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BODY WEIGHT-BEARING WHILE RISING AND SITTING DOWN IN PATIENTS WITH STROKE

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ABSTRACT. Distribution of body weight on the two legs while rising and sitting down was examined in 42 subacute stroke patients and 16 healthy adults during both spontaneous movement and following instruction directed at even weight distribution. Vertical floor reaction forces were measured by two force plates. There was a difference between patients and controls in the tested motor tasks—the patients favoured their non-paretic leg. However, body weight distribution was less asymmetric when patients tried to rise and sit down evenly compared to spontaneous rising/sitting down ($p<0.001$). Patients' own estimation of distribution of body weight documented on a visual analogue scale, correlated with actual body weight distribution while rising ($r_s=0.36$) but not while sitting down. To motivate stroke patients to pay attention to their ability to distribute body weight evenly while rising and sitting down and to create and use adequate self-reports seems a necessary commitment in a rehabilitation programme in order to avoid the learned nonuse syndrome.

Key words: Stroke, body weight-bearing, asymmetry, vertical floor reaction force, rising, sitting down, self-report, visual analogue scale.

To be able to rise from a seated position and to sit down again is a prerequisite for self-reliant locomotion and for many activities of daily living. Clinical experience would suggest that body weight is distributed evenly on both lower extremities in healthy subjects but unevenly in patients with stroke during rising and sitting down (2, 6). The function test Motor Assessment Scale for Stroke (8) demands even body weight-bearing to score full recovery in rising from sitting. During recovery from stroke when the patient becomes able to stand up and to sit down from standing, body weight-bearing on the paretic leg is spontaneously avoided. If neglected, this pattern might become a habit and the patient will develop the learned nonuse syndrome (23). Several studies on normal rising, involving kinematics (16, 19, 21, 22), kinetics (9, 15, 21) and muscle activity (12, 14, 20) have been performed. Few (1, 3, 5, 24) have been directed towards activity patterns relating to rising and sitting down in stroke patients.

The purposes of this study were to (*a*) determine the movement time and body weight-bearing under each foot in stroke patients in the acute phase of recovery during rising and sitting down habitually as well as after instruction directed at even body weight distribution on the two legs and (*b*) to evaluate the patients' own estimation of body weight distribution on the two legs.

SUBJECTS AND METHODS

The criteria for the selection of patients were (1) a hemiparesis secondary to a cerebrovascular disorder (infarction or haemorrhage) in either hemisphere, (2) in the acute phase of recovery (i.e., within a time period of one week and three months after the incidence), (3) that they could understand and follow instructions and (4) could stand up and sit down independently. Patients with normal motor function in the lower extremities or who showed ataxia when standing up were excluded. The group included 42 stroke patients, 26 men and 16 women. They were all in-patients from rehabilitation departments in Stockholm. Table I shows the medical characteristics of the stroke patients.

For comparison 16 age-matched healthy adults with no symptoms from the lower extremities volunteered to participate in the study. Table II summarises the characteristics of the patients and the control group.

Two vertical strain-gauge force transducers attached to two force measuring platforms were used (17) for examination of the vertical floor reaction forces, one under each foot. The recordings from the force transducers were analysed by a specially designed computer program, called KI-Raise. The time integral of vertical force under each foot was measured. These impulses were shown graphically as areas in a force–time curve, as in Fig. 1 or numerically as the product of mean vertical force and time (Ns).

The two variables thus measured by KI-Raise were: the movement time and the impulses of each foot during rising and sitting down, respectively. Body weight distribution was computed as the weight load ratio of the paretic and non-

