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Smoking and musculoskeletal disorders in the metal industry: a prospective study

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Abstract

***Objectives*—To obtain longitudinal information of the relation between smoking and musculoskeletal disorders in an industrial setting.**

***Methods*—The associations of lifetime tobacco exposure (pack-years), current smoking status, and stopping smoking with back and limb disorders were studied in a cohort of white collar and blue collar employees in a metal industry. Measurements were made three times at 5 year intervals. Two thirds of an initial sample of 902 took part in both re-examinations. Musculoskeletal morbidity was measured as the abundance of symptoms during the past year and as clinical findings assessed by a physiotherapist (upper decile score/score difference=index category). Logistic regression and a generalised estimating equation were used, allowing for sociodemographic variables, physical workload, body mass index, exercise activity, and mental distress.**

***Results*—By comparison with never smokers, exposure of 10–<20 pack-years, the odds ratio (OR) (95% confidence interval (95% CI) of the 10 year change in neck-shoulder symptoms was 3.1 (1.4 to 6.8), in low back symptoms 2.4 (1.1 to 5.1), in upper limb symptoms 1.9 (NS), and in lower limb symptoms 3.4 (1.5 to 7.8). The highest exposure category of ⩾20 pack-years was associated with the change in upper limb findings 2.9 (1.4 to 6.2) and lower limb findings 2.9 (1.2 to 7.2). Those who continued to smoke through the follow up period had a higher increase in clinical findings 2.5 (1.1 to 5.9) than never smokers. There was a dose-response in the association of smoking intensity with future musculoskeletal symptoms. Also, those who stopped smoking during the follow up had a higher increase in symptoms 4.4 (2.0 to 9.9) and findings 3.5 (1.4 to 8.8) than never smokers.**

***Conclusion*—Smoking seems to predict the development in the occurrence of musculoskeletal symptoms and signs. Stopping smoking is associated with high morbidity.**

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Keywords: smoking; low back pain; musculoskeletal disorders

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Both smoking and musculoskeletal disorders are common in industry. Evidence has accumulated of a relation between the two: studies of the association of smoking with low back pain have been reviewed by Battié *et al*[1] and Boshuizen *et al*,[2] and further reported in several recent studies.[3–10] Associations of neck pain[11–13] and shoulder pain[14] with smoking have also been found.

A relation between smoking and back pain, if causal, would create possibilities for preventive measures and provide fresh motivation for campaigns in occupational health to stop smoking. However, controversy as to the nature of the relation exists,[15 16] and confounding of the results by physical workload, mental stress, and other components of lifestyle or socioeconomic factors has been suspected.[2 10]

In longitudinal studies results vary. Smoking was predictive of the first time occurrence of back pain in a 1 year follow up of a sample of the general population,[17] of admission to hospital for herniated intervertebral disc in Finnish men,[18] of back injury claims during a 4 year follow up in industrial workers,[19] of the 3 year incidence of sciatica in two male manual occupational groups,[5] and of sciatica in formerly non-symptomatic farmers.[7] In some studies no association between smoking and the incidence of back pain[3 20 21] or sciatica[22] was found, and one study reported an inverse association between smoking and the 1 year incidence of back pain.[23] Similarly, neck pain has been reported both to be[24] and not to be[25] associated with smoking in prospective studies.

The possibility that smoking would be associated with painful musculoskeletal syndromes other than those of the back has received little attention. However, there was a relation between smoking and pain in the limbs as well as pain at several sites in a survey of the general population in Norway, when other lifestyle factors, mental distress, and some occupational factors were taken into account.[10] The association of smoking with pain in the limbs was more pronounced than that with back pain in data from an occupational health service in The Netherlands.[2] In a prospective study of paper industry employees[26] smoking predicted the incidence of pain in the upper limbs.

To obtain longitudinal information on the relation between smoking and musculoskeletal disorders—including both clinical findings and symptoms in the upper and lower limbs, neck, and low back—we studied a cohort of metal industry employees followed up for 10 years. We tried to take the possible confounding effects of occupational class, physical workload, mental distress, and other lifestyle factors, into account.

Material and methods

DATA COLLECTION

The study sample was drawn from the employees of the Valmet factories in Jyväskylä, central Finland. Paper machines, tractors, guns, gauges, etc, were manufactured in the plants, and work tasks varied from foundry work and heavy engineering to precision engineering and clerical and administrative work.

