SEAT DESIGN IN UNSUPPORTED SITTING

Myriam Brunswic
M.Sc,MCSP,Cert.Ed,Dip.TP,MIL

Senior Physiotherapist
London, England

ABSTRACT

The problems of unsupported sitting are analysed and seating solutions reviewed.Two experiments illustrate the effects of seat design and task on spinal posture.Implications for seat design are drawn from the results of these studies.

INTRODUCTION

Seating has been the object of many ergonomic studies and recommendations (Akerblöm 1948,Keegan 1962, Grandjean 1969, Mandal 1976).They describe the configuration of the ideal seat and its backrest. However there are many tasks such as eating writing,assembly work which require that one leans forwards thus losing the benefits of a well designed backrest. This paper analyses the biomechanical problems of unsupported sitting and their implications to seat design.

BIOMECHANICS OF THE SPINE IN SITTING

When sitting the backward rotation of the pelvis is compensated by a flattening or flexion of the lumbar spine, while the trunk remains upright (Akerblöm 1948, Schoberth 1969).During flexion of the spine the annulus fibrosus of the intervertebral disc is compressed anteriorly and stretched posteriorly,while the nucleus pulposus is displaced posteriorly.Annular fibres have a low resitance to stretch and repeated flexion leads to micro trauma and later degenerative changes of these fibres.(McNeill 1980). As demonstrated by Nachemson (1963, 1975) direct measurements of the intradiscal pressure in the L3,L4 disc show a considerable increase during flexion of the lumbar spine and in anterior sitting (fig.1)whether in the upright or relaxed position(Andersson Örtengren,Nachemson,Elfstrom,Broman 1975). This increase was also noted when the back extensor muscles were active.

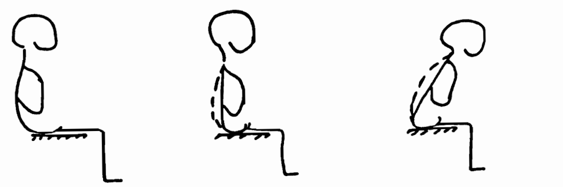


Fig. 1. Illustration of the three sitting positions selected by Andersson during his intradiscal measurements in L3-L4.

It is therefore important to incorporate seat features which allow the maintenance of lumbar lordosis (extension) and an upright trunk with little or no muscular effort, whilst not relying on a backrest for forward reaching tasks.

REVIEW OF UNSUPPORTED SEATING SOLUTIONS

Staffel(1884) recommended that in order to maintain a lordotic attitude of the lumbar spine, the seat should not have a lumbar backrest and that the seat pan should be inclined forwards and down. He proposed a saddle shaped seat although they might prove uncomfortable for prolonged use.

Schlegel(1956) also recommended tilting the whole seat pan forwards. Sliding would be prevented by friction between the seat and clothing and the counteracting thrust of the legs. Pulling on the clothes proved uncomfortable and prolonged muscular activity in the legs induced fatigue.

Kromer(1971) in his review of seating in plant and office mentions the Schneider wedge.The back of the seat is wedged up by 30° and the front remains horizontal. This wedge tilts the pelvis forwards, thus helps maintain lumbar lordosis and avoids the problems of sliding off.The inventors claimed that the device relieved back, shoulder, neck and arm pain in 200 people.

Burandt and Grandjean (1969) compared three seats.One had a flat surface, the other a 30° wedge inserted in the posterior part of the seat and the third had a double wedge(fig.2). One in the centre of the seat the second on top but starting further back.

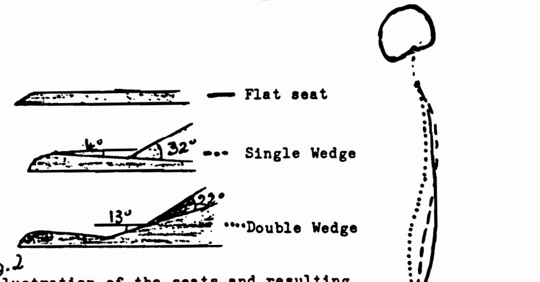


Fig.2
Illustration of the seats and resulting postural alignment as described by Burandt and Grandjean (1969)
Untersuchungen über das Sitzverhalten von Büroangestellten and über die Auswirkungen verschiedenartiger Sitzprofile.

