Long term blood perfusion when sitting on three different cushioning materials

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Summary

In medical literature the effect of a mechanical load on the diffusion of oxygen and metabolites to the cells has been studied extensively, especially in relation to pressure sores (or decubitus). A similar relationship to discomfort is also to be expected. Most authors agree that the most important cause of decubitus is prolonged tissue ischemia that is caused by the mechanical load on the tissue which causes the capillaries (the smallest blood vessels) to be closed. Therefore, the measurement of the mechanical load, especially pressure, is often used to compare different cushions that support the body. However, another important part of the mechanical load, namely shear, is often not taken into account. A drawback of the measurement of the mechanical load on the tissue is that the blood flow in the skin is evaluated in an indirect way. This can be overcome by direct measurement of blood perfusion in the tissue by means of laser Doppler.

Shear force is an important factor in the mechanical load on the tissue during human / material interaction. In order to gain insight in the shear force a special sensor was developed that can measure shear on the contact surface between the tissue and a material (Goossens, 1997). In a study performed by Goossens (2001) with this shear sensor, it was concluded that a seat cushion with LiquiCell® technology produces significantly lower shear stress **on** the skin, compared to either a foam or a gel cushion.

The aim of the present study is to compare the blood perfusion **in the tissue** during real life sitting conditions at the ischial tuberosities when using a LiquiCell® cushion, a foam cushion and a gel cushion.

Blood perfusion was measured on 15 healthy subjects while sitting on three different cushions; a LiquiCell® cushion, a gel cushion, and a foam cushion. Measurement of blood perfusion was done using a Vasamedics Laserdoppler Softflo sensor. The sensor was attached to the bare skin of the right ischial tuberosity of the subject. The subject was then seated in office chair (brand: Hag Credo model: 2260) wearing a pair of jogging trousers. The office chair was ergonomically adjusted to match the dimensions of the subject. The angle of the seat was fixed and tilted 3 degrees backward.

After being seated for a period of 60 minutes, the blood perfusion was significantly better in subjects who had been sitting on the LiquiCell® cushion, 1.8 times better compared to the foam cushion ($P=0.02$) and 2.3 times better compared to the gel cushion ($P=0.005$). These results show that the reduction of shear force on the tissue attributable to the LiquiCell® cushion resulted in a better load situation inside the tissue, which resulted in better blood perfusion.

1 Introduction

The cells in the human tissue need oxygen to survive. For that purpose an extensive circulatory system of blood vessels is integrated in all the living tissue of the body, in such a way that oxygen can be supplied to every single cell.
In medical literature the effect of a mechanical load on the diffusion of oxygen and metabolites to the cells has been studied extensively, especially in relation to pressure sores (or decubitus). A similar relationship to discomfort is also to be expected. Most authors agree that the most important cause of decubitus is prolonged tissue ischemia that is caused by the mechanical load on the tissue which causes the capillaries (the smallest blood vessels) to be closed. Therefore, the measurement of the mechanical load, especially pressure, is often used to compare different cushions that support the body. However, another important part of the mechanical load, namely shear, is often not taken into account. A drawback of the measurement of the mechanical load on the tissue is that the blood flow in the skin is evaluated in an indirect way. This can be overcome by direct measurement of blood perfusion in the tissue by means of laser Doppler.
Shear force is an important factor in the mechanical load on the tissue during human / material interaction. In order to gain insight in the shear force a special sensor was developed that can measure shear on the contact surface between the tissue and a material (Goossens, 1997). In a study performed by Goossens (2001) using this shear sensor it was concluded that a seat cushion with LiquiCell® technology produces significantly lower shear stress than a foam cushion in situations where a shear force acts forward (P=0.001), backward (P=0.038) and in the horizontal position of the seat (P=0.005). When using LiquiCell® instead of foam, there is a reduction of shear stress varying from 28% to 39%.
The LiquiCell® cushion was also compared to a gel cushion. In this situation the LiquiCell® cushion also produces significantly lower shear stress than the gel cushion in situations when a shear force acts backward (P=0.038), and at the P=0.10-level in the horizontal position of the seat (P=0.07), and when the shear force acts forward (P=0.07). When using LiquiCell® instead of gel, there is a reduction of shear stress varying from 24% to 25%.
It can therefore be concluded that the use of a LiquiCell® cushion reduces the shear force on the tissue by at least 25% compared to foam or gel.

