Think Biosolution

Designing QuasaR™ Strap

February 2019

Abstract

QuasaR™ is a wearable device that uses patented optical sensor for measuring biometric data such as heart rate, respiratory rate, blood oxygen saturation, heart rate variability. However for the device to work properly a certain minimum amount of vertical pressure needs to be continuously applied to the optical sensor located in the center of the device. The current version of the device is worn on the subject's chest, and in this study we have iteratively designed an elastic strap system so that it can deliver the maximum as well as consistent pressure on the subject. Our final proposed strap system is a hard material glued on top of an elastic strap, and we have shown how it is significantly better than other types of elastic straps.

Introduction

The QuasaR™ device needs to be in contact with the skin of the user without having any air gap, as well as deliver constant pressure to achieve higher levels of accuracy. In this study, we use pressure measured using a pressure sensor positioned between the human skin and the device to quantify the overall quality of the strap. We begin our experiments by choosing a completely elastic strap and quickly learned that this simple system at comfortable tightness of the strap system can only deliver small pressure on the skin. This, in turn, means that in order to achieve medium pressure using simple strap systems we have to make the straps uncomfortably tight.

In this document, we first describe the participants, the experimental strap systems and the various postures that we use to measure the pressure. We then discuss five sets of experiments that we perform to iteratively correct the quality as well as check the robustness of optimal strap systems.

Participants

Subject	Age	Weight (kg)	Height (cm)	Chest Size (cm)	Gender
1	30	81	180	94	Male
2	30	77	180	101	Male
3	30	67	167	92	Male
4	31	94	180	99	Male
5	31	61	167	92	Female

Table 1 – Details of Participants

Setup

In this study we use pressure measured using a Force Sensitive Resistor (FSR) pressure sensor positioned between the human skin and the device to quantify the overall quality of the strap, we call this setup 'sensor-skin.' Also, we have a second FSR pressure sensor positioned between the device and the strap, and we call this setup 'sensor-strap.' The FSR is controlled using an Arduino as shown in Fig.1. Readings from the FSR were observed on a serial monitor of the Arduino IDE and recorded in arbitrary unit. Two sets of FSR was set up prepared.

The subject wore the provided strap with the QuasaR™ device on their upper chest. The subjects then had to follow ten poses as shown in Table. 2 and hold each pose for 10 seconds. The poses were chosen to represent extreme cases of the position of a wearer's body in daily life. The pressure readings were noted for both the sensors for each of the ten poses. Each experimental setup was repeated thrice for each subject. The results provided in this document are the average of three readings.

