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ARTICLE

Spinal cord injury and development of pressure injury during acute rehabilitation in Norway: a national retrospective cross-sectional study

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Abstract

Study design A national, retrospective, cross-sectional study.

Objectives To analyze the prevalence of pressure injury (PI), and characteristics associated with PI development in the hospitalized population of persons with a newly acquired spinal cord injury (SCI) between 2004 and 2014.

Setting All three specialized Spinal Cord Units in Norway.

Methods Demographic data related to prevalence and potential risk factors were retrieved from the electronic medical record (EMR). Statistical analyses were performed, using IBM SPSS Statistics, version 23.

Results We identified 1012 individuals with a new SCI. Mean age at injury was 48 years (SD 19). The period prevalence of PI was 16% (95% CI = 0.14–0.19), and identified PI associations were complete SCI (OR = 0.1), being injured abroad (OR = 2.4), bowel (OR = 13), and bladder (OR = 9.2) dysfunction; comorbidities like diabetes mellitus 1 (OR = 7.9), diagnosed depression (OR = 3.8), ventilator support (OR = 3.0), drug abuse (OR = 3.0), and concurrent traumatic brain injury (OR = 1.7). Individuals in the age group of 15–29 years had higher odds of PI compared with middle-aged individuals (45–59 years).

Conclusion PI is a serious complication after SCI. The association between depression or comorbidity and PI occurrence should be investigated more thoroughly. We recommend implementation of a simple follow-up program regarding observation and prevention of PI. Increased awareness of factors that could contribute to PI will help to focus on better prevention and early recognition of PI. This will contribute to more optimal rehabilitation.

Introduction

Pressure injury (PI) is defined as localized damage to the skin and the underlying soft tissue, usually over a bony prominence, or related to medical or other devices. It can present as a red spot on intact skin or as an open ulcer and can be painful. It occurs as the result of intense or prolonged pressure, or pressure in combination with shear [1]. A

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systematic review published in 2013 concluded that overall there is no single factor, which can explain the risk of PI, but rather a complex interplay of factors that increase the probability of the development [2]. Impaired motor and sensory function, altered perfusion and circulation, moisture, and incontinence were found to be factors that significantly increased the risk of PI [2].

Due to paralysis, sensory loss, and prolonged exposure to moisture, individuals with spinal cord injury (SCI) are at particular risk for PI [2–5].

The occurrence of PIs during hospitalization of persons with SCI has shown to vary between 6 and 52% [6, 7], and comorbidities can affect the development of severe PI [6].

Persons with SCI are a heterogeneous group, and therefore risk factors may vary in specific subgroups [2, 8, 9]. Verschueren found that both complete injury and tetraplegia were significant risk factors for PI during the acute rehabilitation period [7], while Grigorian et al. found that a higher SCI level was associated with increased risk for PI as compared with the lower level [10]. The actual number of individuals with SCI and PIs in Norway is unknown; moreover, we do not know if the risk factors for PIs in the Norwegian population correspond to risk factors reported in other studies [2–5]. Therefore, a research program (NORSCIPI) at all three spinal cord units in Norway (NSCUs) was conducted to identify characteristics associated with PI development in the hospitalized population of persons with acute SCI [11]. The first study of this research program aims to investigate the prevalence of PI in the population, and further to investigate potential risk factors and associations for PI in these individuals from admission to and discharge from the NSCU [11].

Methods

Setting and population

All individuals acquiring either a traumatic SCI (TSCI) or nontraumatic SCI (NTSCI) during 2004–2014 and admitted to one of the three specialized NSCUs for acute rehabilitation after the injury, were included in the study. The acute rehabilitation period is defined as the continuous time period from admittance to the NSCU and to final discharge from the hospital. The electronic medical record (EMR), at each of the three NSCUs, was used to identify individuals and retrieve data. The system of care for persons with SCI in Norway has been described in a recent publication [12]. Because of the strict legislation regarding privacy, and the data collecting permission from the Ethical Committee [13–16], available information from the acute care hospitals is dependent on the information given in the transfer letters from the acute care hospitals to the NSCUs. These transfer letters do not include any information regarding the time from injury to the arrival at the acute care hospitals, neither any information regarding immobilization during transfer, mode of transport, or use of pressure-relieving devices or interventions.

Study design

We conducted a national, retrospective, cross-sectional study, with the aim to estimate the period prevalence of PI, and investigate potential risk factors for PI during the period between admission to and discharge from the acute rehabilitation. Available information from the EMR at the NSCUs was evaluated to retrieve potential risk factors.

