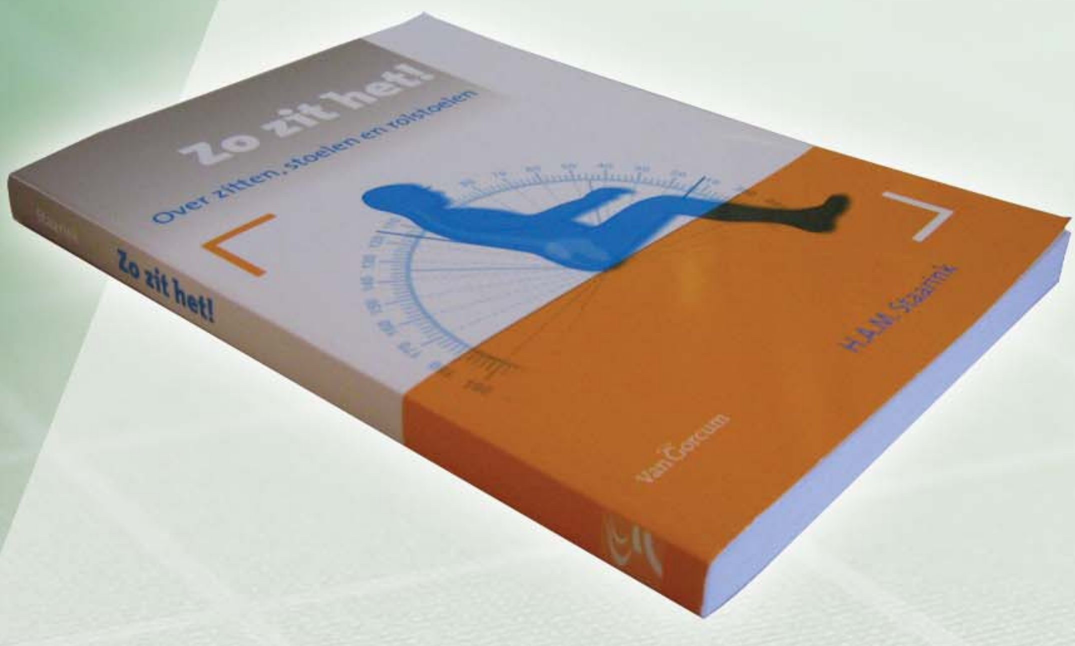
SELLA
PRESSURE RELATED SEATING PRODUCTS

Scientific research



Scientific research on sitting in a wheelchair, pressure distribution and cushions

The scientific research carried out by Dr.ir. H.A.M. Staarink that is the starting point for the development of our products is highlighted in this document.
Sitting in a wheelchair, pressure distribution and cushions will be discussed in turn and, with respect to cushions, a differentiation will be made between covers, pressure distributing media and support constructions.

Sitting in a wheelchair

Due to the enforced character and the motory function disorders that make it necessary, sitting in a wheelchair tends to lead to complications. These complications can be prevented or alleviated by active or passive simulation of natural sitting behaviour combined with optimisation of the sitting situation.

In natural sitting behaviour, a strong desire to relax can be observed. This is achieved by choosing a stable posture as soon as the activities allow.
An anatomically sound stable posture begins when the functional backrest inclination, angle $(\varphi+\alpha)$ measured against the trunk above the lowest point of the small of the back is 115°. When measuring, the back should be supported in its own natural curve. This is achieved by allowing sufficient space for the buttocks.

Figure 1: Definition of the angles of a sitting posture

The alternative for this posture is a stable posture that arises when the lower back is allowed to arch and the vertebrae are in their most extreme positions in relation to each other. This posture is relaxing for the muscles but highly overtaxes the intervertebral disks and the ligaments of the spine.
Moreover, in this posture the head has to be lifted to direct the gaze at the horizon which, of course, demands extra muscle effort. In the long term this posture causes neck and shoulder complaints. It is an anatomically unsound posture.

