Scand J Rehab Med 30: 151–158, 1998

PROPERTIES OF PERSON HOIST SPREADER BARS AND THEIR INFLUENCE ON SITTING/LIFTING POSITION

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ABSTRACT. The purpose of this study is to analyse mechanical lifts with regard to how the spreader bar design, e.g. frontal length, height and sagittal depth, affects sitting positions and safety during lift and transfer. The seven spreader bars available on the Swedish market had two-point to four-point suspensions. Twelve subjects were photographed individually sitting in each of three types of sling: divided, one-piece with divided leg support, and one-piece. All the slings had significant effects on all specific sitting aspects. However, the spreader bar design only affected the sitting position in the hoist. A long (0.62 m) spreader bar gave a relatively upright sitting position. A deep (0.18 m) spreader bar gave a backward inclination. For all specific sitting aspects, there was a significant interaction between slings and spreader bars. This study demonstrates that the design of the spreader bar, as well as that of the sling, is of decisive importance for the sitting position during lifting.

Key words: biomechanics, disability, hoist, lift, locomotor system, sling, transfer, Activities of Daily Living (ADL).

INTRODUCTION

Manual lifts are still more common than mechanical lifts (4, 14), even on modern wards (9) and even though many nursing aides consider patient lifting to be the heaviest nursing task (4). Among others, Takala & Kukkonen (13) have established that lifts with hoist giving a better working method, since stooped and twisted trunk positions occur less often with lifting aids than without. Lagerström et al. (8) have shown that, after training, people who had practised using transfer aids used them more often, and that those who had not used hoists before were willing to do so.

There are, however, few studies of how the lifted person experiences the lift; there is little documentation of knowledge of seating comfort in slings. Only Bell (2) raises the problem of finding comfortable slings. The spreader bar is the link between the hoist and the sling. Spreader bars vary widely in length, height, and number of suspension points. Bell (2) claims that back and thigh pressure can be reduced with a wider spreader bar or one with more than one suspension point for each side. Klint Edlund et al. (6) analysed sitting positions in a selection of slings and observed that the significance of the spreader bar for the sitting position seemed to be more important than expected. The Swedish market offers many spreader bars, but few people know them all and few consider how the design of the spreader bar may affect the patient's sitting position.

The purpose of the present study is to analyse how spreader bar design, e.g. frontal length, height and sagittal depth (the sagittal distance between the suspension points; see Fig. 1), affects sitting positions during lift and transfer in three selected slings available on the Swedish market.

Specific aspects studied were:

- the potential risk of falling through, depending on the sagittal length of the non-supporting parts of the sling
- the sagittal length of the supporting parts of the sling
- the sitting position (trunk and seat inclination).

MATERIAL AND METHODS

Subjects

Twelve healthy persons (6 men and 6 women), free from physical impairment, were lifted in the slings. Their heights varied between 1.64 and 1.92 m (average height 1.77 m) and their weights between 57 and 91 kg (average weight 73.7 kg. The bilateral movement axes for shoulder, elbow, wrist, hip knee and ankle joints were marked on their skin (5).