They reported that the double wedge seat restored lumbar lordosis more than the other two designs but subjects preferred the single wedge and the flat seat. The discomfort was attributed to the sharp angle of the wedges and design improvements were recommended.

Burandt (1969) experimented on seat inclination whilst performing forward reaching tasks. A narrow board supporting the ischial tuberosities was tilted back by -6° and then forwards by +6°. He concluded that the backward tilt of the board with no back support was not acceptable. When the board was tilted forwards, the pelvis was in a neutral position able to rotate passively forwards. The maintenance of the forward position required little or no work.

Mandal (1976) proposed the principle of the tilting seat to meet the varied demands of tasks. He noticed that people often changed their position either by moving their bottom forwards on the seat thus allowing their thighs to slope downwards or by tilting the whole of the chair forwards. The postures either increased the pressure on the blood vessels under the thigh or the danger of overtipping the seat. 20° of forward tilt was selected as being the amount of compensatory flexion in the lumbar spine. The required amount of tilt is obtained by the person moving their weight forwards. Mandal found that maximum benefit was obtained with the seat tilted 15° forwards and the work surface elevated by 10°. He made no mention of the frictional problems involved, nor of the fatigue in the legs or the possible lack of stability when performing tasks requiring force.

The Balans range of seats was designed to overcome the problems mentionned. (fig.3). The seats are inclined forwards by +15° and the knees are flexed under the seat. Weight is taken just below the knees through a padded support. Gliding is thus prevented by the knee pad which also abolishes the need for counteracting leg work.

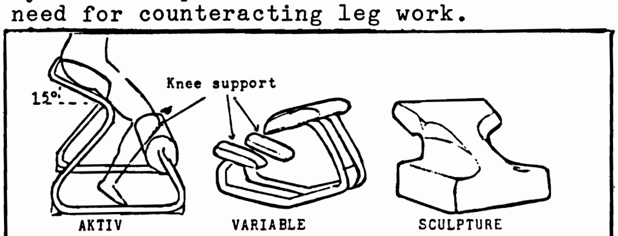


fig.3 Some of the BALANS range of seats

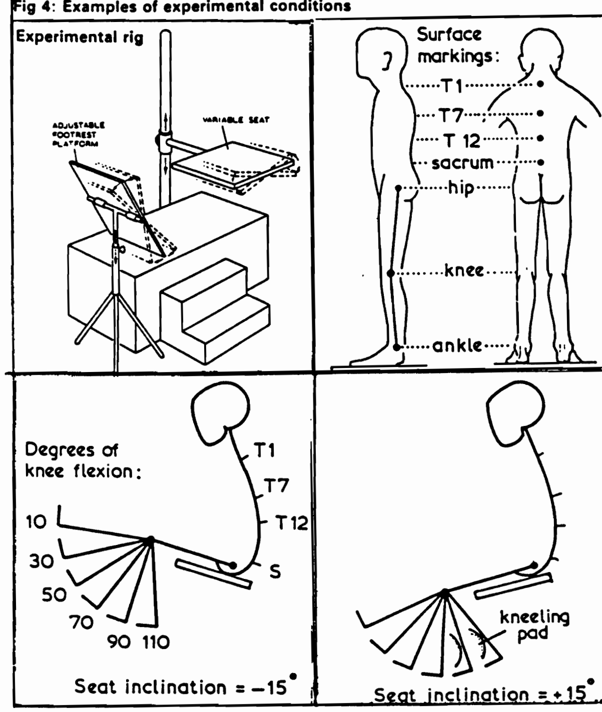
This review highlights the need for a systematic study of the crucial factors governing posture of the spine in unsupported sitting. The following experiment investigates the effect on the spine of systematically varying the angle of tilt of the seat and the position of the lower limbs while the subjects remained upright.