Study variables

Study variables were recorded as "yes" if present, "no" if not present, and "unknown" if the information was missing. The term "PI" was used to describe pressure ulcers/wounds, according to the newest recommendations [1].

The International Standards for Neurological Classification of SCI (ISNCSCI) was used, including the clinical findings standardized by the American Spinal Injury Association Impairment Scale (AIS) [17]. Relevant information recorded from the EMR at the NSCUs were gender (male/female), date of birth, date of injury, marital status (single and living alone, single but living with parents/children, cohabitant, partner/married, divorced, widow/widower, and unknown), level of education (primary school, high school, college/university, and unknown) occupational status (full time, part time, social welfare benefits, retired, and unknown), etiology of the injury (traumatic and nontraumatic), neurological level of the injury (cervical, thoracic–sacral, and cauda equina), and any associated injury (brain injury and multitrauma). A complete examination of the skin was recorded within the first few weeks after the admission to the NSCU. Occurrence of PI, as well as use of alcohol and tobacco, and all abuse of drugs and SCI-associated problems, such as incontinence and ventilator dependence, in conjunction with premorbid comorbidities, such as hypertension, cardiac disease, diabetes mellitus (DM), clinically diagnosed depression, allergy, and skin disease, were recorded from information in the EMR. In addition, attention deficit/hyperactivity disorder (ADHD/ADD), which was previously not evaluated as a potential risk factor for PIs, was recorded if diagnosed before admittance to the NSCUs, and recorded in the EMR. The EMR

documentation used in this study does not specify any diagnostic tools regarding depression or ADHD/ADD; the variables recorded were "yes," "no," or "missing," depending on the information given in the EMR.

Data collection

A selection of 84 EMR diagnoses was scrutinized for SCI, and only individuals with acquired traumatic or non-traumatic SCI between January 1st 2004 and January 1st 2014 were included. Based on data obtained from the EMR, neurological level of injury and the AIS were examined and recorded during the first 3 weeks after admission to the NSCUs [12]. In some cases, the degree of impairment was not registered, but the EMR described the sensory and motor grade and level, as well as the sphincter tonus. In these cases, the impairment was graded by the first author (II) in accordance with the ISNCSCI [17–19].

Ethics

The Norwegian Data and Telecommunications Authority's requirements for safe information flow were followed [14]. The study was approved by the National Regional Ethical Committee (2014/684/REK-Nord) [15, 16].

Statistical analyses

Potential risk factors diagnosed before the occurrence of the PI were included in the analyses. Continuous variables are presented as mean with standard deviation (SD). Categorical variables are presented as counts and percentages.

The categorization of age into age groups is performed, according to the newest recommendations [17, 18].

Participants' demographics and injury characteristics are analyzed descriptively. The term "period prevalence" refers to the 10-year period between 2004 and 2014. To identify factors associated with PI occurrence, potential risk factors were entered into a binary, logistic regression model. Crude and adjusted (for gender and age) odds ratios (ORs) were calculated along with 95% confidence intervals (CIs). p values less than 0.05 were considered significant. The common confounding variables age and gender were adjusted for in the analyses. The adjusted results will be reported and discussed in the paper. As a sensitivity analysis, we also performed logistic regressions where missing values on the PI variable were taken as "no PI." Our reasoning was that if there was no PI during acute rehabilitation, PI would not be mentioned in the EMR.

IBM SPSS Statistics, version 23, was used for all statistical analyses.

Table 1 Demographics.

	N	Percentage
Total	1012	100
Gender		
Male	742	73
Female	270	27
Mean age		
At injury	48, 26 years (min. 0.47–max. 88.48), SD 19.18	
At admission acute rehabilitation	48, 46 years (min. 0.97–max. 88.50), SD 19.16	
Age grouping at admission to the NSCU		
0–14	14	1.4
15–29	201	20
30–44	208	21
45–59	239	24
60–74	273	27
75+	64	6.4
Geographical site of injury		
Norway	959	95
Outside Norway	53	5.2
Drugs/alcohol use at the time of injury		
Yes	110	11
No	715	71
Unknown	182	18
TSCI	639	63
NTSCI	372	37
Level of injury at admission		
C1–C4	224	22
C5–C8	222	22
T1–S3	566	56
Cauda equina	86	8.5
AIS at admission		
A	258	26
B	58	5.7
C	298	30
D	385	38
Unknown	12	1.2
Pressure injury		
No	747/891	84
Yes	144/891	16

SD standard deviation, *min.* minimum, *max.* maximum.