Spreader bars and slings

Suppliers of person hoists were asked to send documentation on

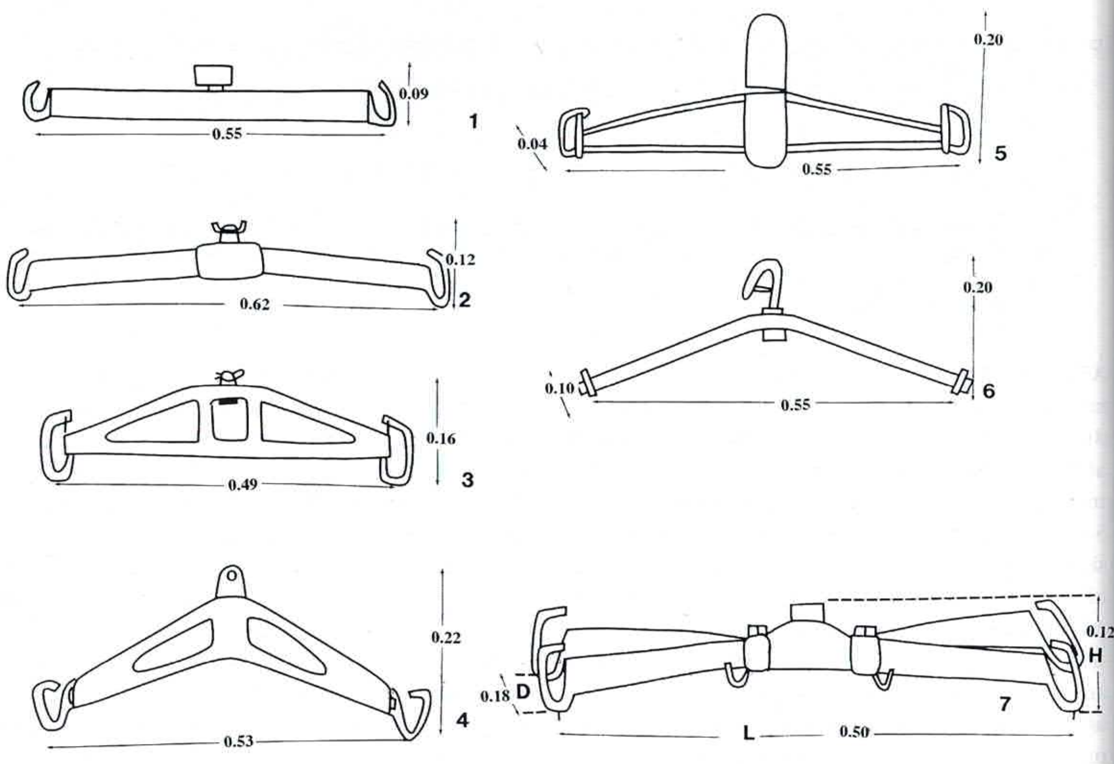

Fig. 1. Spreader bars available on the Swedish market in Oct. 1994. Left: spreader bars with two suspension points. Right: spreader bars with four or six suspension points (m). Abbreviations: Length (L) = distance between hooks in horizontal plane (frontal plane); Depth (D) = distance between hooks in sagittal plane: Height (H) = vertical distance between upper part of hooks and spreader bar suspension point.

their slings and spreader bars and to lend samples. Spreader bars or slings for lifting supine patients were not included.

Six spreader bars were available on the Swedish market in October 1994 (Fig. 1). They were grouped into those with two sling suspension points (Fig. 1: 1–4) and those with four or six points (Fig. 1: 5–6). The frontal length varied between 0.49 m and 0.62 m (median 0.55 m). The height varied between 0.095 m and 0.225 m (median 0.16 m). Two spreader bars had more than two suspension points (nos. 5 and 6) and here the sagittal distance between the hooks was 0.04 m and 0.10 m, respectively. No instructions for use were provided for the slings or spreader bars.

A special spreader bar was constructed for the present study (Fig 1: 7). It admitted both two-point and four-point suspensions because its outer parts, the "wings", were divided and movable on the horizontal plane. Its frontal length was 0.50 m and the sagittal distance between the suspension hooks on the spread wings was 0.18 m.

The slings were grouped according to Swedish Standard SS 2093 (11): A: divided sling, B: one-piece sling with divided leg supports, and C: one-piece sling without divided leg supports (Fig. 2). One sling from each group was chosen for further investigation. The slings are described in detail by Klint Edlund et al. (6).

All subjects were first tested in three of the spreader bars selected at random. After 6 months, the subjects were tested in the other four spreader bars. Thus every spreader bar was tested with all three slings. This made it possible to check for training effects.

Methods

In a laboratory, the slings were suspended with a hoist unit (model 85, LIC Rehab Care, Stockholm, Sweden) so that the subjects were seated 1 m from the floor. The sitting subject was photographed perpendicular to the sagittal plane at a distance of 3 m. Arms were held inside the sling and hands on the lap except when using the sling which had very little cloth (Fig. 2: A), when, for the sake of safety, the subject held onto the suspending straps (6). The one-piece sling with divided leg supports was photographed both with the leg supports crossed under the thighs and crossed between the thighs (Fig. 3).