Sitting posture versus seating support

When discussing the phenomenon sitting, a distinction is made between sitting posture and seating support:

- a sitting posture is determined by the position of the body in space and by the position of the body parts relative to each other. A sitting posture is, therefore, defined in terms of angles (see figure 2);
- a seating support is formed by a seat and a backrest and the measurements of these are expressed in cm.

The magnitude of the forces on the seating support is determined by the posture. In an active posture, there will be hardly any load on the backrest whereas in a relaxed posture there will be a much greater load on the backrest. In this sense, the sitting posture is the basis for the analysis of the quality of a seating support as regards pressure distribution.
Optimisation of the seating support begins, therefore, with the optimisation of the sitting posture. In fact, this is the optimisation of the reactive forces in the support resulting from the load of the body.
It has been shown that with certain relations between the functional backrest inclination, angle $(\varphi+\alpha)$ and the seating angle, angle α there are no frictional forces necessary on the buttocks to achieve the equilibrium of forces.

Basic sitting posture in a wheelchair

Sitting in a wheelchair should conform to the same set of 'rules' that apply for a 'sound sitting posture' and should afford the maximum amount of 'comfort', because the warning mechanisms for over taxation are often impaired or lost in the case of wheelchair users.

The basic sitting posture in a wheelchair can then be nothing other than an anatomically sound, stable sitting posture with a functional backrest inclination, angle $(\varphi+\alpha) > 115°$, a seating angle, angle α, the angle between the functional part of the backrest and the seat under load, of approximately 103° and with an individual support for the back. This means that the back support should afford sufficient space for the buttocks and its position should be adjustable in relation to the lowest part of the small of the back.If

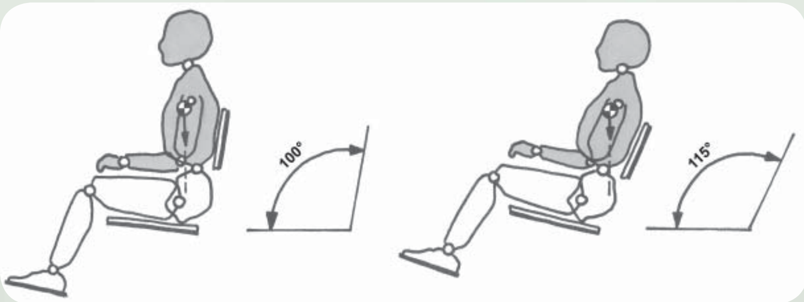


Figure 2: An unstable, therefore active sitting posture and an anatomically sound stable sitting posture with resp. an angle $(\varphi+\alpha)$ =100° and an angle $(\varphi+\alpha)$ =115°

a wheelchair concept only affords one sitting posture, then the anatomically sound basic posture should be seen as a compromise between an optimal transfer posture with a seating angle, angle φ of 0° and an average individually preferred posture with an angle $(\varphi+\alpha)$ of approximately123°.

Wheelchairs that can be adjusted by the user should at the very least be able to move between a transfer posture and a relaxed preferred posture where the size of angle α is adjusted to the stable posture, that is angle α is 103° - 105°.

By continually adjusting one's posture to suit one's activity, the necessary dynamism is introduced that works preventively on the development of decubitus. The body is, after all, not suited to long-term static loads. It is both physiologically and neurophysiologically dependent on movement. Movement entails changing the loads on the body. Movement is also necessary for conscious and unconscious perception, and conversely, perception depends on movement.

Neurophysiologically seen, the position of the head in balance on the trunk with the relaxed gaze directed at the horizon is the reference posture for all manipulations. With the head in this position the body can be controlled with the most precision in carrying out activities. The main characteristic of the relaxed preferred posture is the position of the head in balance on the trunk.

The relaxed preferred posture with an angle $(\varphi+\alpha)$ of, on average, 123° is indeed the basic posture for wheelchair users with an impaired warning system and/or an impaired control system in the brain. With this posture as starting point the necessary movements or (small) changes of posture can be realised either passively or actively.

