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ERGONOMIC WHEELCHAIR POSTURE*

A better sitting posture, stability, pressure distribution and driving in hand-propelled wheelchairs.

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Introduction

Active user wheelchairs are characterised by, among other things, rearward angled seat frames. Such a sitting angle / wedge angle is brought about by the fact that the seat frame of the wheelchair is higher at the front than at the back.

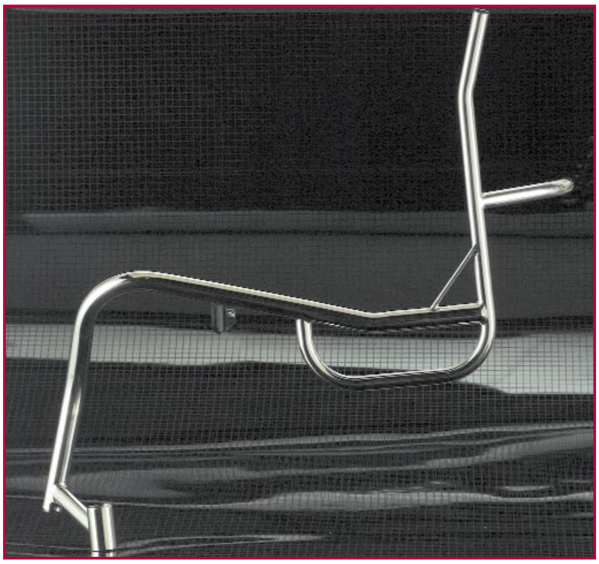
Such a "wedge seat" has advantages over the fully horizontal seat. These advantages concern sitting posture, sitting stability and propelling of the wheelchair. However, the wedge seat also has a number of disadvantages, such as, for example, greater exertion of pressure on the tuber (ischium or seat bone).

The "ergonomic" sitting posture is in fact an improved version of wedge sitting. The sitting factors of: posture, stability, pressure distribution and wheelchair propelling can be optimally and individually adjusted by means of ergonomic sitting.

This article describes and elaborates the ergonomic seat with respect to its advantages in relation to sitting posture, stability, pressure distribution and wheelchair propelling. In order to convey a good understanding of the relationship of ergonomic seating / sitting posture to each named item, the item itself will first be dealt with, often in comparison with horizontal or with wedge seating.

Ergonomic seating

The ergonomic seat combines as it were the flat (horizontal) part of the seat with the wedge seat (anged part of the seat). The "kink" in the surface of the seat, where the horizontal part joins the upward sloping part, is formed by a bend in the tubular seat frame. The ergonomic back combines a chair back where the first part of which is vertical and the second part slopes backwards over one or more centimetres.



(Good) sitting posture

The state of the joints and the shape of the vertebral column (spine) are the variables that determine the sitting posture. The various parts of the vertebral column normally each possess a characteristic curvature (Figure 2).

- The 7 neck vertebrae form the cervical part, which has a slight lordosis (curvature with the concave edge at the back).
- The 12 chest vertebrae form the thoracic part, with a kyphosis (curvature with convex edge at the back)
- The 5 lumbar vertebrae form the lumbar part, with a lordosis.
- The 5 sacral vertebrae are fused together to form the sacrum (sacred bone), which is kyphotically curved.

Basic shape of the vertebral column

The sacrum is more or less solidly bound to the pelvis and thus follows any movement of the latter. The state or position of the pelvis thus determines the state (position and angle) of the vertebral column and hence the position and angle of the head! The vertebral column exhibits variable mobility; the lumbar part assumes most of the forward / backward curvature. The cervical and lumbar part can vary between concave and convex and from lordosis to kyphosis. As good as possible maintenance of the shape of the lumbar part of the vertebral column, such as is the case when standing, is one condition for a comfortable sitting posture. This lordosis state of the lumbar vertebral column is the most desirable, both from the physiological and from the biomechanical point of view. When the pelvis sags downwards the result is a kyphotically convexly shaped back. The back "hangs" in the ligaments of the vertebral column, which puts extra pressure on the intervertebral discs. The neck muscles must then be tightly stretched in order to keep the head upright. The horizontal line of sight of the eyes can thus be maintained only by a strong cervical lordosis. This can in time result in neck complaints. Extreme states of the lumbar vertebral column are thus compensated at high level, namely at cervical level.