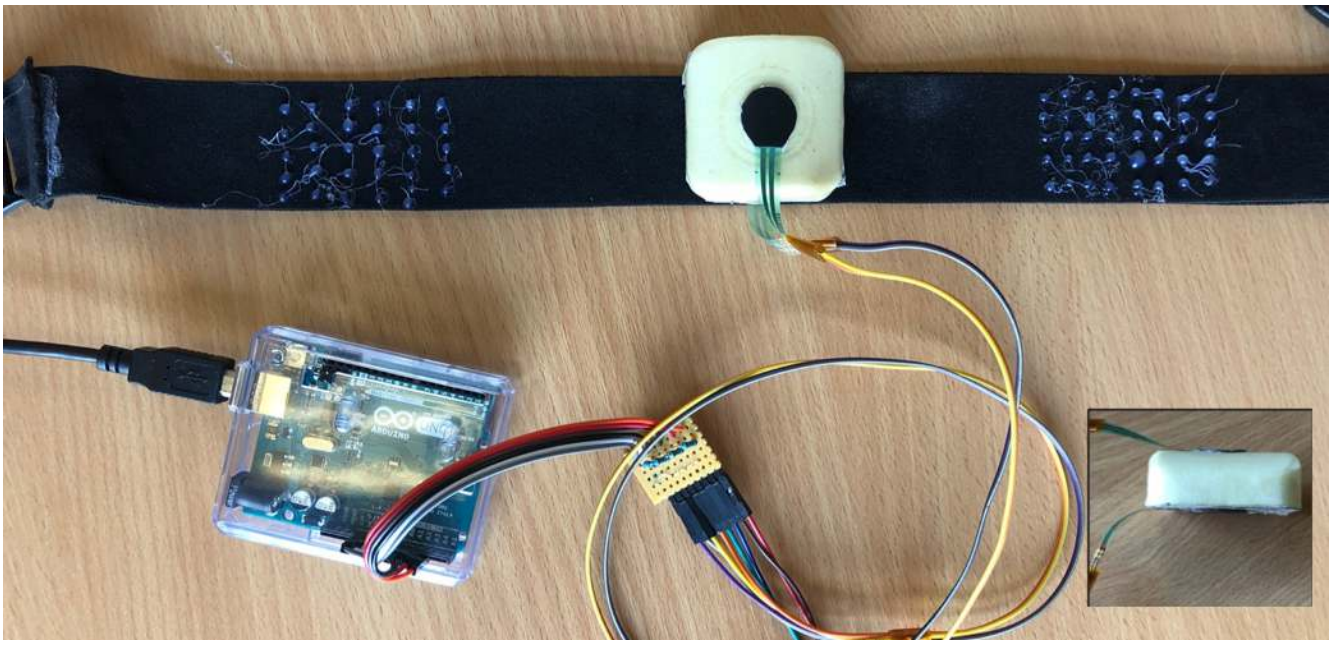


Figure 1 – Circuit diagram of Arduino board having 2 connected FSR pressure sensors. Insert image showing the position of FSRs in the front and back of the device.

Strap Number and Name	Description
1- Single Elastic	Elastic strap of width 38mm, without any layers attached to it
2 - Stitched	A strap having a non-elastic portion of length 200mm stitched at both end to the elastic strap. Width 38mm
3 – Glued (Hard Strap – Medium)	A strap having a non-elastic portion of length 200mm glued to the elastic strap. Width 38mm
4 – Triple Elastic	An elastic strap having two layers of the same material of length 200mm, glued to it. Width 38mm

5 – Double Elastic	An elastic strap having 1 layer of the same material of length 200mm, glued to it. Width 38mm
6 – Glued (Hard Strap – Short)	A strap having a non-elastic portion of length 100mm glued to the elastic strap. Width 38mm
7 – Glued (Hard Strap – Long)	A strap having a non-elastic portion of length 400mm glued to the elastic strap. Width 38mm

Table 2 – Details of straps used in the study

Figure 2 – Different Straps used in the study

Standing Pose	Image		Sitting Pose	Image
Standing 1 - Hands over head			Sitting 1 - Hands over head	

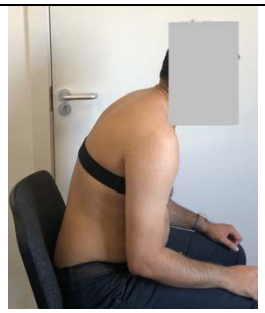
Standing 2 - Hands behind back			Sitting 2 - Hands behind back	
Standing 3 – Hands in front			Sitting 3 - Hands in front	
Standing 4 - Hands by side			Sitting 4 - Hands by side	
Standing 5 – Slouch			Sitting 5 - Slouch	