INFLUENCE OF SEAT TILT ON SPINAL POSTURE

Experimental method

Using a test rig the angle of the seat was tilted in 5° increments from -25° backwards from the horizontal representing the angle of a deep sofa through to +25° forwards representing a sit-stand stool as used in some factory assembly line. In each of the 11 positions of the seat the knees were flexed successively at 110°, 90°, 70°, 50°, 30°, 10°. The configuration of the spine was monitored with a hydrogoniometer (Loebl 1967) and readings taken at the level of S2, T12, T7, T1. Throughout the experiment subjects were asked to sit upright and their feet were supported on an adjustable platform. When the seat tilt varied between +15° and + 25° and the knees were flexed at 110° and 90° body weight was transmitted through a knee pad to ensure stability. (fig.4).

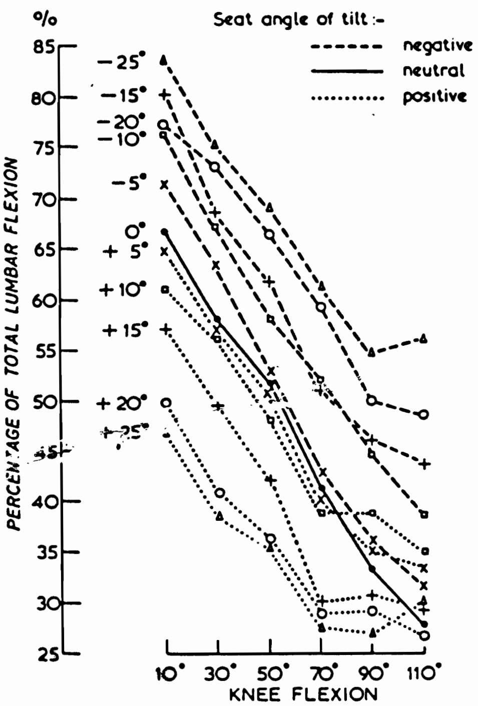
Fig 4: Examples of experimental conditions



Results

The results are expressed in percentage of lumbar flexion defined as the actual amount of flexion occuring in the lumbar spine expressed as a proportion of total lumbar flexion thus allowing for individual variation of total lumbar mobility.

A virtually linear relationship between the percentage of lumbar flexion and the angles of the hip and knees was established such that an increase in the flexion of the hips and in the extension of the knees both increased the percentage of lumbar flexion. The effect of moving the hips and knees was additive in a 1:2 proportion such that an increase extension of the knees of 20° corresponded roughly to a 10° flexion of the hips. The simultaneous alteration of these two components would flex the spine in a proportion equal to the addition of each phenomenon taken separately (fig.5).



(fig.5) Graph showing the relationship of knee flexion to the percentage of lumbar flexion for each angle of seat inclination.

These results can be explained anatomically by the role of the hamstring muscles as a posterior rotator of the pelvis, extensor of the hip and flexor of the knee. In order to maintain an upright trunk the posterior rotation of the pelvis is compensated by an increased flexion in the lumbar spine.

These results are particularly valuable when assessing situations where there are constraints to the sitting position such as the location of foot pedals or fixed work surface.

IMPLICATIONS FOR SEAT DESIGN

Both experimentally and clinically lumbar flexion is a factor of lumbar stress therefore, seat design solutions minimising lumbar flexion are recommended.

<u>When the knees are flexed at 110° to 90°</u> the lumbar mechanism is not very sensitive to small alterations in the position of the hips and knees as dictated by the angle of tilt of the seat.

Therefore the seat pan could assume any angle from -5° to + 25°. However tilting the seat further back rapidly increases the percentage of lumbar flexion. Furthermore, in unsupported sitting, the body is thrust so far back that increased muscular activity is required to maintain the upright position.

<u>When the knee are flexed 70° or less</u> the lumbar mechanism is extremely sensitive to small alterations of the hip flexion angle as determined by the inclination of the seat. When the knee position is determined by the location of pedals to operate machinery or by a support bar the angle of tilt of the seat becomes crucial and should be tilted by at least +10° forwards, when the knee position varies between 70° and 30°.

A +15° of forward tilt affords a measurable reduction in the percentage of lumbar flexion whatever the position of the knees. Tilting the seat to +20° further reduces the lumbar flexion.

The positon of the hips and knees as determined by the angle and height of the support and by function must be determined before making recommendations for seat selection.