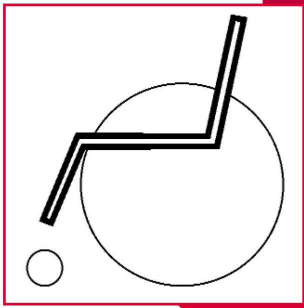


Fig. 1a

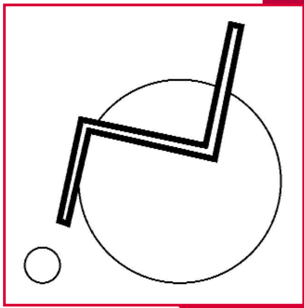


Fig. 1b

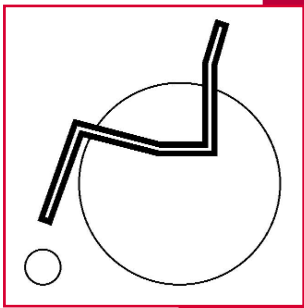


Fig. 1c

Fig. 2

Maintenance of the shape of the lumbar vertebral column results in reduction of intervertebral pressure

The lumbar depth is a "sensitive" parameter; only 0.5 cm more or 0.5 cm less has a noticeable effect!
The above-mentioned lumbar support is necessary as the pelvis has a tendency to tilt over backwards; this is caused by the weight of the torso causing a backwards-turning force to be exerted on the ischium, which is the support point or fulcrum of the pelvis. Hence in order to prevent the pelvis from tilting over backwards, a counteracting force needs to be exerted on the pelvic ridge, including the sacrum, on the back edge of the pelvis. A correctly shaped back-rest can provide this force. It may be clearly deduced from the aforesaid that the state of the back of the wheelchair seat is an important design criterion. Modern Active wheelchairs should have a comfortable cushioned seat-back covering. This must be adequately adjustable by means of velcro bands over the entire length of the user's body / back in order to get the correct back profile. But why the "kink" in the seat surface here? In other words: how does the ergoseat relate to the aforesaid?

Ergonomic seat and sitting posture

The pelvis is pushed over backwards in a wedge seat. This more or less stabilizes the position of the pelvis, though in this way it is more difficult for the torso to move forward. The shape assumed by the thoracic vertebral column is that of a (strong) kyphosis / flexion. (Fig. 5).

Wedge seat in principle pushes the pelvis backwards

We therefore think that at any rate the first part of the seat back, which supports the user's back, should if at all possible be vertical so that it can constantly exert the aforesaid force on the pelvic ridge / sacrum. But now see what the result is: a small angle (less than 90º) is formed between seat surface and the first part of the back support in the wedge seat. The sharper the wedge, the smaller the angle, the more tightly the pelvis is pushed over backwards and hence the greater is the compensatory force required of the seatback covering. Too small an angle between (wedge) seat and seat-back / back support also results in too small an internal abdominal cavity volume, resulting in greater pressure on the internal organs. Midriff breathing is made more difficult by the presence of tension in the abdominal skin. People of "large abdominal girth" would obviously also have a problem here. We can overcome part of this problem by "contouring" the seat. We have all seen the importance of this for the back, but this is also highly recommendable for the seat. Here contouring means making the (seat) covering looser under loading for the purpose of moulding it to the desired anatomical shape. This gives not only greater stability, but also better pressure distribution. Contouring of the seat thus ensures a larger angle between seat (covering) and seat-back (covering). Result: less pressure on the internal organs in the abdominal area and a less tightly backwards-pressed pelvis. (Fig. 6).