Table 3 – 10 Poses for the experiment

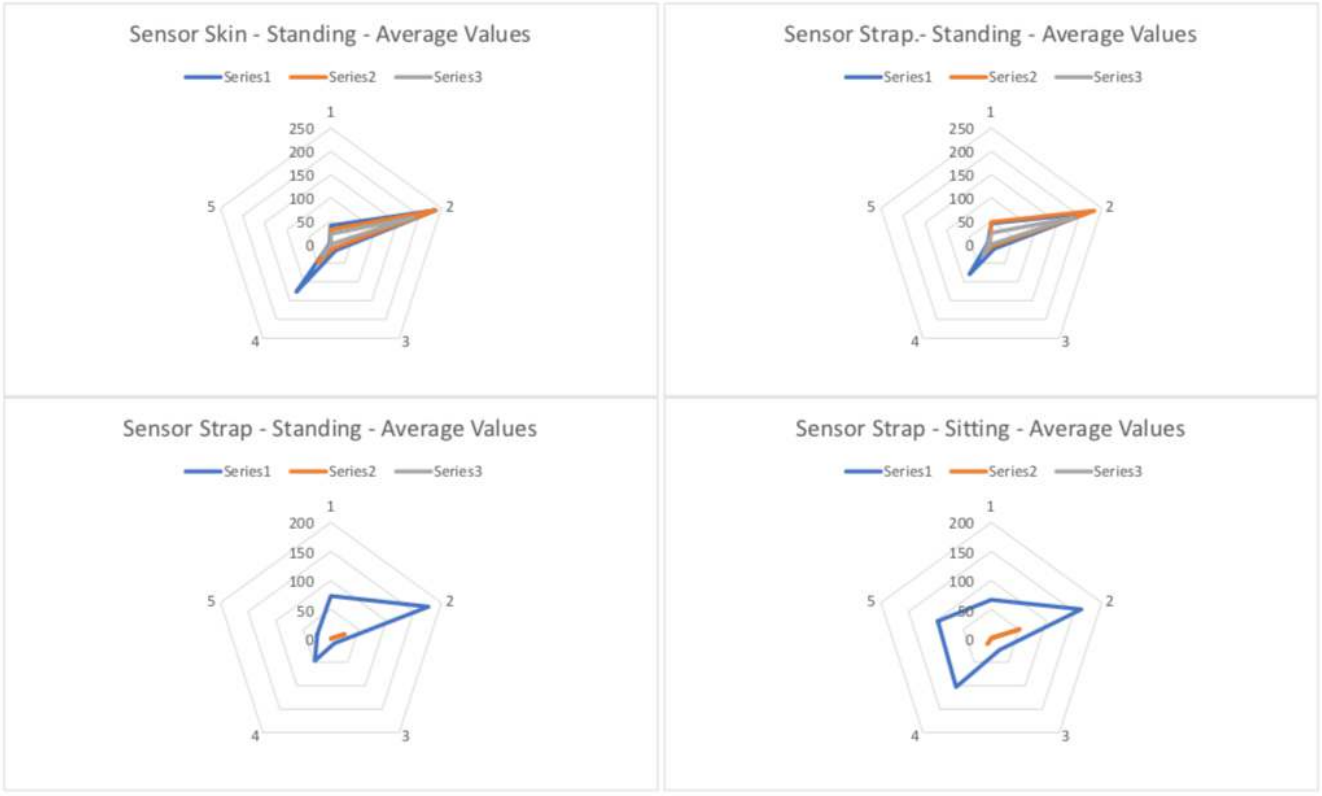
Results and Discussion

Experiment 1: Comparing three types of straps (glued, stitched and single elastic)

This experiment aimed to find the best method to prepare a strap from a mix of two materials. Three types of straps were prepared, one was simple elastic, the second had the non-elastic (hard) material stitched at the rim of the elastic material, and third where the non-elastic (hard) material was glued on the top of the elastic material. These straps are described as straps 1,2 and 3 in Table.2.

The experiment was carried out on Subject 1 with Straps 1,2,3, with 2 different strap lengths. The results from the experiment with a strap length of 788 mm have been provided in Figure 3 and with strap length 711 mm in Figure 4.

The results from the experiment indicate that the strap 3, provided better pressure than the other two straps. Also, strap two was better than strap 1.



Series 1 – Glued, Series 2 – Stitched, Series 3 - Elastic

Figure 3 – Comparing three strap systems (Glued, Stitched and Single Elastic) – Strap length 788 mm

Figure 4 – Comparing three strap systems (Glued, Stitched and Single Elastic) – Strap length 711 mm

Experiment 2: Measuring the consistency of the glued strap

This experiment was carried out to measure the consistency of the results of the glued strap system on multiple subjects. This strap is described as strap 3 in Table.2.

The experiment was carried out on Subjects 1,2,3,4, with strap 3 having a length of 762 mm. The results from the experiment have been provided in Figure 5.

