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Sitting position – Posture and performance in C5 – C6 tetraplegia

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Objectives: To investigate how sitting position and seating affect posture and performance (balance, transfers, wheelchair skills, physical strain during wheelchair propulsion, spasticity and respiration) in persons with C5 and C6 tetraplegia.
Setting: Outpatient clinic 'Spinalhälsan', Göteborg, Sweden.
Method: Baseline measurements of sitting position and performance were performed followed by an intervention period. The intervention was individually adapted to each person with emphasis on reduction of kyphotic posture and pelvic obliquity. Furthermore, a functional requirement was that the new sitting position was used in everyday life and did not impair balance, transfers, wheelchair skills, physical strain during wheelchair propulsion, spasticity and respiration.
Results: Four persons with complete C5–C6 tetraplegia who reported dissatisfaction with posture and seating took part in the study. A comparison of photographs before and after the intervention showed a reduction of kyphotic posture and pelvic obliquity. Balance, transfers, wheelchair skills, physical strain during wheelchair propulsion, spasticity and respiration were affected by the sitting position in an individual manner.
Conclusion: Solution of problems concerning sitting and posture for persons with C5–C6 tetraplegia requires good knowledge of the physical impairment, wheelchair adaptation, seating systems and cushions as well as an understanding of the individual's demands and wishes. Due to the complexity of the issue, standard solutions are not applicable. Thus, an analytical working method is required and co-operation between professionals – occupational therapists and physiotherapists – is important.
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Introduction

Among spinal cord injured (SCI) persons, 70% to 80% are dependent on lifetime use of wheelchairs for mobility.[1,2] Thus, the wheelchair is vital for the spinal cord injured person to lead an active, independent and productive life. The design of wheelchairs has changed rapidly during the last decades. A passive device for transportation of a disabled person, being pushed by helpers, has been replaced by lightweight equipment. These wheelchairs are adjustable to the individual and enhance the possibilities of the disabled individual's being independently mobile. The disabled athletes involved in wheelchair sports have been given credit for the revolution in wheelchair design and performance.[3–5] The emphasis in wheelchair design has been on driving properties and wheelchair weight. The effects of wheelchair design and adaptations with the aim of maximising the performance of the individual in sport activities have been demonstrated.[4,6,7] The improvements in wheelchair technology have also changed the design of the standard wheelchair, used in everyday life.[3,4,6,8] The use of a modern lightweight wheelchair has improved the mobility of people with tetraplegia.[6] To improve the SCI individual's performance in wheelchair propulsion, the focus is set on three interrelated issues: (1) the mechanical properties of the wheelchair; (2) the wheelchair/user interface, ie, the individual 'fit' of the wheelchair; and (3) the physical capacity and propulsion technique of the user.[6–8] The task of wheelchair propulsion can be defined as endurance of propulsion during a specified time interval or at a specific velocity, the capacity of graded propulsion, and the velocity and timekeeping of defined distances.[8,9] In community settings, skills of manoeuvring and climbing curbs are important to enhance the individual's mobility.[3,9]

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Persons with cervical and high thoracic lesions have a reduced trunk control due to the paralysis of the trunk muscles.[2] Stability in sitting, maintaining equilibrium and enabling the person with a SCI to make use of his or her arms and hands without falling needs to be achieved by other means than muscle strength, such as a stabilising sitting position[3] or an external trunk support.[10] Studies have shown that the orientation of the pelvis is essential to a balanced posture of the upper body. As the posture of the spine is related to pelvic orientation, a good sitting position is facilitated if the posterior rotation of the pelvis is reduced.[11–15] It has also been shown that there are distinct differences in the spinal/pelvic alignment between spinal cord injured persons and non-injured persons.[12] According to this study, the person with a SCI will sit in a neutral position with a 15 degrees more posteriorly tilted pelvis compared to non-injured persons. Consequently, a C-shaped sitting posture is very common among spinal cord injured persons.[3,16] Clinical experience in a spinal unit confirms the risk of a kyphotic sitting position after SCI. The posture of the person with a SCI is an important factor in wheelchair prescription and adaptation, demanding individual solutions. The impaired postural function of the trunk causes a posteriorly tilted pelvis that results in a flattened lumbar spine, a kyphotic thoracolumbar spine, and extension of the cervical spine. This is a functional position that provides biomechanical stability, enabling activities of daily living and wheelchair propulsion. However, this position is also a non-ergonomic sitting position that may result in spinal deformities, increased spasticity, increased risk of pressure ulcers, increased pain in the neck and shoulders and decreased respiratory function.[3,12,14,16] A functional and ergonomic sitting position is necessary to attain a high level of independence and to prevent secondary complications.[3,12,16,17]

