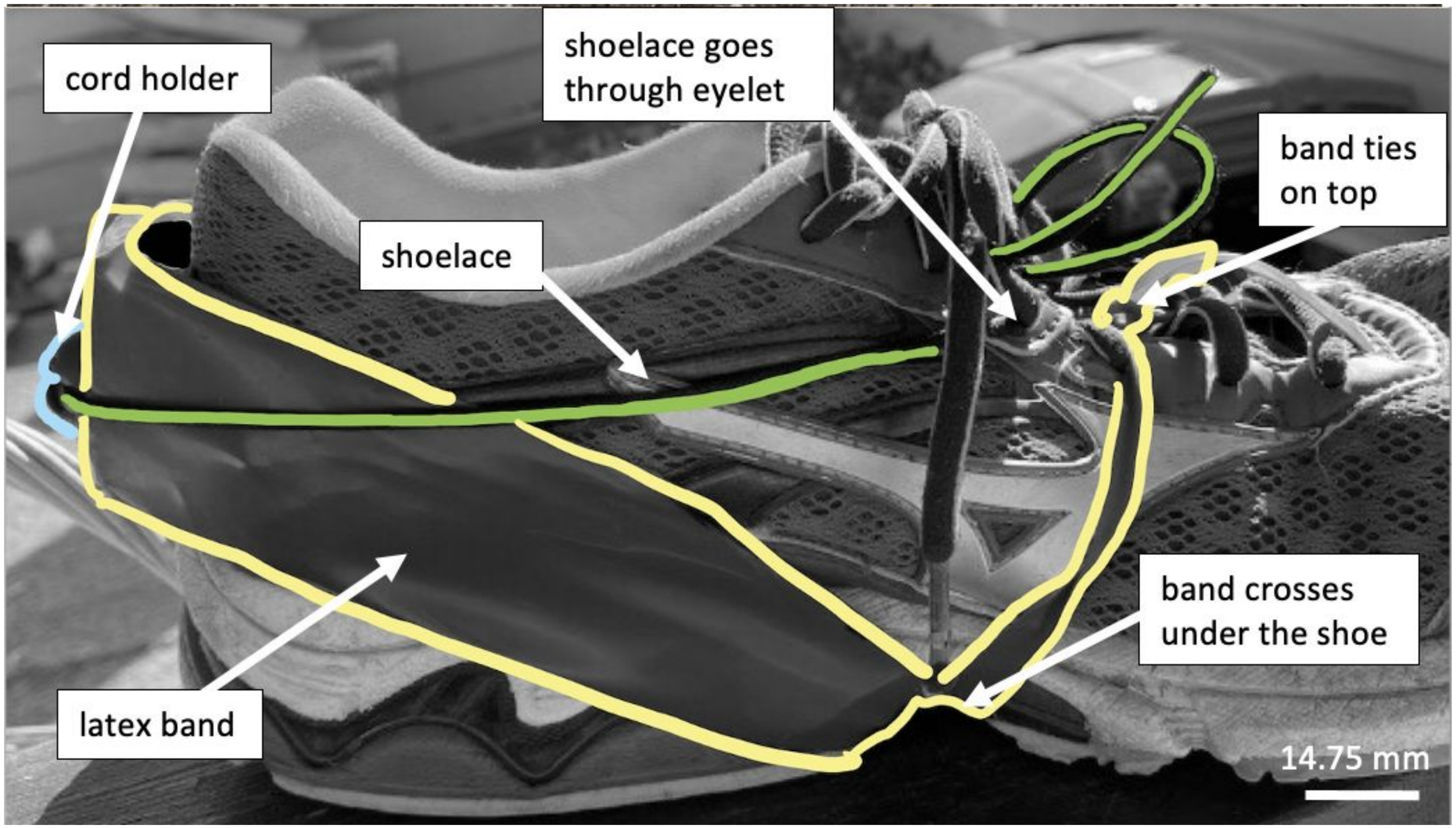


Figure 2b. The two prototypes for the Clip design. The one on the left uses copper wire and the one on the right uses steel wire.