Contouring of the seat: more stability, better pressure distribution

However, the ergonomically shaped seat gives a better result here. The horizontal part of the seat gives the pelvis a free and vertical position. The obliquely upward sloping part opposite this provides the necessary stability. The size of the horizontal part of the seat is chosen so that this supports the pelvis, while the obliquely upward sloping part of the ergoseat supports the thigh (femur). The ergoseat thus divides the seat area into two parts: one part for supporting the pelvis and one part for supporting the thigh. The neutral state of the pelvis, made possible by (the horizontal part of) the ergoseat, ensures that the lumbar vertebral column can more easily assume a natural curvature (lordosis). The compensatory force exerted on the pelvic ridge / sacrum is still nearly always necessary (for neutralizing the downward rotary turning force), though it can be (much) smaller than the latter.
A well contoured base part of the back-covering can easily bring this about. This guarantees the so-called sacral support. However, we also create with the ergoseat the desired "ischial support".
The kink (transition from horizontal to obliquely upward sloping part) of the ergoseat provides support for the front of both ischial bones and prevents these from sliding down and outwards.
The pelvis is thus now supported at two points, namely at the sacrum and at both ischia. This guarantees maintenance of the correct sitting posture. (Fig. 7).

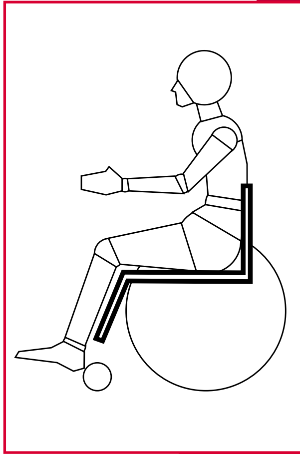


Fig. 3

Ergonomic sitting position: neutral state of the pelvis with sacral support and ischial support

The absence of the ischial support is one of the shortcomings of the 100% horizontal seat; the pelvis quickly sags down, which leads to kyphotisation of the vertebral column. The excellent neutral state of the pelvis in the ergoseat can nevertheless be annulled when the thighs show too much flexion at the hip and the feet are pushed forwards. The muscles from the thighbone (femur) to the pelvis and the base of the back in any case govern the backward tilting of the pelvis. With increasing flexion of the thigh the muscles at the back of the leg (ischiocrural group) will contract, while those on the upper or front side of the thigh will simply relax. The pelvis will therefore tend to tilt over backwards.

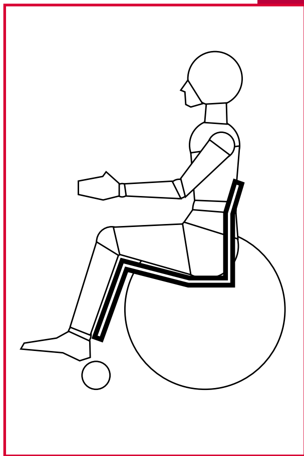


Fig. 4

Certain muscles on the back of the thigh are of course polyarticular, that is, they run over several joints; not only over the hip but also over the knee joints. Stretching of the lower part of the leg (calf) (when the feet are placed further forwards) thereby increases the backward tilting of the pelvis. This means that an ergoseat in which the kink between horizontal part and obliquely upward sloping part is large (great flexion of the thigh in the hip joint is logical only when this is used in a short framework (in which the person sits with the calves vertical or even slanting backwards somewhat).

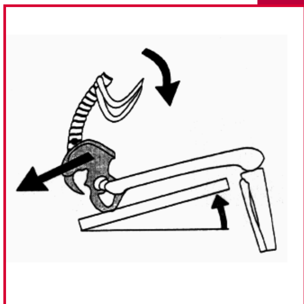


Fig. 5

The neutral state of the pelvis, brought about by the horizontal part of the ergoseat, also improves the possibilities for forward movement of the torso. The following paragraph will illustrate this.

Stability

The way in which stability of the upper part of the body is achieved is determined by the location of the centre of gravity of the whole of the upper part of the body – head, torso