Results

Description of the population

After reviewing data from 1488 EMRs at the three NSCUs, 1012 individuals, 742 men (73%), and 270 women (27%) were included in the study. Demographics are presented in Table 1.

Period prevalence and location of the pressure injuries

We had information about PI in 891 of the individuals, and the period prevalence of PI in the studied population was

144/891 (16%, 95% CI = 0.14–0.19). We found that 61% of the population with a known number of PIs had a single PI (86/142 individuals), while 39% (56/142 individuals) had two or more.

The total number of PIs recorded from the EMR were 373. Most of the PIs were located at the coccyx (33%) (Fig. 1).

Factors associated with pressure injury development, classified by categories

A detailed overview of factors associated with PI in our population is provided in Table 2.

Gender

Men had an overall period prevalence of PIs of 19% (95% CI = 0.16–0.22), compared to 9.0% (95% CI = 0.05–0.13) among women.

Age

The mean age at injury was 48 years, SD 19 (minimum 0.47 years–maximum 88 years). The age group of 45–59 years had significantly decreased odds of PI (OR = 0.5, 95% CI = 0.3–0.9) compared with the reference group (15–29 years).

Marital status, education, and occupational activity

We did not find any significant variation in the occurrence of PI concerning marital status, level of education, or occupational activity at the time of injury.

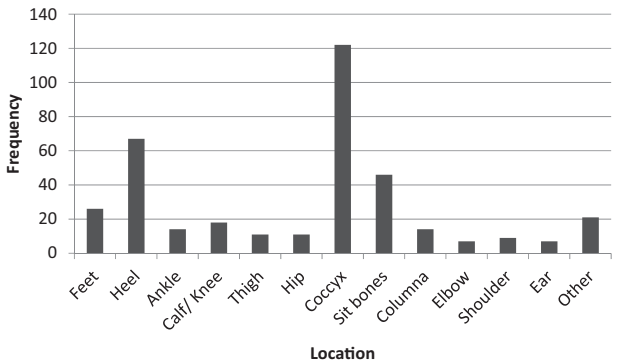

Fig. 1 Location and frequency of the PIs in the studied population. Most of the PIS were located at the seat ($n = 168$, hereof the coccyx $n = 122$ and the sit bones $n = 46$), and heels ($n = 67$). The feet ($n = 26$), ankle ($n = 14$), calf/ knee ($n = 18$), thigh ($n = 11$), hip ($n = 11$), column ($n = 14$), elbow ($n = 7$), shoulder ($n = 9$), ear ($n = 7$). The group other ($n = 21$) consists of PI at the chest/ abdomen ($n = 3$), face/ nose ($n = 2$), occipital ($n = 2$), neck ($n = 2$), penis ($n = 4$) and unknown location ($n = 8$).

Cause and severity of the spinal cord injury at admission

The occurrence of PI was higher among those who were injured outside Norway.

There was no significant difference in the occurrence of PI, based on having a traumatic or nontraumatic injury, or based upon the neurological level.

Individuals with AIS D had a 90% decreased odds of PI, compared to individuals with AIS A (OR = 0.1, 95% CI = 0.1–0.2, $p < 0.001$). The decrease in odds of PI for individuals with AIS C was 70%, compared to individuals with AIS A (OR = 0.3, 95% CI = 0.2–0.5, $p < 0.001$). A test for trend in the AIS categories showed a significantly decreasing trend ($p < 0.001$) (Fig. 2).

Spinal cord injury sequelae

A significantly higher occurrence of PIs was observed among individuals with bladder and bowel dysfunction related to the SCI, compared to no dysfunction. A corresponding pattern was found regarding the need for ventilator support before or at admission to the NSCUs. The occurrence of multitrauma together with the SCI did not associate with the occurrence of PI; however, having a concomitant traumatic brain injury did.

Comorbidity, acquired prior to the spinal cord injury

For patients diagnosed with diabetes mellitus type 1 (DM1) ahead of the SCI, there was approximately an eight-time increased odds of PI, compared with individuals with no DM1 diagnosis (OR = 7.9, 95% CI = 2.4–26, $p = 0.001$); however, we did not find any increased PI occurrence for DM2. Other comorbidities, such as hypertension (OR = 3.7, 95% CI = 2.3–5.9, $p < 0.001$) and cardiovascular disease (OR = 3.6, 95% CI = 2.3–5.9, $p < 0.001$) also significantly increased the odds of PI.

Clinically diagnosed depression was present in 285 (28%) of the total population during the acute rehabilitation, and there was a higher PI occurrence in those with depression, than in those without. ADHD/ADD diagnosed before the SCI did not show any association with PI occurrence.

