In a field study an adjustable VDT workstation was given to each of the 68 operators for one week. The preferred settings, the body postures and subjective evaluations were assessed during normal working activities of the operators. The preferred ranges were: for keyboard height (home row above floor) 71-87 cm, for screen height (center above floor) 92-116 cm, for viewing angles (eye to screen center) +2 to -26°, and for visual distance (eye to screen) 61-93 cm. There was practically no correlation between preferred settings and anthropometric data of body length or eye levels above floor. The study of body postures has revealed that the great majority of operators tend to lean backwards with trunk inclinations between 97° and 121° (95% confidence interval). Some of the preferred settings strongly differ from those recommended in many brochures and standards. The physical complaints in the neck-shoulder and back area are diminished with the preferred settings.

The reports on physical impairments of office machine operators (Hunting et al., 1980, 1981; Maeda et al., 1980) due to postural efforts lead to the assumption that an adjustable VDT workstation should reduce the risk of intolerable static loads and uncomfortable body positions. Thus, we assessed in a field study the preferred settings of 68 VDT operators and examined the effects on body postures as well as on physical impairments. Details of the analysis are given by Grandjean et al. (1982b).

METHODS

The experiments were conducted in offices of 4 different companies. Five experimental VDT workstations were tested by employees while doing their normal daily job. Each employee used the experimental workstation with their own visual display and keyboard. Each experiment lasted one week for each operator. During this period the preferred settings were checked every day. An adjustable workstation was developed. The adjustability limits are shown in Fig. 1. The
adjustment of keyboard and screen heights was done by means of an electrical motor set in motion by a push button. Screen angle and distance were mechanically controlled by hand.

All keyboards were standard models with the home row height of 8 cm above the desk level. Because of this, a forearm-wrist support was used and tested being 13 cm in depth (front to back edge), 6 cm in back height, and 18° in inclination.

At each experimental workstation, a chair provided with a high backrest (of 50 cm in height above the seat level) and adjustable inclination was used. The subjects could easily lean the full trunk onto the backrest. Figure 2 is a photograph of this chair.

The mean age of the 68 subjects was 28. Their body height ranged between 153–184 cm, with the mean height of 168 cm.

The body postures were measured during the normal working activities. For evaluating postural comfort, a drawing of the anatomy of the body was presented in a questionnaire and the subjects were asked to report for each part of the body their physical feelings by making a cross in one of the following: “relaxed” (entspannt), “tense” (angespannt) or “impaired” (beschwerlich).

**PREFERRED WORKSTATION SETTINGS**

The results disclosed that the mean values of preferred settings remained
Table 1. Preferred workstation settings (236 observations 59, subjects).

<table>
<thead>
<tr>
<th>Settings</th>
<th>Mean</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Keyboard* height above floor (cm)</td>
<td>79</td>
<td>71-87</td>
</tr>
<tr>
<td>Screen height above floor (cm)</td>
<td>103</td>
<td>92-116</td>
</tr>
<tr>
<td>Screen distance to table edge (cm)</td>
<td>64</td>
<td>50-79</td>
</tr>
<tr>
<td>Visual distance to screen (cm)</td>
<td>76</td>
<td>61-93</td>
</tr>
<tr>
<td>Screen inclination** (°)</td>
<td>94</td>
<td>88-103</td>
</tr>
<tr>
<td>Seat height above floor (cm)</td>
<td>48</td>
<td>43-57</td>
</tr>
<tr>
<td>Home key to table edge (cm)</td>
<td>20</td>
<td>9-43</td>
</tr>
</tbody>
</table>

* Key top level of the home row.
** Angle in relation to a horizontal plane.

Fig. 3. Preferred keyboard heights above floor (236 observations, 59 subjects).
Fig. 4. Preferred viewing angles (224 observations, 56 subjects).

Negative figures correspond to angles between the line eye to screen center and a horizontal plane.

practically the same during the experimental week. In Table 1 are reported the mean values of the week as well as the ranges of all preferred settings. The range of the preferred keyboard height is of special interest, since this element must have a considerable influence on the static load of hands, arms and shoulders. The frequency distribution of the preferred keyboard height is shown in Fig. 3. The preferred height distributed in a large range, the 95\% confidence range lying between 73 and 85 cm.

The home row height of the keyboards used was 8 cm; many keyboards of about 3 cm in height are currently marketed. If these figures are subtracted from the preferred keyboard height above floor, the following ranges of desk levels can be deduced: 63 to 79 cm for 8 cm keyboards and 68 to 84 cm for 3 cm keyboards. Therefore a table which would suit all the preferred keyboard heights for keyboards available on the market should be adjustable between 63 and 84 cm. If one takes
into consideration the 95% confidence levels, this range of adjustability would lie between 65 and 82 cm. This seems to be a reasonable recommendation for workstation manufacturers.

The distance between the seat height and the preferred keyboard height was calculated for all the subjects. The mean value was 32 cm (n=232 observations), with the standard deviation of 3.0 cm and the range of 24–38 cm.