Research concerning the sitting position and posture of wheelchair users has mainly been descriptive and has not explored the effects of altered conditions. The present study was therefore initiated to elucidate the connection between posture and performance of spinal cord injured wheelchair users. The aim of this study was to investigate how spasticity, balance, respiration, transfers, wheelchair propulsion, wheelchair skills and physical strain during wheelchair propulsion were affected by the sitting position of a person with C5–C6 tetraplegia.

Method

Design

The study was performed as an A-B-A single subject experimental design.[18] Baseline measurements (BLM) were performed during a period of 3–6 weeks. The length of the intervention period varied individually (2–14 months) depending on the extent of the intervention. The purpose of the intervention was to improve the individual fit of the wheelchair[6–8] regarding sitting position and posture. The intervention was individually adapted to each person, with emphasis on reduction of kyphotic posture and pelvic obliquity. Furthermore, a functional requirement was that the new sitting position was used in everyday life and that it did not impair spasticity, balance, respiration, transfers, wheelchair skills and physical strain during wheelchair propulsion. When the individual plan and the functional requirement of use in everyday life was fulfilled, the intervention was considered to be completed. Post-intervention measurements (PIM) evaluated the results of the intervention and were performed 6–8 weeks after the intervention was finished to ensure stable conditions. Visual analysis was used for interpretation of the data.

Measurements

Each test person was photographed, without clothing on the upper body, in the lateral and frontal view using two positions: (1) unsupported trunk and (2) the trunk supported with the arms in the lap. Key points of the foot, knee, hip, shoulder and head were marked with a dot to make interpretation of the photographs feasible. *Balance* was measured using the Modified Functional Reach Test (MFRT).[19] This test is modified for SCI persons and was performed with the test person sitting in the wheelchair. *Transfers* were assessed using one item from the Functional Independence Measurement (FIM).[20] *Wheelchair propulsion* was assessed using a set of wheelchair tasks. These activities were performed with time-keeping. The tasks chosen for wheelchair propulsion were Cooper's test[21] and two short distances of 20 m forward and 10 m backward. The capacity of graded propulsion was recorded using two uphill slopes of 7.5 m and 21 m respectively and an inclination of 4°. *Wheelchair skills* were assessed using a manoeuvring test on a slalom course and a test of ability to climb curbs of 5, 7 and 11 cm respectively. *Physical strain* was assessed using the maximum heart rate recorded during the wheelchair tasks and compared with the results of the task. *Spasticity* was assessed using the Ashworth scale.[22] *Respiration* was measured as vital capacity by a spirometer test, the test person sitting in the wheelchair. *Perceived changes* in balance, transfers, wheelchair propulsion and wheelchair skills, spasticity and respiration were recorded using a questionnaire with a five-point response scale: much improved, improved, unchanged, deteriorated, much deteriorated.

Test persons

The inclusion criteria of the present study were complete C5–C6 tetraplegia and at least 2 years since time of injury. Exclusion criteria were severe complications, such as joint contractions of the lower limbs and decubitus ulcers. Four persons who had reported dissatisfaction with posture and seating, were invited to participate in the study. The test persons' age, height, weight, time since injury and functional independence as measured by the FIM are shown in Table 1.

Assessment and intervention

Test person 'A' Test person 'A' reported severe problems in most daily activities, caused by impaired balance in the sitting position. 'A' experienced that his upper body easily swayed and that he often fell forward and was not able to get back into an upright position without help. This was perceived as a limiting factor in all activities. 'A' could propel the wheelchair neither safely nor maximally, and was therefore dependent on assistance in outdoor mobility. Furthermore, the instability of the air-filled wheelchair cushion caused difficulties in positioning his body correctly.