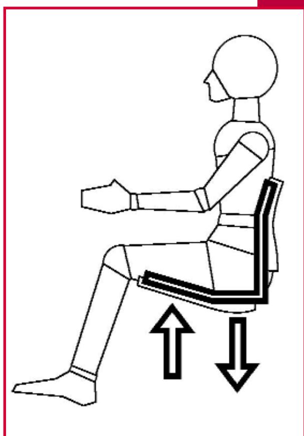


Fig. 6

and arms – in relation to the lumbar pivoting point (this being taken as model). The centre of gravity of the entire upper part of the body with the arms in the lap is situated approximately in the axilla region (between the armpits). A good stable posture then is a posture in which the gravitational axis runs through centre of gravity of the whole upper body through and to behind the lumbar vertebrae (lumbar pivoting point). Stability of the upper body can be found / controlled by the wheelchair driver raising his hands in front of his body and seeing how the torso reacts. For wheelchair users who as a result of a spinal cord lesion (paraplegia) have lost the ability to assume a more active posture, the aforesaid is described as "semi-active" sitting posture, the most "active" sitting posture attainable by such disabled people. (Fig. 8).

Semi-active sitting posture: torso balance by sitting posture

As we have seen, the wedge seat presses the pelvis back against the chair back. In other words, the lumbar pivoting point is displaced backwards. Hence in order to get the gravitational axis on or behind the lumbar pivoting point, we must push (the second part of) the back support backwards. The torso is thereby displaced backwards, the wheelchair driver meanwhile keeping his line of vision horizontal: kyphosis is then a threat. (Fig. 9).

Wedge seat displaces the lumbar pivoting point backwards: threat of kyphosis

The following situation is however even less desirable. If we do not move the back support backwards, then there is a risk that the gravitational axis for the lumbar pivoting point will drop, which means that the torso will slump forward. The wheelchair driver will try to compensate this by slumping the pelvis. He or she will thereby "gridlock" the lumbar vertebral column; the vertebrae will hang completely kyphotically in their ligaments. This will displace the pivoting point from the lumbar vertebrae to the two ischia, thus creating a new balance situation through the shifted sitting posture. However, this imparts poor stability to the torso and is characterised by aspects that we would rather avoid, such as high intervertebral disc pressure, stretched ligaments, kyphosis, (compensatory) neck extension and finally, if this sitting posture is adopted for years, an immobile vertebral column. (Fig. 3).

Ergonomic seat and stability

So what is the role of the ergoseat in relation to torso stability? The pelvis, by means of the horizontal part of the ergoseat, is allowed to assume a neutral, vertical position (at any rate while the lumbar vertebral column is (still) mobile). In this way the lumbar pivoting point comes to lie more forward than in the wedge seat (where the pelvis is pressed backwards). This means that the gravitational axis from the centre of gravity has more forward and backward latitude before a labile equilibrium is established. In concrete terms this means that the torso has more possibilities for forward movement before the balance is lost or the back support can be made more vertical. The ergoseat however thus ensures that the upper part of the body needs to be brought back only very slightly in order to attain the desired stable posture. (Fig. 10).

Ergo-seat pushes lumber pivoting point forward, providing more possibilities for forward movement of the torso

Expressed numerically: with a seat height difference of 7 cm between the front and the back of the wheelchair frame (wedge being 7 cm) and a seat depth of 40 cm, the pelvis (or the ischia) can however preferably drop 2 cm when an ergonomic seat with a 12 cm horizontal part is used in comparison with the wedge seat. (Fig. 11).

Comparison of wedge seat with ergo-seat; ischia sag in ergo-seat

a: wedge seat (depth 40 cm).
b: horizontal part of ergo-seat
c: obliquely upward sloping part of ergo-seat.
d: vertical part of seat-back
e: obliquely sloping part of seat-back.)

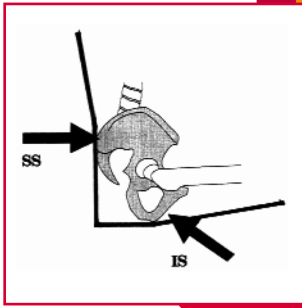


Fig. 7

When the ischia sag 2 cm, the lumbar pivoting point comes to lie about 2 cm further forward (and lower). This gives the thoracic vertebral column, at the top, an estimated increase in its forward movement possibility by a factor 3, hence 6 cm in this example. The result of this is that in addition to the 2cm central displacement of the lumbar pivoting point, stretching of the thorax also takes place due to the neutral state of the pelvis. The stretching brings the part centre of gravity of the torso further backwards, thus increasing the possibilities for forward movement. This is of course a mobility gain. This is the reason why wheelchair users with a C5 lesion, in a wheelchair with an ergo-seat, can sit upright and yet also still have a possibility for forward movement of the torso.