Final Design: The Straps



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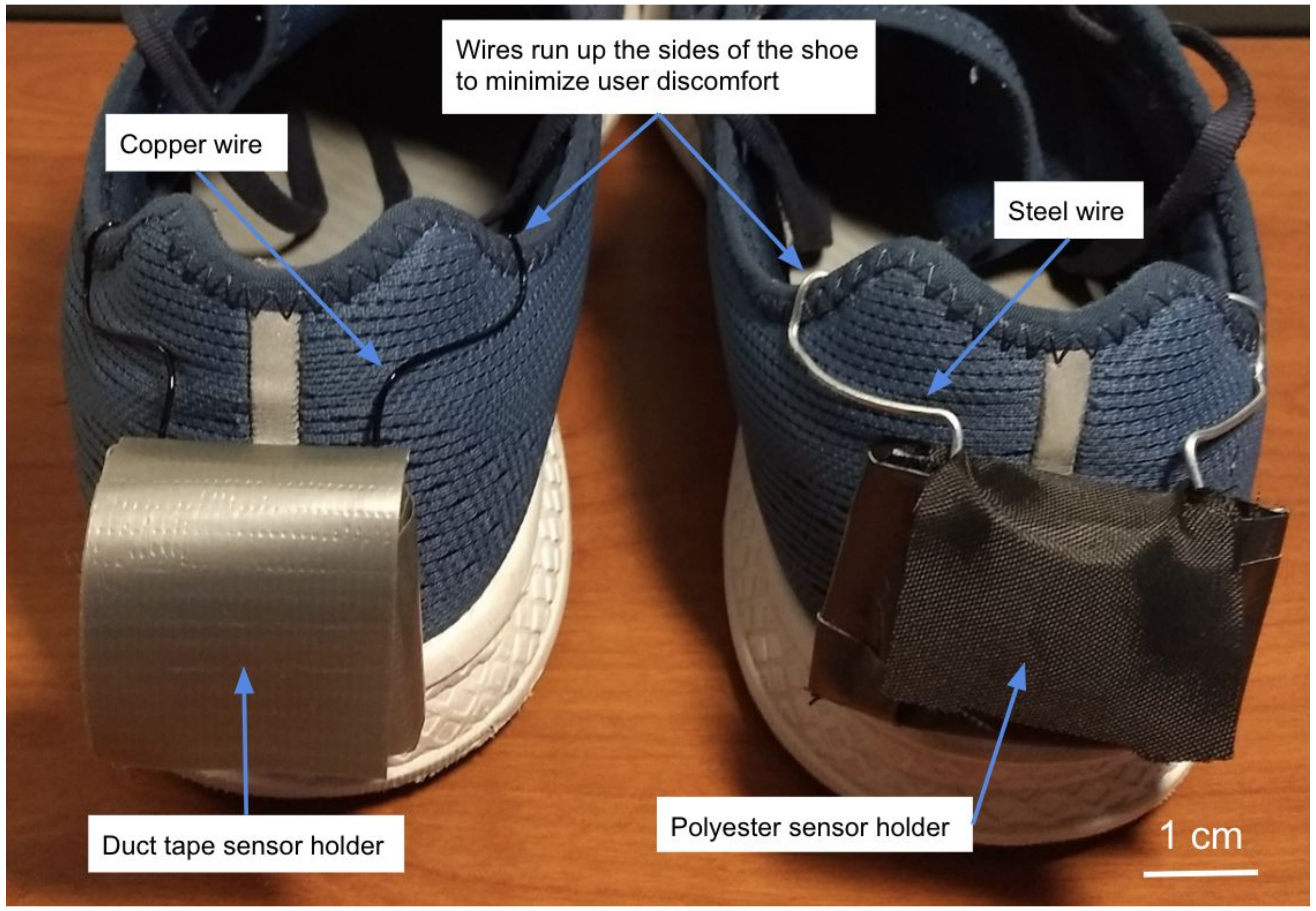

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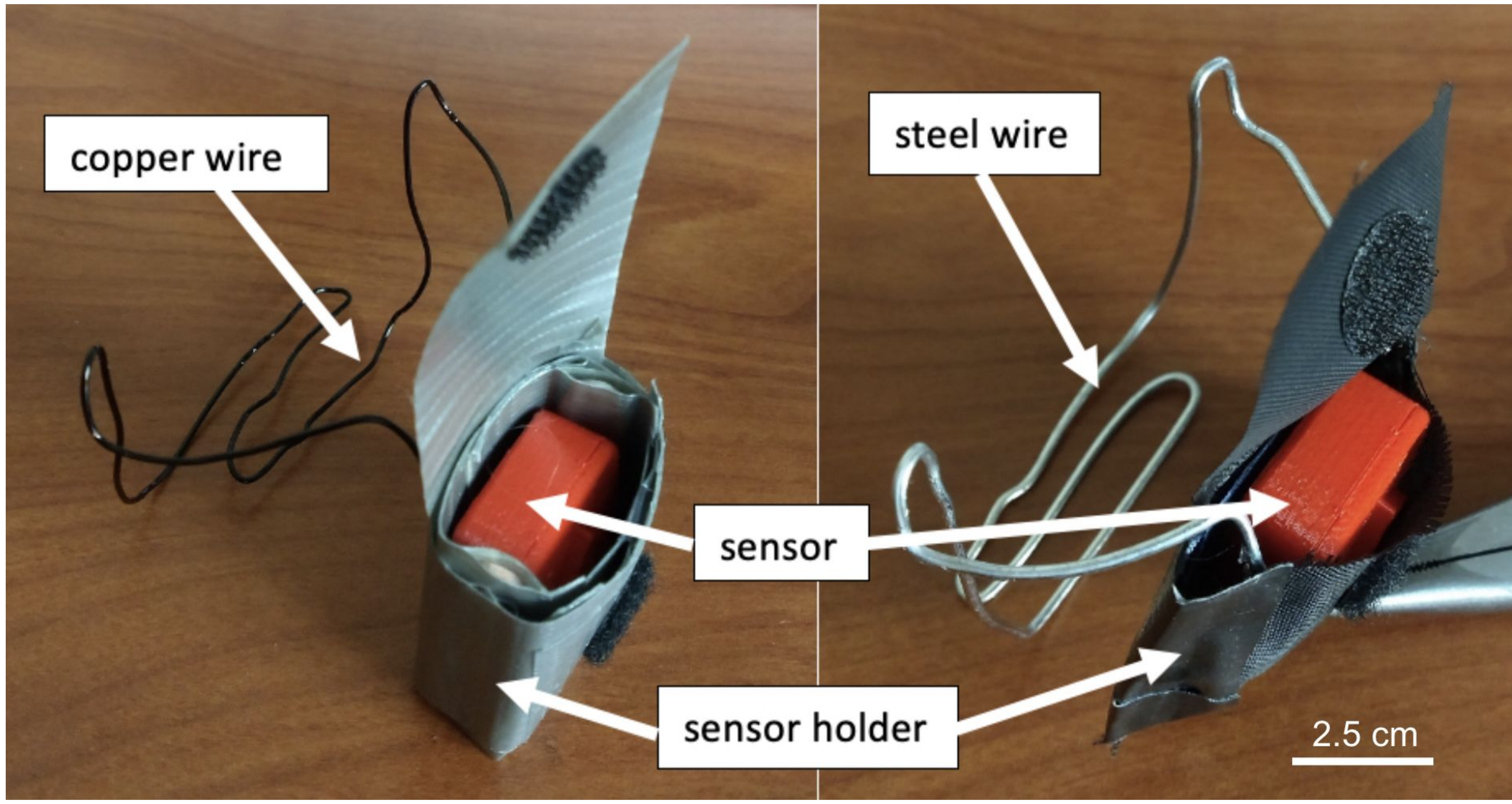