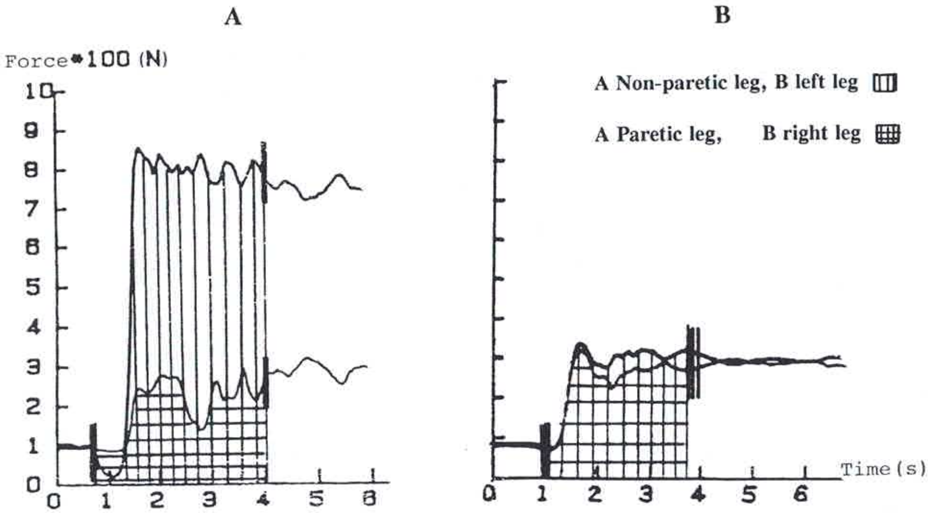

Fig. 1. The impulses under the force–time curve of each leg of a stroke patient (A) and of a normal subject (B).

paretic leg for the stroke patients and of the right and left leg for the control group. Start and end of the movement for rising and sitting down was assessed visually by the examiner. The standing up movement began when the subject's head started to move anteriorly and ended when no further forward displacement of the pelvis occurred. The sitting down movement began, when the head started to move anteriorly and ended, when the back reached the back support of the chair. The start and end of the movements were indicated by the examiner, standing by the side of the patient, pressing a button connected to the computer and registered as vertical bars on the force–time curve (Fig. 1).

Tests started with the patients sitting in a standardised position on an adjustable armless chair with a back support. The seat height was set to 100% of the subject's knee height, determined as the distance from the lateral knee joint line to the floor, when the tibia was perpendicular to the floor. The trunk was in an upright position so that the line between the acromion and the upper part of mid-iliac crest was kept vertical. The thighs were supported for 3/4 of the femoral length and positioned so that the line between the greater trochanter and the lateral femoral condyle was kept horizontal. The arms hung by the side or rested in the lap. The subjects placed one foot on each force platform directly above the vertical force transducer. The feet were parallel and 10–18 cm apart. Knee angles were 100–105 degrees with the knees pointing straight ahead. Heel heights ranged from 1–4 cm. The subjects looked straight forward and were requested to maintain a stable body position. Two different standardised instructions were given: "Please, stand up as you usually do", and after one minute of standing, "Please, sit down as you usually do". No other comments were made to control the transfers, which were referred to as "habitual". The second standardised instruction was: "Please stand up with your body weight distributed evenly on both feet". These transfers were referred to as "even". The subjects were allowed a few

Table I. *Medical characteristics of the stroke patients (n=42)*

Cerebral haemorrhage	6
Cerebral infarction	34
Unspecified	2
Involved side, left/right	21/21
Hemianopia, left/right	3/3
Sensory function	
Normal	22
Light touch and proprioceptive deficit	11
Light touch deficit	1
Proprioceptive deficit	2
Light touch and proprioceptive loss	4
Light touch loss and proprioceptive deficit	2

Table II. *Characteristics of the patients (n=42) and the controls (n=16)*

	Patients		Controls	
	X	SD	X	SD
No. of men/women	26/16		6/10	
70 years of age or older	10		4	
Mean age	64.4	±7.9	58.7	±11.1
Mean weight	71.5	±11.4	69.3	±13.6
Mean height	170.4	±9.2	172	±9.
Limb dominance right/left	42/0		15/1	
Mean days since stroke onset	38	±22		

Table III. *Difference in milliseconds between the examiner's judgement of start and end of the movements and the recordings from the motion analysis system (E.L.I.T.E.)*

Positive numbers indicate delayed and negative too early judgements

	Start			End		
	Mean	SD	Range	Mean	SD	Range
Standing up	87.2	±60.5	0–188.2	−147.8	±102.3	−373.3–0
Sitting down	27.3	±43.0	0–129.6	−97.8	±76.3	−234.4–0

pretest trials in order to become accustomed to the testing procedure. A mean of three trials for rising and sitting down was presented.