Data were gathered in 1973, 1978, and 1983 by questionnaire (missing data completed in interviews), interviews, and clinical examinations.[27] The study population included those who had been employed by Valmet for at least 15 months at the beginning of the study (n=2653). A systematic equal spaced non-proportional sampling (n=902) was made by strata according to sex, age (three groups: born in or before 1925, 1926–45, and 1946 or later) and occupational class (four groups: managers, other office staff, skilled workers, semiskilled workers). For the present analyses managers and office staff were pooled (white collar employees), and so were skilled and semiskilled workers (blue collar employees).

Forty two subjects died during the 10 year follow up. Six hundred and fifty four subjects (76.0% of those alive) took part in the 10 year follow up examination. There were 607 people (70.6%) for whom the total set of data from three examinations was available. At the first follow up, 80% of the participants were employed by Valmet and 10% had retired from work. At the end of the data collection a quarter of the cohort had retired, another quarter had changed employer, and the rest were still employed by Valmet. Those lost to follow up are discussed later.

SMOKING

At each examination, the subjects were asked: "Have you ever smoked regularly during your lifetime? (yes/no)", "For how many years have you smoked regularly (almost every day for at least a year)?", "Do you smoke regularly at present? (yes/no)" and "How many cigarettes/cigars/pipefuls a day on average do you regularly smoke (or smoked before you stopped)?".

The data on the different modes of tobacco consumption were summed and the daily number of cigars and pipefuls were weighted according to their mean nicotine concentration. Smoking intensity was calculated as:

(cigarettes+2.5×pipefuls+4×cigars)/20.

Pack-years were calculated as regular smoking time (years)×intensity, and categorised as 1=never smokers (until baseline), 2=<10 pack-years, 3=10–<20.00 pack-years, 4=⩾20.00 pack-years.

When studying associations between stopping smoking and morbidity, the categorisation of smoking was as follows: 1=never smokers (until the 10 year follow up), 2=stopped before baseline, 3=stopped during follow up, 4=current smoker both at baseline and at follow up.

OTHER COVARIATES

Body mass index (BMI) and exercise activity

The questionnaire included a 29 item check list of leisure time physical exercise during the past year. In an interview, the frequency, duration, and intensity of each type of exercise was coded, as were deviances from routine. Estimates of mean energy expenditure for each behaviour were obtained from publications. A detailed description of the method is given elsewhere.[27] An index of exercise activity was constructed as Σ (time x energy expenditure). In the generalised estimating equation (GEE) analyses (see later) a classification into tertiles was used: 1=<500, 2=500–999, 3=⩾1000.

The BMI (kg/m^2) was based on measured weight and self reported height and categorised for the GEE analyses into tertiles as follows: 1=<23, 2=23–<26, 3=⩾26.

Physical workload

The questionnaire item "What is your work like?" described the following grades of physical strenuousness: 1=sedentary work (sitting at a table or by a machine while doing light work with the hands), 2=light work (standing without strenuous work movements; sitting while doing strenuous work with the hands; moving about without heavy loads), 3=work of medium strenuousness (constant light work movements such as light lifting or turning of handles or levers; constant standing or walking; alternating between sitting and heavy work), 4=heavy physical work (almost constant heavy work such as hammering, forging, loading, wheeling, etc). In the analyses, classes 3 and 4 were pooled together.

Stress symptoms

The questionnaire included the question "Have you had some of the following symptoms and how often during the past year?" with a list of the following items: heartburn or acid troubles, loss of appetite, nausea or vomiting, abdominal pains, diarrhoea, sleeping difficulties, nightmares, headache, sexual unwillingness, dizziness, tachycardia or irregular heartbeats, tremor of the hands, excessive perspiration without physical effort, dyspnoea without physical effort, lack of energy, fatigue or feebleness, anxiety or nervousness, irritability, or fits of anger. The scoring was from 1 (seldom or never) to 4 (often or continuously). The items were summed to form a stress symptoms score (a measure of internal consistency, Cronbach's α=0.84 at baseline). In the GEE analyses, the score was categorised into tertiles: 1=⩽23, 2=24–28, 3=⩾29.

