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SITTING—AN ELECTROMYOGRAPHIC AND MECHANICAL STUDY

By

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Technical advances in the last few decades have resulted in an increasing number of sedentary occupations as well as an increase in the average number of hours a day people spend in the sitting posture. This has in turn led to changes in the functional use of skeletal and muscular systems. People walk less and less and sit more and more in cars or other vehicles. During leisure hours they sit before the television screen etc. An ever increasing number of people complain of back pain when sitting. It was thought that examination of subject with and without back-symptoms might prove useful in he design of a chair providing the maximum degree of rest for the back.

The mechanics and statics of sitting have been carefully studied by *Schobert* (1962). He showed roentgenographically that on a change of posture from standing to sitting the pelvis is rotated on the average 40° and that this rotation is accompanied by a simultaneous compensatory kyphotic movement of the lumbar spine. During upright sitting the backward rotation is reduced and the kyphosis diminished by contraction of the muscles of the back (Figure 1).

Before the publication of Schobert's work opinions had differed widely on the statics of sitting (*Staffel* 1884, *Schulthess* 1905, *Spitsy* 1926, *Fick* 1911, *Heuer* 1930, and others). All investigators interested in the problem of sitting had, however, agreed that a support for the back was a most important part of a proper chair. *Staffel* (1884 and 1889) wrote that "chairs are designed more for the eye than for the back". Like *Meyer* (1873), he meant that it is impossible to rest properly in a chair without a back. Meyer recommended a support at the level of Th XII. *Staffel* concluded that the position of the back in the sitting posture should be as near as possible to that during standing, *i.e.* lumbar-

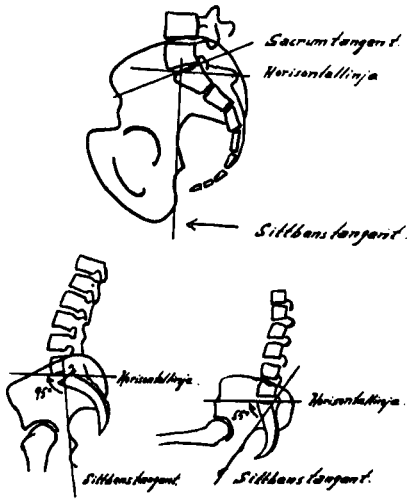

Figure 1. Pelvic rotation by change from standing to sitting posture.

lordosis should be prevented as far as possible from being straightened out. To prevent this he recommended a support at the level of the deepest point of the lumbar lordosis. In 1911 *Fick* had the opposite opinion and recommended the straightening out of this curvature of the spinal column. In 1913 *Strasser* claimed that the back should be bent forward in order to keep the upper part of the body vertical over its support, the tuber ischii. This position can be maintained by moder-

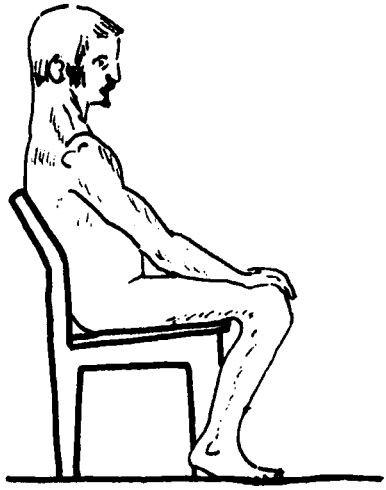

Figure 2. Strasser's chair.

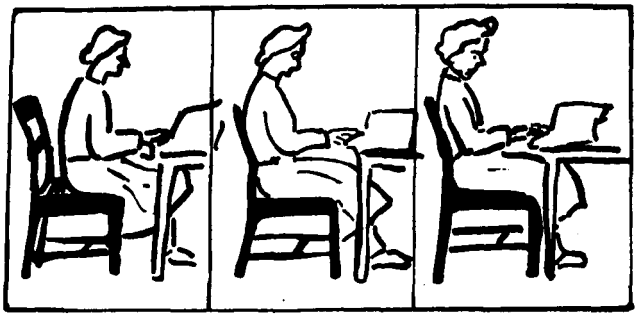

Figure 3. Akerblom's chair.

ate contraction of the muscles of the back. If the muscles become tired, the body falls forward and kyphosis occurs. He therefore recommended a chair with an upper backward slope for the thoracic spine (Figure 2).