The results from the experiment indicate that strap 3 can be used to measure relatively stable and higher pressure on all 4 subjects. There is no qualitative difference in pressure when the subjects are sitting and standing. Also, the relative trends on measured pressure for different poses remain similar in all subjects. For example, pose 2 (hands behind back) always yields the best result followed by poise 4 (hands by side). Pose 3 (hands in front) has the worst result followed by pose 1 (hands overhead). Pose 5 (slouch) is interesting as It can show both high and medium pressure depending on the subject's chest shape. In the case of subject 2 who has a muscular chest, the pressure readings outperform the other subjects. Also, for him, pose 5 yields significantly better results.

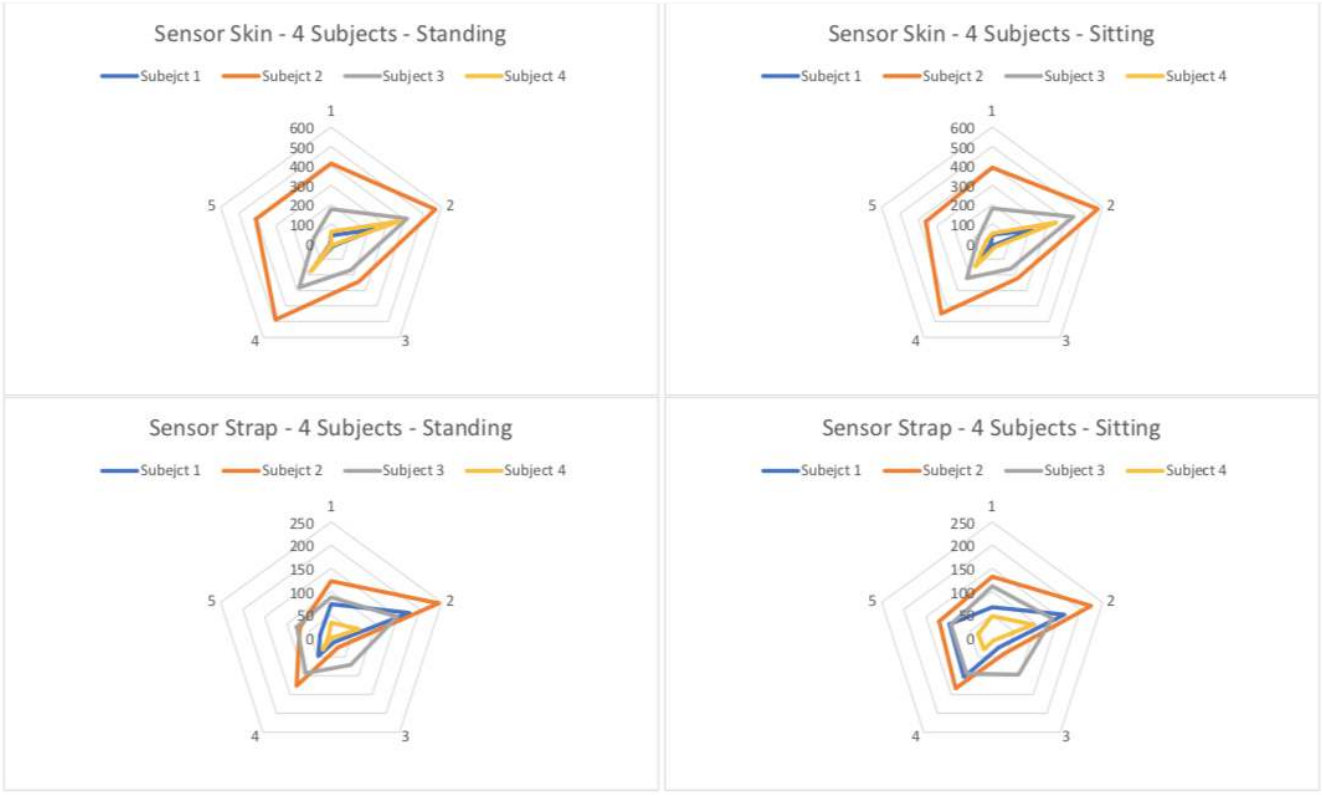


Figure 5 – Measuring consistency of glued strap with four subjects. Strap length – 762 mm