MUSCULOSKELETAL MORBIDITY

Symptoms

The questionnaire asked: "Have you felt ache, stiffness, sensitivity to movement, numbness, or pain in joints or muscles in the places listed below, and how often, during the past 12 months?" The list included: (*a*) shoulder, upper arm, (*b*) elbow, forearm, (*c*) wrist, hand, fingers, (*d*) hip joint, (*e*) thigh, (*f*) knee, (*g*) calf, (*h*) ankle, foot, (*i*) sole, or toes, (*j*) neck, cervical, and occipital region, (*k*) radiation of cervical pain to the arm, (*l*) thoracic region, (*m*) lumbosacral region, (*n*) radiation of lumbosacral pain to the leg. Each item was scored from 1 (never) to 4 (often or continuously). Right and left side were scored separately.

The musculoskeletal symptoms score is the sum of all items. Low back symptoms were the sum of the last two items in the list, the neck-shoulder symptoms the sum of the items a, j, and k, the upper limb symptoms that of the items b and c, and the lower limb symptoms the sum of the items d–i.

Clinical findings

Two trained physiotherapists performed a clinical examination of the musculoskeletal system. Pains in the joints and muscles were assessed by palpation and restrictions in the movements of joints and the spine mainly in active movement were measured. The guidelines of the American Association of Orthopaedic Surgeons[28] were used as follows: 0=symptomless, 1=pain in the movement of the joint or in palpation, 2=the range of movement restricted by 25% to 50%, 4=restriction by >50%.

In the cervical spine the 4th grade was: restriction by more than 60° plus positive compression or foramen intervertebralis sign, and in the lumbosacral spine: marked inflexibility or neurological signs in the lower limbs (positive Lasegue's or Ely's test). Myalgia in the limbs was scored from 0=no to 2=bilaterally, and myalgia of the trapezius muscle from 0=no to 1=yes.

Twenty one variables were summed to form the total musculoskeletal findings score. The score of the low back was used as the measure of low back findings whereas the neck-shoulder findings score (range 0–5) was the sum of two items: cervical spine and myalgia of the trapezius muscle. The score of the upper limb findings (range 0–19) was the sum of the items (both right and left side): humeroscapular joint, elbow joint, wrist, arthrosis of fingers, myalgia of the upper arm, myalgia of the lower arm, and epicondylitis. The score of the lower limb findings (range 0–16) was the sum of the items (right and left side): hip joint, knee joint, ankle joint, myalgia of the thigh, and myalgia of the calf.[27]

The reliability between observers for the total musculoskeletal findings score was assessed in 1973 in a sample of 54 subjects examined a second time within two weeks from the first examination. The reliablity was r=0.93 in men and 0.77 in women. In 1978 and 1983 54 subjects had a second examination by another physiotherapist directly after the first one. The κ coefficients of some items (in 1978/83) were as follows: 0.70/0.64 (left humeroscapular joint), 0.76/0.61 (cervical spine), 0.79/0.55 (myalgia of the upper arm), and 0.74/0.40 (lumbosacral spine).

Classification of musculoskeletal morbidity scores

Each morbidity score difference (level at the 10 year follow up minus level at baseline) was dichotomised by taking the upper decile of the frequency distribution as the index category. In the GEE analyses, the scores were analogously dichotomised (upper decile at baseline=index category).

LOSS TO FOLLOW UP

Loss to follow up was selective as to smoking: those subjects who did not partake in the 10 year follow up examination had higher lifetime smoking exposure at baseline (mean of pack-years 11.1) than those who took part in it (mean 7.5). Loss to follow up was not associated with the (total) musculoskeletal disorder scores. In men there were no significant differences in age or type of work between those lost to follow up and those who participated; the women that did not take part in the re-examinations were somewhat younger than the participants.[27 29]

Information on the lifetime exposure (pack-years) of smoking was available at baseline for 646 subjects of the 654 that took part in the 10 year follow up. All the necessary data for the analyses in pack-years of smoking were available for 636 of the 646 subjects when studying the 10 year changes in the different musculoskeletal symptoms scores and for 644 when studying the changes in clinical findings.

At the first follow up, the clinical examination by a physiotherapist and measurement of body weight were not made for the youngest age group for economic reasons. This reduces the size of the available material to 445 subjects in the GEE analyses on clinical findings; BMI information was taken from the baseline measurement.