Schede 1935, on the other hand, recommended a backward slope of the entire back of the chair and *Schulthess* (1905) believed 100°–105° to be a suitable angle between the seat of the chair and the back of school benches. *Morant* (1947) recommended a corresponding angle of 110° for the alert position and 110–125° for the resting position. *Sällfors* (1941) was of the opinion that the support for the back should be concentrated below the shoulder blades and above the diaphragm, while *Kindstrand* (1944) recommended a support for the lumbar region. *Vernon* (1924) stressed the importance of changing the position often in order that the muscles under tension may rest. At the same time he pointed out that the designers of chairs believe that there is only one ideal position. In 1949 *Akerblom* said that the most important criterion for a good chair is that it should allow the assumption of different resting positions. He spoke of three different resting positions:

1. With the trunk bent forward without support for the spinal column.
2. Sitting with a lumbar support.
3. Sitting with a backwardly inclined support providing good support for both the lumbar and the thoracic spine.

Akerblom, who used electromyography, showed that support of the lumbar spine is sufficient to rest the back muscles, which he thought was the most important thing. The height of the seat of the chair, *i.e.* the distance between the floor and the seat, has also been discussed. The height recommended has varied between 38 cm and 47 cm.

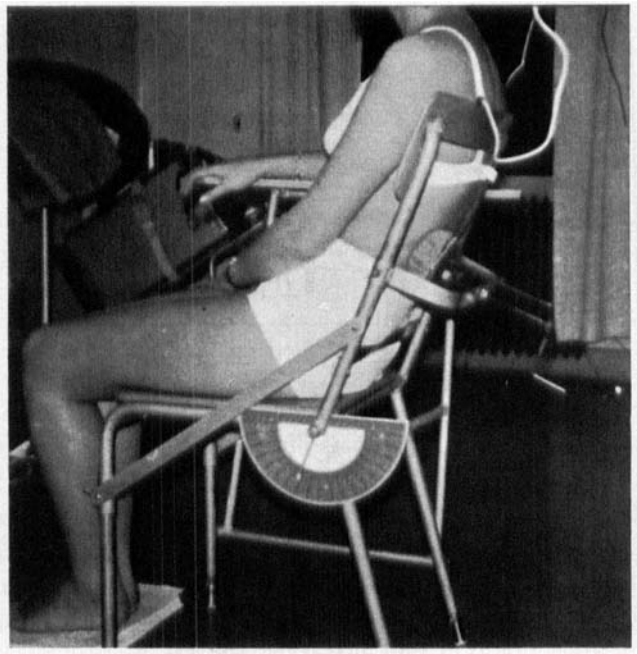

Figure 4. The examination chair.

In order to form an opinion of different sitting postures and of individual variations we used a specially designed chair made at the workshops of the department. The chair was designed so as to allow adjustment of the height of the seat by shortening or lengthening its legs (Figure 4).

The back has a transverse support down near the seat and a wider one higher up. The back is fixed to the posterior edge of the seat with a hinge allowing forward and backward adjustment of the angle of the back. A protractor is fitted to the chair so that it is possible to read the angle between its seat and its back. Between the upper and lower transverse parts of the back of the chair is a pad, which can be adjusted in the vertical and horizontal planes. For adjustment in the horizontal plane there is a special screw device with an inbuilt scale. This makes it possible to read the exact position of the pad, *i.e.* it provides a measure of lordosis or kyphosis in centimetres.

The patient was first allowed to sit comfortably in the chair with the sacrum and thoracic spine resting against the lower or upper transverse part of the back of the chair. The height of the seat was adjusted and set at such a level that the knee was flexed 90°. The arms were

relaxed with the hands on the thighs. The head was kept directed forwards and the patient was asked to fix his eyes on a point at the level of the face. The muscular activity was recorded electromyographically by introducing an electrode into the m. sacrospinalis on each side at the level of Th XII–LI. The electrodes were connected to electromyographic channels 1 and 3. At the same time channel 2 served as a calibration channel. The examination was carried out first with an angle of 100° between the seat and back of the chair and then with an angle of 110°. At each angle recordings were made without the dorsal pad, called 0-position, and then with the pad at the level of L IV screwed forward 1, 2 and 3 cm, and resulting in corresponding degrees of lordosis, called +1, +2, and +3-positions. Measurements were then made again in the 0-position, after which the pad was screwed backward 1, 2 and 3 cm with corresponding kyphosis called —1, —2 and —3-positions.

