Spinal Cord (2013) 51, 273–277

www.nature.com/sc

ORIGINAL ARTICLE

Factors influencing optimal seating pressure after spinal cord injury

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Study design: Retrospective, cross-sectional design.
Objectives: To identify factors that predict unsatisfactory seating pressure in spinal cord-injured (SCI) individuals.
Setting: Seating Clinic at the University Hospital, Norway.
Methods: All wheelchair users with traumatic SCI hospitalized between 1 January 2007 and 31 December 2010 were included. Individual assessment by a team was performed. To measure seating pressure, a computerized seating pad with sensing points 40 × 40 cm was used. Primary end points were defined as satisfactory or unsatisfactory seating position based on measured pressure (more or less 100 mm Hg), clinical findings and physical activity level. To explore possible risk factors for high seating pressure, both univariate and multivariate regression analysis were performed.
Results: A total of 75 persons with SCI were assessed, 39 (52%) with unsatisfactory result. Statistical analysis revealed that use of manual wheelchair (odds ratio (OR) = 6.86, confidence interval (CI) 1.77–26.63) and history of pressure ulcer (OR = 8.47, CI 2.46–29.13) significantly increase the risk of unsatisfactory seating pressure. Paraplegia caused significantly higher risk (OR = 2.5, CI 0.99–6.34) in the univariate model, probably because the SCI with tetraplegia do prefer electrically powered wheelchairs.
Conclusions: Use of manually driven wheelchairs and persons with previous pressure ulcer are at significant risk of high seating pressure and consequently developing new pressure ulcers. The patients from these subcategories need close follow-up regarding seating position and prevention of pressure ulcers.
Spinal Cord (2013) **51,** 273–277; doi:10.1038/sc.2012.163; published online 8 January 2013

Keywords: rehabilitation; seating assessment; seating clinic; risk factors; pressure ulcer

INTRODUCTION

Spinal cord injury (SCI) may cause lifelong disability with reduced mobility and sensation below the injury. Wheelchair users with such impairments are at risk of developing pressure ulcers because of lack of feedback and changed use of muscles in the seating area. Up to 37% of patients with SCI develop pressure ulcer before admission to a specialized rehabilitation centre.[1] Pressure ulcers are secondary complications to SCI that lead to lower quality of life and are expensive to treat.[1–3]

The least expensive and most difficult management of pressure ulcers is prevention.[4] Persons with SCI are prone to develop high seating pressure because of spine deformities, muscle imbalance and deteriorated perception.[5] Pressure measurement in the seating assessment clinic exposes high pressure on the skin of the seating area before development of pressure ulcers.[6,7]

The Seating Clinic was established at the Spinal Cord Unit, Haukeland University Hospital in Bergen, Norway in 2005. All wheelchair users who are admitted to the Spinal Cord Unit are offered a consultation at the seating assessment clinic. The assessments are performed by a team of nurses, occupational therapists and physiotherapists. The team provides a holistic approach to patients' seating problems and recommends solutions to change lifestyle and seating habits, use of different cushions and wheelchairs.

We aimed to identify factors such as concomitant diseases and previous complications to SCI, lifestyle, use of special cushions and type of wheelchair that may predict risk of high seating pressure. As a consequence we may identify the persons who need close follow-up to prevent development of pressure ulcers.

MATERIALS AND METHODS

Population and design

The retrospective cross-sectional study was carried out at the Seating Clinic at the Spinal Cord Unit, Haukeland University Hospital, between 1 January 2007 and 31 December 2011. We included all wheelchair users with traumatic SCI admitted in this period. No one refused to be measured.

Intervention

The patients were assessed individually by a team. The clinic uses a rotating system, which means that at least two disciplines are represented at each assessment. Some patients have had several assessments. Only their first measurement as the most informative regarding the risk factors for unsatisfactory high seating pressure has been included in this study.

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Received 21 June 2012; revised 7 November 2012; accepted 26 November 2012; published online 8 January 2013