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Final Design: The Chest Band

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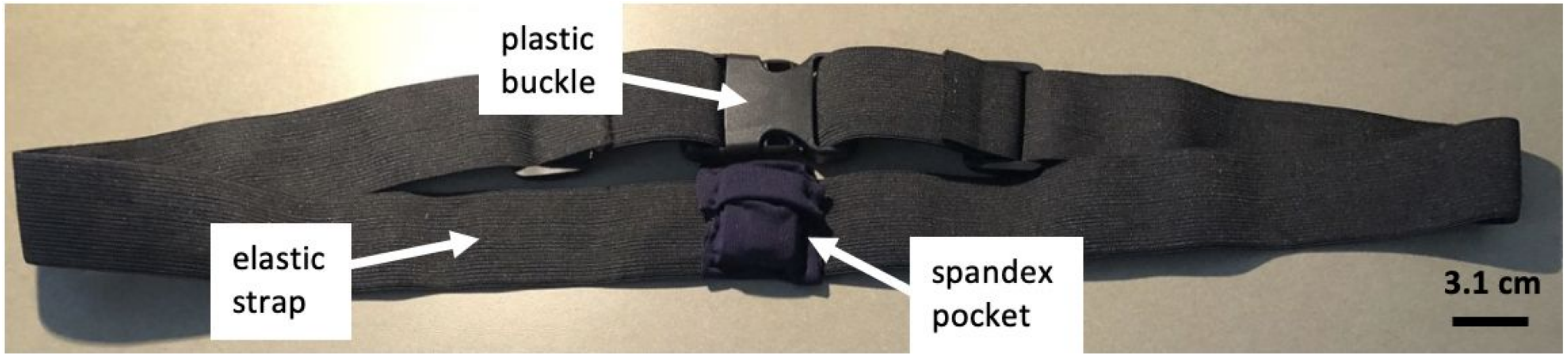