The material consisted of four groups:

1. Healthy subjects.
2. Patients with back pain without roentgenographically demonstrable changes, back weakness.
3. Back pain with slight roentgenographic changes, disk degeneration.
4. Back pain with severe roentgen changes, spondylosis deformans.

Group 1. This group consisted of 40 healthy subjects (20 males and 20 females) who had never had back symptoms. The males were doing their military service in an infantry regiment and the females were nurses, physical therapeutists and other hospital personnel. The average age of the males was 19.3 years (range 19–20 years) and the average height 180.1 cm (range 170–188 cm). The mean age of the females was 23.1 (range 16–55 years) and the average height 164.2 cm (range 158–175 cm).

Group 2. This group with back pain without roentgenographic changes consisted of 10 subjects (3 males and 7 females). None of them showed any roentgenologic or neurologic changes and in all of them the mobility of the back appeared normal. The average age of the males was 33.3 years (range 16–51 years) and the average height 171.6 cm (range 168–180 cm). The mean age of the females was 32.4 years (range 17–50 years) and the average height 163.6 cm (range 157–172 cm).

Figure 5. Number of examinations in different positions.

100°	−3	−2	−1	0	+1	+2	+3
Group 1, normal cases	3	16	28	40	38	36	30
Group 2, insuff. dorsi	0	4	9	10	10	10	5
Group 3, degeneratio disci	0	2	8	10	10	10	8
Group 4, spondylosis deform.	0	5	9	10	10	10	5
110°	**−3**	**−2**	**−1**	**0**	**+1**	**+2**	**+3**
Group 1, normal cases	4	13	23	40	30	30	25
Group 2, insuff. dorsi	0	2	7	10	10	10	5
Group 3, degeneratio disci	0	2	7	10	10	10	9
Group 4, spondylosis deform.	0	2	9	10	10	10	4

Group 3. This group with back pain with slight roentgenographic changes, (disk degeneration) consisted of 10 persons (8 males and 2 females). None of them showed neurologic signs and in all the mobility of the spine was practically normal. The average age for the males was 42.6 years (range 26–58 years), average height 178.4 cm (range 171–191 cm). The average age of the females was 52.0 years (range 51–53 years), and the average height 164.5 cm (range 164–165 cm).

Group 4. This group with back pain and severe roentgenographic changes consisted of 10 persons (7 males and 3 females). All had roentgenologically demonstrable changes of spondylosis deformans without neurologic signs, and in all of them the mobility of the spine was decreased. The average age of the males was 59.4 years(range 43–68 years), average height 173.1 cm (range 164–182 cm). The average age of the females was 49 years (range 42–59 years), the average height 163.3 cm (range 159–167 cm).

Groups 2, 3 and 4 consisted of patients who had sought advice at the outpatient department of orthopedic surgery because of back pain.

All of them were examined electromyographically in the O-position, *i.e.* without the pad, as well as when the angle between the seat and the back of the chair was 100° and when it was 110°. On the other hand, examination was not always possible with the use of the pad, especially in position −3, owing to decreased mobility of the spinal column. The patients who were examined electromyographically in the various positions with an angle of 100° and 110° between the seat and the back of the chair are summarized in Figure 5.

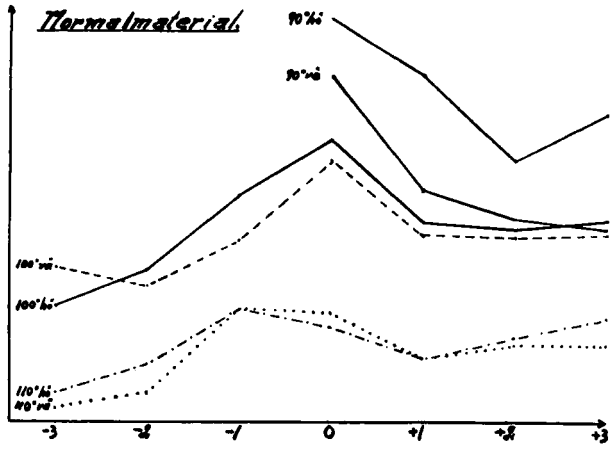

Figure 6. Group 1. Normal cases.