Stimulants

Abuse of illegal or prescribed drugs before the SCI and registered in the EMR seemed to be associated with an increased occurrence of PI (OR = 3.0, 95% CI = 1.5–6.9, $p = 0.002$), while being under the influence of alcohol or drugs at the time of the injury (20% of the population) did

Table 2 Pressure injury associations.

	n PI/n subgroup	PI percentage	Crude values			Adjusted (gender and age) values		
			OR	95% CI	*p* value	OR	95% CI	*p* value
Gender								
Male	123/654	19	1.0			1.0		
Female	21/237	9.0	0.4	0.3–0.7	0.001	0.4	0.3–0.7	**0.001**
Age at injury								
0–14	1/15	6.7	0.3	0.04–2.1	0.22	0.3	0.04–2.2	0.22
15–29	39/188	21	1.0			1.0		
30–44	31/189	16	0.8	0.4–1.3	0.23	0.7	0.4–1.3	0.28
45–59	26/210	12	0.5	0.3–0.9	0.03	0.5	0.3–0.9	**0.03**
60–74	35/240	15	0.7	0.4–1.1	0.10	0.7	0.4–1.1	0.14
75+	12/49	25	1.2	0.6–2.6	0.62	1.4	0.7–2.9	0.40
Geographical location at the time of injury								
Norway	130/847	15	1.0			1.0		
Abroad	14/44	32	2.6	1.3–5.0	0.005	2.4	1.3–4.8	**0.009**
Marital status at injury								
Single, living alone	37/193	19	1.0			1.0		
Single, not living alone[a]	27/136	20	1.0	0.6–1.8	0.9	1.1	0.6–1.9	0.76
Cohabitant	23/135	17	0.9	0.5–1.5	0.62	0.9	0.5–1.6	0.69
Married/partner	48/372	13	0.6	0.4–1.0	0.049	0.61	0.4–1.0	0.068
Divorced	4/19	21	1.1	0.4–3.6	0.84	1.2	0.4–3.8	0.78
Widow/widower	2/12	17	0.8	0.2–4.0	0.83	1.1	0.2–5.5	0.94
Unknown	3/24	13						
Educational level at injury								
Not finished primary school	6/26	233	1.7	0.6–4.6	0.30	1.8	0.6–5.2	0.31
Primary school	36/242	15	1.0	0.6–1.7	0.97	1.0	0.6–1.7	0.96
High school	33/234	14	0.9	0.5–1.6	0.77	0.9	0.5–1.6	0.76
College/university	29/193	15	1.0			1.0		
Unknown	40/194	21						
Occupational activity at injury								
Full-time work	49/329	15	1.0			1.0		
Part-time work	4/62	6.5	0.4	0.1–1.1	0.084	0.5	0.2–1.3	0.14
No work[b]	70/409	17	1.2	0.8–1.8	0.42	1.3	0.8–1.9	0.26
Unknown	21/90	23						
Cause of injury								
Traumatic	96/567	17	1.0			1.0		
Nontraumatic	48/324	15	0.9	0.6–1.2	0.41	1.0	0.7–1.5	0.95
Neurological level of injury at admission								
C1–C4	25/191	13	0.8	0.5–1.3	0.39	0.8	0.5–1.3	0.32
C5–C8	40/197	20	1.4	0.9–2.1	0.15	1.4	0.9–2.1	0.15
T1–S3	79/503	16	1.0			1.0		
Tetraplegia	65/386	17	1.1	0.8–1.5	0.67	1.1	0.7–1.5	0.74
Paraplegia	78/501	16	1.0			1.0		
AIS at admission[c]								
AIS A	77/233	33	1.0			1.0		
AIS B	14/51	28	0.8	0.4–1.5	0.44	0.8	0.4–1.6	0.54
AIS C	33/263	13	0.3	0.2–0.5	<0.001	0.3	0.2–0.5	**<0.001**
AIS D	18/331	5.4	0.1	0.1–0.2	<0.001	0.1	0.1–0.2	**<0.001**
Unknown	2/13	15						
Cauda equina								
No	140/812	17	1.0			1.0		
Yes	4/79	5.1	0.3	0.1–0.7	0.01	0.3	0.1–0.7	**0.01**
SCI-associated problems diagnosed before the PI occurence								
Bladder dysfunction								
No	5/194	2.6	1.0			1.0		