As demonstrated in another study (Goossens et al., 1994) shear force measured **on** the surface of the tissue turned out to be a good predictor of occlusion of the blood flow **within** the tissue. In that study, it was concluded that shear force applied to the surface of the tissue has a significant influence on occlusion of the blood flow within the tissue. It was found that cut-off pressure (i.e. the level of external pressure on the skin at which ischemia of the skin can be expected) is significantly lower when a combination of pressure and shear are applied to the skin, compared to a situation in which only pressure is applied. These measurements were done under laboratory conditions with the load on the skin applied locally to the sacrum while the subjects were in relaxed prone position.

From the above studies, the question arises in what way the reduction of shear forces, influences the long term blood perfusion in real life situations (non laboratory conditions) , when using the LiquiCell® cushion. The aim of the present study is therefore to compare the blood perfusion during real life sitting conditions at the ischial tuberosities, using a LiquiCell® cushion, a foam cushion, and a gel cushion.

2 Method and materials

Blood perfusion in the tissue was measured with a thin, flexible laser Doppler sensor in a healthy population, while sitting and watching a movie for one hour. The subjects were instructed to remain seated for the period of 1 hour and posture changes were allowed.
Measurement of blood perfusion was done using a Vasamedics Laserdoppler Softflo sensor. The measurements are in mlLD/min./100g, here called arbitrary units [AU]. The values give insight in the blood flow inside the tissue.
The sensor was attached to the bare skin of the right ischial tuberosity of a healthy subject while sitting on an office chair (brand: Hag Credo model: 2260) wearing a pair of jogging trousers.
The office chair was ergonomically adjusted to match the dimensions of the subject. The angle of the seat was fixed and tilted 3 degrees backward. Three different cushions were evaluated: a foam cushion, a gel cushion and a Liquicell® cushion. The cushions were placed on top of the seat surface.
The order of the cushioning situations was randomized and the sensor remained attached at the tuberosity during all three measurements. In between two measurements there was a short break of 10 minutes in which the subject was standing upright, without support force at the tuberosity. The 15 subjects were chosen so that there was a large distribution in age and weight (table 1).

	Gender	Age [yr]	Height [cm]	Weight [kg]
1	M	18	180	74
2	M	58	187	90
3	F	57	176	62
4	F	19	164	58
5	M	39	187	108
6	F	38	175	70
7	F	40	167	85
8	F	45	172	58
9	M	39	179	75
10	M	28	185	78
11	F	41	176	61
12	F	62	176	90
13	M	40	192	98
14	F	18	177	68
15	M	35	189	85
mean		38.5	178.8	77.3
s.d.		13.8	8.0	15.2

Table 1. Age, height and weight of the subjects that were used in the present study

The perfusion data was collected and stored on a computer every second. For each subject the average was calculated per period of 600 seconds (10 minutes), beginning at the start of the measurements. Data was excluded from the statistics in those cases where a subjects' data became unstable (exceeded or fell below maximum or minimum values) for a certain period.

The average data for each cushion was calculated, using the data of all the subjects that were seated on that cushion. The average Doppler readings for the cushions obtained using this method were compared using the non-parametric Wilcoxon signed-rank test for paired observations. The program SPSS 12.0.1 was used with a level of significance $\alpha = 0.05$.

3 Results

Some typical data can be seen in figure 1, in which subject 14 is using the LiquiCell® cushion. In this figure it can be seen that there is a steady upward trend in the blood perfusion when sitting on a LiquiCell® cushion.