Biomechanical analyses

The sagittal plane photographs served as a basis for the calculations. The image length of the supporting areas of the sling was measured and converted into real length (mm) (6). The shortest sagittal length of the non-supporting area was measured from the photographs.

The angle of inclination of the trunk and the angle between the thighs and the horizontal plane were chosen as biomechanical measurements considered relevant to the tendency to fall

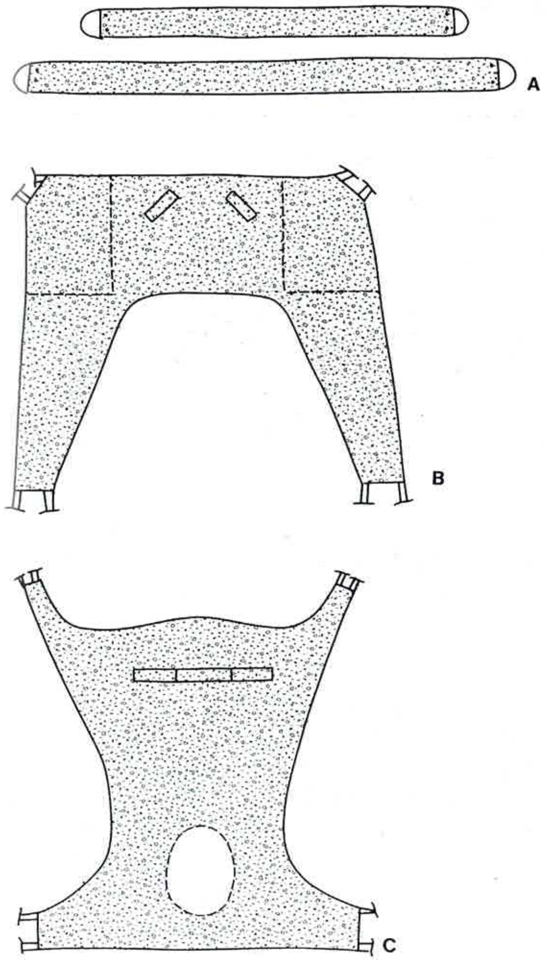

Fig. 2. (a) Divided sling. *(b).* One-piece sling with divided leg supports. *(c).* One-piece sling.

forward out of the slings. Thus in the figure, the bilateral movement axes of the shoulder and hip joints were connected with a line, as were the movement axes of the hip and knee joints. A vertical line and a horizontal line, respectively, were drawn through the hip joint. The three angles α, β and γ were defined (6) as:

angle α = slope of thigh relative to horizontal plane.
Positive angle: upward-inclined thigh, angle between trunk and thighs $< 90°$
angle β = backward inclination of trunk relative to vertical plane
angle γ = hip angle (angle between trunk and thighs, i.e. $90° - \alpha + \beta$).

Statistics

The ANOVA model (1) with two dependent factors (spreader bars and slings) was used to test for differences in the risk of falling through, i.e. the sagittal length of the non-supporting

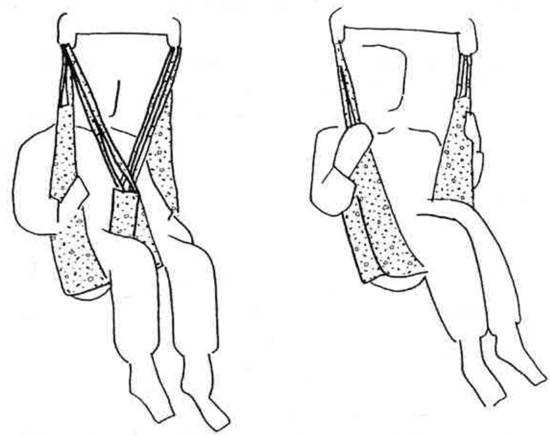

Fig. 3. One-piece sling with divided leg supports *(a)* crossed between and *(b)* crossed under thighs.

parts, the sagittal length of the sling supporting parts, and the sitting position, respectively, between the different spreader bars.