Baseline: The impaired balance forced 'A' to use the muscles of his neck, shoulders and arms uninterruptedly to maintain position. The backrest of the wheelchair did not give sufficient support. A strap around his thighs was used to avoid hip abduction. Photographs in the frontal view (Figure 1) showed asymmetry of the trunk and shoulders and a lateral alignment of the upper body. 'A' leaned against the right side of the backrest due to pelvic obliquity and impaired balance.

'A' was unable to carry out two parts of the baseline measurements as insufficient physical capacity, allergy and allergy-related tiredness interfered. The baseline measurements are therefore incomplete concerning wheelchair propulsion and the Ashworth test.

Intervention: A new wheelchair was prescribed since the existing one did not have enough adaptive potential. The new wheelchair was equipped with a specifically designed backrest, raised 6 cm and narrowed at the top to support the trunk better and thereby improve balance and reduce body asymmetry. The seat unit was lowered 2 cm. Furthermore, the use of a supporting brace (Rehband back support Dosi EQ X high) was initiated to improve balance and a wheelchair cushion was supplied, providing stability and supporting the thighs.

Sitting position: The frontal view (Figures 1 and 2) showed an improved symmetry of the trunk and shoulders even without the supporting brace. The subject did not lean against the right side of the backrest after the intervention. The lateral view showed a reduction of pelvic posterior tilt, cervical lordosis and thoracal kyphosis. The compensatory use of the neck, shoulders and arms required to maintain balance was reduced. There was no difference in the upper body height after the intervention compared to baseline measurements.

Test person 'B' 'B' reported dissatisfaction with kyphotic posture and a tendency to fall forward in the wheelchair. Furthermore, the instability of the air-filled wheelchair cushion caused difficulties in positioning his body correctly. 'B' also expressed a wish to use the adaptive potentials of the wheelchair to improve his ability to propel and manoeuvre the wheelchair.

Baseline: The frontal view showed a lateral pelvic tilt and an asymmetric, rotated trunk. The upper body was arched due to scoliosis of the thoracic spine. However, the scoliosis was not fixed as it was reduced when the test person was sitting on a firm and flat surface. The lateral view showed a variance of pelvic posterior tilt during the baseline measurements. This was interpreted as being caused by difficulties in positioning and the instability of the air-filled wheelchair cushion. A considerable amount of muscular compensation of the neck and shoulders was required to maintain position during wheelchair propulsion.

Intervention: Wheelchair adaptations were performed with an increase of the posterior slope of the seat. The backrest was tilted forward to reduce the reclining angle. A cushion of contoured foam to reduce the lateral pelvic tilt and provide better stability replaced the wheelchair cushion.

Sitting position: The frontal view (Figures 3 and 4) showed an improved symmetry and a reduction of the arched spine of the upper body during PIM. The sitting position and seating were reported by 'B' to be improved. The posterior and lateral tilt of the pelvis was reduced. The upper body height as measured from the mastoid process to the greater trochanter was increased approximately 2 cm. Photographs in the lateral view showed a more erect posture in relation to a vertical line through the greater trochanter during the post intervention compared to the baseline measurements.

Table 1 Subject characteristics

Test person	*Age (years)*	*Time since injury (years)*	*Neurological level Frankel grade*	*Weight (kg)*	*Height (cm)*	*FIM Physical score Range (13–91)*
A	25	5	C5A	95	195	35
B	28	3	C6A	65	190	76
C	28	9	C5A	70	193	43
D	22	6	C6A	100	175	47

Figure 1 Test person 'A'. Frontal view before the intervention

Figure 2 Test person 'A'. Frontal view after the intervention

Test person 'C' 'C' reported back pain occurring daily for 1 year. The pain was located to the lower thoracic spine and occurred after several hours of wheelchair use. 'C' also complained of difficulties in keeping his feet in place on the footplate due to severe spasticity.

Baseline: Photographs of the sitting position in the lateral view (Figure 5) showed a reclined sitting position with a pronounced posterior rotation of the pelvis and a kyphotic thoracic spine.