The reproducibility of the tests of vertical floor reaction forces during rising and sitting down "habitually" were analysed in 16 healthy volunteers. They performed the rising and sitting down transfer on five different occasions: in the morning, after 10 min, in the afternoon, after 1 week and after 2 months. The coefficient of variation, as computed from the results of the five different tests, was 6.8% for rising and 8.5% for sitting down. The reliability of the examiner's accuracy on the judgement of start and end of rising and sitting down was evaluated against a motion analysis system (E.L.I.T.E.—Elaboratory Illuminatore Televisione, BTS, Bioengineering Technology & Systems, Via Capecelatro, 66-20148 Milano, Italy). Reflective markers were attached to the head and the pelvis of the subjects and to the remote switch held by the examiner. Recordings of linear displacements antero-posteriorly were done and compared with recordings from the examiner's switch during 15 transfers of rising and sitting down in one patient and in one healthy volunteer (Table III). The time difference between the displacements of the head and pelvis respectively, and the switch was within the range of 0–188 ms *after* the start of the patients' rising and sitting down, and within the range of 0–373 ms *before* the end of the patients' rising and sitting down. These systematic differences, when connecting and disconnecting the measurement of time, were considered negligible as the movement time for the stroke patients was within the range of 2.3–6.9 s (mean 3.7) in rising and 2.3–6.2 s (mean 4.0) in sitting down.

Patients' own estimations

Two continuous visual analogue scales (VAS) (11), were used for evaluations of the patients' perception of evenness of body weight distribution during rising and during sitting down "habitually". The scales were horizontal, 100 mm long, titled "I get up to standing/sit down with even body weight distribution on the two feet", respectively, anchored by the words "No, not at all"—"Yes, no problem", where 100 mm represent even body weight-bearing on the two legs.

Statistical methods

Statistical analysis was based on Student's paired and unpaired *t*-test, where the level for significance chosen was 1%. Correlations were performed using Spearman's Rank correlation coefficient where the level for significance chosen was 5%.

The study was approved by the Karolinska Hospital Ethics Committee.

RESULTS

Time needed to rise

When the subjects were instructed to rise "habitually" the mean time needed was 3.7 s in the patients and 2.3 s in the control group ($p<0.001$). When the subjects were instructed to rise "evenly" the mean time needed was 3.8 s and 2.9 s, respectively ($p<0.001$), as shown in Fig. 2. When rising after two different instructions, "habitually" and "evenly", the difference in movement time was significant only in the control group ($p<0.01$), i.e., the control group needed a longer time when performing "evenly", as shown in Fig. 3.

Time needed to sit down

When the subjects were instructed to sit down "habitually" the mean time needed was 4.0 s in the patients and 2.5 s in the control group ($p<0.001$). When the subjects were instructed to sit down "evenly" the mean time needed was 4.0 s and 3.0 s, respectively ($p<0.001$), as shown in fig. 2. When sitting down after two different instructions, "habitually" and "evenly" the difference in movement time was significant only in the control group ($p<0.01$), i.e., the control group needed a longer time when performing "evenly", as shown in Fig. 3.