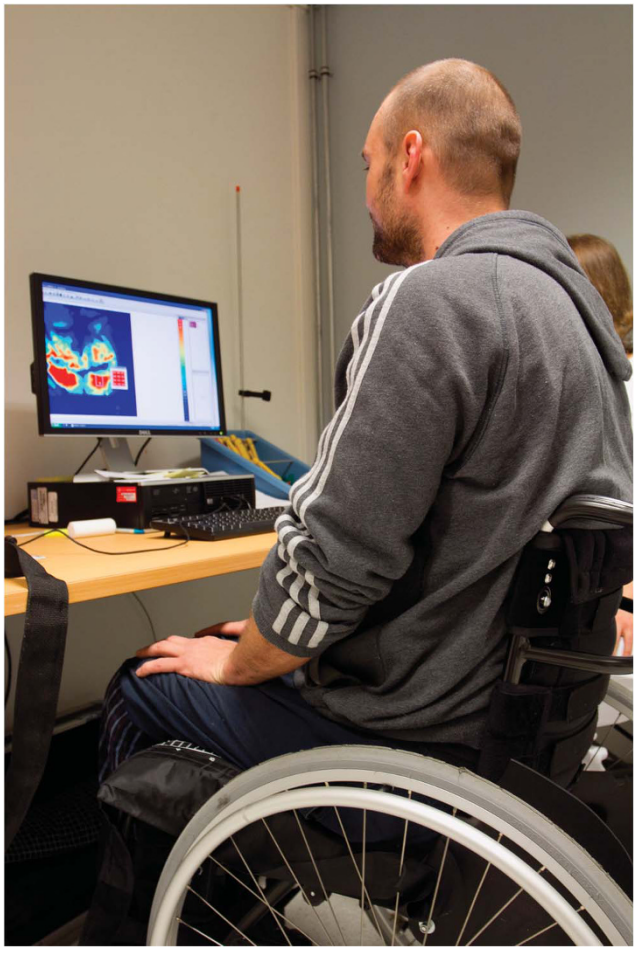

Figure 1 Assessment with X-sensor system during the consultation.

Table 1 Interview guide for seating clinic consultation

Checkpoints	*Comments*
Manual wheelchair	
Non-folding frame	
Folding frame	
Electrical wheelchair	
Tilt	
Adjustable seat height	
Adjustable footrest	
Adjustable back	
Standing option	
Steering	
Cushion	
Model	
Size	
Age	
Area of use	
Inside	
Outside	
Duration of time	
Other wheelchairs	
History of pressure ulcer	
Present ulcer	
Localization	
Special activities	
Procedures of relief	
Standing	
Use of other chairs	
Change of position	
Lying	
Seating position	
Usual position	
Method of transfer	
Independent, no aids	
Independent, with board	
Lift	
Dependent, other help	

Seating pressure was measured by a computerized seating pad 40-by-40 cm with sensing points (Xsensor Technology Corporation, Calgary, Alberta, Canada), in which all members of the seating team were trained to use (Figure 1). Seating pressure was measured in mm Hg with a cutoff level between possible satisfactory and unsatisfactory level of 100 mm Hg. The limit was chosen because it has been shown that seating pressure on and above 100 mm Hg is dangerous to tissue health in persons with SCI.[8] The pad was connected to a PC screen to produce a visual image of the seating pressure (software: Xsensor Pressure Mapping system Models X2/X3 Medical Mattress system v 6.0 ©2008, Xsensor Technology Corporation). The image displayed all sensing points in colours; with pressure on and above 100 mm Hg as possible high seating pressure was shown in red.

Possible risk factors were collected from the patient's file, through semistructured interview (Table 1) and observation during the assessment. Obtained information was classified according to International Classification of Functioning, Disability and Health (ICF).[9] Factors such as activity level, procedures of relief, transfer, wheelchair and cushion used during the seating assessment were included to the assessment.

We recorded age and sex, level and completeness of injury, height and weight. Age and years since injury were used as continuous variables. The diagnosis of diabetes, history of pressure ulcer, spasticity and smoking habits were recorded and dichotomized as yes or no. Affirmative answers to history of pressure ulcer led follow-up question about present pressure ulcer, also dichotomized as yes or no. The body mass index (BMI) was calculated and grouped according to the guidelines of the hospital as underweight (BMI <20), normal (BMI between 20 and 24.9) or overweight (BMI $\geqslant 25$). Pressure ulcer was classified according to the international classification and dichotomized as pressure ulcer (stages 2–4) or risk of pressure ulcer (stage 1 or no pressure ulcer).[10] Level of injury was divided as tetraplegia or paraplegia, completeness of injury as complete ASIA (American Spinal Injury Association) A, or incomplete ASIA B, C, D. Data of present pressure ulcers were treated equally to the history of previous pressure ulcers.

The most frequently used transfer technique was recorded and classified as independent, use of transfer board or use of lift. Wheelchair was classified as electrically powered or manually driven. If seating clinic was conducted several times with more than one chair, then the results were recorded as separate measurements. Cushions were classified as Roho (ROHO Inc, Belleville, IL, USA) (air-filled type), other air-filled cushions or other cushions not filled with air.