The pressure distributing properties of the supporting elements play a role in the manner in which the reactive forces are transmitted to the seating surface.

Frictional forces in the seating surface should be avoided by ensuring a correct sitting posture, a correct relation between the seating angle, angle φ and the hip angle, angle α te worden vermeden.

Reducing the load in areas around the ischial tuberosities as much as possible is the essence of good pressure distribution and will prevent the onset of decubitus.

Pressure distribution

The human posterior comprises a pelvis which is surrounded by soft tissue all enclosed in skin. The weight of the upper part of the body is transmitted by way of the spinal column into the pelvis which in turn transmits the load through the soft tissue and the skin to the cushion. The skin has the function of holding the mass of soft tissue together. The soft tissues in combination with the skin form a pressure-distributing medium for the pelvis.

Every posterior has its own specific pressure distributing capacity. This capacity depends on the amount and the thickness of the layer of soft tissue.
The pressure-distribution of the posterior is at its most effective when it is maintained under load.

Sitting load
The seat reacts on the sitting load with a reaction force that is equal to the weight of the upper part of the body. This reaction force is the load that is brought to bear on the buttocks.
It has been shown that this load is not equally distributed over the buttocks. Figure 1 shows the general pattern of distribution across the buttocks as can be measured between the buttocks and the cushion. This is called the interface pressure. This pattern is characteristic and is found in all studies.

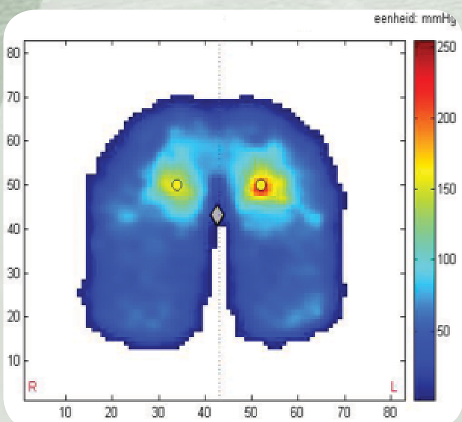


Figure 3: A typical pattern of pressure distribution across the buttocks showing that the interface pressure is highest under the ischial tuberosities and decreases towards the outer edges.

The highest pressure is always seen under the ischial tuberosities. This is also the area where, generally, most problems occur.
One of the important pressure distributing properties of a cushion is, indeed, the capacity to reduce the pressure under the tuberosities as much as possible. The tuberosities need to be relieved of as much of the load as possible. As the total sitting load stays the same in any given posture, the areas around the tuberosities must take up – a little – more of that load: the pressure is 'distributed' in favour of the pressure under the tuberosities.

Factors that determine the pressure distributing effect of a cushion
The pressure distributing effect of a good cushion stems from its capacity to maintain the natural shape of the buttocks under load as this is when the personal pressure distributing capacity of the buttocks is at its greatest.
The cushion should take on the shape of the buttocks without causing high reaction forces as it distorts.
The shape of the support construction and the properties of the pressure distributing medium are the determining factors here.
It has been shown that the more readily (with little resistance) a cushion adapts to the shape of the buttocks, the better the pressure distribution.

The shape of the support construction determines the extent to which the pressure distributing medium has to distort to adopt the shape of the buttocks. The more this shape (under load) resembles the shape of the buttocks, the less the pressure distributing medium has to distort and generally the better the pressure distribution. A layer of foam on a hammock usually gives a better result than the same foam on a rigid flat surface. On distortion, the foam produces a reactive force that becomes greater as the distortion or the extent to which the cushion is depressed becomes greater.

In practical applications it has been shown that relative distortion is important. There is an essential difference between the working of cushions filled with foam and those filled with air or liquid.