Most ergonomic recommendations related to VDT workstation dimensions are based on anthropometric data in common postural positions. Some authors combine the mean seat height (48 cm) and the mean elbow height above seat (24 cm) as a basis for requiring a horizontal plane of the forearm at 72 cm above floor. According to these considerations, they recommend that the height of the home row of the keyboard above floor should be between 72 and 75 cm (The VDT Manual, 1979).

The German rules of the “Verwaltungs-Berufsgenossenschaft” (1980) prescribe that non-adjustable keyboard-supporting tables must be 72 cm high and that the keyboard height above floor should not exceed 75 cm. The German DIN standard No. 4549 (1981) proposes for VDT workstations a desk level of 72 cm; this level must be lowered if keyboards higher than 3 cm are used.

It is obvious that these recommendations are based on anthropometric considerations of upright sitting operators. The present study shows that, in practice, the VDT operators prefer higher keyboard levels. The recommended level of 75 cm would suit only 4% of the operators, while the rest of them prefer levels between 76 and 87 cm.

From the figures of preferred screen heights and of eye levels above floor, it was possible to determine the preferred viewing angles for the operators as angles between the line from the eyes to the screen centre in relation to a horizontal plane. The frequency distribution of these angles are shown in Fig. 4.

The results show a nearly normal distribution. The 95% confidence range between $-4^\circ$ and $-14^\circ$.

Lehmann and Stier (1961) determined the comfortable viewing angles for reading subjects in a sitting posture. The mean angle was $-38^\circ$ and the 95% confidence interval between $-26^\circ$ and $-50^\circ$. It is obvious that VDT operators lies prefer a definitely smaller viewing angle.

PREFERRED SETTINGS AND PHYSICAL IMPAIRMENTS

The mean indices of complaints felt at the previous workstation are compared in Fig. 5 with those reported on the 2nd day (with forearm-wrist supports) and with those of the 4th day (without forearm-wrist supports). An index of less than 0.5 means that the majority of the subjects rated their body postures as relaxed. Indices of more than 0.5 means that many subjects indicated feelings of tense muscles or sometimes even of impairments.
From the figure it is clear that the indices were distinctly higher at the previous workstations and lower while working at stations with preferred settings.

Here it must be pointed out that the subjects had traditional office chairs with relatively small backrests at the previous workstations, while at the studied adjustable workstations they were provided with a specially suitable office chair with a high backrest and with adjustable inclination. These chairs allowed good relaxation of the whole back. It is therefore reasonable to assume that the decrease of physical complaints reported at the adjustable workstations were partly due to the preferred settings and partly also to the proper chairs.

PREFERRED SETTINGS AND BODY POSTURES

The results of the measured postural elements expressed as mean values and ranges are given in Table 2. If these results are compared with those of a previous laboratory experiment (Grandjean et al., 1982a) or with those obtained with the same operators at their previous workstations, the following conclusions can be drawn:

The postural elements are of the same order of magnitude at the previous workstation and in the present field study with preferred settings.

The body postures measured under practical conditions at previous workstations and at preferred settings are characterized by a marked trunk inclination in the sense of a pronounced backward leaning. On the contrary, the trunk is nearly in an upright position in the laboratory experiment which lasted only 10 min.

Compared to the laboratory experiments, the present field study shows a clear decrease in physical complaints at the preferred workstations.
Table 2. Mean values of postural measurements with preferred workstation settings (236 observations, 59 subjects). The postural elements are described in detail in Grandjean et al., 1982a, 1982b).

<table>
<thead>
<tr>
<th>Postural elements</th>
<th>$\bar{x}$</th>
<th>s</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trunk inclination (°)</td>
<td>104</td>
<td>6.7</td>
<td>91–120</td>
</tr>
<tr>
<td>Head inclination (°)</td>
<td>51</td>
<td>6.1</td>
<td>34–65</td>
</tr>
<tr>
<td>Upper arm flexion (°)</td>
<td>113</td>
<td>10.4</td>
<td>91–140</td>
</tr>
<tr>
<td>Upper arm abduction (°)</td>
<td>22</td>
<td>7.7</td>
<td>11–44</td>
</tr>
<tr>
<td>Elbow angle (°)</td>
<td>99</td>
<td>12.3</td>
<td>75–125</td>
</tr>
<tr>
<td>Ulnar abduction (°)</td>
<td>9</td>
<td>5.5</td>
<td>0–20</td>
</tr>
<tr>
<td>Distance acromion-home key (cm)</td>
<td>51</td>
<td>5</td>
<td>42–62</td>
</tr>
</tbody>
</table>

In Fig. 6 the mean trunk inclination as well as the observed range is illustrated in a simple drawing.

The analysis of all observed postural angles allows the following conclusions:

The trunk inclinations approximate a normal distribution. The 95% confidence range lies between 97° and 121°; the majority of the subjects give preference to trunk inclinations between 100 and 110°. Only 10% demonstrated an upright trunk posture.