STATISTICAL METHODS

The differences by occupational class and sex in the mean pack-years were studied by two way analysis of variance (ANOVA).

The association of pack-years with the musculoskeletal morbidity indices was studied by multiple logistic regression analysis, with age, sex, occupational class, physical workload, exercise activity, BMI, and stress symptoms as covariates. Logistic regression analyses were also performed on the association between stopping smoking and continuing it with morbidity change during the 10 year follow up.

The relation of the intensity of smoking and these covariates with musculoskeletal disorders at the next examination (5 years apart) was studied by GEE models.[30]

$$\text{logit}\ \mu_{ij} = \mathbf{x}_{i,j\text{-}5}\,\hat{\boldsymbol{\beta}}$$

where μ_{ij} is a marginal mean of outcome variable y_{ij} for subject i in period j, $\mathbf{x}_{i,j-5}$ is a vector of explanatory variables for subject i in period j-5 (in the measurement made 5 years earlier) and $\hat{\boldsymbol{\beta}}$ is a vector of the parameter estimates.

Table 1 Lifetime history of smoking (pack-years) reported at baseline, by sex and occupational class, among those who took part in the 10 year follow up

	White collar			*Blue collar*		
	n	*mean*	*SEM*	*n*	*mean*	*SEM*
Women	118	1.48	0.42	116	2.23	0.42
Men	172	10.08	1.06	240	11.25	1.45

p=0.000 for sex; p=0.163 for occupational class by ANOVA.

Table 2 Association of lifetime history of smoking at baseline (pack-years) with the change in musculoskeletal symptoms and clinical findings during the 10 year follow up

	Change in musculoskeletal symptoms (upper decile=index category)		Change in clinical findings (upper decile=index category)	
	OR*	95% CI	OR*	95% CI
Neck-shoulder:				
1	1.00		1.00	
2	1.80	0.94 to 3.47	0.94	0.60 to 1.47
3	3.07	1.39 to 6.80	1.41	0.80 to 2.48
4	2.60	1.01 to 6.70	1.54	0.84 to 2.84
Upper limb:				
1	1.00		1.00	
2	1.90	1.01 to 3.57	1.17	0.56 to 2.44
3	1.93	0.84 to 4.43	1.15	0.47 to 2.81
4	0.77	0.25 to 2.32	2.89	1.36 to 6.15
Low back:				
1	1.00		1.00	
2	1.57	0.83 to 2.96	1.35	0.69 to 2.65
3	2.35	1.09 to 5.08	1.53	0.70 to 3.35
4	1.55	0.59 to 4.06	1.40	0.64 to 3.04
Lower limb:				
1	1.00		1.00	
2	1.61	0.78 to 3.32	0.99	0.41 to 2.43
3	3.44	1.52 to 7.76	1.31	0.47 to 3.66
4	1.62	0.57 to 4.59	2.94	1.20 to 7.21
Total:†				
1	1.00		1.00	
2	1.74	0.89 to 3.42	1.88	0.83 to 4.29
3	2.82	1.24 to 6.40	2.35	0.93 to 5.92
4	1.13	0.36 to 3.50	3.66	1.57 to 8.54

*As covariates: age, sex, occupational class, physical workload, exercise activity, BMI, and stress symptoms (baseline values).
†Number of subjects by pack-year classes: 1 (318), 2 (161), 3 (79), 4 (87) for all outcome variables in clinical findings; slight variation in the local symptom scores (total n 636–646) for musculoskeletal symptoms.
Logistic regression analysis. Classification of pack-years: 1=none, 2=0.05–<10, 3=10–<20, 4=⩾20.

Table 3 Association of smoking intensity among current smokers with the total musculoskeletal symptoms and clinical finding scores (upper decile at baseline = index category)