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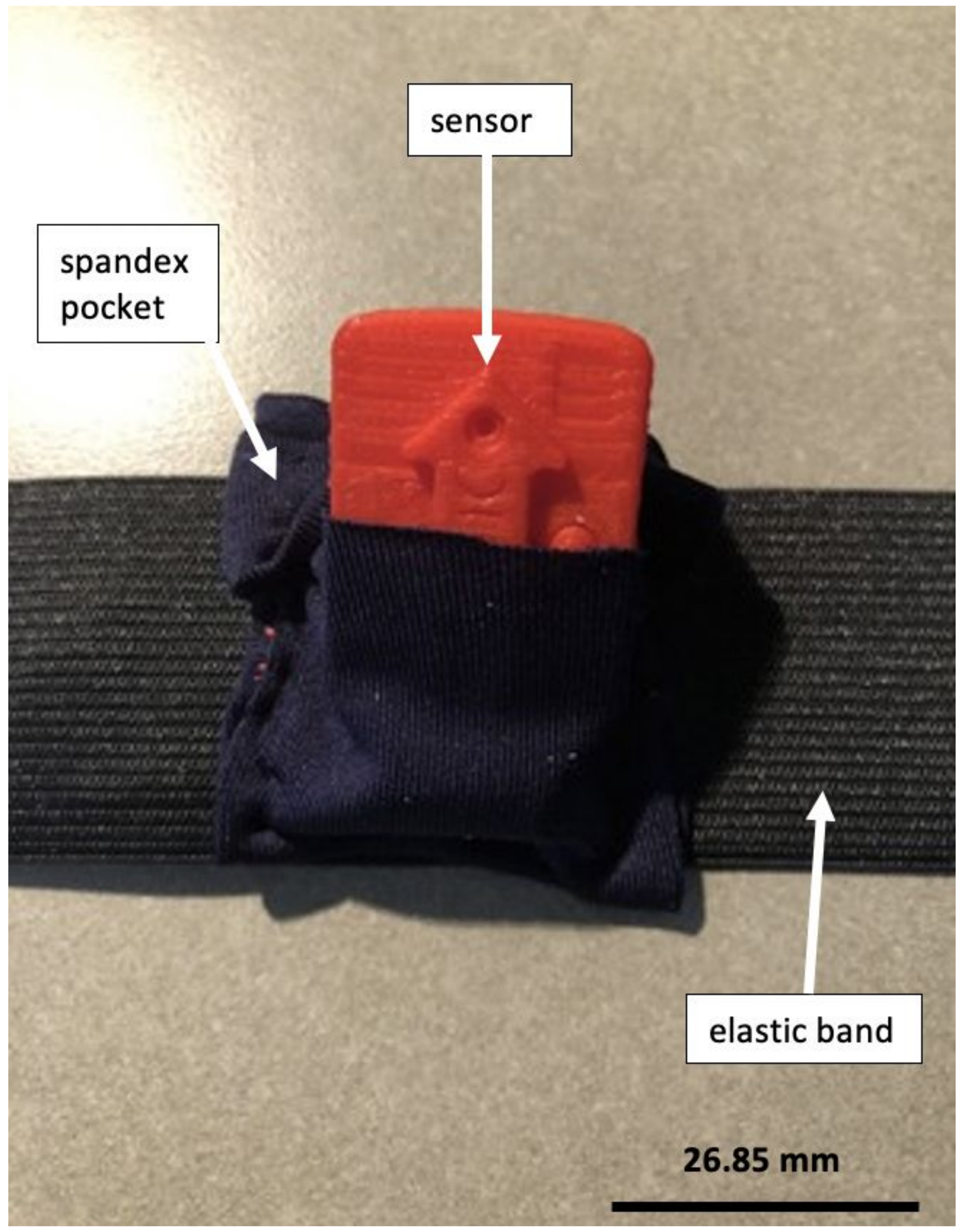

Figure 6: A close up view of the pocket holding the sensor. There is no zipper or fastener. It is held in place solely by the spandex pocket with the flap overtop.