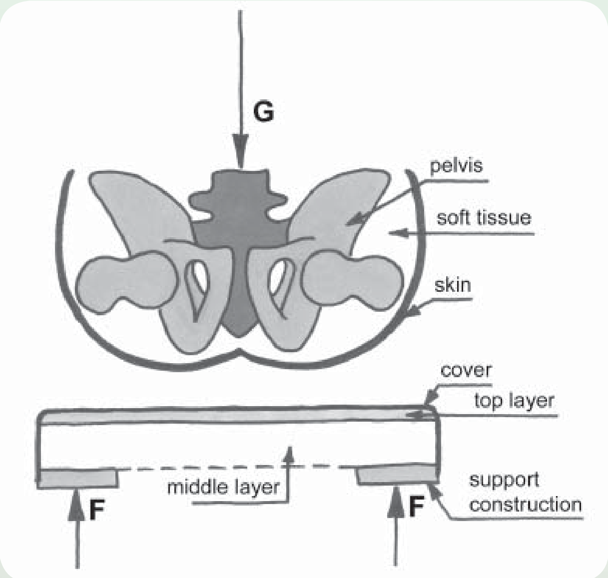


*Figure 4: Structure of buttocks and cushion in the frontal plane at the ischial tuberosities: G=2*F*

The distortion of foam results in a reactive force that increases as the distortion increases. The reactive forces in air and liquid filled cushions, on the other hand, depend solely on the surface area that is brought under load.

The properties of the cover or, with air and liquid filled cushions, of the casing can have a negative effect on pressure distribution. This is because under load they sometimes work with the pressure distributing medium in such a way that tensile stress occurs. This tensile stress stands in the way of total conformity. There is a definite connection between the air pressure, or, hydrostatic pressure in the system and this tensile stress. The tensile stress in the surface under load can be advantageously influenced and reduced by dividing the surface into small areas.

The pressure distributing effect of any given cushion can, in principle, be analysed and understood by answering these four questions:

- To what extent does the support construction assist in adaptation to the natural shape of the buttocks? In other words, to what extent will the pressure distributing medium be depressed, or – in the case of foam - what relative depression will occur?;
- What is the relationship between depression and the reactive force of the pressure distributing medium used?;
- To what extent does (undesirable) tensile stress occur in the surface under load as a whole and what influence does the cover have on this phenomenon?;
- Does the pressure distributing principle allow the reactive forces to be reduced around the ischial tuberosities?

In practice, the interface pressure that is measured under the tuberosities is approximately half of the internal pressure that can be measured at that point. The magnitude of the interface pressure may in no way be compared to the capilliary pressure in the blood vessels.

Apart from the pressure distributing quality, the moisture and heat regulation are important comfort determining properties. When these properties are good enough they can also assist in the prevention of the onset of decubitus.

Cushions: covers, pressure distributing media and support constructions

In order to be able to manipulate the pressure distributing effect of cushions it is necessary to understand the construction and working of various types of cushions.
A cushion always consists of:

- a support construction that conveys the sitting weight to the frame;
- a pressure distributing layer;
- usually a soft top layer;
- an upholstered cover.

There are various types of pressure distributing media:

- foam, in various densities (kg/m^3) and hardness or rigidity;
- rubberised hair/natural fibres, in various densities (kg/m^3) and hardness;
- air, in various constructions;
- liquid gel, in various constructions or combinations;
- non-liquid gel (proves to be hardly effective in distributing pressure);
- combinations of these, for example, foam and liquid gel.

If the support construction has the shape of the buttocks or takes on this shape under load, then this means that the pressure distributing medium that is on top of it will only have to change shape slightly to take on the shape of the buttocks.
When foam or rubberised hair are used as a pressure distributing medium this results in a spectacular improvement of the distribution of pressure compared with the same materials on a flat plank of wood.
A soft top layer can be added to improve the softness of the surface and may also play a role in the regulation of heat and moisture.

The cover should be smooth, soft and stretchy as otherwise the quality of the pressure distribution may be negatively influenced due to the introduction of an extra horizontal aspect, known as the hammock effect.
The quality of the cover also has an effect on the magnitude of the softness of the surface. Folds in the clothing should disappear into the cushion, not into the skin!