Body weight distribution in rising

The body weight distribution ratio after instruction to rise "habitually" was 0.60 in the patients and 0.99 in the control group ($p<0.001$), equivalent to 37.5% body weight born on the paretic leg and 49.7% body weight born on the right leg. When the subjects were instructed to rise "evenly" the ratio was 0.80 (44.4% body weight) and 0.97 (49.2% body weight), respectively ($p<0.001$), as shown in Fig. 4. When rising

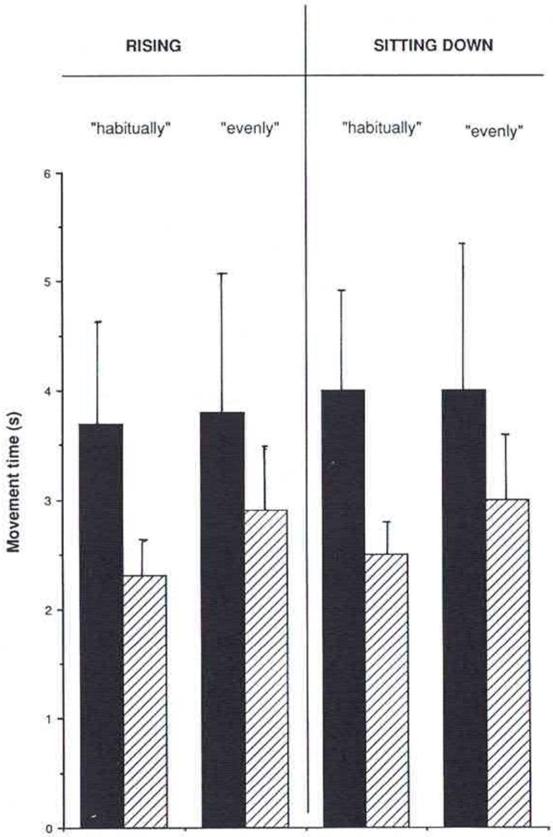

Fig. 2. Movement time while rising ($p<0.001$) and sitting down ($p<0.001$) "habitually" and "evenly" in stroke patients ($n=42$) and a control group ($n=16$). Mean and SD are given. ■, patients; ▨, controls.

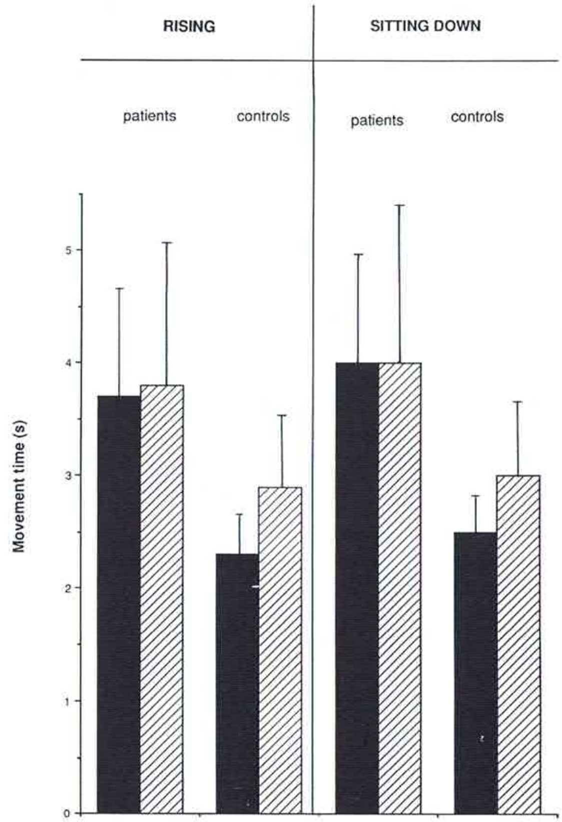

Fig. 3. Movement time while rising and sitting down after two different instructions in stroke patients ($n=42$), (n.s.) and in a control group ($n=16$), ($p<0.01$). Mean and SD are given. ■, habitually; ▨, evenly.

after two different instructions, "habitually" and "evenly", the difference in body weight distribution was significant only in the patients ($p<0.001$), i.e., the body weight distribution was less asymmetric rising "evenly", as shown in Fig. 5.