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Video Demo

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Testing Procedures

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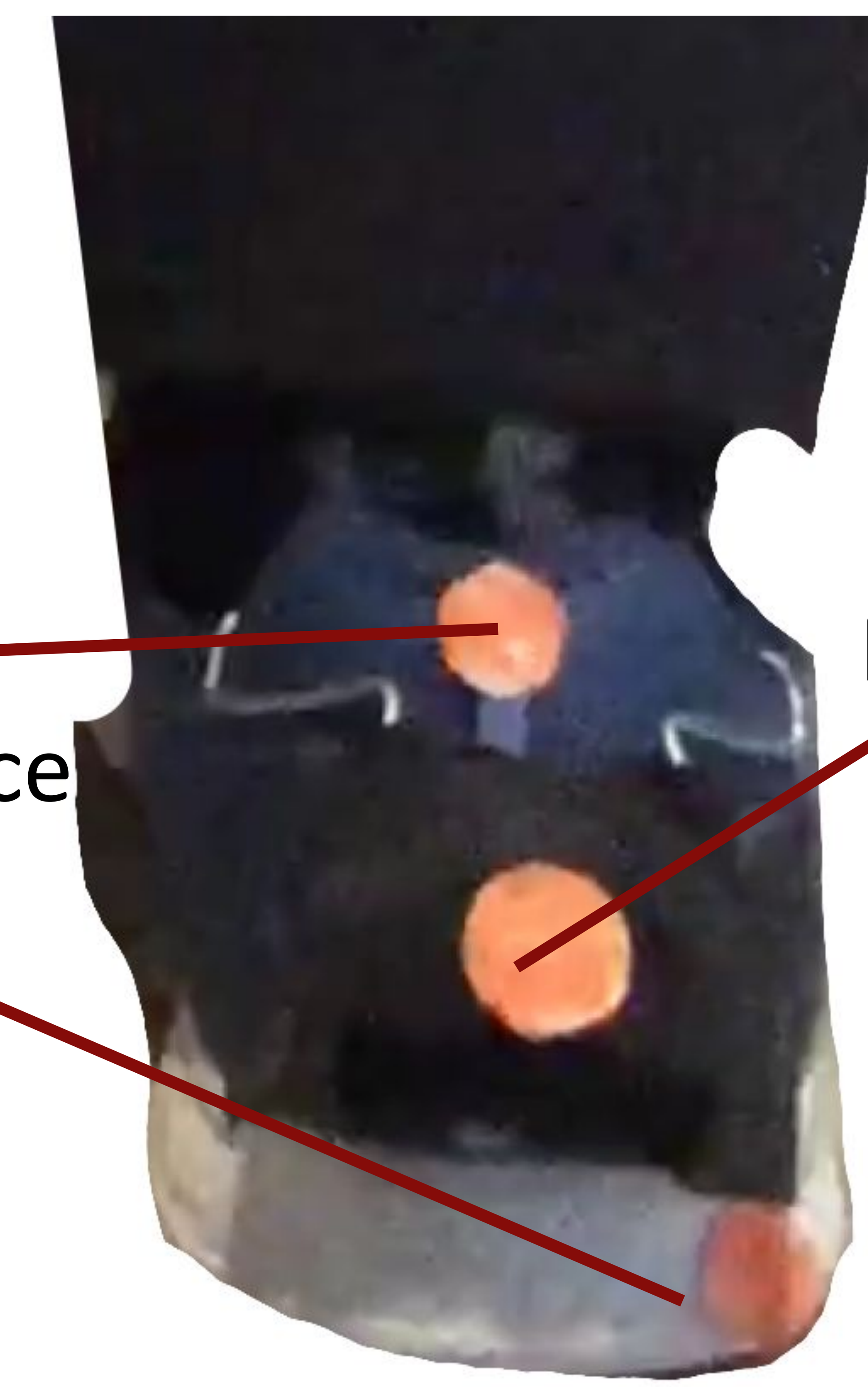
Phase 1 Procedure-

