BLOOD FLOW AND OXYGEN LEVEL CHARACTERIZATION OF THE FOREARM WITH CHANGES IN NORMAL AND SHEAR LOAD

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INTRODUCTION

Decubitus ulcers are localized areas of tissue-breakdown in the skin and the underlying tissues. Ulcers are more prevalent in subjects who are wheelchair-bound or bed-ridden. The external factors leading to pressure ulcers include pressure, friction, shear force and moisture.

It is well known that mechanical loading is a major factor affecting tissue breakdown. However, it is not clear how the external loading conditions, including normal and shear forces, affect regional blood flow and tran-cutaneous oxygen levels.

Thus, our goal was to study the oxygen levels and blood perfusion in the skin when normal and shear loads were applied to the forearm. Results of this study will provide information that can be related to ulcer development and help inform seating design.

For this study, our hypothesis was that with the addition of shear loading (normal load already present), the blood perfusion and the oxygen levels would decrease as compared to when only a normal force was applied.

METHODS AND PROCEDURES

A total of 15 human subjects were tested for changes in blood perfusion and trans-cutaneous oxygen during the application of normal and shear forces. Each subject participated in two test sessions, with a gap of one week between each session. Each session consisted of 7 test conditions (Table 1). Each condition lasted for a minute, and any two conditions were separated by a resting time of 2 minutes.

A continuous measurement of blood perfusion and trans-cutaneous oxygen was performed on the forearm using a laser Doppler system. The forearm was resting on a fixture connected to an AMTI multi-axis load cell. Along with the two physiological measures, the normal and shear forces were measured by fixing two probes on the lower side of the forearm. A wooden fixture was carved out in such a way that the probes fit into the fixture. The temperature of the blood perfusion probe was maintained constant at 37°C.

For each test condition a time interval of 20 seconds was selected in which the fluctuations of the force values were minimal. Then, the mean values of the blood perfusion and oxygen levels were calculated for the pre-selected 20 second time interval. A statistical analysis was performed to determine the effect of loading on the blood flow and the trans-cutaneous oxygen.

RESULTS AND DISCUSSION

Results of our data show that that the shear and normal loads were highly

individualized. For a relaxed resting arm, ranges from 9.7 N to 33.1 N were obtained. The condition where the subjects applied what they felt to be their maximum amount of shear loading to the base of their forearm showed ranges of shear values from 0.4 N to 35.6 N. Finally, for the condition when the subjects were asked to lean on their forearm using the weight of their upper body and to apply as much load as they felt comfortable, the following ranges of normal 24.9 N to 117 N, and shear 3.1 N to 57.6 N were obtained.

Because of the highly individualized loads, the results of the blood flow and trans-cutaneous oxygen levels were evaluated for with-in subject comparisons. We compared the blood perfusion and oxygen levels between conditions 2 and 3 (Table 1). A Paired t-test (α =0.05) was used to assess blood perfusion. However, the data for the trans-cutaneous oxygen levels did not demonstrate normality. Hence, a Wilcoxon Signed Rank Text (α =0.05) was performed for these measures.

The results of these tests indicated that significant differences were exhibited between the condition of normal loading, and the combination of normal and shear loading. Specifically, blood perfusion and oxygen levels were reduced with the addition of shear loading ($p=0.006$ and $p<0.001$ respectively).

SUMMARY/CONCLUSIONS

From the statistical analysis, we obtained positive results that support our hypotheses; the blood perfusion and the trans-cutaneous oxygen levels decreased when there was combined loading (shear and normal).

One limitation to this work is the variability of the forces across subjects. This will be addressed in future studies.

REFERENCES

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Table 1: Description of test conditions

Test condition	Description of loading while blood perfusion and trans-cutaneous oxygen levels are measured.
1.	No load is applied on the forearm and no contact with load cell.
2.	The forearm rests on the load cell arrangement, without the application of any additional loads.
3.	A shear force is applied to the base of the forearm in addition to the weight of the arm (normal force)
4.	An additional 2 lbs is applied on the forearm without applying shear force.
5.	A shear force is applied to the forearm in addition to the force mentioned in 4.
6.	An additional 4 lbs is applied on the forearm without applying shear force.
7.	Normal and a shear forces are applied by resting all the body weight on the forearm.