Low p values (α-level = 0.05) were chosen as significant, and gave evidence against our null hypothesis, i.e. that there are differences between spreader bars in this respect.

RESULTS

As in an earlier study (6), regardless of which spreader bar was used, the divided sling A had the largest opening (Table I, Fig. 4). The opening was smallest in sling B when the leg supports were crossed under the thighs (Table I, Fig. 4). The largest supporting sagittal length was in the one-piece sling C (Table I, Fig. 5). During the lift, all the slings entailed a backward-inclined trunk and forward–upward-inclined thigh support (Table II, Fig. 6).

The three slings (A, B and C) interacted (Table III) with the spreader bars to give significant effects on all specific aspects of sitting. However, spreader bar type only affected sitting angles. Observing this interaction, we discovered that the effect of the spreader bar depends on which sling is used with it. Therefore, the comparison between slings alone and spreader bars alone was no longer of interest.

Non-supporting length of sling

In Fig. 4 the non-supporting lengths of the different slings in different spreader bars are shown. Apart from sling C, which has no hole, spreader bar 3 (the shortest, Fig. 1: 3) used with sling B, with the leg supports crossed under the thighs, gave the smallest non-supporting length (mean

Table I. *Survey of mean (sd) non-supporting length (mm) and supporting area (mm) in slings A, B and C used with spreader bars 1–7*

	non-supporting length			supporting area		
	sling			sling		
SPREADER BAR	A	B between	B under	B between	B under	C
1	299.6 (12.2)	123.3 (22.3)	119.2 (19.9)	402.1 (34.1)	392.1 (22.2)	527.9 (33.0)
2	292.6 (19.6)	110.4 (22.2)	115.8 (17.9)	375.8 (46.9)	405.4 (50.5)	555.0 (36.8)
3	303.8 (33.2)	112.5 (22.7)	87.5 (22.4)	369.2 (53.1)	424.2 (65.9)	542.1 (45.6)
4	301.7 (25.1)	110.8 (29.9)	105.0 (14.7)	367.5 (54.8)	396.7 (51.0)	526.7 (45.6)
5	310.0 (29.7)	117.1 (17.8)	109.2 (20.6)	370.0 (54.6)	380.4 (52.7)	527.1 (37.8)
6	312.9 (21.3)	119.2 (14.6)	104.6 (13.5)	378.8 (16.8)	401.3 (44.3)	531.3 (33.2)
7	296.7 (8.2)	104.6 (23.7)	107.5 (26.8)	428.8 (20.8)	401.3 (52.2)	543.8 (38.7)

NOTE: In the one-piece sling C without a hole, the non-supporting sitting length was 0 mm. In the divided sling A, the supporting area was 150 mm regardless of spreader bar.

87.5 mm, Table I) which was significantly different from the lengths generated by spreader bars 1 and 2.

Supporting length of sling

Spreader bar no. 7 (the deepest, Fig. 1: 7) gave most support when used with sling B, when the leg supports were crossed between the thighs (Fig. 5) and a significant difference from the effects of spreader bars 2 to 6. The supporting length was smallest when spreader bars 1 and 7 were used with sling B, with the leg supports crossed under the thighs, and the opposite was true for the other spreader bars.

Sitting position

All spreader bars gave forward–upward-inclined thigh support (average $\alpha = 29.5°$, range $-7°$ to $62°$).