Body weight distribution in sitting down

The body weight distribution ratio after instruction to sit down "habitually" was 0.61 (37.9% body weight) in the patients and 1.02 (50.5% body weight) in the control group ($p<0.001$). When the subjects were in-

Table IV. *Correlations between degree of paresis/sensory function and movement time/body weight distribution during standing up and sitting down, habitually and evenly*

	Time Habitually		Weight ratio Habitually		Time Evenly		Weight ratio Evenly	
	up	down	up	down	up	down	up	down
Motor function		−0.33	0.38					
Sensory function							0.46	

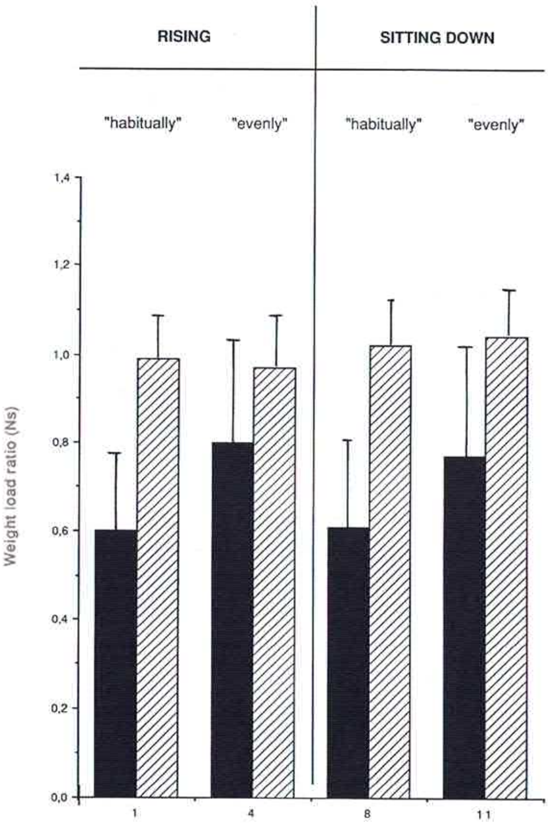

Fig. 4. Weight load ratio while rising ($p<0.001$) and sitting down ($p<0.001$) "habitually" and "evenly" in stroke patients ($n=42$) and a control group ($n=16$). Mean and SD are given. ■, patients; ▨, controls.

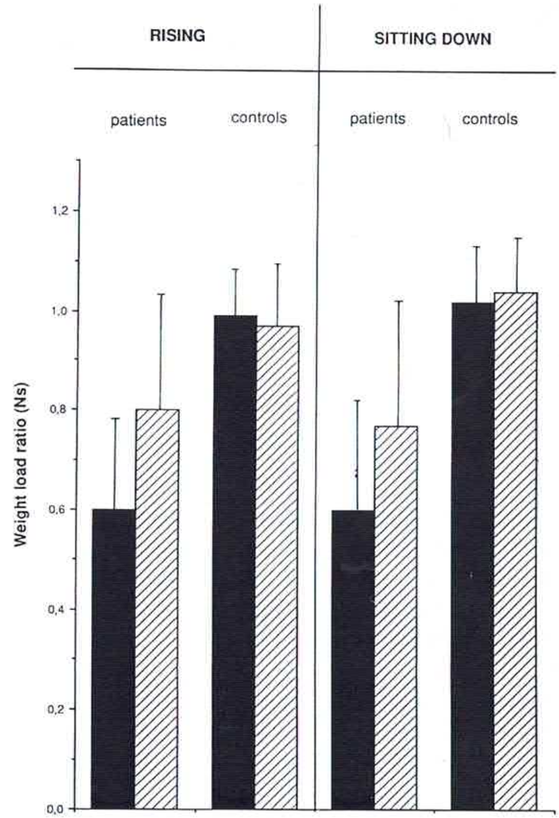

Fig. 5. Weight load ratio while rising and sitting down after two different instructions in stroke patients ($n=42$), ($p<0.001$) and in a control group ($n=16$), (n.s.). Mean and SD are given. ■, habitually; ▨, evenly.

structed to sit down "evenly" the ratio was 0.77 (43.5% body weight) and 1.04 (51% body weight), respectively ($p<0.001$), as shown in Fig. 4. When sitting down after two different instructions, "habitually" and "evenly", the difference in body weight distribution was significant only in the patients ($p<0.001$), i.e., the body weight distribution was less asymmetric sitting down evenly, as shown in Fig. 5. Correlations performed to assess the influence of the patients' degree of paresis and sensory function (10) on movement time and body weight distribution on the two legs are shown in Table IV.