Intervention: A new wheelchair with a narrowed leg and footrest to stabilise the feet was provided. To achieve improved lumbar support, the reclination angle of the backrest was decreased and the height of the backrest was increased by 3.5 cm. The strap-adjustable back was contoured so as to be more supportive and the seat depth was increased.

Sitting position: The frontal view showed no change in posture after the intervention. The lateral view (Figures 5 and 6) showed a reduction of the pelvic posterior tilt and reclination of the upper body. The upper body height as measured from the mastoid process to the greater trochanter was increased by approximately 2 cm. The sitting position and seating were reported by 'C' to be improved. Furthermore, 'C' experienced no back pain and less muscle tension in the neck.

Test person 'D' 'D' was dissatisfied with his kyphotic posture and sitting position.

Baseline: Photographs of the sitting position in the lateral view showed a strongly posteriorly tilted pelvis, a flattened lumbar spine and a prominent C-shaped kyphotic spine (Figure 7). The hips were abducted and in external rotation. Insufficient seating width was a contributory cause of the kyphotic posture as the wheelchair was too narrow and the backrest was too low to provide sufficient lumbar and pelvic support.

During the intervention period, test person 'D' received an intrathecal baclofen pump for treatment of spasticity. As the operation was presumed to interfere with the results of this study, extra baseline measurements were carried out. The extra baseline measurements were performed post surgery and before the intervention of this study was completed. The extra baseline measurements illustrate the influence of baclofen on performance.

Figure 3 Test person 'B'. Frontal view before the intervention

Figure 4 Test person 'B'. Frontal view after the intervention

Intervention: A new wheelchair was prescribed with an increased seating width. The backrest was raised five centimetres and contoured individually to give full lumbar and pelvic support. A strap was provided around the thighs to avoid hip abduction and thereby increase stability and balance and decrease the pelvic posterior tilt.

Sitting position: The frontal view showed a reduction of external rotation and abduction of the hips. The lateral view (Figures 7 and 8) showed a reduction of the kyphotic thoracolumbar posture and a decreased cervical lordosis. A more erect posture was attained and the upper body height was increased approximately 3 cm compared to BLM. The pelvis was slightly more anteriorly tilted.

Results

Balance
The balance was considerably improved for test person 'A' (Table 2) as measured by the MFRT as well as by self-assessment. 'B' (Table 3) and 'C' (Table 4) perceived their balance to be improved even though the MFRT did not show any obvious change. 'D' (Table 5) perceived his balance to be much deteriorated even though the MFRT did not show any obvious change.

Transfers
As shown in Tables 2–5, transfers as measured by the FIM were unchanged for all test persons even though 'A', 'B' and 'C' perceived transfers to be more difficult to perform. 'D' perceived no change in transfer ability.

Wheelchair propulsion
Wheelchair propulsion was improved for 'A' both objectively and by self-assessment (Table 2). 'B' (Table 3) and 'C' (Table 4) perceived their wheelchair propulsion to be improved even though Cooper's test and uphill slope propulsion did not show any obvious change. 'D' (Table 5) assessed wheelchair propulsion to be improved. An improvement was also recorded in the test of uphill slope propulsion, even though Cooper's test showed a deterioration.

Figure 5 Test person 'C'. Lateral view before the intervention

Figure 6 Test person 'C'. Lateral view after the intervention

Figure 7 Test person 'D'. Lateral view before the intervention

Figure 8 Test person 'D'. Lateral view after the intervention

Table 2 Test person 'A' – changes in performance as measured objectively and by self-assessment

Test	*Objective measurement*	*Self-assessment*
Balance	Improved	Much improved
Transfers	Unchanged	More difficult
Wheelchair propulsion		
Cooper's test	Improved	Much improved
Uphill slope	Improved	Much improved
Wheelchair skills		
Manoeuvring test	Improved	Much improved
Climbing curbs	Not tested	Much improved
Spasticity	Unchanged	Decreased
Respiration	Unchanged	Improved

Table 3 Test person 'B' – changes in performance as measured objectively and by self-assessment