Spreader bar 4 (the highest, Fig. 1: 4) gave the most forward–upward-inclined thigh support (mean 43.2°, Table II) with sling A (divided sling), a significant difference from spreader bars 5 and 6. For the same sling,

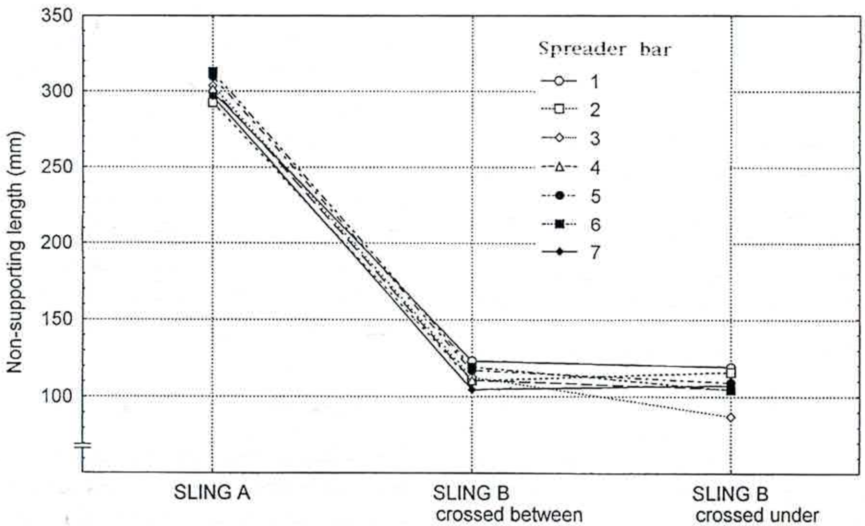

Fig. 4. Average non-supporting length (mm) in sling A and sling B crossed between and under the thighs in spreader bars 1–7.

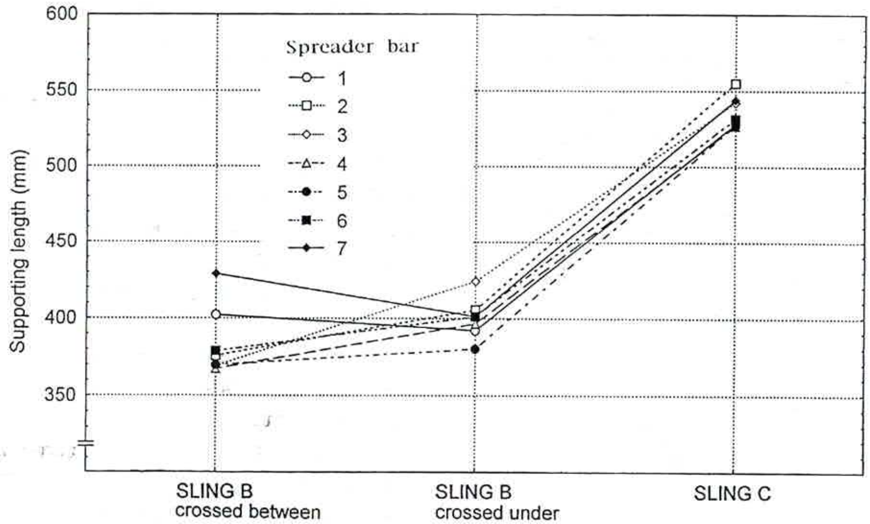

Fig. 5. Average sagittal length of supporting area (mm) in sling B (crossed between and under the thighs) and sling C in spreader bars 1–7.

spreader bar 7 also gave a large α angle, significantly different from spreader bar 5, which also gave the smallest forward–upward-inclined thigh support in sling B with the leg supports crossed between the thighs. Spreader bar 2 (the longest) gave a large α angle (mean 36.7°) in sling B with leg supports crossed under the thighs, significantly different from spreader bar 6. Spreader bar 3 (the shortest) gave a small α angle (mean 23.9°) used with sling C (Fig. 6 and Table II), which again was significantly different from spreader bars 1, 2, 6, and 7. Spreader bar 3 also gave a smaller α angle in use with sling C, in contrast to sling B with leg supports crossed under the thighs.

When the subject sat in the lift, all spreader bars caused the trunk to incline backwards (average $\beta = 27.3°$, range 7° to 46°). Spreader bars 1, 6 and 7 gave a large backward-inclined trunk position in use with sling C (the one-piece). Spreader bar 3 gave the smallest β angle in the same sling, differing significantly from spreader bars 1, 2 and 5–7. In sling B with leg supports crossed under the thighs, spreader bar 7 (the deepest) gave a large β angle (mean 35.0°), significantly different from 1, 2, 4, 5 and 6. Spreader bar 7 also gave a large β angle in use with sling B with leg supports crossed between the thighs, a significant difference from the effect of spreader bar 1. Spreader bars 1, 2 and 3 caused a small backward-inclined trunk position with sling A (divided sling, Fig. 6 and Table II) which was significantly different from 4, 6 and 7.