Experiment 3: Comparing four types of the glued strap (hard, triple elastic, double elastic and single elastic)

Since from the previous experiments we knew that glued strap systems outperform stitched and simple elastic strap systems, the aim of this experiment was to compare three types of the glued strap with the basic elastic strap. The glued strap systems either had non-elastic (hard) material glued on top, or two elastic layers glued on top, or one elastic layer glued on top of the elastic strap. The final strap was the simple elastic strap and was used for comparison. The straps were numbered as 3,4,5,1 in Table 2.

The experiment was carried out with 2 subjects. The results from Subject 1 are presented in Figure 6 and from Subject 2 in Figure 7.

The results show that strap number 3 with non-elastic (hard) material glued on top of an elastic strap showed the highest pressure for both subjects. This is clearer in the case of Subject 2 than Subject 1. However, even for Subject 1 the strap number 3 outperforms other straps in pose 4 (hands by the side) and is the most common pose during real-world usage of the device.

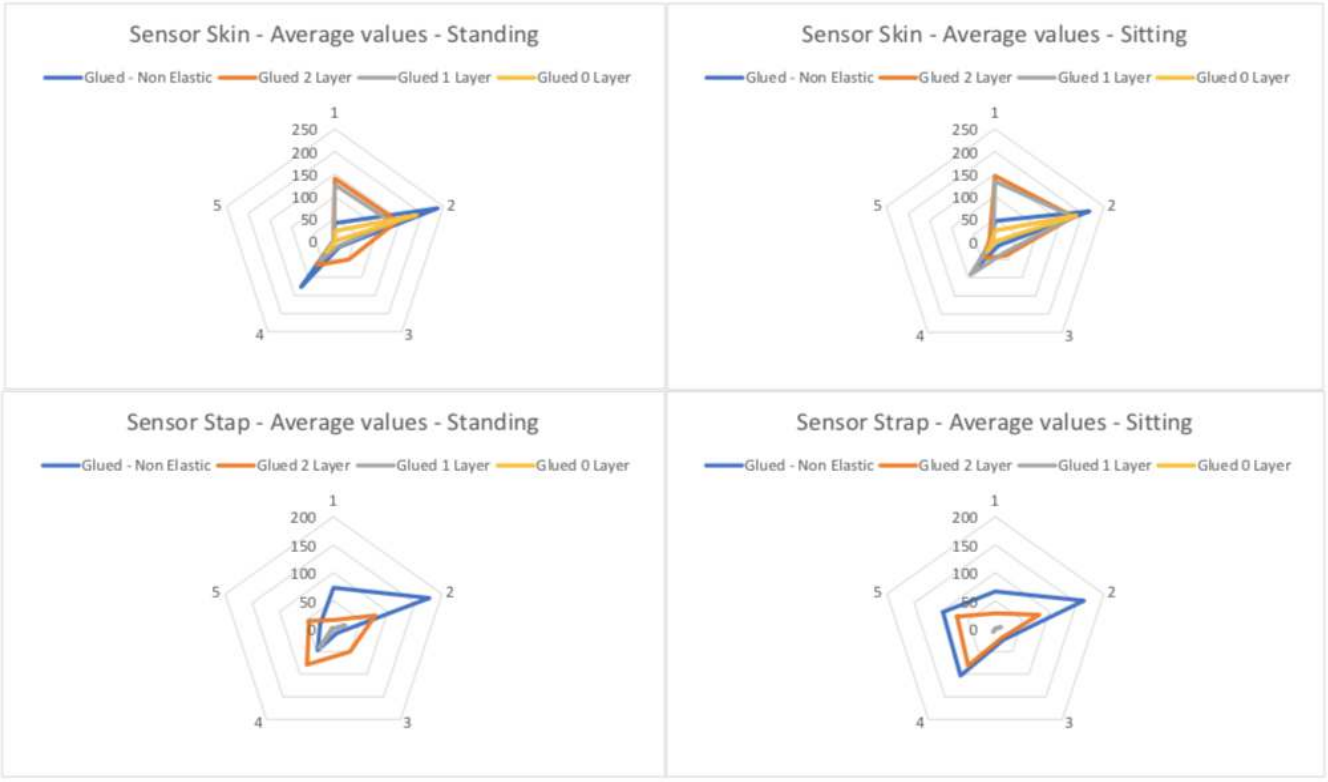


Figure 6 – Comparing four types of glued straps (hard, triple elastic, double elastic and single elastic) on Subject 1