Test	*Objective measurement*	*Self-assessment*
Balance	Unchanged	Improved
Transfers	Unchanged	More difficult
Wheelchair propulsion		
Cooper's test	Unchanged	Improved
Uphill slope	Unchanged	Improved
Wheelchair skills		
Manoeuvring test	Unchanged	Improved
Climbing curbs	Improved	Improved
Spasticity	Unchanged	Increased
Respiration	Unchanged	Unchanged

Table 4 Test person 'C' – changes in performance as measured objectively and by self-assessment

Test	*Objective measurement*	*Self-assessment*
Balance	Unchanged	Improved
Transfers	Unchanged	Unchanged
Wheelchair propulsion		
Cooper's test	Unchanged	Improved
Uphill slope	Unchanged	Improved
Wheelchair skills		
Manoeuvring test	Unchanged	Improved
Climbing curbs	Improved	Improved
Spasticity	Unchanged	Unchanged
Respiration	Unchanged	Unchanged

Table 5 Test person 'D' – changes in performance as measured objectively and by self-assessment

Test	*Objective measurement*	*Self-assessment*
Balance	Unchanged	Much Deteriorated
Transfers	Unchanged	Unchanged
Wheelchair propulsion		
Cooper's test	Deteriorated	Improved
Uphill slope	Improved	Improved
Wheelchair skills		
Manoeuvring test	Deteriorated	Improved
Climbing curbs	Improved	Improved
Spasticity	Decreased	Unchanged
Respiration	Deteriorated	Deteriorated

Wheelchair skills

Wheelchair skills were improved for 'A' (Table 2) as measured by the manoeuvring test as well as self-assessed. No change was recorded for 'B' (Table 3) and 'C' (Table 4) regarding the manoeuvring test. A deterioration of the results of the manoeuvring test was recorded for test person 'D' (Table 5). 'B', 'C' and 'D' perceived their wheelchair skills to be improved and they were also improved as measured by the ability to climb curbs (Tables 3–5).

Physical strain

Great variations in maximum heart rate were noted in all test persons during Cooper's test and uphill slope propulsion during baseline and post-intervention measurements.

Spasticity

As shown in Tables 2–5, the level of spasticity as measured by the Ashworth scale was considered unchanged for 'A', 'B' and 'C', whereas it was decreased for 'D'. 'A' perceived a decrease in his level of spasticity. 'B' perceived an increase in his level of spasticity. 'C' and 'D' perceived no change in their level of spasticity.

Respiration

No obvious change was recorded for 'A' regarding vital capacity even though 'A' perceived his respiration to be improved (Table 2). 'B' (Table 3) and 'C' (Table 4) perceived no change in respiration and there was no change in their vital capacity. 'D' considered his respiration to be deteriorated, which was confirmed by the measurements of vital capacity.

Self assessment

The test persons' ratings on the self-assessment scales are shown in Tables 2–5.

Test person 'A' reported improvements regarding overall sitting position and wheelchair propulsion. When using a supporting brace, his balance was greatly improved. 'A' reported that he was more independent as most daily activities were easier to perform. 'A' stated; 'It's like a new world opening', and 'I'm not afraid to go out on my own anymore'. 'A' reported his respiration to be improved and also found it easier to speak in a loud voice when using the supporting brace.

Test person 'B' perceived an improvement of his sitting position and wheelchair driving properties during the post-intervention measurements. Post-intervention photographs and measurements also showed an improvement of sitting position symmetry and a more erect upper body compared to BLM. 'B' reported transfers initially to be more difficult to perform. However, these difficulties were temporary and were improved after a short period of training.

Test person 'C' experienced elimination of back pain with the new sitting position, which was a stable condition 6 months post intervention. Photographs of the new sitting position showed an improvement regarding kyphotic posture. Measurements of performance showed no obvious changes although 'C' perceived an improvement regarding balance, wheelchair propulsion ability and wheelchair skills.

Test person 'D' estimated his overall sitting position to be much improved compared to BLM, as was also shown by photographs post intervention. No obvious objective change in balance was noted although 'D' reported his balance to be much deteriorated.

During the intervention period, 'D' received an intrathecal baclofen pump. This may have had an impact on his physical abilities such as respiration, wheelchair propulsion ability and physical strain. Interpretation of the influence of the sitting position on performance was hereby impossible. A comparison of photographs taken before and after the baclofen pump was in use showed that the baclofen did not affect the subject's sitting position.