RESULTS

Of the curves obtained for the individual subjects a mean curve was drawn for each group, for an angle of 100 and 110° between the seat and the back of the chair and for the right side and for the left, respectively.

In Group 1 normal material, (Figure 6) the curves for the right side and those for the left, which often differed from one another in one and the same individual, fused in the mean curve.

Furthermore, a small group examined with an angle of 90° between

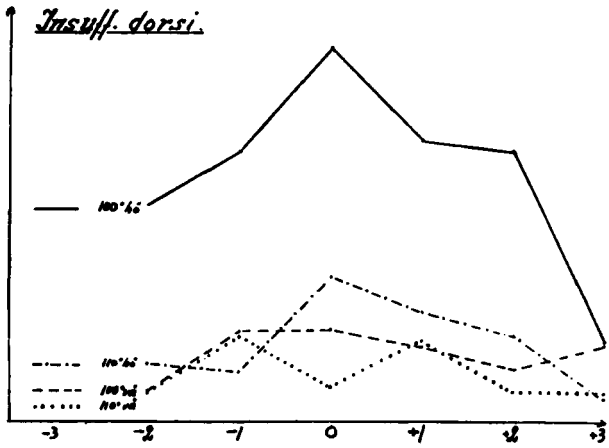

Figure 7. Group 2. Back weakness.

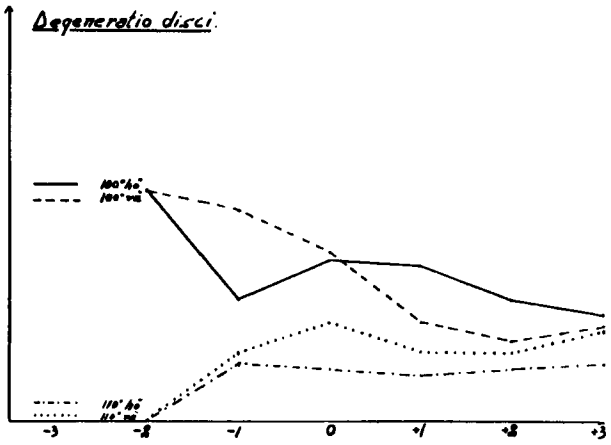

Figure 8. Group 3. Disc degeneration.

the seat and the back of the chair, showed a clearly higher activity than for the other two angles. The activity noted at an angle of 100° was higher than that recorded at an angle of 110°, and the highest activity was regularly noted for the O-position.

In Group 2, patients with back pain without roentgenographic changes, or back weakness (Figure 7), there was an increased activity on the right side at angle of 100 as well as of 110° between the seat and the back of the chair.

This is remarkable because most of the subjects in this group had a feeling of fatigue on the right side where muscular tension was found clinically to be higher. Six of the subjects in the group showed this picture, while only one had left-sided symptoms. As to the effect of the slope of the back of the chair, the activity was lower at 110° than at 100°.

In Group 3, with slight roentgenographic changes and disk degeneration (Figure 8), the symptoms were equally common on both sides. As in the normals, the activity on both sides was higher at 100° than at 110°.

In Group 4, with severe roentgen changes and spondylosis deformans (Figure 9) the symptoms were equally frequent on both sides. In this group it is remarkable that both the right and the left curves for the examinations with the use of the pad (kyphosis) showed a much higher activity at 110° than at 100°. This was thus the opposite to that found in the other three groups.

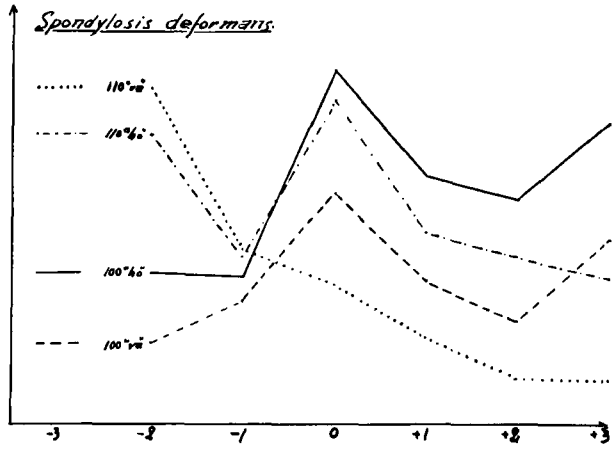

Figure 9. Group 4. Spondylosis deformans.