	Musculoskeletal symptoms (n of observations=1344)		Musculoskeletal findings (n of observations=1143*)	
	OR	95% CI	OR	95% CI
Never smokers	1.00		1.00	
Current smokers:				
<1 pack/day	0.83	0.49 to 1.42	1.16	0.75 to 1.81
⩾1 pack/day	2.17	1.31 to 3.66	1.29	0.82 to 2.03
Stopped smoking	1.50	0.95 to 2.36	1.51	1.05 to 2.18
Time:				
2nd examination	1.00		1.00	
3rd examination	0.91	0.71 to 1.42	3.26	2.48 to 4.28
Age group:				
1	1.00		1.00	
2	2.60	1.48 to 4.58	2.69	1.75 to 4.13
3	3.60	2.04 to 6.36	9.51	5.88 to 15.38
Sex:				
Women	1.00		1.00	
Men	0.44	0.29 to 0.66	0.85	0.60 to 1.20
Occupational class:				
White collar	1.00		1.00	
Blue collar	2.13	1.28 to 3.54	1.52	1.02 to 2.26
Exercise activity:				
<499	1.00		1.00	
500–999	1.16	0.83 to 1.61	0.87	0.64 to 1.19
>1000	0.72	0.48 to 1.06	0.98	0.71 to 1.36
BMI:				
<23	1.00		1.00	
23–<26	1.27	0.79 to 2.03	1.11	0.77 to 1.61
⩾26	1.64	1.01 to 2.65	1.37	0.94 to 2.01
Physical workload:				
1	1.00		1.00	
2	0.81	0.49 to 1.35	0.95	0.63 to 1.41
3–4	1.11	0.67 to 1.84	1.12	0.72 to 1.73
Stress symptoms:				
<23	1.00		1.00	
23–28	1.76	1.19 to 2.60	1.63	1.18 to 2.24
⩾29	2.79	1.86 to 4.17	2.08	1.48 to 2.91

*Data on musculoskeletal findings in the youngest age group available only for the 3rd examination.
Analysis of a generalised estimating equation with a 5 year time lag between determinant and outcome variables.

The SPSS 7.5 for Windows and the SAS (Genmod)[31] statistical packages were used.

Results

The duration of smoking history differed markedly between women and men. The white collar women had smoked regularly for 2.9 years and the blue collar women for 4.0 years on average at baseline, whereas among men the respective figures were 10.1 and 11.4 years. The mean pack-years of smoking by sex and occupational class are in table 1.

The occurrence of musculoskeletal disorders varied by sex (women with higher levels of morbidity than men) and occupational class (the blue collar with higher morbidity than the white collar employees). Detailed morbidity distributions have been reported elsewhere.[32]

Pack-years of smoking were significantly associated with the change in all musculoskeletal symptom scores during the 10 years of follow up and with the change in the clinical findings scores of the limbs (table 2). When musculoskeletal symptoms were considered, the medium smoking exposure of 10–<20 pack-years gave the highest ORs, whereas the highest ORs relative to clinical findings were seen in the group with the highest tobacco exposure of ⩾20 pack-years.

Among current smokers, the intensity of smoking was associated with musculoskeletal symptoms: the consumption of at least a pack a day carried a higher risk of symptoms measured at the next follow up examination (5 years apart) as compared with the never smokers (OR 2.1, 95% CI 1.3 to 3.6), whereas those consuming <1 pack a day had no increased risk (table 3). Here the time lag of 5 years was essential: when smoking intensity, the other covariates, and morbidity were measured at the same occasion, no significant increase of risk was found. Age, sex, occupational class, BMI, and stress symptoms were also associated with symptoms at the next follow up. No association between the intensity of smoking and musculoskeletal findings in the current smokers was found with a 5 year time lag (table 3). Age, occupational class, and stress symptoms were also associated with clinical findings.

As to the possible effects of changes in smoking exposure, there were only nine people that started to smoke during follow up who had never smoked previously. Thus an analysis of their development of morbidity was not practical. It was possible to study a decrease in smoking exposure. Those who had stopped smoking (before baseline or during follow up) and those current smokers at baseline who continued to smoke until follow up, were compared with the never smokers for the development of morbidity during follow up. It was found that those who stopped smoking during follow up had the most unfavourable change in both symptoms and clinical findings of the musculoskeletal system (table 4; also table 3). Musculoskeletal findings increased more among the continuous smokers than among the never smokers, but no such difference was found in the change in musculoskeletal symptoms.

Table 4 Association of stopping smoking and continuing to smoke with the 10-year change in the total morbidity scores

	Change in musculoskeletal symptoms (upper decile=index category)			Change in clinical findings (upper decile=index category)		
Smoking	*n*	*OR*	*95% CI*	*n*	*OR*	*95% CI*
Never smokers (untill follow up)	318	1.00		317	1.00	
Stopped before baseline	148	1.62	0.74 to 3.53	148	1.80	0.82 to 3.96
Stopped during follow up	61	4.40	1.96 to 9.91	61	3.52	1.41 to 8.82
Continued smoking (untill follow up)	107	0.94	0.38 to 2.34	107	2.51	1.07 to 5.89

Logistic regression analysis.
*As covariates: age, sex, occupational class, physical workload, exercise activity, BMI, and stress symptoms (baseline values).