The shoe with lines indicating the positions of the sensor pre- and post-run

Phase 2 Procedure-

Screenshot of a side-view straps testing video that was analyzed in Kinovea



Screenshot of a back-view clip testing video that was analyzed in Kinovea

Phase 1: Testing Results

Preliminary Strap Prototypes Testing

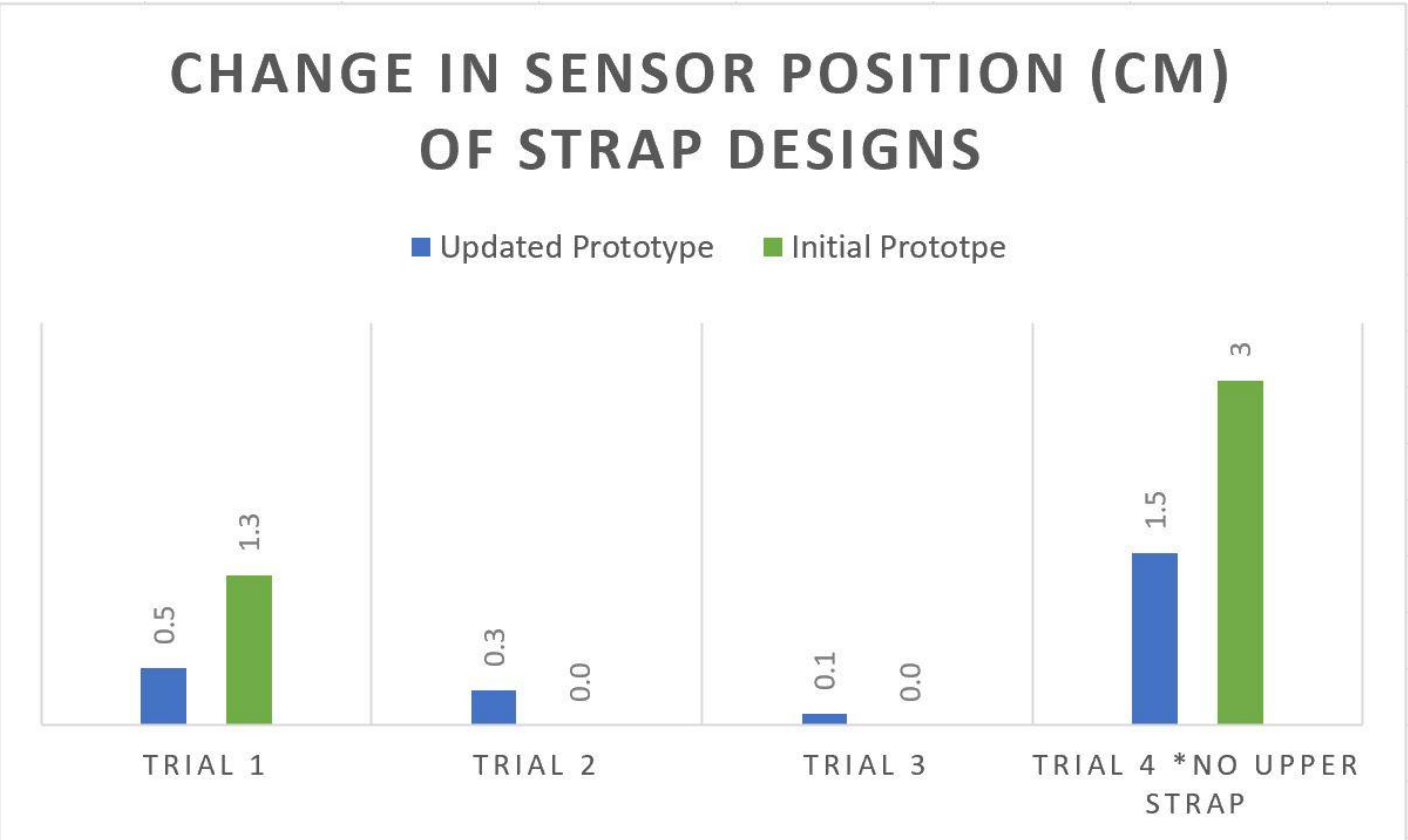
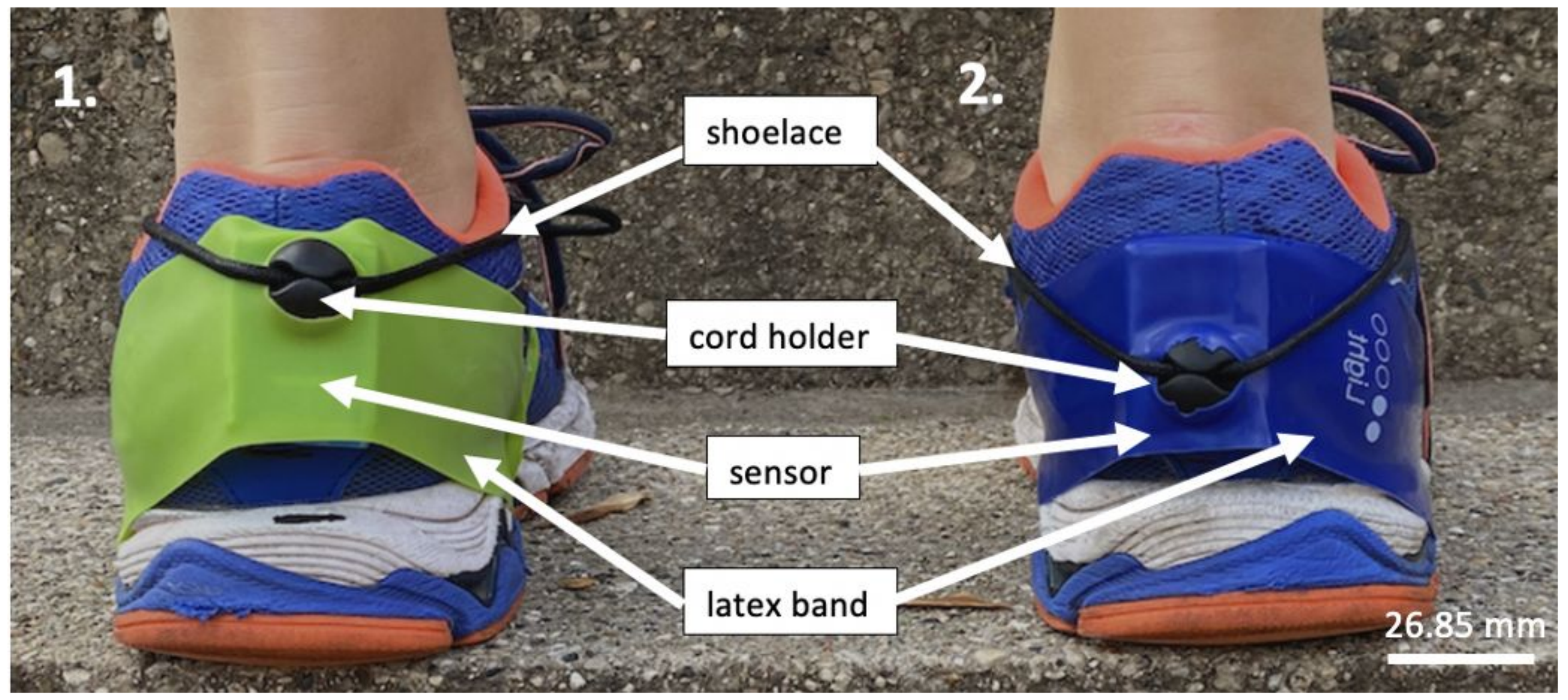