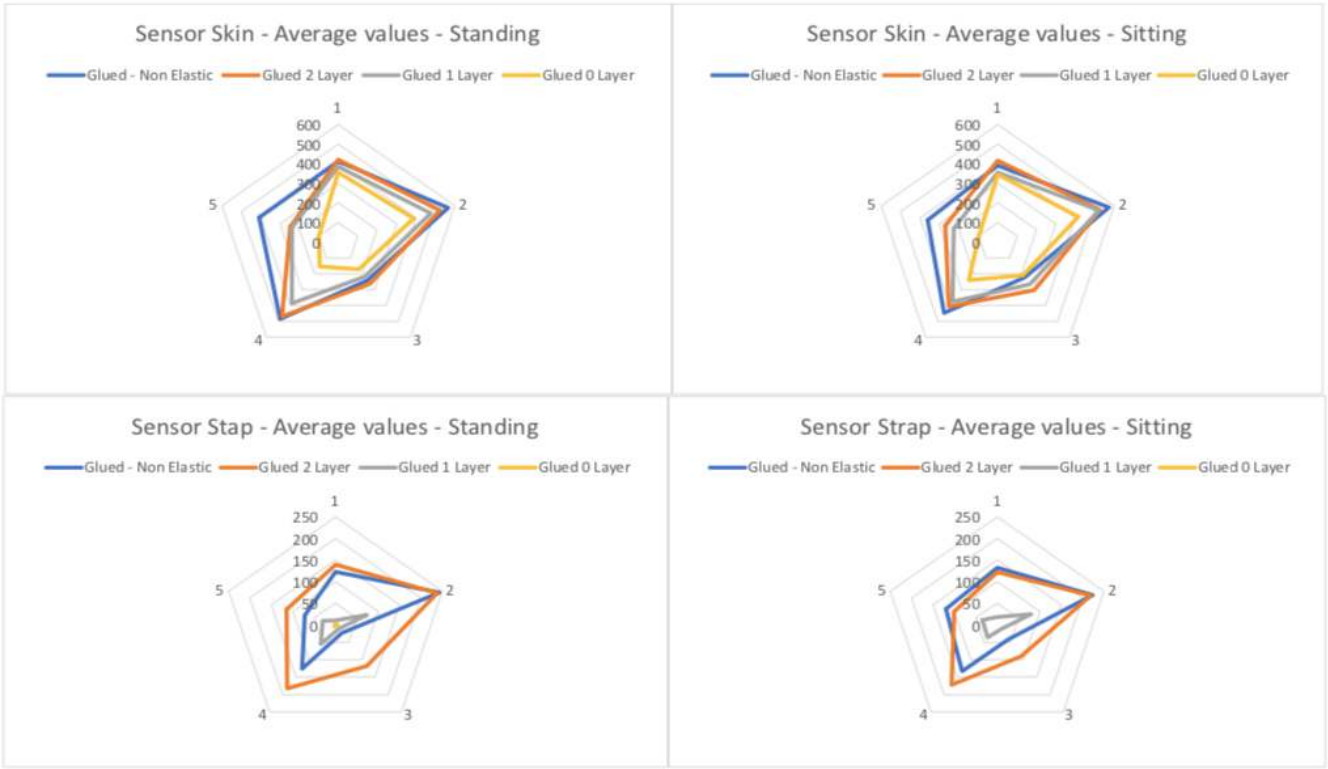


Figure 7 – Comparing four types of glued straps (hard, triple elastic, double elastic and single elastic) on Subject 2

Experiment 4: Comparing three types of the glued hard strap (long, medium, short)

The results from experiment 1,2 and 3 showed that an elastic strap with a non-elastic (hard) material glued to it was the best among the 3 chosen straps. In this experiment, we further try to optimize the length of the non-elastic (hard) material. So, three straps of different lengths 100mm, 200mm and 400mm of the non-elastic (hard) part were tested. The straps were strap numbers 6,3,7 from Table 2.