The upper arm flexion shows also a nearly normal distribution. The 95% confidence range lies between 103° and 123°.

If the upper arms would be elevated proportionately to the backward inclination of the trunk, one should expect a mean upper arm flexion of 104°. In fact,

![Diagram of mean body posture]

Fig. 7. The "mean body posture" under practical conditions at preferred settings of a VDT workstation.
the subjects tend to elevate the upper arm to a greater proportionate degree, since they show a mean upper arm flexion of 113°.

The elbow angles were not normally distributed. The 95% confidence range lies between 87° and 111°, and a clear majority of the subjects demonstrated angles between 90° and 110°. The subjects therefore appeared to increase the elbow angle by about 10° when their upper arms are elevated.

Based on mean values it can be said that the subjects tend to widen the elbow angle to the same extent that they elevate the upper arm above the normal trunk inclination.

The mean angles of trunk, upper arms and elbow are shown in Fig. 7.

CONCLUSIONS

The present field study confirmed an impression which many observers had already perceived when visiting offices or workshops with VDT workstations: The majority of the operators do not maintain an upright trunk posture as it is being claimed in brochures and standards dealing with ergonomic recommendations for VDT jobs (German safety rules for VDT workplaces, 1980; CAKIR et al., 1979). In fact, the great majority of the operators lean backwards even if the chair is not suitable for such a posture.

The present study reveals that, in practice, operators with preferred workstation settings tend to lean backwards with a trunk inclination between 97° and 121° (95% confidence range). But also at fixed workstations, the same operators show a clear tendency to lean backwards.

Figure 8 is illustrating these facts: commonly recommended and actual postures.

An important question arises now: is the upright posture healthy and therefore recommendable or is the relaxed position with the backward leaned trunk preferable? It is a fact that some orthopaedists recommend an upright posture with a slight lordose (curvature of the spine convex to the backsupport) of the lower

Fig. 8. Recommended and actual postures.
Left: The upright trunk posture required in many brochures and standards corresponding to “wishful thinking.” Right: The actual body posture mostly observed at VDT workstations allowing the operators a full relaxation of the back and shoulders.
part of the spine. On the other hand, a Swedish group of orthopaedists (NA-
CHEMSON and ELFSTRÖM, 1970) measured the pressure inside intervertebral discs
as well as the electric activities of back muscles in relation to different sitting
postures. When the backrest angle of the seat increased from 90° to 110° they
recorded on their subjects an important decrease of the intervertebral disc pres-
sure and of the electro-myographic activities of the back.

Similar results were observed by YAMAGUCHI et al. (1972) who also advise
a seat-backrest angle of 115°-120° as the best condition for relaxation of the spine.
All these results indicate that resting the back against a sloping backrest transfers
a proportion of the weight of the upper part of the body to the backrest and reduces
noticeably the physical load on the intervertebral discs as well as the static strain of
the back muscles. From this point of view one must admit that the VDT operators
exhibit a good instinct when they prefer a backward leaned trunk posture and ignore
the recommended upright trunk position.

RECOMMENDATIONS

From the present study we can conclude that adjustable VDT workstations
can substantially contribute to comfortable and suitable working postures. Work-
stations for office machines, especially for VDTs, should therefore be conceived as
flexible as possible. We can summarize the recommendations for a proper design
of a VDT workstation or similar office machines as follows.

Adjustable workstation

A proper VDT workstation should be adjustable in the following ranges:

- Keyboard height (middle row to floor) 70–85 cm
- Screen center above floor 90–115 cm
- Screen inclination to horizontal plane 88–105°
- Keyboard (middle row) to table edge 10–26 cm
- Screen distance to table edge 50–75 cm

A VDT workstation without an adjustable keyboard height and without an
adjustable height and distance of screen is, for a continuous job at VDTs, not
suitable.

Adjusting workstation dimensions

The controls for adjusting the dimensions of a workstation should be easy to
handle, especially at workstations for rotating shift work.

It is nearly impossible for an operator to adjust the workstation dimen-
sions by himself. Another person should be in charge of handling the controls,
while the operator is working at the VDT workstation.

Space for the legs

Insufficient space for the legs causes unnatural body postures. The space at
the level of the knees should be at least 60 cm from the table edge, and at least 80 cm at the level of the feet.

*Seat for a VDT station*

A backward leaning posture is justified, since it allows relaxation of the back muscles and decrease of the load on the intervertebral discs. The traditional office chairs with relatively small backrests are not suitable for a VDT workstation.

The chair should have a 50 cm long backrest (above the seat surface) and an adjustable inclination. The backrest should show a lumbar support (10 to 20 cm above seat level) and a slightly concave form on the thoracic level. It should be possible to fix the inclination of the backrest at any position desired.

We wish to express our appreciation to Embru-Werke, Rüti (CH) for providing the adjustable workstations and to Giroflex-Entwicklungs-A. G., Koblenz (CH) for making available office chairs especially adapted to VDT workstations.

**REFERENCES**