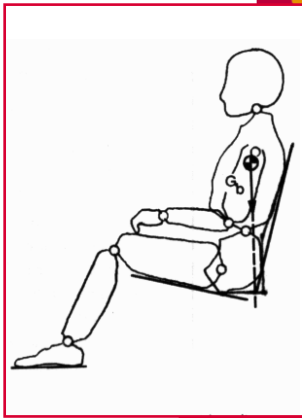


Fig. 8

It has already been described how the lumbar vertebral column can become immobile as a result of sitting for years with a sagging pelvis. However, when this irreversible situation has arisen an ergo-seat is contraindicated. Introduction of an obliquely upward sloping part (of the ergo-seat) will of course not prevent the occurrence of kyphosis and compensatory neck extension. The sagging may even be made worse by putting the polyarticular hamstring muscle group under tension by the obliquely upward sloping part of the ergo-seat and thereby pushing the pelvis further backwards. A better solution for this seating problem is to use a (large) wedge seat (e.g. 10º) in combination with a larger angle between seat surface and back support than the 90º of the ergo-seat (e.g. 110º). The result will then be that not only will the neck extension be cancelled out, but also the angular loading on the lumbar vertebral column will disappear. The gravitational axis will be displaced downwards by the backward displacement at any rate on the lumbar vertebral column and not in front of it. (Fig. 12).

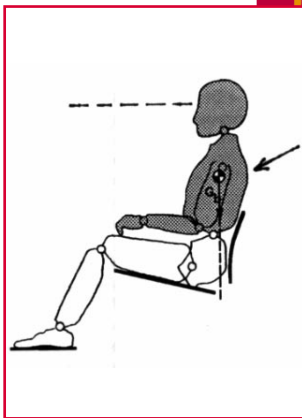


Fig. 9

Pressure distribution

The sitting posture determines the way in which the body is stressed. Seat sores (decubitus) occur mainly by burdening the seat surface for long periods with excessively high pressure and friction forces. The combination of friction and pressure is especially disastrous.

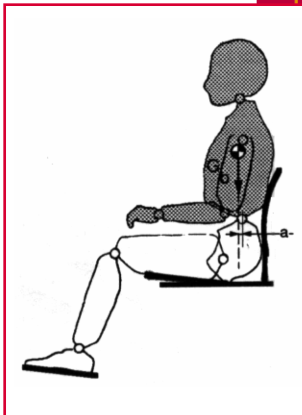


Fig. 10

Let us begin with the friction forces. These cause sliding stresses in the seat and thighs, which in turn are responsible for deformations of the soft tissues.

However, friction forces should not occur with a good sitting posture. Friction forces are not reduced by a cushion, as is sometimes asserted, but they are reduced by a good sitting posture. Friction forces occur immediately when the angle between seat and back support becomes greater than 90º. The larger the angle, the greater the friction forces.

Increase in friction forces on the seat (Rz,t with increasing angle between seat and back (a).) (Fig. 13).

An exception to this is when the whole seat is tilted. We have achieved this by tilting the back of the wedge seat over backwards. Each wedge angle ideally has a certain angle between seat and back support at which the friction force is smallest. With a wedge angle of 8º the angle between seat and back must be 106º if the friction forces are to be kept small. This is precisely the state of the back-rest that we would rather not want (the pelvis is pushed back too far). Concerning "pressure" we can state the following. The pressure distribution over the surface of the seat is generally not uniform. The greatest pressure is found under the ischia nodules (tubers). A good pressure distribution is a pressure distribution that distributes the pressure uniformly over the surface of the seat and reduces the pressure under the tubers as much as possible. This is achieved when the backside's own pressure-distributing capacity is put to the best possible use. This happens when the shape of the backside remains intact under pressure.