Table 2 (continued)

	n PI/n subgroup	PI percentage	Crude values			Adjusted (gender and age) values		
			OR	95% CI	*p* value	OR	95% CI	*p* value
Yes	136/676	20	9.5	3.8–24	<0.001	9.2	3.7–23	**<0.001**
Unknown	3/20	15						
Bowel dysfunction								
No	5/239	2.1	1.0			1.0		
Yes	136/623	22	13	5.0–33	<0.001	13	5.3–33	**<0.001**
Ventilator support								
No	128/848	15	1.0			1.0		
Yes	15/41	37	3.2	1.7–6.3	<0.001	3.0	1.6–5.9	**0.001**
Premorbid comorbidity								
Multitrauma								
No	85/611	14	1.0			1.0		
Yes	50/259	19	1.5	1.0–2.2	0.045	1.4	0.9–2.1	0.14
Unknown	9/21	43						
Brain injury[d]								
No	106/746	14	1.0			1.0		
Yes	29/126	23	1.8	1.1–2.9	0.01	1.7	1.1–2.8	**0.021**
Unknown	9/19	47						
Diabetes mellitus								
No	111/774	14	1.0			1.0		
Diabetes mellitus 1	7/12	58	8.4	2.6–27	<0.001	7.9	2.4–26	**0.001**
Diabetes mellitus 2	12/56	21	1.6	0.8–3.2	0.15	1.6	0.8–3.2	0.19
Unknown	13/47	28						
ADHD/ADD								
No	129/848	15	1.0			1.0		
Yes	4/13	31	2.5	0.8–8.2	0.14	2.7	0.8–9.1	0.11
Unknown	11/30	37						
Cardiovascular disease								
No	78/653	12	1.0			1.0		
Yes	51/192	27	2.7	1.8–4.0	<0.001	3.6	2.3–5.9	**<0.001**
Unknown	15/46	33						
Hypertension								
No	78/653	12	1.0			1.0		
Yes	52/193	27	2.7	1.8–4.0	<0.001	3.7	2.3–5.9	**<0.001**
Unknown	14/45	31						
Depression								
No	47/492	9.6	1.0			1.0		
Yes	67/251	27	3.4	2.3–5.2	<0.001	3.8	2.5–5.8	**<0.001**
Unknown	30/147	20						
Allergy/eczema[e]								
No	94/613	15	1.0			1.0		
Allergy	30/188	16	1.0	0.7–1.6	0.84	1.2	0.8–1.9	0.44
Exema	20/90	22	1.6	0.9–2.7	0.1	1.5	0.9–2.7	0.13
Stimulants								
Alcohol/drug use at the time of injury								
No	91/632	14	1.0			1.0		
Yes	19/97	20	1.4	0.8–2.5	0.19	1.3	0.8–2.3	0.33
Unknown	33/159	21						
Regular use								
Tobacco								
No	47/356	13	1.0			1.0		
Yes	35/197	18	1.4	0.9–2.3	0.15	1.4	0.8–2.2	0.22
Unknown	62/338	18						
Snuff								
No	29/229	13	1.0			1.0		

Table 2 (continued)

	n PI/n subgroup	PI percentage	Crude values			Adjusted (gender and age) values		
			OR	95% CI	*p* value	OR	95% CI	*p* value
Yes	8/32	25	2.3	0.9–5.6	0.07	2.2	0.9–5.6	0.09
Unknown	107/630	17						
Alcohol								
No	13/141	9.2	1.0			1.0		
Yes	60/365	16	1.9	1.0–3.7	0.041	1.8	0.9–3.4	0.07
Unknown	71/385	18						
Drug abuse (illegal and prescribed)								
No	26/216	12	1.0			1.0		
Yes	19/64	30	3.1	1.6–6.1	0.001	3.0	1.5–6.0	**0.002**
Unknown	99/610	16						

The values in bold show variables with significant associations with PI.

OR odds ratio, *CI* confidence interval.

[a]The "Single, not living alone" subgroup consists of persons living with their parents and kids, in a collective, etc.

[b]The "No work" group consists of people on sick leave, retirement, disability benefits, unemployment benefits, and other social welfare benefits.

[c]AIS American Spinal Injury Association Impairment Scale, AIS A motor/sensory complete, AIS B motor complete/sensory incomplete, AIS C and D motor/sensory incomplete, AIS E normal examination.

[d]Brain injury consists of all kinds of injury affecting the brain function, including concussion.

[e]The "Allergy/skin disease" group consists of all kinds of allergy, eczema, and skin diseases.