Discussion

We found associations between lifetime smoking and the 10 year change in musculoskeletal disorders at several anatomical sites, independent of sociodemographic factors, other aspects of health related lifestyle, mental distress, and broad categories of physical workload. Those who were current smokers both at baseline and at follow up developed more clinical musculoskeletal findings than never smokers. We also found a dose-response association between smoking intensity and subsequent musculoskeletal symptoms among current smokers.

Stopping smoking seemed to be associated with high musculoskeletal morbidity: those who had stopped smoking before the baseline measurement and especially those stopping during follow up contracted a higher level of musculoskeletal disorders than never smokers. The association may be understood through tobacco related comorbidity.[33 34] As smoking is an established risk factor of cardiovascular, respiratory, and neoplastic diseases, the smokers probably had received advice to stop because of these.

The data in the present study were mostly based on self reports. The available indicators of musculoskeletal disorders, symptoms and the results of a physiotherapist's examination, were both to some extent subjective. However, the structured clinical examination was an attempt at a more objective way of assessment. Although the duration of lifetime history of smoking and the daily amount of tobacco products consumed probably are subject to errors of estimation, the report of having stopped smoking and present status as a regular smoker *v* non-smoker seem more reliable. The results obtained with different ways of describing smoking exposure compared well with each other.

Loss to follow up was associated with smoking history but not with musculoskeletal morbidity. Thus the results cannot be due to selective participation rates, rather, this kind of selection is liable to dilute associations between smoking and musculoskeletal disorders.

A time latency seemed necessary for the relation to be manifest. Associations between concurrently measured smoking intensity and musculoskeletal disorders were very modest. A smoking history of >10 pack-years was needed for associations between smoking and symptoms, and of >20 pack-years for those with clinical findings to be found.

Interestingly, symptoms were most common in the range of 10–20 pack-years, higher exposure not being significantly associated with symptoms. The occurrence of symptoms could be an incentive to stop smoking and might also be more readily reversible than that of clinical findings. Another possibility is that those who continue smoking the longest are a selected group with lower than average ability to perceive musculoskeletal (or other) symptoms.

An association between smoking and musculoskeletal pain could conceivably arise without any direct effect of smoking on the musculoskeletal system. Nicotine as a psychostimulant or other compounds in the tobacco smoke could have an influence on the perception or report of pain signals. On the other hand, starting to smoke is a decision that only some people make. In our opinion the pattern of associations reported here points towards the possibility of more direct influences of tobacco exposure on the musculoskeletal system.

There is no obvious mechanism for the association of smoking with musculoskeletal disorders. Theories on the effect of smoking on the back, mostly the disc, have been forwarded but only sporadically tested.[35] Our results, as well as some previous ones[2 10] call for a general mechanism of smoking on musculoskeletal health. Speculatively, it is plausible that smoking could bring about nutritional deficiencies in the muscle-tendon system, joint structures, and the disc through vasoconstriction, carboxyhaemoglobin production, an atherogenic effect or fibrinolytic defect.[15] Metabolic or direct toxic effects seem possible as well.[36] An increased risk of osteoporosis has been found in smokers.[37]

Although being supported by evidence from other surveys on smoking and musculoskeletal symptoms, our results are at variance with those on smoking and radiographically verified osteoarthrosis of the knee. In, for example, the HANES I and Framingham studies,[38] as well as in a study of occupational groups in building construction,[39] an inverse association between smoking and osteoarthrotic findings in the knee joint was found. Symptoms may arise from several anatomical structures apart from the joints and it is possible that the effects of tobacco on, for example, muscles might be different from its effects on for example cartilage. In the present material, however, a sum score of myalgias only was not associated with smoking.

To learn more of the relation between smoking and musculoskeletal disorders more epidemiological research and studies of the biological effects of smoking on this organ system are needed. Possible musculoskeletal effects should also be taken into consideration in planning studies of interventions to prevent and stop smoking.

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