In other words, the more the seat part (including cushions) is capable of assuming the shape of the bottom without deforming the latter, the better will the backside's own pressure-distributing ability be utilised and hence the better will be the pressure distribution. The need for so-called contouring of the seat comes to the fore here, earlier described as the loosening of the seat-covering of the wheelchair under loading for the purpose of following the desired anatomical shape (bottom). Contouring provides optimum pressure distribution and stability. When Active wheelchairs have a non-adjustable seat-covering, contouring cannot take place. It is then very desirable to use a contoured seat cushion. (Fig. 14).

The flat seat always puts less pressure on the ischia than the wedge seat. A wedge seat of 10% also appears to put an extra 10% pressure on the ischia. From the point of view of pressure distribution / pressure reduction, a flat seat is thus to be preferred over a wedge seat.

Ergonomic seat and pressure distribution

Friction forces are produced as soon as the angle between seat and back-rest exceeds 90º. The ergo-seat, however, has an angle of 90º between seat component and back support. The seat component is moreover horizontal.

Such a specific shape also makes the ergo-seat better able to assume the shape of the bottom than any other seat, certainly when contouring also takes place (see Figure 6). The kink in the seat surface of the ergo-seat makes it possible to mould the seat surface to the shape of the buttocks and to reduce pressure on the tubers. A well contoured ergo-seat shifts the pressure more to the thighs, thus favouring pressure reduction under the tubers. The pressure is thus distributed evenly. It has already been pointed out that a flat seat appears to give less pressure than a wedge seat. The ergo-seat, with its horizontal part under the pelvis, fulfils these conditions. When an antidecubitus cushion is not necessary, use of a foam cushion is satisfactory. This is adjusted to the kink of the ergo-seat under loading with the driver sitting in the wheelchair. A contour cushion is not necessary here, as contouring can be achieved with the seat-covering itself. When antidecubitus cushions are used in the ergo-seat, the cushions also assume the shape of the ergo-seat under loading with the driver sitting in the wheelchair. Varilite, Roho, Vicair and Jay Extreme cushions do that without further ado. This retains the specific shape of the ergo-seat and hence its pressure-distributing capacity.

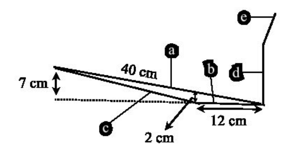


Fig. 11

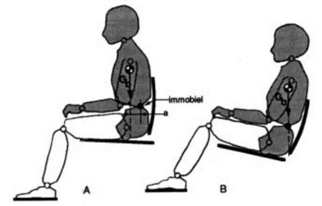


Fig. 12

Ergonomic seat and propelling the wheelchair

The ergo-seat is particularly well suited for propelling the wheelchair, especially for the following three reasons:

- It forms a stable basis.
- It enables the driver to hand-propel the wheelchair with greater force by means of the wheel-hoops.
- It improves the torso flexion.

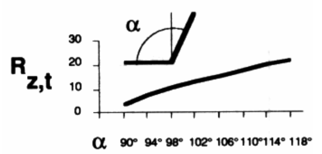


Fig. 13

Stable base

The ergo-seat ensures a stable position of the pelvis. The contoured back-covering forms a sacral support at the back. On the underside at the front the kink of the ergo-seat forms an ischial support. This "grounding" of the pelvis is necessary when the shoulders/arms/hands set the wheelchair in motion against resistance. When the wheelchair cannot be driven from a stable base (the pelvis) the efficiency diminishes noticeably. The combination of sacral and tuber (ischial) support is all the more important when we realize that the pelvis, when the wheelchair is being driven against resistance, tends to tilt over backwards. Both forms of support together however prevent the pelvis from tilting and thus ensure that the good sitting posture is maintained, even when the wheelchair is being hand-propelled. (Fig. 7).

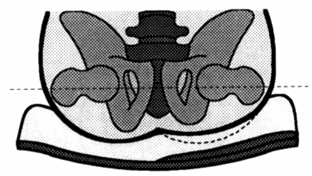


Fig. 14

Greater propulsion force on the wheel-hoops

For efficient propulsion of the wheelchair it is necessary that the wheelchair driver is sitting sufficiently deeply. Only then is it possible to exert sufficient "hoop force", that is, to exert a sufficiently strong push on the wheel-hoop. A principle for this may be that the elbow of the arm bent at 90º with driver in the upright sitting position is situated about 5 cm above the tyre of the rear wheel. (Fig. 16).