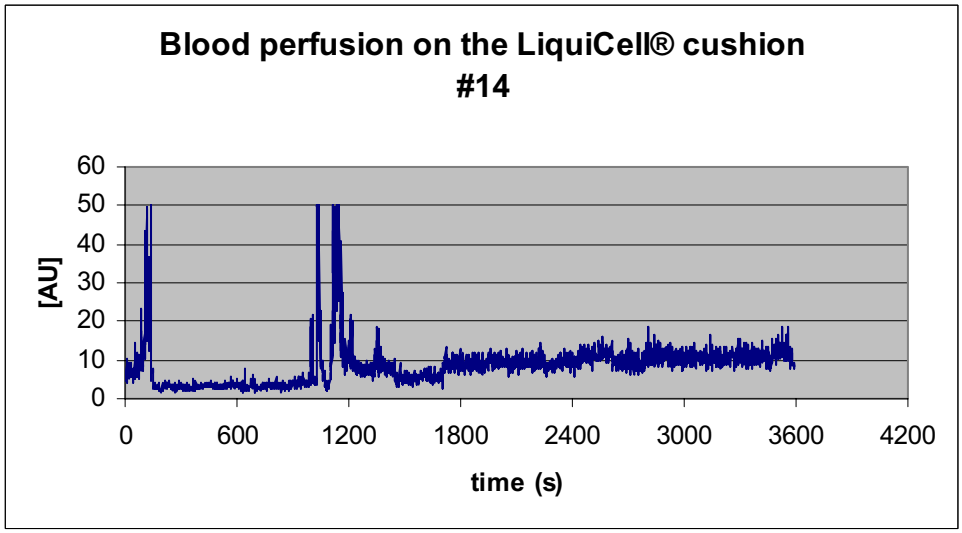
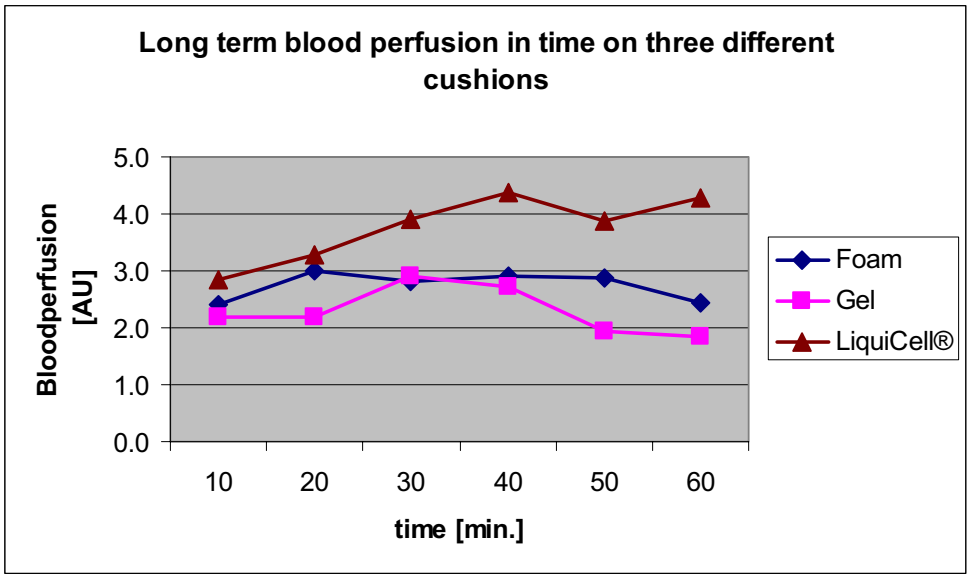


Figure 1. Blood perfusion during one hour sitting on a seat cushion with a LiquiCell® pad inside. It can be seen that gradually the blood perfusion increases and thus there is an upward trend. There are small instabilities in the measurement at the start (0 s) and after 20 minutes (1200 s).

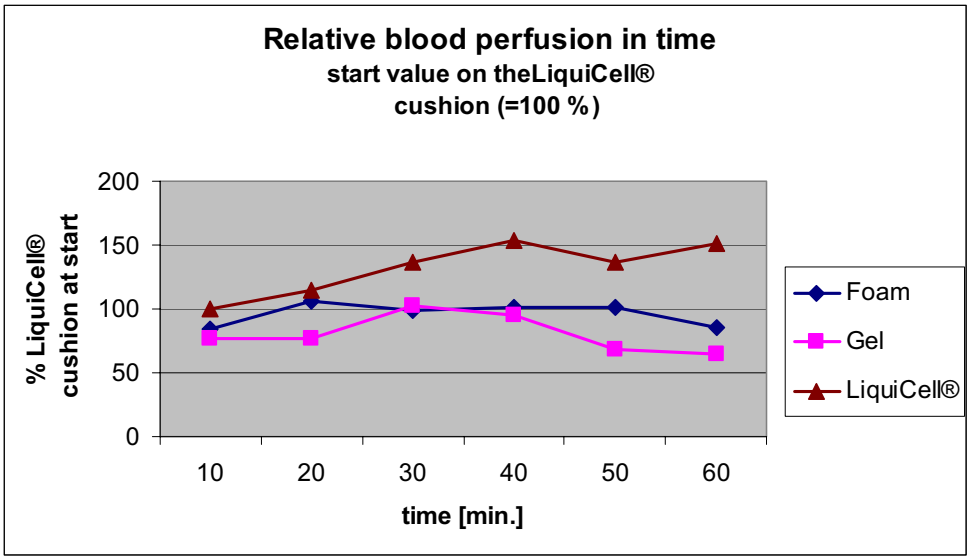
The average perfusion calculated for all the test subjects can be seen in figure 2. There is a slight difference between the LiquiCell® cushion and the foam and gel cushion. After 10 minutes the gel cushion slightly increases and then decreases below the initial value. The blood perfusion as measured on the foam cushion also increases and decreases over the hour. The blood perfusion on the LiquiCell® cushions shows an upward trend.