Figure 10: Phase 1 results: change in position of the sensor after one minute of running.

Initial Design Updated Design



Phase 2: Testing Results

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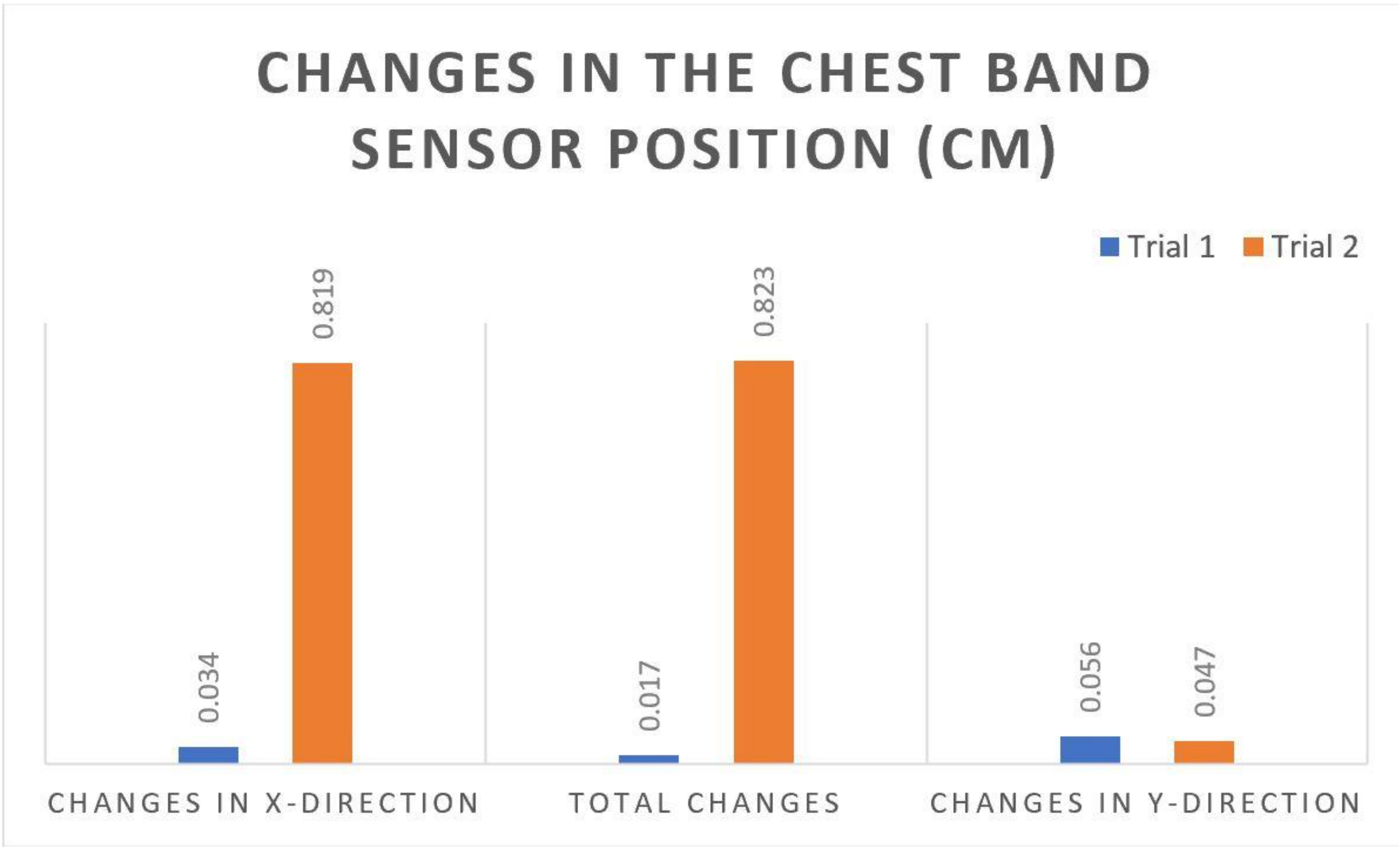
Chest Holder Results



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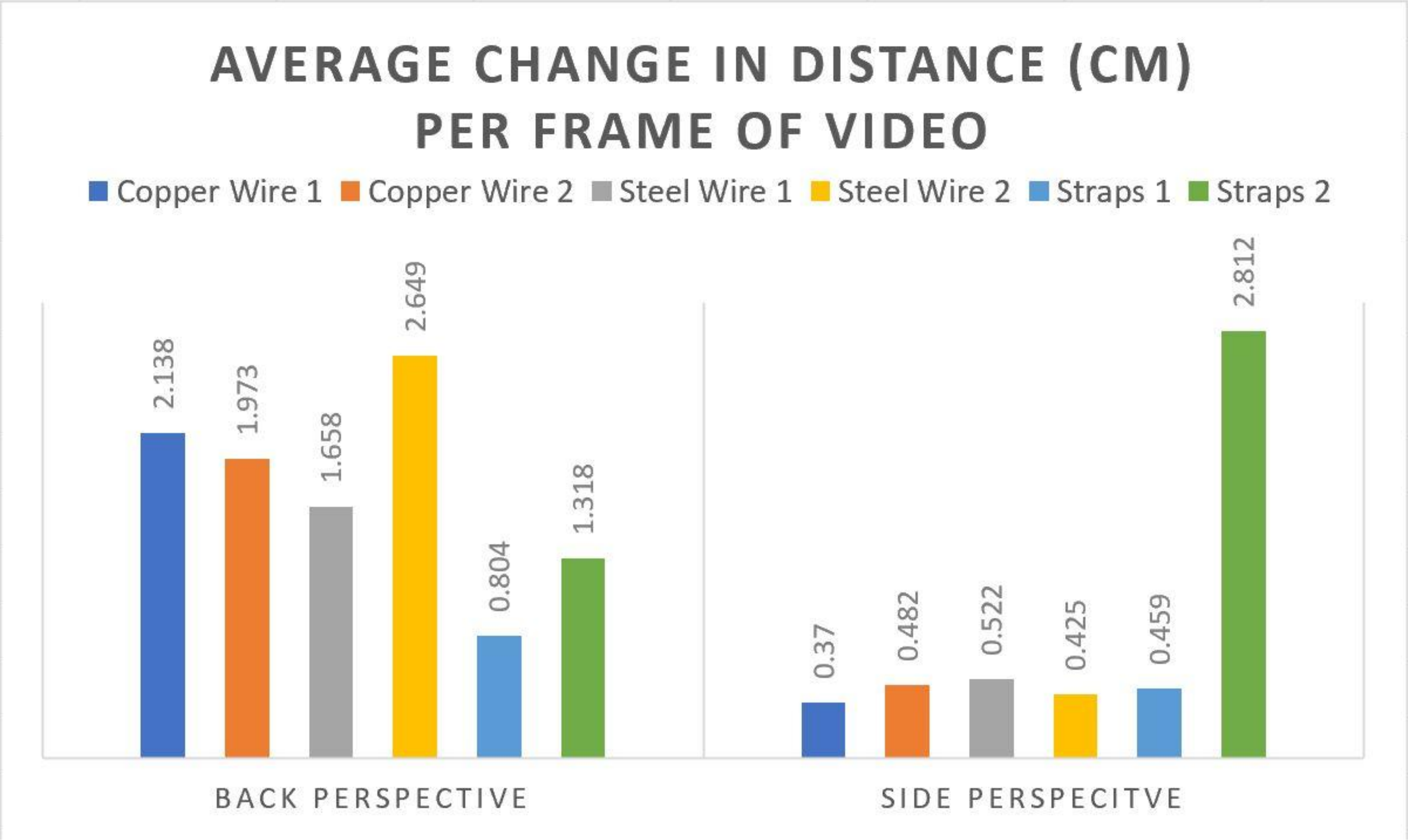
Phase 2: Testing Results