Properties of foam

Foam behaves, in principle, like a spring: the greater the compression (read: distortion) the greater the reactive force. This distortion does not only have a vertical, but also a horizontal, component. Vertical incisions break the horizontal relationship which causes the cushion to be softer at that point. This can be used strategically in certain places, for example, around the tuberosities.

One possible special application of foam is in socalled 'custom contoured seats'. These must definitely be constructed with a 'custom contoured' support construction and positioning of the buttocks in the cushion may not be too critical a matter. Most existing custom contoured seats are cut to shape in foam after an impression of the buttocks has been made and use a flat plank as support construction. In view of the properties of foam, this approach is far from optimal. It is far better to make a custom contoured support construction and to cover this with a layer of fairly soft foam.
Individual back supports are also often cut from a block of foam. This approach does not result in an aesthetically pleasing or good support.

Properties of rubberised hair and coir

Rubberised hair or coir has properties comparable to foam, depending on the density and rigidity. In any case, this material also has a definite horizontal component in the reactive force to the sitting load. Once again the support construction will also have a great influence on the extent of the necessary distortion. As long as it is covered with a fabric that allows moisture to permeate, this type of pressure distributing medium has excellent heat and moisture regulating properties. These aspects are extremely important for the perception of comfort and in the prevention of decubitus.

Properties of air, water and liquid gel

The pressure distributing working of cushions filled with air, water or liquid gel is based on one and the same principle. The pressure distributing medium is necessarily enclosed in a casing. It takes very little force to distort the pressure distributing medium inside the casing.
Equilibrium occurs as soon as the pressure of the fluid or air in the casing is equal to the average pressure on the surface under load. As a result of the air or hydrostatic pressure, an undesired tensile stress will, in principle, arise in the casing. This problem is alleviated by dividing the surface into very small, separate components that are connected with each other, comparable to the incisions made in foam cushions. This is the principle behind the well-known Roho cushion.
Due to this principle, Roho cushions do not afford any sitting stability at the sides unless a left and a right compartment are created that can be closed off from each other. During the closure between these compartments one has to sit 'properly' and symmetrically, and to sit down in that manner after every transfer. In practice this proves to be rarely the case.

The pressure that occurs within this sort of system lies in the region of 35 mmHg. A comparable pressure is often found as the average pressure in interface pressure measurements.
An important variable in this sort of system is the amount of air that is in the system. If there is too much air one will be balancing on top of the cushion and the surface under load will be too small; if there is too little air then there is a risk that one will sit 'right through it' and that there will be no pressure distribution whatsoever. The top surface that arises under load, a crumpled layer of distorted rubber sacks, renders interface pressure measurement using pressure mats extremely difficult. Because of this, measurement results are difficult to interpret.
Existing air, water and liquid gel cushions have no special facilities that reduce the pressure at the location of the tuberosities but this is possible with cushions that use foam as a pressure distributing medium.

A good cushion also has the following properties:

- it is lightweight;
- it can be easily taken out of the wheelchair, replaced and fixed in position;
- it offers good stability at the sides;
- it has a solution to reducing the pressure where the tuberosities are located;
- it easily allows a transfer;
- it has a cover that allows moisture, but not water, to permeate;
- it has good heat and moisture regulation.

More information

If you have any questions or comments, or if you would like to see a demonstration of the SMS seating advice: go to our website www.pr-sella.nl!

For extensive work on sitting and pressure distribution, see the following books:

Staarink, H.A.M. Zo zit het! Over zitten, stoelen en rolstoelen*, Assen: Van Gorcum. 2007

Asbeck, F.W.A. van (red.). Handboek dwarslaesie revalidatie, paragraaf 18.1.1: Biomechanische en (neuro)fysiologische achtergronden van het zitten, tweede herziene druk, Houten: Bohn Stafl eu Van Loghum. 2007

*'All there is to know about sitting, sittingbehaviour, seats and wheelchairs'. This English translation is in preperation.