	10	20	30	40	50	60
Foam	2.4	3.0	2.8	2.9	2.9	2.4
Gel	2.2	2.2	2.9	2.7	1.9	1.8
LiquiCell®	2.8	3.3	3.9	4.4	3.9	4.3

Figure 2. Average long term blood perfusion for 15 subjects as measured on three different cushions. It can be seen that the during the first 10 minutes there is a slight difference between the LiquiCell® cushion and the foam and gel cushion. From then on, different trends can be seen in the signals.

In figure 3 the data is presented as the percentage of the average blood perfusion as initially measured on the LiquiCell® cushion. As this figure clearly shows, the blood perfusion increases by 50% to 150% while using the LiquiCell® cushion. After 60 minutes the blood perfusion on the foam cushion is 85% of the initial blood perfusion while using the LiquiCell® cushion. On the gel cushion it is 65%.



	10	20	30	40	50	60
Foam	84	106	99	102	101	85
Gel	77	77	102	95	68	65
LiquiCell®	100	115	137	154	136	151

Figure 3. The average blood perfusion in time as measured on 15 subjects, while using three different cushions. The blood perfusion is compared to the average blood perfusion in the first 10 minutes while using the LiquiCell® cushion. An upward trend can be seen for the LiquiCell® cushion.

Table 2 shows results of the statistics. In the table the quotient of the compared cushions is presented and the significance is indicated in brackets. For example the value of 1.2 in the left upright cell means that the blood perfusion as measured in the first 10 minutes on the LiquiCell® cushion is 1.2 times the blood perfusion measured in the first 10 minutes on the foam cushion. Values in bold indicate a significant difference between the compared cushions.

It can be seen that after 40 minutes blood perfusion is significantly higher for the LiquiCell® cushion compared to the gel and foam cushions. After 60 minutes there is significantly better blood perfusion when sitting on the LiquiCell® cushion, 1.8 times better than the foam cushion (P=0.02) and 2.3 times better than the gel cushion (P=0.005). The difference between the gel and foam cushion is not significant for the entire test period of 60 minutes.

Cushions compared	**10**	**20**	**30**	**40**	**50**	**60**
LiquiCell® / Foam	1.2 (P=0.75)	1.1 (P=0.10)	1.4 (P=0.27)	**1.5 (P=0.02)**	1.3 (P=0.06)	**1.8 (P=0.02)**
LiquiCell® / Gel	1.3 (P=0.21)	**1.5 (P=0.05)**	1.3 (P=0.40)	1.6 (P=0.08)	**2.0 (P=0.01)**	**2.3 (P=0.005)**
Foam / Gel	1.1 (P=0.85)	1.4 (P=0.77)	1.0 (P=0.26)	1.1 (P=0.50)	1.5 (P=0.40)	1.3 (P=0.25)

Table 2. Results from the Wilcoxon signed rank test. Values in bold indicate a significant difference.

4 Discussion

In previous measurements comparing a gel, foam and LiquiCell® cushion it was demonstrated that the shear force is reduced remarkably when sitting on a Liquicell® cushion. The measurements in the present study on blood perfusion show a significant higher blood perfusion in the tuberosities when sitting on a LiquiCell® cushion after 60 minutes. It can also be observed that during the first 10 minutes there is not a significant difference and blood perfusion is equal for all the cushions. This could mean that after first contact with the cushion the circulatory system reacts differently to the different supporting materials. In measurements on the influence of shear on skin oxygen tension (Goossens et al. 1994), it was also noticed that after the application of a mechanical load it took some time before a stationary blood perfusion level was reached.

An explanation for the long term effect might be that the blood circulation of the tissue establishes a new equilibrium with the external load situation when seated on a cushion. The blood perfusion of foam and gel remains more or less at a constant level. But when seated on a LiquiCell® cushion the level of blood perfusion increases to a higher level compared to the first 10 minutes. This can be due to the reduced shear force, which is a known factor in the reduction of skin oxygen tension. It might also be that the thin layer of fluid in the LiquiCell® cushion does not hinder the pulsating blood circulation as much as the foam and gel cushion.

In a pilot with a measurement frequency of 10 Hz, a pulsating effect was observed when using the LiquiCell® cushion (figure 4). The pulsating frequency was not that of the heartbeat but about 0.5 Hz (1 every 2 seconds).