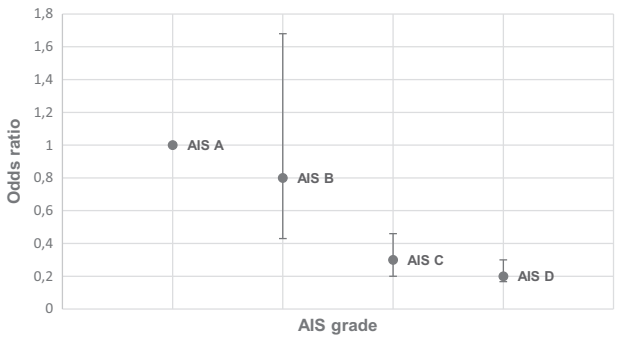

Fig. 2 The trend between the AIS grade and the PI risk in the studied population. The figure shows estimated odds ratios with corresponding 95% CI for AIS grades B, C and D compared to the reference grade AIS A.

not. Regular use of tobacco and alcohol did not show any significant increase in the risk of PI.

Discussion

NORSCIPI is the first national study of PI in the SCI population in Norway. Our study population was representative and comparable with previous studies in Norway [20, 21]. An important finding in our study was the association between psychological impairments and the risk of PI, which is in accordance with previous studies [2, 22].

It should be noted that no standardized instrument to assess depression was applied in this study, since we build on information retrieved from the EMR. There is some ambiguity in the recorded depression diagnoses; however, we refer to it as depression, based on clinical evaluation.

We found that the level of injury was insignificant regarding the risk of having a PI, while individuals with AIS A and B were more at risk of having a PI, compared with AIS C and D. Previous findings are inconsistent when it comes to the association between the degree of impairment, evaluated by the AIS grade and PI [23–26]. However, our results are in accordance with previous studies, where the completeness of the injury determines the risk of having a PI [2, 7, 23, 24]. In our study, the occurrence of PI was 16%, which is lower than previous studies [6, 27, 28], and lower than the occurrence of PI in the general inpatient population in both Norway and other comparable countries [6–9, 27–30]. Mawson et al. postulated that the most likely time for the development of PI is the immediate postinjury period of spinal shock, and that some of the PIs appearing during acute care may be the visible result of ischemic injuries occurring prior to acute admission [26]. Unfortunately, we could not obtain documentation on how patients were immobilized during transfer to the acute care hospitals or the NSCUs, the mode of transport, transfer surfaces used, or whether pressure-relieving devices or interventions were utilized during transportation and hospitalization [28]. In our study, 5% of the population were injured abroad, and the occurrence of PI among them was significantly higher, compared with those injured in Norway. We believe that delay in admittance to the NSCUs might explain the findings of the increased occurrence of PI in those injured abroad. Because of strict Norwegian guidelines, regarding the prevention of multiresistant bacteria, patients injured