The experiment was carried out on Subject 2 with straps having length 762 mm. The results from the experiment have been presented in Figure 8.

The results from the experiments show that the strap with the 400 mm non-elastic portion provides marginally better results than the 200 mm non-elastic strap. Both of them are better than the 100 mm non-elastic strap.

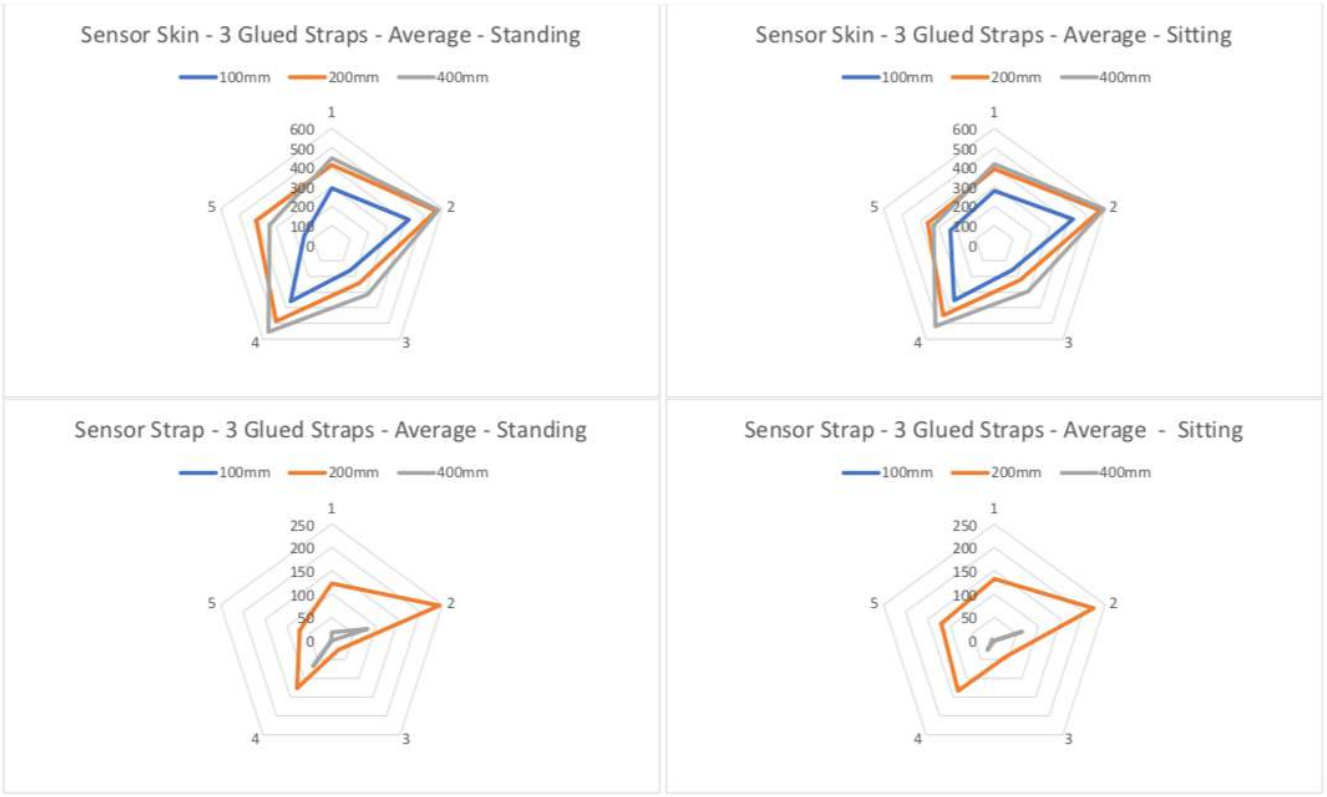


Figure 8 - Comparing 3 types of glued hard strap system (long, medium, short) on Subject 2

Experiment 5: Measuring the consistency of the glued hard long strap

From the earlier experiments, it was evident that the strap with the longest non-elastic part glued to it had the best results. This experiment was carried out to measure the consistency of the results with four subjects.