Primary end point was defined as satisfactory or unsatisfactory seating position. To decide if a patient belonged to the satisfactory or unsatisfactory group measured pressure from X-sensor, data from interview and clinical data were used.

Procedure

Using the patient's own wheelchair and cushion, the patient was assessed as follows:

1. Observation of seating in wheelchair without any intervention during semistructured interview (Table 1).
2. Pressure mapping. The first mapping is done with the patient sitting in his/her preferred seating position for up to 10 min and a mean is calculated by the software and then presented on the screen. The screen is visible to the patient throughout the mapping. Easily adjustable reasons for high seating pressure, that is, change of air level of cushion, use of alternative cushions or elevation/lowering of footrest will be done and a new pressure mapping will be performed as a basis for further recommendations.
3. A conclusion will be reached, based on a total assessment of current seating pressure seen in relation to the patient's level of activity, clinical findings and procedures of relief. The primary outcome of the study after reviewing interview, clinical data and pressure mapping was dichotomized as 'satisfactory' or 'unsatisfactory.'
4. Discussion with patient regarding the results and recommendation of further referral.

Statistical analysis

SPSS (SPSS Inc., Chicago, IL, USA), version 18 was used for all the statistical analyses. We used descriptive statistic to summarize the clinical characteristics of the sample. Chi-square with Fisher's exact test was used to explore the relationship between unsatisfactory seating pressure and each of the possible risk factors. Logistic regression was performed to estimate odds ratios (ORs), first in univariate models until a multivariate model was fitted based on a modelbuilding strategy. Variables with univariate $P<0.25$ were selected as candidates in the multivariate analysis following a modelbuilding strategy as described by Hosmer and Lemeshow.[11] Level of significance was set at $P<0.05$.

Statement of ethics

The study was approved by local Ethical Committee as a clinical study securing quality improvement of services.

RESULTS

A total of 75 patients with SCI were assessed, 39 (52%) with unsatisfactory result. The sample characteristics and the relationship between primary end point and each of the risk factors are shown in Table 2. Significant associations were found for history of pressure ulcer and type of wheelchair.

Table 2 Relationship between seating clinic results and risk factors

Variables	*Unsatisfactory seating pressure*		*Satisfactory seating pressure*		*Total*	
	N	*(%)*	N	*(%)*	N	P-*value*
Demographic factors						
Sex					75	0.78
Female	9	(56.3)	7	(43.8)	16	
Male	30	(50.8)	29	(49.2)	59	
Age[a]	46.6	(±17.2s.d.)	47.8	(±18.2s.d.)	75	0.33
Years since injury[a]	13.3	(±11.4s.d.)	8.6	(±9.5s.d.)	75	0.42
Clinical and functional factors						
Anatomical level of injury					75	0.13
C1–C8	14	(40.0)	21	(60.0)	35	
T1–T6	11	(68.8)	5	(31.3)	16	
T7 and under	14	(58.3)	10	(41.7)	24	
Completeness of injury					75	0.48
Complete	27	(55.1)	22	(44.9)	49	
Incomplete	12	(46.2)	14	(53.8)	26	
Present pressure ulcer					32	0.24
No	7	(58.3)	5	(41.7)	12	
Yes	16	(80.0)	4	(20.0)	20	
History of pressure ulcer					75	0.001*,**
No	17	(36.2)	30	(63.8)	47	
Yes	22	(78.6)	6	(21.4)	28	
Spasticity					75	1.00
No	14	(51.9)	13	(48.1)	27	
Yes	25	(52.1)	23	(47.9)	48	
Functional level of injury					75	0.07
Tetraplegia	14	(40.0)	21	(60.0)	35	
Paraplegia	25	(62.5)	15	(37.5)	40	
Transfer					75	0.14
Independent without aids	27	(61.4)	17	(38.6)	44	
Board	7	(43.8)	9	(56.3)	16	
Lift	5	(33.3)	10	(66.7)	15	
Lifestyle factors						
Body mass index					55	0.60
Underweight	6	(60.0)	4	(40.0)	10	
Normal weight	11	(52.4)	10	(47.6)	21	
Overweight	10	(41.7)	14	(58.3)	24	
Diabetes					75	1.00
No	34	(52.3)	31	(47.7)	65	
Yes	5	(50.0)	5	(50.0)	10	
Smoking					75	0.16
No	28	(47.5)	31	(52.5)	59	
Yes	11	(68.8)	5	(31.3)	16	
Aids						
Wheelchair					75	0.008
Electrically powered	5	(25.0)	15	(75.0)	20	
Manually driven	34	(61.8)	21	(38.2)	55	
Cushion					75	0.42
Airfilled Roho	10	(41.7)	14	(58.3)	24	
Other airfilled	14	(60.9)	9	(39.1)	23	
Other not airfilled	15	(53.6)	13	(46.4)	28	

*Significant within $P\leqslant 0.05$.
**Significant within $P\leqslant 0.001$.
[a]Mean.