Patients' own estimations

The subjective estimations of even body weight-bearing documented on the visual analogue scale averaged 47 mm (SD 28.8) for rising, and 55 mm (SD 27.5) for sitting down. The frequency distribution of the different estimations is seen in Fig. 6. There was a correlation ($r_s=0.36$) between the patients' estimation of evenness in body weight distribution and actual weight load ratio during rising, but none in sitting down, as shown in Table V.

DISCUSSION

Time to rise and to sit down

There was a difference in the time needed to rise and to sit down between the patients and the control

Table V. *Correlations (r_s) between the patients' estimation of body weight distribution on the two legs and actual body weight load ratio*

Standing up	0.36	$p=0.022$
Sitting down	0.17	$p=0.291$

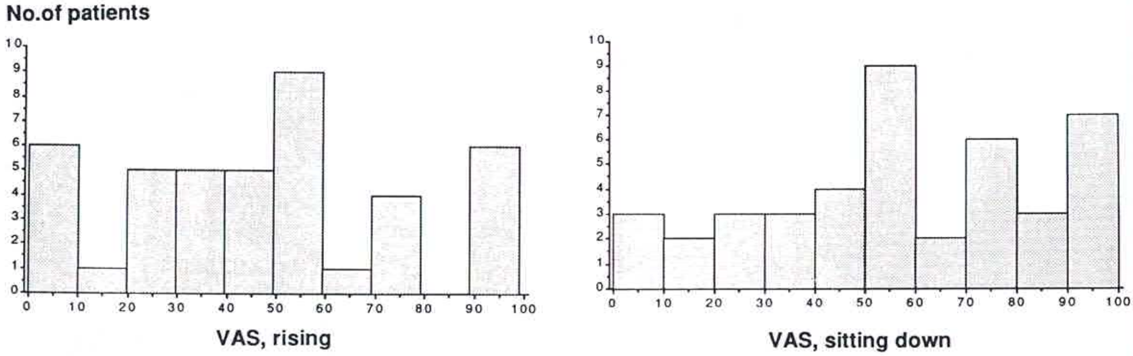

Fig. 6. Frequency of patients' subjective estimation of evenness in body weight-bearing while rising and sitting down, documented on a visual analogue scale (VAS). (0 = no weight-bearing on the paretic leg, 100 = even body weight distribution on both legs).

group. The patients needed a longer time. This agrees with Yoshida et al. (24), who studied 20 healthy adults, 20 elderly persons and 10 hemiparetic patients. They explained this through the patients lack of vigor and that the patients required a longer time to stabilise sway about the centre of force when rising. They also found that healthy elderly subjects needed more time than younger individuals to stabilize the antero-posterior sway during rising. This could explain why the mean time (2.3 s) of rising for the control group in our study differs from Nuzik et al. (16). They studied 55 healthy adults (mean age 26.4) and found that the average movement time for rising was 1.8 s (range 1.3–2.5 s). Pai & Rogers (18) have studied sit-to-stand transfer at self-selected fast and natural speeds in eight healthy subjects (30–38 years). The maximum oscillation in antero-posterior direction when coming up to standing, was significantly greater ($p<0.01$) at fast speeds than at natural speeds, suggesting greater instability for the faster movement in sit-to-stand transfer. This may explain the decreased velocity seen in our patients during rising. The patients, having just learnt how to rise, were not ready to expose themselves to speedy adjustments when coming up from a three point support to a two point support. They were not yet sufficiently stable to counteract antero-posterior body sway for balance control. There was no difference in time required for the patient group between rising and sitting down "habitually" and "evenly". In contrast there was a difference within the control group. This may add to the knowledge that rising is a movement under the control of an acquired automatised central program. The patients had not yet acquired an automatic engram and the control group, when trying to concentrate on rising up and sitting down with even weight distribution on the legs, were deprived of theirs.