Angle γ depended on angles α and β (average $\gamma = 91.6°$) and varied from 52° (spreader bar 2, regardless of sling) to 113° (spreader bar 1 with sling B, leg supports crossed between the thighs). Used with sling C, spreader bar 7 gave the largest angle, significantly larger than that induced by spreader bars 1–5 (Fig. 6). In the same sling, spreader bar 2 gave the smallest γ angle, which was significantly different from 3, 6 and 7. Spreader bar 2 also gave a small γ angle in combination with sling B, leg supports crossed under the thighs (Fig. 6), significantly different from 1, 3, 4, 6 and 7. Spreader bars 1 and 2 gave a small hip angle in use with sling A, significantly different from 5 and 6. In use with sling B with leg support crossed between the thighs, there was no significant value regardless of spreader bar.

DISCUSSION

We wished to analyse the basic variables of spreader bars and their effects on the sitting position in three different slings. In an earlier study Klint Edlund et al. (6) established the significance of sling choice for lift and transfer, where the risk of slipping out varied from very large to non-existent. The sitting position during lifting varied from erect to supine, and this in turn affected the experience of discomfort during the lift.

To compare different spreader bars, twelve persons of different height, weight and sex were lifted. The subjects were free from physical impairment. The relationship between the angles of the sitting position was observed in relation to bodily constitution. However, when lifting

Table II. *Survey of mean (sd) sitting position (°) in slings A, B and C used with spreader bars 1–7*

SPREADER BAR	sitting position											
	sling											
	A			B between			B under			C		
	α	β	γ	α	β	γ	α	β	γ	α	β	γ
1	34.8 (3.9)	19.0 (3.0)	74.6 (6.4)	20.2 (10.3)	21.9 (2.9)	97.9 (9.4)	23.3 (4.8)	27.3 (3.6)	95.4 (4.4)	37.3 (9.1)	36.1 (3.4)	85.7 (8.3)
2	39.3 (11.0)	22.0 (3.8)	75.1 (11.5)	19.1 (4.0)	24.7 (4.6)	96.4 (5.2)	36.7 (11.2)	26.9 (3.9)	81.6 (10.9)	39.1 (10.1)	25.8 (5.4)	76.6 (9.1)
3	38.3 (8.2)	23.6 (2.7)	76.7 (9.5)	23.3 (3.2)	23.7 (7.2)	92.3 (9.0)	32.1 (9.6)	32.9 (5.7)	92.8 (9.0)	23.9 (3.8)	19.7 (4.7)	85.8 (5.3)
4	43.2 (8.3)	29.7 (5.7)	83.3 (11.6)	19.2 (9.2)	26.8 (5.6)	97.1 (9.6)	27.1 (10.1)	26.8 (5.7)	89.8 (7.9)	31.7 (5.0)	24.3 (4.5)	83.8 (5.0)
5	30.9 (8.9)	26.8 (3.8)	85.8 (5.9)	14.8 (4.9)	24.5 (5.2)	99.3 (4.2)	28.3 (7.0)	28.1 (4.4)	89.6 (6.9)	31.3 (5.6)	26.6 (8.4)	84.5 (3.9)
6	33.4 (8.9)	29.7 (4.3)	85.5 (3.1)	15.3 (4.8)	27.7 (2.7)	100.3 (3.7)	19.1 (4.5)	26.4 (4.3)	97.3 (2.7)	33.3 (4.6)	35.2 (5.2)	90.2 (4.7)
7	42.8 (3.5)	28.8 (2.9)	80.4 (7.6)	19.5 (4.8)	28.8 (4.7)	95.8 (6.2)	29.6 (3.3)	35.0 (5.7)	93.9 (6.1)	34.3 (7.3)	40.4 (4.0)	94.0 (7.2)

persons with impairments, the sitting position might be altered due to various pareses and/or amputation.