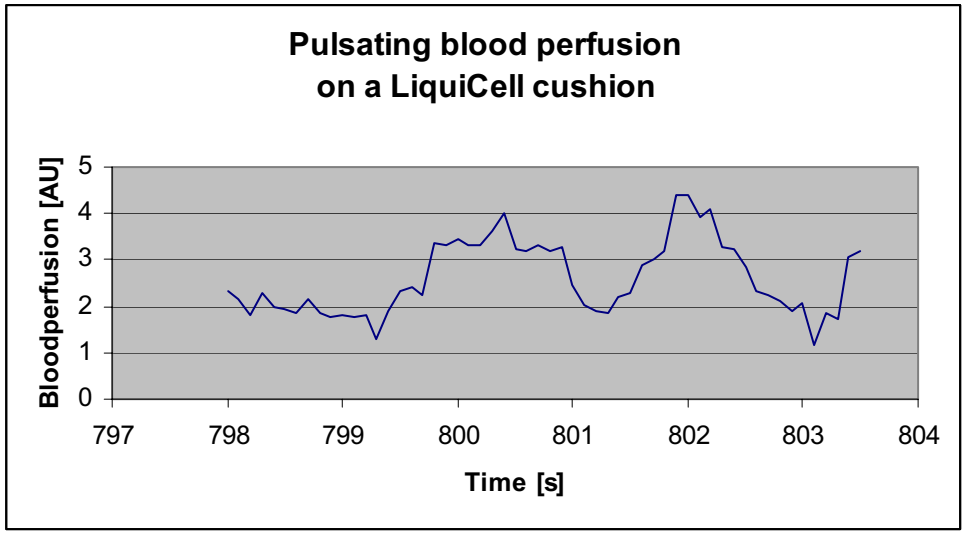


Figure 4. Pulsating blood perfusion as measured on a LiquiCell® cushion. The frequency of the pulsation is 0.5 Hz.

In the same pilot it was observed that for a foam cushion this pulsating effect was not of the same magnitude (figure 5).

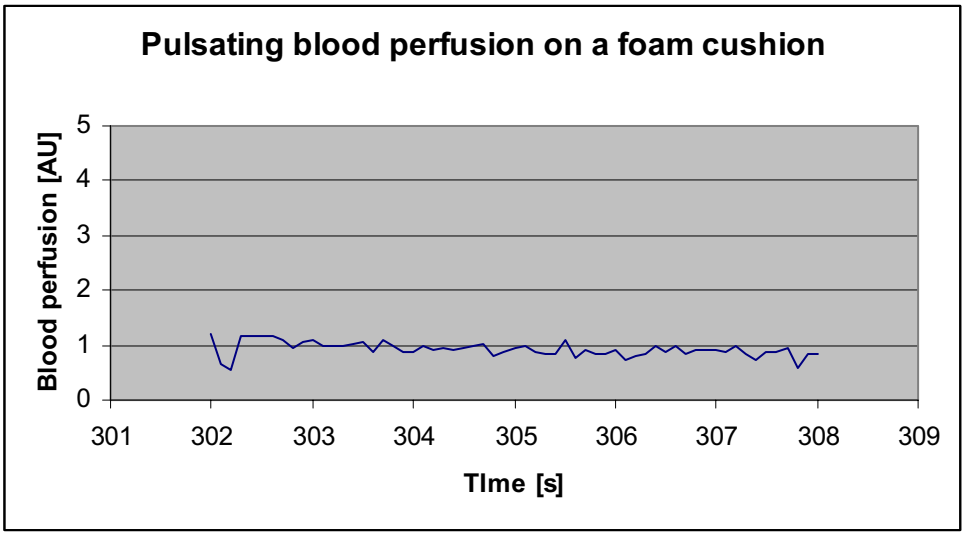


Figure 5. Pulsating effect on a foam cushion. Notice that this figure has the same scale as figure 4, and that the pulsating effect is hardly visible.

5 Conclusion

Blood perfusion was measured on 15 healthy subjects while sitting on three different cushions; a LiquiCell® cushion, a gel cushion, and a foam cushion. After 60 minutes there is a significantly better blood perfusion when sitting on the LiquiCell® cushion, 1.8 times better compared to the foam cushion (P=0.02) and 2.3 times better compared to the gel cushion (P=0.005). These results show that the reduction of shear force on the tissue caused by the LiquiCell® cushion results in a better load situation **inside** the tissue, which results in better blood perfusion.

References

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