Weight distribution in rising and sitting down

In the patient group the load on the paretic leg was 37.5% body weight, when the patients rose habitually. In contrast, when the patients rose following instructions to bear body weight evenly, the weight load on the paretic leg was 44.4% body weight. When sitting down the weight load was 37.9 and 43.5% body weight, respectively. Yoshida et al. (24) found in their study that the centre of force was deviated primarily to the non-paretic leg in their stroke patients. Our study further emphasises this "lack of vigor" when rising, as correlations revealed that the degree of paresis correlated with weight load ratio in rising habitually. No other correlations were seen when rising or sitting down habitually.

However, patients with intact sensibility are likely to perform better, in this case move faster and with less asymmetric body weight bearing than those with sensory deficits. Thus our stroke patients' degree of sensory function did not influence the distribution of body weight neither in rising nor in sitting down habitually. These findings were surprising but are in accordance with Kelso et al. (13), who suggested that joint afferent information was not crucial for the control of movement. On the other hand when performing evenly there was a correlation between sensory function and weight load ratio in rising, i.e., the patients with intact sensibility performed better.

After a stroke the automatic program for rising seems to become asymmetric for obvious reasons, i.e. paralysis, paresis, loss of postural control. Patients can rise or sit down using the one leg, they can rely upon. To be able to rise, no matter how it is achieved, "is good enough" for the patient. This study though showed, in accordance with clinical experience, that stroke patients, when reminded, are able to put more weight on the paretic leg than they habitually do. If there is a continuous neglect to put weight on the paretic leg, learned nonuse (23) may be reinforced. Even if the patients, when rising habitually, in average put 37% of the body weight on the paretic leg, which is 74% of what is expected in normal subjects, habituation of the uneven body weight distribution might result in different secondary impairments. Shortened muscle length and joint capsule tissue, increased muscle tonus, poor balance on one leg, loss of muscle activity, lack of stimulation from tactile and proprioceptive stimuli might disable the patients in locomotion and in activities of daily living. To motivate the patients to pay attention to their ability to distribute body weight evenly when rising and sitting down thus seems a necessary commitment in a stroke rehabilitation programme.

Patients' estimations

The visual analogue scale (VAS) has been recommended as a reliable assessment of pain intensity (4, 11). To our knowledge there is no study using the VAS for self-estimation of parameters other than that of pain. In this study the VAS was used to document the patients' own opinion of body weight distribution on the two legs during rising and sitting down. There was a correlation, albeit low, between the patients' own estimations of evenness of body weight distribution and actual body weight load ratio during rising but none during sitting down. This may indicate either that the patients were not properly instructed to use the scale, that the visual analogue scale might be too crude and too abstract to be adequate or that the patients were poorly aware of their body weight distribution, when rising and not at all when sitting down. Stroke patients, especially those with visual deficits may have physiological as well as spatial restraints to accurately document on a vertical or on a horizontal scale any kind of self-estimation. However, bearing in mind the importance of self-report in motor relearning (7), it is suggested that the use of a visual analogue scale, carefully elaborated, or other types of reliable self-estimations might be appropriate in stroke patients in order to facilitate motivation and active participation in a rehabilitation programme, enhancing motor relearning.