Table 3 Risk of unsatisfactory seating pressure in logistic regression-univariate model

Variables	*Unsatisfactory seating pressure*		
	OR	*CI (lower–upper)*	P-*value*
Demographic factors			
Sex			0.70
Female vs male	0.81	(0.27–2.45)	
Age	1.00	(0.98–1.03)	0.76
Years since injury	0.96	(0.92–1.00)	0.07
Clinical and functional factors			
Anatomical level of injury			0.13
C1–C8 vs Th1–Th6	3.30	(0.94–11.58)	
C1–C8 vs Th7 and under	2.10	(0.73–6.04)	
Completeness of injury			0.46
Complete vs incomplete	0.70	(0.27–1.81)	
Present pressure ulcer			0.20
No vs yes	2.86	(0.59–13.96)	
History of pressure ulcer			0.001**
No history vs history	6.47	(2.20–19.08)	
Spasticity			0.99
No vs yes	1.01	(0.39–2.59)	
Functional level of injury			0.05*
Tetraplegia vs paraplegia	2.50	(0.99–6.34)	
Transfer			0.14
Independent without aid vs board	0.49	(0.15–1.56)	
Independent without aid vs lift	0.32	(0.09–1.08)	
Lifestyle factors			
Body mass index			0.58
Underweight vs normal	0.73	(0.16–3.38)	
Underweight vs overweight	0.48	(0.11–2.14)	
Diabetes			0.89
No vs yes	0.91	(0.24–3.45)	
Smoking			0.14
No vs yes	2.44	(0.75–7.88)	
Aids			
Wheelchair			0.007*
Electrically powered vs manually driven	4.86	(1.54–15.33)	
Cushion			0.42
Airfilled Roho cushion vs other airfilled	2.18	(0.68–6.99)	
Airfilled Roho cushion vs other not airfilled	1.62	(0.54–4.85)	

CI, confidence interval; OR, odds ratio.
*Significant within $P \leqslant 0.05$.
**Significant within $P \leqslant 0.001$.

Logistic regression analysis was performed to assess the impact of a number of factors on the likelihood to increase unsatisfactory seating pressure at the seating clinic, and how well the predictor factors could explain the unsatisfactory result. The simple model (Table 3) contained 14 potential risk factors. The strongest, single predictor was history of pressure ulcer, followed by type of wheelchair and patients functional level. The result indicated that individuals with a history of pressure ulcer were about six times more likely to have unsatisfactory seating pressure than those without such a history. Use of a manual wheelchair caused almost five times higher risk of having unsatisfactory seating pressure than in an electric wheelchair. Individuals with paraplegia were almost three times more likely to have an unsatisfactory seating pressure than those with tetraplegia.

Table 4 Risk of unsatisfactory seating pressure in logistic regression-multivariate model

Variables	*Unsatisfactory seating pressure*		
	OR	*CI (lower–upper)*	P-*value*
History of pressure ulcer			0.001**
No history vs history	8.47	(2.46–29.13)	
Wheelchair			0.005*
Electrically powered vs manually driven	6.86	(1.77–26.63)	

CI, confidence interval; OR, odds ratio.
*Significant within $P \leqslant 0.05$.
**Significant within $P \leqslant 0.001$.

In further analysis, we included seven covariates, all with a *P*-value of <0.25. The full model (Table 4) included functional and anatomical level of injury, type of wheelchair, history and present pressure ulcer, smoking and the mode of transfer. Age and sex have little impact and were therefore not included to the final calculation.

The results indicated that the risk of unsatisfactory seating pressure is significantly high among patients with history of pressure ulcer, followed by use of manually driven wheelchair. Due to a strong correlation between using a manual wheelchair and having had paraplegia ($P<0.001$) new multivariate analysis replacing wheelchair by functional level was done. The results show that having paraplegia is not a statistic significant predictor of unsatisfactory seating pressure ($P=0.06$). History of pressure ulcer is still a statistic significant predictor ($P=0.001$) and the risk of having unsatisfactory seating pressure remained still strong with an OR of 6.75 (CI 2.21–20.63). No statistical correlation was found between having paraplegia and having had previous pressure ulcer ($P=0.64$). There is no statistical correlation between using a manual wheelchair and having had previous pressure ulcer ($P=1.0$).