Discussion

The individual adaptations which were made improved the test persons' sitting position and reduced or solved their specific problems. A decreased pelvic posterior tilt in combination with full pelvic and lumbar support gave a more erect sitting position and an increased upper body height in three of the test persons. During the intervention period the test persons had some difficulties accepting the new sitting position. There was a tendency to resume the original sitting position, which became more obvious with increased time since injury.

The use of pressure-relieving wheelchair cushions has reduced the problem of pressure ulcers in SCI persons.[23,24] However, the use of air-filled wheelchair cushions was found to decrease the stability of the sitting position, resulting in difficulties in positioning and a risk of pelvic obliquity. In three of the test persons, the use of a more stable wheelchair cushion seemed to reduce these problems, without pressure ulcers occurring.

The altered sitting position had an impact on performance that varied in an individual manner. The improvement of the user/wheelchair interface seems to have a positive influence on wheelchair propulsion and wheelchair skills. Thus, the changes in performance post intervention could be caused by an increased efficiency of applied muscular force and developed movement energy. It could also be the result of increased daily activities and physical capacity, in terms of muscular strength and endurance, secondary to improved balance. The more erect posture during the post-intervention measurement is likely to have positive effects by preventing secondary complications such as pressure ulcers, spinal deformities and pain.

Sitting position

In this study, the pelvic tilt angle was defined as the angle between the anterior superior iliac spine, the greater trochanter and the vertical plane. Some earlier studies[12,16] have used X-rays for evaluation of posture. However, this is a method that cannot always be used in the clinical situation because of high costs and practical difficulties. Nevertheless, an easy way of measuring pelvic tilt would be of great value in clinical work. Shields and Cook[11] describe a method of measuring pelvic tilt that does not vary from radiographic measurements more than 5 degrees. This method is valid and reliable and is routinely used to detect early femoral acetabular pathologies in persons with SCI.[11] However, this method includes marking of the posterior superior iliac spine (PSIS). This was impossible to achieve in the present study as PSIS was hidden by the backrest of the wheelchair. Palpation was used for location of the anatomical landmarks. This method requires personal skills of the investigator. However, there was conformity between the measurements regarding anatomical markers and the photographs and the measurements provided a valuable tool for assessment.

Balance

The balance test used in this study was originally made for able-bodied persons and has been modified to be suitable for spinal cord injured persons. The MFRT has been developed using a standardised chair with the aim of finding a method of evaluating the influence of seating on the balance of the spinal cord injured person.[19] In the present study, the MFRT was performed in the test person's wheelchair to measure and evaluate balance when sitting. Two of the test persons reported their balance to be slightly improved in the new sitting position whereas the MFRT showed no obvious change. This indicates that the persons' perception of balance is more complex than that measured by the MFRT. The assessment of balance is based on experience of daily activities and not only on the ability to reach forward while sitting in the wheelchair.

A more posteriorly tilted pelvis results in a better balance as measured by the MFRT. This supports the clinical observation that the C-shaped posture is the result of compensating for impaired balance.

The test persons used different techniques while performing the MFRT test. The result is likely to be influenced by whether the test person held his breath (Valsalva manoeuvre[25]) or not and the kinematics of the shoulder joint. Thus, the performance of the test needs to be more standardised if the MFRT is to be used in the clinical situation.

Transfers
Three of the test persons reported that transfers were more difficult to perform after the intervention. This was probably due to the increased seat inclination. These negative changes were temporary and the transfers could be improved by training. In spite of these perceived changes in transfers, there was no change in the FIM score, which indicates that the FIM is not sensitive to small changes.