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REFERENCES

1. Ada, L. & Westwood, P.: A kinematic analysis on recovery of the ability to stand up from a chair following stroke. Proc X Int Congr WCPT, pp. 925–929. Sidney, Australia, 1987.
2. Bobath, B.: Adult hemiplegia: Evaluation and Treatment, pp. 105–106. Heinemann Medical Books, London, 1978.
3. Canning, C.: Training standing up following stroke. Proc X Int Congr WCPT, pp. 915–919. Sidney, Australia, 1987.
4. Carlsson, A. M.: Assessment of chronic pain. Aspects of the reliability and validity of the visual analogue scale. Pain *16*:87–101, 1983.
5. Carr, J. H.: Analysis and training of standing up. Proc X Int Congr WCPT, pp. 383–388. Sidney, Australia, 1987.
6. Carr, J. H. & Shepherd, R. B.: A motor relearning programme for stroke. 2nd ed. Aspen Systems, pp. 100–111. Rockville, Maryland, 1987.
7. Carr, J. H. & Shepherd, R. B.: A motor learning model for rehabilitation. *IN* Movement Science, Foundations for Physical Therapy in Rehabilitation (ed. J. H. Carr & R. B. Shepherd), p. 52. Heinemann Physiotherapy, London, 1987.
8. Carr, J. H., Shepherd, R. B., Nordholm, L. & Lynne, D.: Investigation of a new motor assessment scale for stroke patients. Phys Ther *65:* 175–180, 1985.
9. Ellis, M. I., Seedhom, B. B., Amis, A. A., Dowson, D. & Wright, V.: Forces in the knee joint whilst rising from normal and motorized chairs. Engineering Med *8:* 33–40, 1979.
10. Fugl-Meyer, A. R., Jäsköö, L., Leyman, I., Olsson, S. & Steglind, S.: The post-stroke hemiplegic patient. I. A method for evaluation of physical performance. Scand J Rehab Med *7:* 13–31, 1975.
11. Huskisson, E. C.: Measurement of pain. Lancet *11:* 1127–1131, 1974.
12. Kelley, D. L., Dainis, A. & Wood, G. K.: Mechanics and muscular dynamics of rising from a seated position. *In* Biomechanics V-B (ed. P. V. Komi), pp. 127–134. University Park Press, Baltimore, 1976.
13. Kelso, J. A. S., Holt, K. G. & Flatt, A. E.: The role of proprioception in the perception and control of human movement. Percept Psychophysics *28:* 45–52, 1980.
14. Munton, J. S., Ellis, M. I. & Wright, V.: Use of electromyography to study leg muscle activity in patients with arthritis and in normal subjects during rising from a chair. Ann Rheum Dis *43:* 63–65, 1984.
15. Murray, M. P., Seireg, A. & Scholz, R. C.: Center of gravity, center of pressure, and supportive forces during human activities. J Appl Physiol *23:* 831–838, 1967.
16. Nuzik, S., Lamb, R., Van Sant, A. & Hirt, S.: Sit-to-stand movement pattern, a kinematic study. Phys Ther *66:* 1708–1713, 1986.

17. Olsson, E., Öberg, K. & Ribbe, T.: A computerized method for clinical gait analysis of floor reaction forces and joint angular motion. Scand J Rehab Med *18:* 93–99, 1986.
18. Pai, Y.-C. & Rogers, M. W.: Balance control in sit-to-stand transfer. APTA/CPA Joint Annual Conference, Las Vegas, 1988.
19. Pai, Y.-C. & Rogers, M. W.: Control of body mass transfers as a function of speed of ascent in sit to stand. Med Sci Sports Exerc. In press.
20. Richards, C. L.: EMG activity level comparisons in quadriceps and hamstrings in five dynamic activities. *In* Biomechanics IX-A (ed. D. Winter), pp. 313–317. Human Kinetics Publishers, Illinois, 1985.
21. Rodosky, M. W., Andriacchi, T. P. & Andersson, G. B. J.: The influence of chair height on lower limb mechanics during rising. J Orthop Res *7:* 266–271, 1989.
22. Schenkman, M., Berger, R., Riley, P. O., Mann, R. W. & Hodge, W. A.: Whole-body movements during rising to standing from sitting. Phys Ther *70:* 638–648, 1990.
23. Taub, E.: Somatosensory deafferentation research with monkeys: Implications for rehabilitation medicine. *In* Behavioral Psychology in Rehabilitation Medicine: Clinical Implications (ed. L. P. Ince), pp. 371–401. Williams and Wilkins, Baltimore, 1980.
24. Yoshida, K., Iwakura, H. & Inoue, F.: Motion analysis in the movements of standing up from and sitting down on a chair. Scand J Rehab Med *15:* 133–140, 1983.

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