DISCUSSION

History of pressure ulcer may indicate that person with SCI have had high seating pressure over a long period of time. Our study confirms previous findings that history of pressure ulcers is a risk factor for recurrent pressure ulcers.[12,13] Previous studies have proposed follow-up programs and educational measures to prevent new pressure ulcers.[9,12] Regular assessment of seating pressure at the seating clinic in combination with education has previously shown favourable outcome in clinical studies.[4,14] Assessments at the seating clinic have demonstrated improved outcome after the first pressure ulcer.[15] Our study confirms the need of preventive measures and follow-up for the patients with history of pressure ulcers.

We found that use of a manually driven wheelchair significantly increased the risk of high seating pressure. To our knowledge, the use of specific type wheelchair as a risk factor has not been studied before.[1] The neurological level and functional status have been shown to be predictive factors for pressure ulcers in previous clinical studies.[1,12,16] In our study, the functional status, tetraplegia or paraplegia, was a relative

risk factor related to type of wheelchair being used. However, the functional status, type of transfer (which is indirectly connected to functional status) or anatomical level of SCI did not cause increased risk of unsatisfactory high seating pressure. In Norway, almost all patients with tetraplegia (American Spinal Cord Injury Association Impairment Scale grade A or B on the cervical level) use electrical wheelchairs. The expenses are covered by Social Security Service and type of wheelchair is proposed by the medical staff during the primary rehabilitation in the Spinal Cord Units. Therefore, availability of wheelchairs for patients with disability is not restricted by economic reasons. Our finding of better seating pressure among the more disabled patients was unexpected, but explainable by use of different types of wheelchairs. Based on our study, we propose that the seating is better designed in the electrically powered wheelchairs than in manually driven wheelchairs for patients with SCI.

The effect of different cushions on preventing development of pressure ulcers has previously been studied on a limited number of persons with SCI using different outcome measures.[1] The impact of cushions has been unclear, but based on available data, the use of various cushions has been associated with potentially beneficial reduction of risk of developing pressure ulcers.[1] No association is found between different types of cushions and sitting posture.[17] We did not find any relation between satisfactory seating pressure and use of different types of cushions in our study.

Concomitant diseases such as cardiovascular diseases, diabetes, lower limb fractures, deep venous thrombosis and pneumonia may increase the risk for pressure ulcers, but results from previous studies are conflicting.[1,18] We studied impact of anatomical level of SCI, completeness of SCI, presence of spasticity and diabetes without finding increased risk for high seating pressure in such conditions. General positive health behaviours such as regular physical activity, healthy lifestyle and avoidance of cigarette smoking, alcohol abuse and use of sleeping pills may protect against pressure ulcers.[1] High and low body weight has shown to be a contributor to tissue injury.[19,20] Our study did not establish smoking or high or low BMI as a risk factor for high seating pressure. However, the number of studied factors was high. Further large studies are needed for exploration of possible risk factors for high seating pressure.

Limitations

Our study was retrospective and limited to the patients who were hospitalized at the Spinal Cord Unit. The selection of patients was not random and was based on voluntary participation in the seating clinic. On the other hand, the study was performed on the patients who are usually included for assessment at a seating clinic and the selection was based on clinical findings and indications, not as a part of a research. In the future, we recommend prospective analysis to examine the further development of seating pressure after the initial recommendations have been followed. Laboratory research have demonstrated difficulty with test-retest reliability using the average and peak pressure. We therefore welcome standards of how to relate interface pressure variables to clinical measurements of wheelchair users.[21]

We did not succeed in showing body weight to be a risk factor. However, mapping of muscle atrophy or prominent skeletal structures may be more precise clinical factors in the future studies. We recommend further studies regarding interaction of the bone structure in the seating area, body weight and seating pressure. Patients may acquire pressure ulcer in different situations and on different arenas. In the actual study, we have focused on the pressure measurement using wheelchair only.

Conclusions

Our study revealed that previous pressure ulcer increases the risk of having unsatisfactory high seating pressure even after the ulcer is healed. The subgroup of patients with SCI and history of pressure ulcers are at risk of developing new pressure ulcers in the seating area. This finding is in line with the results of previous studies and confirms the need for thorough follow-up of this subgroup of patients. The patients using manually driven wheelchairs or having paraplegia should be followed up regarding seating pressure and optimal seating.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

ACKNOWLEDGEMENTS

We acknowledge Jan Aarseth, PhD at the Norwegian National Multiple Sclerosis Registry for valuable help with the statistical analysis.

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