Shoe Sensor Holder Results



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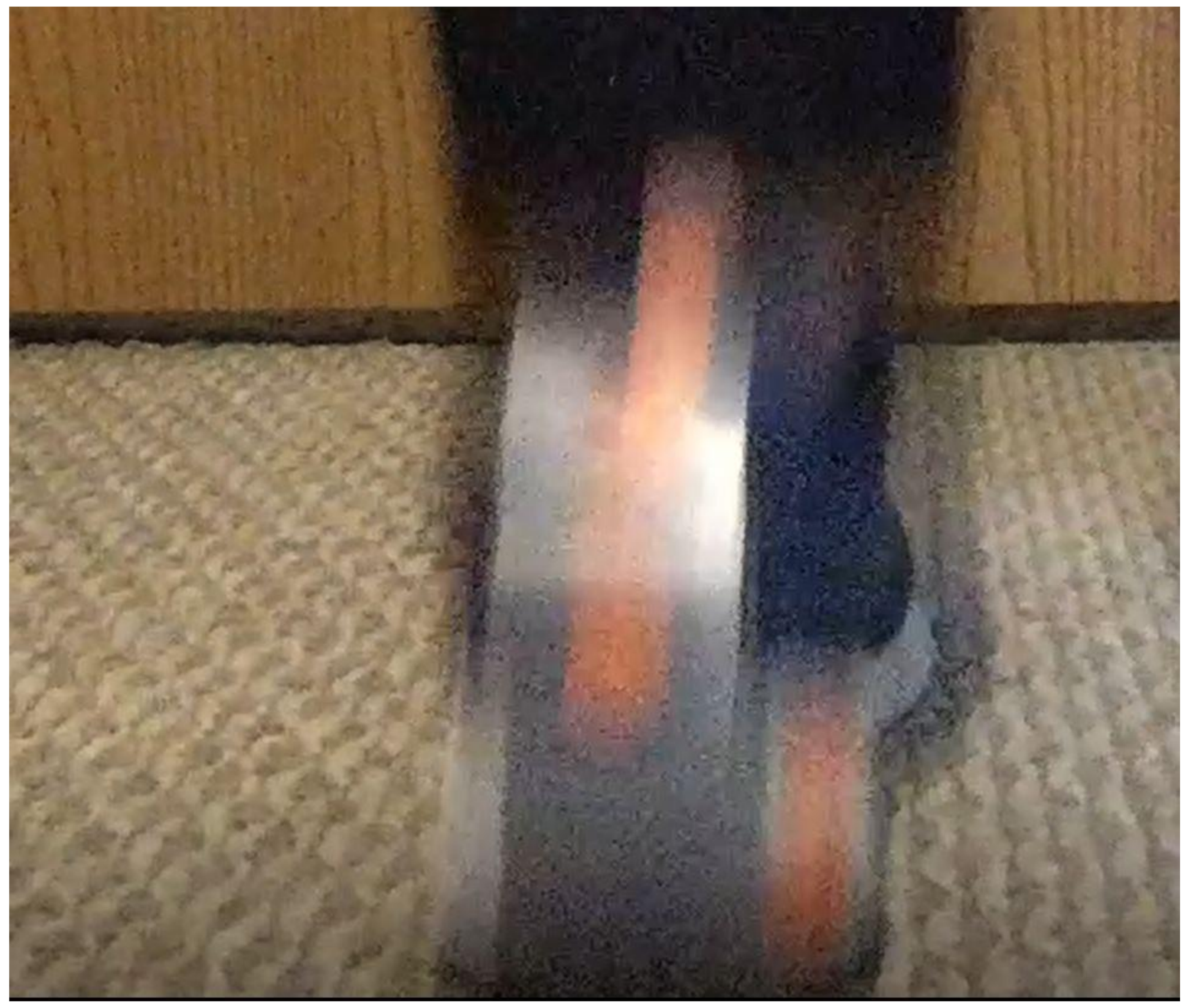

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[2] Delsys Incorporated, “Trigno® Wireless Biofeedback System User's Guide,” Trigno Wireless Biofeedback System User's Guide, Feb-2020. [Online]. Available: https://delsys.com/downloads/USERSGUIDE/trigno/wireless-biofeedback-system.pdf. [Accessed: 06-Oct-2020].

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