Few authors (2, 6, 7) have studied sitting position in connection to lift and transfer, perhaps because the actual transfer is so brief that a good lifting/sitting position has not been considered important. Users, however, declare that they feel insecure, are afraid of slipping out and think that slings pinch and pull them. Some, therefore, do not accept being lifted in slings, making lift and transfer difficult and unnecessarily uncomfortable for all involved.

Although there are many spreader bars on the Swedish market to cover most situations, the variation nevertheless appears to be small. The spreader bar in Sweden is considered a part of the hoist, not a part of the sling. The hoist is chosen based on where to lift, while the sling is chosen based on who is being lifted, and how easy it is to handle the sling. Until now, the function of the spreader bar has been neglected.

The study indicated that a short spreader bar lessens the risk of falling through and offers more supporting area. The supporting area is significant for the feeling of safety in the sling. A small sling may seem unsafe, while the one-piece sling seems to give all-round support. The earlier study (6) demonstrates that the one-piece sling with divided leg supports (B) gives a supporting area greater than that of the one-piece sling in combination with all spreader bars except no. 7. On the other hand, a larger sling may make handling unnecessarily difficult and may prevent the patient from seeing what is going on during the transfer.

The sitting position greatly affects how the patient experiences the transfer and its result. A lift usually involves a change in position from lying to sitting or from sitting to sitting (10), for example from bed to wheelchair or from wheelchair to toilet seat. The thigh inclination (α, Table II, Fig. 6) should be at least 7° forwards–upwards from the horizontal plane (e.g. trunk-thigh angle $> 83°$) (3) so that the person will not slip out. The backrest backward inclination (β, Table II, Fig. 6) ought to be 20° to 25° (3) to give a slight backward inclination in the sitting/lifting position, allowing the user to be active. This inclination gives a hip flexion angle of 103°–108°. In the present study, only spreader bar no. 6 gave a mean hip flexion angle less than 100° in one of the slings. For people with stiff and/or painful hip joints, an impaired hip flexion angle can severely limit the choice of a suitable sling. With a large flexion angle (i.e. α more than 30°) in combination with a large opening, as in almost all the spreader bars used with the divided sling A, the risk of