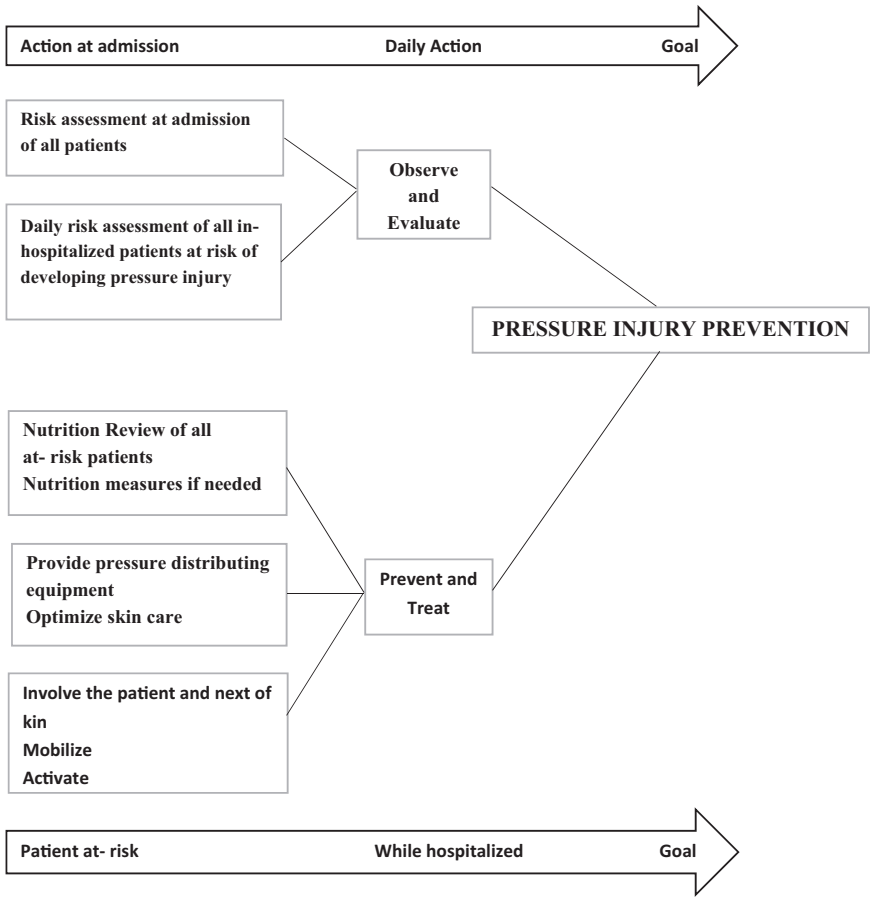

Fig. 3 Suggested action plan for prevention of PI. This should start with a risk assessment of each patient at admission to the spinal cord unit, followed by daily observation and re- evaluation of the risk. The patients, together with their families should be included in all parts of the prevention and treatment at all stages of the rehabilitation stay. Nutrition review and nutrition measures should be provided to all hospitalized at- risk patients, together with pressure distributing equipment and optimal skin care.

abroad are isolated at home or at the local hospital, and not admitted to the NSCUs until their infection status is clarified [31]. PI-preventing routines for the transportation, in-hospital preventing care at both the acute care wards, and the NSCUs are important issues in the future PI-preventing recommendations. Knowledge about PI prevention should be a part of the education and training for all staff members, as well as newly injured individuals, and their relatives [32]. The Norwegian "In safe hands" program (https://www.pasientsikkerhetsprogrammet.no/om-oss/innsatsomr%C3%A5der/_attachment/3304?_download=false&_ts=14e26104012) could be implemented as a simple way to identify patients at risk of developing PI, by asking three questions for risk assessment immediately after admittance to hospital:

(1) Does the patient have PI now?
(2) Does the patient need assistance in position changing?
(3) Is the patient at risk of developing PI during the hospitalization?

If the answer to any of these questions is "yes," an action plan should be initiated, with the aim to prevent the occurrence of any PI, or to treat an already-existing PI. The flowchart in Fig. 3. provides a visual overview of the action plan and recommended measures to achieve the "No PI" goal (Fig. 3). Checklists should be used to record this information in the EMR.

In NORSCIPI, the occurrence of PI was more than double among men, compared with women. The association between gender and PI has been studied with mixed results in previous studies [24, 26, 33]. We speculate that individuals with risk-taking behavior may continue this behavior into rehabilitation, and if there is more risk-taking behavior in the male population in our study, they may be more vulnerable to PI? This question requires further investigation. Another possibility is the difference in fat distribution in women versus men, as women often have increased adipose tissue at the buttocks and thighs, two areas that are especially vulnerable to PI [34]. Even if the cause for the gender difference is not sufficiently explored, it highlights the need for repeated information about prevention actions in vulnerable individuals, and that staff planning the rehabilitation are assessing each patient's risk for PI individually.

It is known that aging causes reduction of the microvascularization and of the proliferative activity of the dermis, as well as changes in the elasticity of the skin,

enhancing the effect of local pressure and stretch on the skin, and thus increasing the risk of PI [28]. Nevertheless, previous studies show contradictory results concerning the association between age and PI [23, 24, 26]. In the present study, the age group of 45–59 years actually had a 50% reduced odds of PI compared with the reference group (15–29 years). An analysis regarding differences in the age groups identified a higher occurrence of depression and AIS grades A–B in the age group of 15–29 years, and we believe that these were the reasons for the increased PI odds. These findings reinforce the need to focus on particularly at-risk individuals, or subgroups, during rehabilitation.

We did not find any association between the occurrence of PI and level of education or occupational activity. The social welfare system in Norway gives everyone the same opportunity for health care, regardless of education, occupation, or income [35], and this may influence the results in our study, compared with other reports [2, 23, 24].

Our findings reiterate that risk factors, such as incontinence, lack of sensation, ventilation support, hypertension and cardiovascular disease increase the odds of PI [2, 3, 5, 28, 36, 37].