The experiment was carried out with Strap 7 having length 788 mm on Subjects 2,3,4 and 5. The results from the experiment have been provided in Figure 9.

The results from the experiment show that the strap with the longest non-elastic portion provides consistent results with multiple subjects.

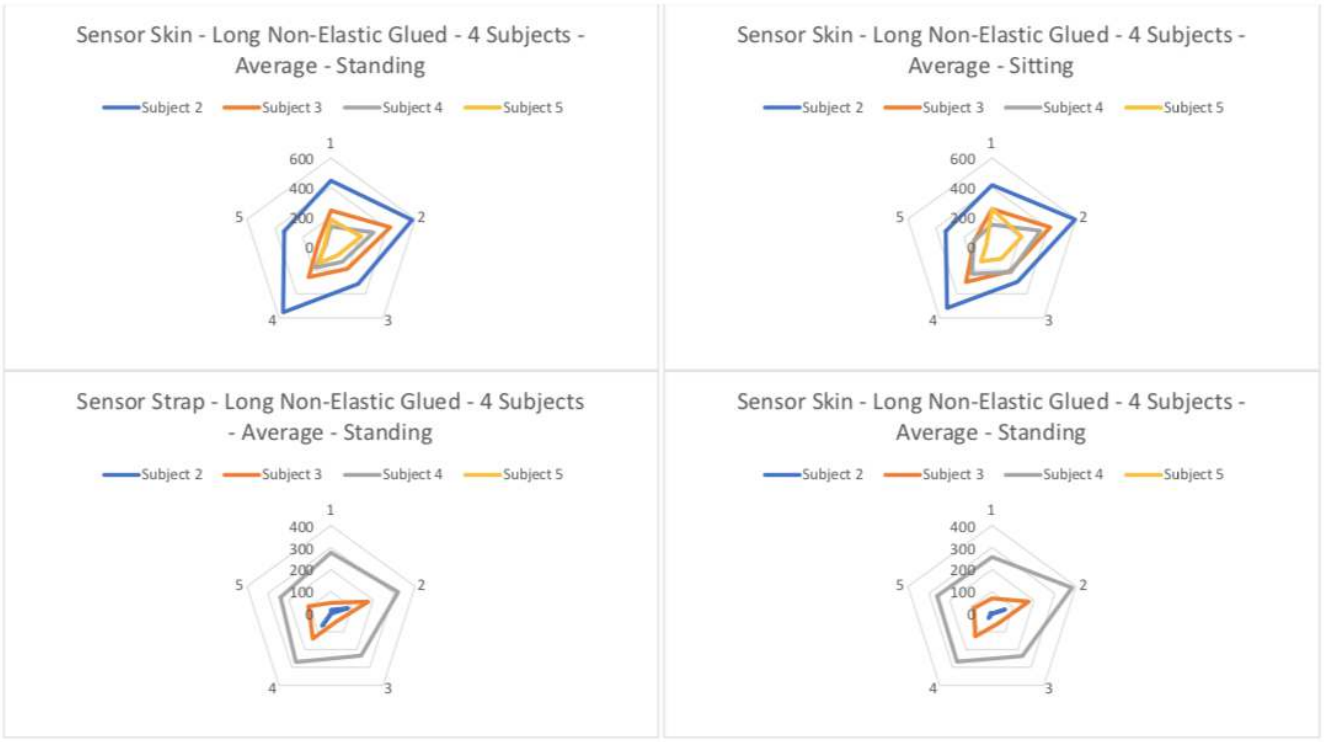


Figure 9 – Measuring the consistency of glued hard long strap with 4 subjects