Wheelchair propulsion and wheelchair skills
Cooper's test, uphill slope propulsion and wheelchair skills, eg, the manoeuvring test and climbing curbs, proved to be tasks that could be used for measuring changes regarding wheelchair propulsion. Parziale[6] showed that there is no difference in propulsion velocity between a standard and a lightweight wheelchair when conducting a 4 min maximum distance test. There was only a significant difference over short distances due to the reduced power required to initiate propulsion in a lightweight wheelchair compared to a standard wheelchair.[6]

In the present study, the test of propulsion 20 m forward, 10 m backwards and propulsion on bumpy ground did not show any difference between BLM and PIM. This indicates that the new seating did not influence the power needed to initiate propulsion. Furthermore, the perceived change of wheelchair propulsion ability and the objective measurements did not correspond in all cases. All of the test persons perceived improvements while the objective measurements showed no change. This could reflect the fact that the person's own assessment is based on their ability to propel the wheelchair in everyday life, which includes a greater spectrum of activities than is measured by the tasks used in this study.

Physical strain
It has been suggested by Janssen *et al*[26] that a quantitative and objective way of measuring physical strain in spinal cord injured persons is by maximum heart rate response. Heart rate was measured on one occasion during different ADL tasks such as transfers, climbing curbs and ascending a ramp. According to Bhambhani and Eriksson,[27] heart rate is a reliable physiological response for measuring peak physiological response. They conducted a study including two measurements for each task of ADL.

In the present study, the maximum heart rate varied a great deal between different measurements. Environmental and situational factors such as ambient temperature and humidity, and the intake of, for example, caffeine, nicotine or medicine, may influence heart rate response. The heart rate may also be influenced by the bladder pressure.[2] This indicates that using maximum heart rate as a measure of physical strain requires standardised physical and environmental conditions, which are very difficult to achieve in a clinical setting.

Spasticity
In the present study, the assessment of spasticity was performed using the Ashworth test. The Ashworth test is performed with the test person in a supine position and was used to record the basic level of spasticity. However, the Ashworth test provides inadequate information in the clinical situation when one is evaluating the influence of seating on spasticity level. As the Ashworth test does not measure all aspects of spasticity, it is important to consider if the spasticity interferes with the person's daily life. Therefore, the test persons in the present study were asked to report changes in perceived level of spasticity related to the new sitting position. The influence of sitting position and seating on the level of spasticity was assessed using the results of the Ashworth test in comparison with the test persons' perceived level of spasticity. Test person 'A' reported a reduced level of spasticity with the new sitting position while the Ashworth test showed no change. This indicates that the person's new sitting position had a positive influence on the level of spasticity.

Respiration
As shown by Chen *et al*,[28] vital capacity increases by 14% when SCI persons change from the sitting to the supine position. In the present study, there were no obvious changes in vital capacity for 'A', 'B' and 'C' in spite of the improvements regarding posture. Great variations were noted during baseline and post-intervention measurements. Thus, conclusions can not be drawn regarding the validity of this method for evaluating the influence of posture on respiration. The test person's perception of respiration includes perceived changes in inspiration and expiration capacity as well as the difficulty in breathing. This probably explains the discrepancy noted for 'A' between objective measurement and self-assessment. The baclofen probably caused the deterioration of vital capacity recorded for 'D' due to decreased tone in the rib-cage.

Conclusions
The test persons in the present study achieved an improvement of their sitting position and posture after

the intervention and demonstrated a clinically significant improvement regarding each individual's main problem related to the sitting position. The impact on performance varied individually. The negative changes in performing transfers were temporary and were improved by training. Initial negative changes in performance should therefore not hinder adjustment of sitting position and seating. This is a process that requires time and patience.

The results of the objective measurements of performance regarding balance, transfers and spasticity did not correspond with the test person's perceived changes of performance, indicating a need for more reliable and sensitive objective measurements. Solution of the problems concerning posture and performance requires a good knowledge of the physical impairment, wheelchair adaptation, seating systems and cushions as well as a good understanding of the individual's demands and wishes. Due to the complexity of the issue, standard solutions are not applicable. Thus, an analytical working method is required and co-operation between professionals – occupational therapists and physiotherapists – is important.

Implications for future studies

Further studies are required to develop and evaluate methods for assessment and documentation of the relationship of sitting position and performance in spinal cord injured persons. Focus on ergonomic issues and daily activities could facilitate the measures to achieve improvements of posture and performance for spinal cord injured persons. As the use of a trunk support was shown to improve the posture and performance of a person with tetraplegia, the long-term effects on performance when using a supporting brace should be investigated.

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