Patients with DM1 showed a higher occurrence of PI, with an OR close to 8. Although we cannot claim a causal association, PI-preventing actions regarding persons with DM1 who are acquiring a SCI, should be in focus at all terms of postinjury care and follow-up. In contrast to previous research [2, 27, 28], we did not find an association for PI and DM2. There is limited information about the differences in the risk of PI in DM1 compared with DM2, and neuropathic abnormalities, together with poor circulation and immune function changes, each contributing to vulnerable alteration in the tissue among individuals with DM1 and DM2 [38]. One study found that independent risk factors include renal insufficiency [39]. About 30% of individuals with DM1 (juvenile onset), and 10–40% of those with DM2 (adult onset), eventually will suffer from kidney failure [40]. We speculate that renal insufficiency contributed to the differences in the association between DM and PI in our population; however, the population with DM1 in NORSCIPI only consisted of 13 individuals, with a mean age of 42 years, while there were 68 individuals with a mean age of 62 years with DM2. Thus, with this small population, further research is warranted.

Surprisingly, we did not find any association between the use of tobacco or alcohol and PI, while abuse of drugs seems to be associated with PI development. Thus, our findings do not support findings in previous studies related to the use of tobacco or alcohol [41]; however, uncertainty in the number of reported users in the investigated population may partially explain our results.

Study limitations

There are a number of limitations in our study related to the clinical care of patients with SCI in Norway. Individuals with SCI not admitted to one of the NSCUs post injury due to the limited need for third-line rehabilitation, or comorbidity are not included in the study. Clinical transfer protocols for individuals with newly acquired TSCI as compared with NTSCI are well known in Norway [12], but acute rehabilitation after NTSCI is less well defined. Thus, our NTSCI sample does not include all affected individuals, in contrast to our TSCI sample. Finally, we would optimally have divided the time between injury through acute rehabilitation into two separate periods: accident to acute rehabilitation transfer, and the acute rehabilitation period. Unfortunately, this was not possible to do, given the available information in the EMRs, and this is a limitation in our study.

Because of variable reporting in the EMR, there was missing information about PI in 121 of the individuals. This may reduce the statistical power of the results [42]; however, clinical experience indicates that if there is no information about PIs in the EMR, there is generally not a PI problem. Moreover, performing a logistic regression, by setting the missing PI to "No PI," did not change the (significance of the) results.

Information about drug abuse at the time of the injury is retrieved from available information in the transfer letter from the acute care hospital. Any missing information in this document will also be missing in the study. The lack of recorded information in the EMR regarding those who use tobacco, alcohol, and/or illegal drugs, and those who do not, results in missing data, and is another limitation of our study.

We have investigated a high number of potential risk factors. Thus, it was infeasible to develop causal models for all of them, and to adjust for all confounding factors. Hence, the identified associations should be taken as indications, worthy of further investigations to clarify casual relationships. We have also performed a high number of statistical significance tests, increasing the risk of type I errors [43]; however, most of our significant findings seem clear and robust; thus, we feel quite confident about our conclusions.

Conclusion

NORSCIPI has a unique design, because variables are recorded over a 10-year period, and data are retrieved from the EMR. The results are unique because they represent the national status of PI in the entire SCI population of Norway. We identified several factors, including DM1 and depression that may be worthy of further research to clarify their

role in the causal path to PI. We give recommendations for a simple program on observation and prevention of PIs for health care providers, patients, and next of kin. An increased understanding of factors that associate with PI will allow providers to focus on patients at particular risk. Checklists on factors associated with the occurrence of PI, as well as checklists and better focus on PI prevention should be a part of the acute care SCI rehabilitation. For better outcomes, further research should focus on PI prevention routines and actions during the acute post-injury rehabilitation.

Data availability

The data set is stored in a locked and fireproof research cabinet at the research department, Sunnaas Rehabilitation Hospital, Norway, and can be made available on request, according to the Norwegian Data and Telecommunications Authority's requirements for safe information flow [14].

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Author contributions II is a medical doctor (MD) at Sunnaas Rehabilitation Hospital, and a PhD fellow at the University of Oslo. She is the main investigator of the study, and the only investigator with access to the complete data set collected in the study. She is also the main contributor in the writing of the paper. TR is the main supervisor. TR and II were responsible for the design of the study. JKS is the research director at Sunnaas Rehabilitation Hospital, and the project manager. JMH and RJ are co-supervisors in the project. MA is a collaborator in the project. MT is a statistician, guiding in the statistical design of the study and analyses of the results. JKS, TR, JMH, RJ, MA, and MT all contributed to the draft of this paper. All authors read and approved the final paper before submission.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The research project was carried out in accordance with current ethical guidelines and privacy rights for health services in Norway [14], based on the Code of Ethics of the World Medical Association (Declaration of Helsinki) [44] for experiments involving humans. The research project was approved by the Norwegian Regional Ethical Committee (REC) on January 9th 2015 (2014/684 REK-Nord) [15], and registered in Clinical Trials.gov in May 2016 (NCT02800915).

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