<u>Implication to car seat design</u>. Clinically there is a high incidence of back ache associated with driving (Buckle 1981). Most car seats are tilted back by -10° and the depression of the upholstery further increase the effective angle of tilt to -15°,-20°. To reach the pedals and especially to depress the clutch the knees are extended to between 50° and 10° depending on the size of the driver and the proximity of the seat to the pedals. The backrest is usually upright to enable the driver to monitor the road. By reference to the graphs(fig.5) this position imposes a great percentage of lumbar flexion. Andersson recorded a particularly high intradiscal pressure when drivers changed gear. This could be due to the increased knee extension and muscular activity required. For the driver, the body constraints are maximum:feet positon dictated by the pedals, hands by the steering wheel, head and trunk by the road it is therefore difficult to change position. The backward tilt of the seat makes any attempt to change one's position even more difficult as it is against gravity.

According to these results back pain may be eased by moving the seat forwards thus allowing more knee flexion. But care must be taken not to increase the flexion of the hips. The addition of a pillow in the rear portion of the seat may compensate for the backward tilt of the seat.

An automatic gear box would also be an improvement.

Seat design must be integrated with task and workspace design.

THE INFLUENCE OF TASK ON SPINAL POSTURE

As highlighted in the review and by Burandt and Grandjean(1969) and Mandal(1976) sitting posture is often determined by the task performed.

An experiment was designed to establish how seat design could influence posture whilst performing two representative desk tasks: typing which did not require desk support and writing which did.

Experimental Method

Two chairs were selected: a standard typist chair with a horizontal seat, adjustable in height and tripod swivel leg and the Balans Aktiv junior seat (fig.3) with a seat tilted forwards by +15° and a knee pad for stability.

Desk height was standardised at elbow height of the seated subject throughout the experiment. On the standard seat feet were supported on a horizontal platform with hips and knees at right angle at the start of the experiment.

Results

Between seat analysis. There was no significant difference between the spinal posture adopted on the Balns Aktiv seat and on the standard seat during the activities Some differences in the position of the legs were recorded but did not affect the posture of the lumbar spine.

Between task analysis. There were some significant differences (p 0.01) between the postures adopted whilst typing and writing on either chair. In writing use of the desk is accompanied by a very large increase in flexion of the lumbar spine consequent to an inclination of the trunk and not a modification of pelvic attitude. Posture while writing could be improved by changing features of the desk (inclination, height) rather than those of the seat.

Implications for seat design

Location of task, viewing distance will dictate the position of the head and trunk. The nature of the task will determine the need for support from the work bench, the quality of visual monitoring and the freedom of movement. These factors will in turn also determine the position of the trunk.

These results show the importance of considering seat design as an integral part of task and workspace design rather than in isolation.

Physiological considerations

During the experiment the standard chair group adopted positions of the lower limbs similar to that imparted by the Balans seat; knees flexed, feet under the seat, thighs sloping downwards. As pointed out by Mandal (1981), the front edge of the seat presses on the posterior aspect of the thighs and impedes the circulation in the main blood vessels. Further in this position people have a tendency to slide off and their balance is precarious. To overcome this problem they stretch their legs. Since little weight is going through the feet they slide forwards and slouch. Stability is also of great importance in tasks requiring force or accuracy.

In order to perform tasks, people overcome the problems of conventional seats. The price is an unstable position, impedance to the circulation and a potential strain on the lumbar spine. The Balans Aktiv seat overcomes some of the problems of sitting at a desk. The forward tilted seat is designed to remain parallel to the body tissues thus reducing skin and vascular compression. Stability is ensured by the knee pad. Lumbar strain is minimised by a decreased angle of hip flexion and the knees are supported at 120°. The benefits of such a seat could be more fully appreciated in conjunction with a modification of desk height and angle to improve the posture of the trunk over the hips. The introduction of the knee pad may affect the design of desks, consoles and work benches.

CONCLUSION

The concept of the perfect seat must disappear. Seat design must be integrated in job, task and work space design. One wears different shoes for different functions and occasions one must now also think of seat design adapted to function.

However governing rules of design and fit remain fairly constant.

They must aim at:

- Decreasing lumbar stress by
  - a) maintaining lumbar extension
  - b) decreasing muscular activity
- Respect physiological constraints
  - a) blood circulation
  - b) skin pressure
  - c) friction
- Enable the user to move freely
- Be comfortable and attractive.

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