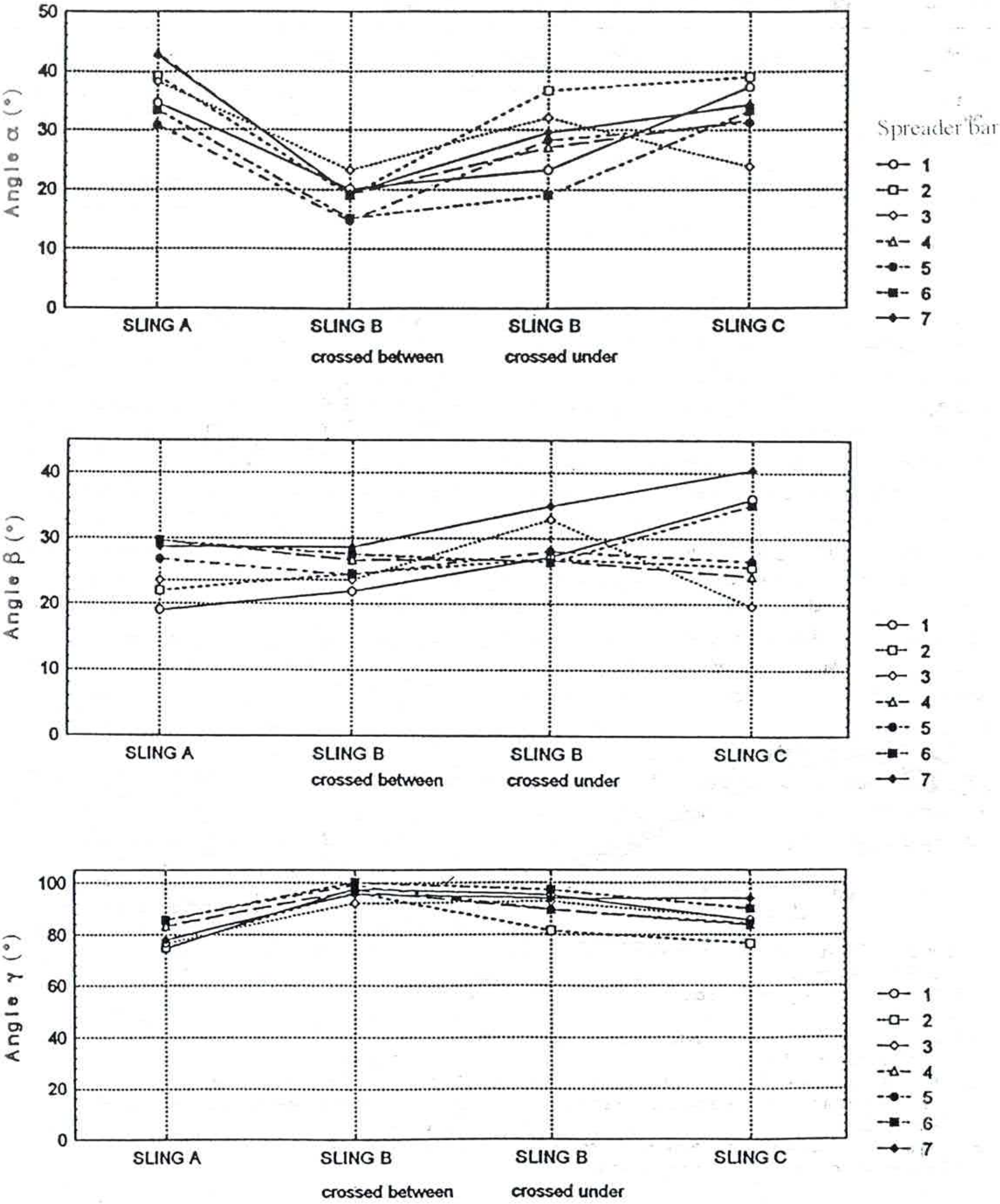

Fig. 6. Average sitting position (in °) in angle α, angle β and angle γ in sling A, sling B crossed between and under the thighs, and sling C in spreader bars 1–7.

"jack-knifing" is large. If sling B was used, the risk of falling through would increase. However, a large opening is indeed preferable for toilet visits, to facilitate undressing and dressing, sitting on the toilet without taking off the sling, and still being able to wash and dry afterwards.

Too much backward trunk inclination often means that the backrest must be lengthened with a neck and headrest,

Table III. *Analysis of variance (ANOVA) with two dependent variables*

Variable	Non-supporting length	supporting length	α–angle	β–angle	γ–angle
Sling	< 0.001***	< 0.001***	< 0.001***	< 0.001***	< 0.001***
Spreader bar	$p = 0.33$	$p = 0.29$	< 0.001***	< 0.001***	< 0.001***
Interaction between spreader bars and slings	< 0.002**	< 0.001***	< 0.001***	< 0.001***	< 0.001***

$* = p < 0.05$, $** = p < 0.01$, $*** = p < 0.001$.

since otherwise muscular control of the neck is required to keep the head upright during the lift. Too much back inclination is also problematic during sitting-to-sitting lifts, e.g. to a wheelchair, because it is difficult to end up sufficiently far back in the chair. The consequence is that the person lands on the chair edge and therefore easily slips out unless a manual adjustment is made. A small backrest inclination, on the other hand, requires good upper body control to prevent a fall forward. Most of the spreader bars in this study gave a relatively upright sitting position and hence should be combined with slings with many suspension points in the backrest to give an optimal back inclination. Most slings on the Swedish market (6), however, only have one or two backrest suspension points.

In summary, the study shows the importance of the user's awareness of the differences between spreader bars combined with the one-piece sling and combined with the one-piece sling with divided leg supports.

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Accepted September 23, 1997

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