It should be added that these patients preferred to sit at 100° than at 110°, while in the other three groups the subjects preferred to sit with the back at 110°. Furhermore, in all positions the activity was much higher in this group with severe roentgen changes than in the other groups studied. There is possibly a correlation between the roentgen changes and fixation, and then probably because of muscle contractures.

Finally, the right and left values in each group were pooled and their means were calculated. At 100° between the seat and back of the chair (Figure 10) it was found that in the 0-position the activity was

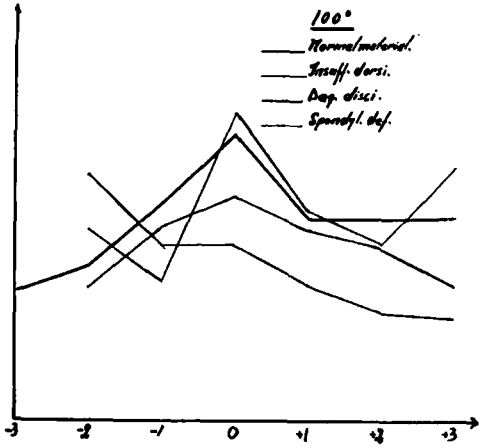

Figure 10. 100° between the seat and the back of the chair.

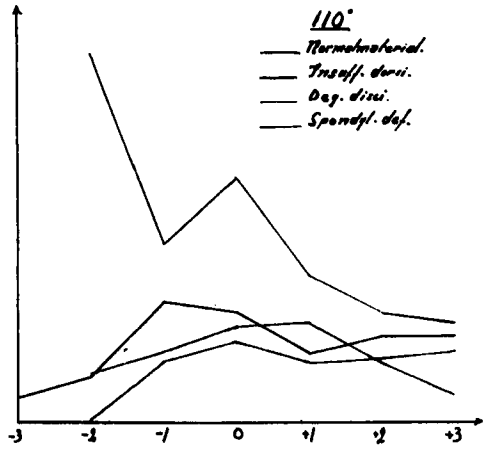

Figure 11. 110° between the seat and the back of the chair.

highest in the normals, in the group wihout roentgenographic changes and in the group with severe roentgenographic changes, while in the group with slight roentgenographic changes the activity was highest in position —2. With the pad in position the activity decreased fairly constantly in the normals, in the group without roentgenographic changes and in the group with slight roentgenographic changes. On the other hand, the activity increased again after position +2 in the group with severe roentgenographic changes.

At 110° between the seat and the back of the chair (Figure 11) there was a distinctly higher activity in the group with severe roentgenographic changes. This is in accord with what was said previously, *i.e.*, that these patients liked this angle less. It is also clear from the curve, as mentioned previously, that there is a distinctly higher activity in the group with severe roentgenographic changes and the activity noted during kyphosis was substantially higher than in the other groups.

Notes were also made of the positions in which the patients reported that they felt most rested and comfortable. All except those with severe roentgen changes found an angle of 110° between the seat and the back of the chair to be more comfortable. It was also noted that at both angles of the back of the chair most of the subjects in all of the groups reported position +1, *i.e* lordosis of 1 cm, most restful and comfortable (Figure 12).

Then came the position +2, *i.e.*, lordosis up to 2 cm. None of the subjects studied found kyphosis to be restful for more than a short period.

It would thus appear that at least 2 designs are desirable, one with an angle of 110° between the seat and the back of the chair for persons with a normal spine and one with an angle of 100° for persons with decreased mobility of the spinal column. In both cases the back should be curved to fit a spinal column with 1–2 cm lordosis.

Figure 12. Most restful and comfortable position.