The ergo-seat lowers the seat position. Rule of thumb for efficient hoop hand propulsion: elbow about 5 cm above tyre

Such a position can never be attained, especially by taller people, with a flat wheelchair seat; the length of their calves does not permit such a position. Sufficient space must in any case be left between the soles of their shoes and the ground if they are to ride the wheelchair at all (unless they use a long wheelchair, in which the driver sits with the feet [and legs] lying forward [more or less horizontally]. However, this is for various reasons not desirable). This is one important reason why the wedge seat was introduced. [In the wedge seat] the buttocks are lower than the knees, making a lower sitting position and hence a stronger hoop propulsion force possible. We have however been able to predict what additional problems will then occur: the pelvis is passively pushed over backwards, bringing the lumbar pivoting point backwards and hence reducing torso stability and flexion. There is less space for the contents of the abdomen and there is increased pressure on the tubers. The ergo-seat not only resolves these problems, but also provides the tubers and hence the entire vertebral column with a lower position compared with the wedge seat. The ergo-seat thus brings the shoulders closer to the wheel-hoops, resulting in a powerful hoop propulsion force, which is a major condition for efficient propulsion and prevention of shoulder complaints.

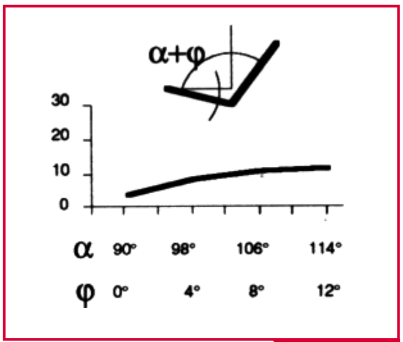


Fig. 15

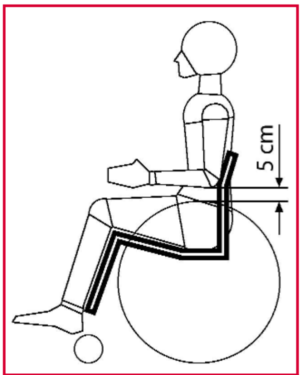


Fig. 16

Torso flexion
The ergo-seat brings the lumbar pivoting point forward and thereby permits greater torso flexion. The torso flexion can be brought into action by hand-propulsion of the wheelchair. The flexion of course brings the shoulder closer to the propulsion hoop and thereby makes a greater propulsion force possible. The weight of the torso can also be used as extra propulsion force. This is certainly useful when extra power needs to be generated, for example when going up a step, slope or ramp with the wheelchair. (Fig. 17).

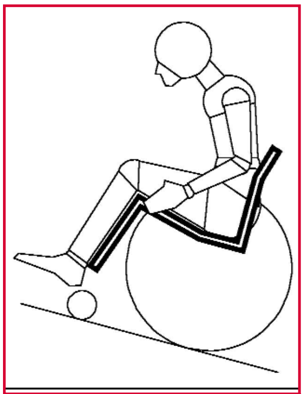


Fig. 17

The ergo-seat makes increased stable torso flexion possible

Conclusion
The ergonomic seat is the development of the wheelchair seat that is produced when the positive properties of the flat seat and the wedge seat are "matched". Sitting posture, torso stability, pressure distribution and wheelchair propulsion are improved by use of the ergonomic seat. (Fig. 17).

It is nevertheless not an "all purpose" seat. Many individual choices still remain, e.g. how long do we make the horizontal part, how high do we place this part, how much wedge do we give as a result of the obliquely upward sloping part, how high do we make the sacral support, how high do we make the whole of the chairback and how far back do we set the second part of the latter? It therefore goes without saying that the wheelchair will actually have to be a custom-made product, tailored to the individual sitting posture and measurements of the wheelchair user. Finally, I would like to conclude by quoting the statement by wheelchair seat expert H. Staarink that "a wheelchair is like a tailor-made suit. It must fit perfectly. Any condition such as "he must sit like a statue" is no longer applicable anywhere and particularly to a wheelchair driver in his wheelchair".