Position of the saddle cushion		0	0 and +1	+1	+1 and +2	+2	+2 and +3	Don't know
100°	Group 1	5	–	29	–	4	1	1
	Group 2	1	–	7	–	2	–	–
	Group 3	1	1	6	–	2	–	–
	Group 4	1	–	8	–	1	–	–
	Sum	8	1	50	–	9	1	1
110°	Group 1	3	–	25	–	2	1	9
	Group 2	1	–	7	–	2	–	–
	Group 3	–	–	7	1	2	–	–
	Group 4	–	–	7	–	2	1	–
	Sum	4	–	46	1	8	2	9
	Total sum	12	1	96	1	17	3	10

SUMMARY

In order to study different sitting positions and individual differences between such positions a special chair was designed with an adjustable seat height, adjustable angle of the back, and a back-pad adjustable in the vertical as well as the horizontal plane. With an angle of 100° and of 110° between the seat and the back of the chair the electromyographic activity was recorded in the long extensors of the back without and with the back pad screwed forwards 1, 2, and 3 cm with consequent lordosis, and backwards 1, 2 and 3 cm with a corresponding degree of kyphosis. The material studied consisted of:

1. Subjects with healthy backs,
2. Patients with back pain without roentgenographically demonstrable changes, back weakness,
3. Patients with back pain with slight roentgenographic changes, disk degeneration, and

4. Patients with back pain with severe roentgenographic changes, spondylosis deformans.

None of the subjects had neurological signs.

It seems that two different designs of chairs are desirable, one with an angle of 110° between the seat and the back of the chair for persons with a normally mobile spine and one with an angle of 100° for persons with decreased mobility of the spinal column. In both cases the back should be curved to fit a spinal with 1–2 cm lordosis.

RESUME

Afin d'étudier différentes positions assises et les différences individuelles entre ces positions, une chaise spéciale a été construite avec hauteur adaptable du siège, angle adaptable du dossier et un coussin du dossier adaptable aussi bien dans le plan vertical qu'horizontal. Avec un angle de 100° et de 110° entre le siège et le dossier de la chaise, l'activité électromyographique a été enregistrée pour les longs extenseurs du dos sans et avec le coussin du dos, avancé de 1, 2 et 3 cm, donc en lordose constante, et coussin reculé de 1, 2 et 3 cm., avec un degré correspondant de cyphose. Le matériel d'observation étudié se composait de:

1. Sujets ayant le dos normalement sain.
2. Malades ayant des douleurs dorsales, mais sans altérations radiologiquement décelables, faiblesse dorsale.
3. Malades ayant des douleurs dorsales et présentant de légères modifications radiologiques, dégénération discale, et
4. Malades ayant des douleurs dorsales avec de graves modifications radiologiques, spondylose déformante.

Il semble que deux modèles différents de chaises sont souhaitables, l'un avec un angle de 110° entre le siège et le dossier de la chaise pour les personnes ayant une colonne vertébrale normalement mobile et l'autre avec un angle de 100° pour les personnes ayant une mobilité diminuée de la colonne vertébrale. Dans les deux cas, le dos doit être courbé de manière à placer la colonne vertébrale avec 1–2 cm de lordose.

ZUSAMMENFASSUNG

Um die verschiedenen Stellungen im Sitzen und die individuellen Verschiedenheiten zwischen derartigen Stellungen zu studieren wurde ein

besonderer Stuhl mit verstellbarer Sitzhöhe, verstellbarem Rückenwinkel und einem Rückenkissen, das sowohl in der vertikalen als auch in der horizontalen Ebene verstellbar war, konstruiert. Bei einem Winkel von 100° und von 110° zwischen dem Sitz und dem Stuhlrücken wurde die elektromyographische Aktivitet der langen Rückenstrecher ohne und mit Rückenkissen, das 1, 2 und 3 cm mit folgender Lordose nach vorwärts und 1, 2 und 3 cm nach rückwärts mit folgender Kyphose geschraubt wurde, verzeichnet.

Das untersuchte Material bestand aus:

1. Personen mit gesunden Rücken,
2. Patienten mit Rückenschmerzen ohne röntgenologisch nachweisbaren Veränderungen, Rückenschwäche.
3. Patienten mit Rückenschmerzen und leichten röntgenologischen Veränderungen, Scheibendegeneration, und
4. Patienten mit Rückenschmerzen und schweren röntgenologischen Veränderungen, Spondylosis deformans.

Es ergibt sich daraus, dass zweierlei Konstruktionen wünschenswert sind, die eine mit einem Winkel von 110° zwischen Sitz und Stuhlrücken für Personen mit normal beweglicher Wirbelsäule und eine andere mit einem Winkel von 100° für Personen mit verminderter Beweglichkeit der Wirbelsäule. In beiden Fällen sollte die Rückenlehne so gekrümmt sein, dass sie einer Wirbelsäule mit 1–2 cm Lordose entspricht.

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