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Associations between recreational exercise and chronic pain in the general population: Evidence from the HUNT 3 study

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ABSTRACT

The evidence for an association between leisure-time physical activity and prevalence of pain is insufficient. This study investigated associations between frequency, duration, and intensity of recreational exercise and chronic pain in a cross-sectional survey of the adult population of a Norwegian county (the Nord-Trøndelag Health Study; HUNT 3). Of the 94,194 invited to participate, complete data were obtained from 46,533 participants. Separate analyses were performed for the working-age population (20–64 years) and the older population (65 years or more). When defined as pain lasting longer than 6 months, and of at least moderate intensity during the past month, the overall prevalence of chronic pain was 29%. We found that increased frequency, duration, and intensity of exercise were associated with less chronic pain in analyses adjusted for age, education, and smoking. For those aged 20–64 years, the prevalence of chronic pain was 10–12% lower for those exercising 1–3 times a week for at least 30 minutes duration or of moderate intensity, relative to those not exercising. Dependent on the load of exercise, the prevalence of chronic pain was 21–38% lower among older women who exercised, relative to those not exercising. Similar, but somewhat weaker, associations were seen for older men. This study shows consistent and linear associations between frequency, duration, and intensity of recreational exercise and chronic pain for the older population, and associations without an apparent linear shape for the working-age population.

1. Introduction

Pain complaints are major health problems accounting for extensive health care utilizations [14,34], work absence [44], and disability [4,15]. Pain may be classified according to a variety of factors [45], and epidemiological studies of pain are highly heterogeneous in ascertaining pain cases [11]. However, prevalence figures tend to be high, with up to 80% of the adult population reporting pain during the past month [27], and 20% of the European adult population reporting moderate to severe chronic pain [6].

Pain is associated with a wide range of risk factors such as gender, age, and socioeconomic status [2,12,13], work characteristics [37,39], and psychological distress [35,50]. It is widely suggested that physical inactivity is a perpetuating factor causing pain to become chronic [48]. Accordingly, guidelines for the treatment of musculoskeletal pain frequently include recommendations of exercise to prevent development into chronic pain [1,17,29]. However, there is conflicting evidence for the efficacy of exercise treatment in preventing pain [31,33,47] and there is limited evidence for an association between leisure-time physical activity and prevalence of pain in the general population [9,21,25].

Few studies have explicitly differentiated between acute and chronic pain when investigating the relationship with physical activity. In one study, chronic low back pain was not associated with physical inactivity [41]. Considering load of the activity, moderate, but not vigorous activity has been associated with lower prevalence of chronic low back pain [20] and chronic widespread musculoskeletal pain [24]. These studies did not include additional information on pain intensity when ascertaining cases. This might be important because a large proportion of those with chronic pain in the general population report mild pain [8,12].

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Moreover, among older adults, exercise has been shown to prevent an increase in pain with age [7] and a reduced risk of both short-term and long-term low back pain episodes [18]. Thus, associations between chronic pain and leisure-time physical activity may be dependent on age.

In summary, progress in identifying a relationship between physical activity and pain in the general population may have been constrained by a lack of explicit case definitions and limited knowledge of which activity types and loads are important. To expand on previous studies, the current study investigates the associations between frequency, duration, and intensity of recreational exercise and prevalence of chronic pain of at least moderate intensity. Furthermore, previous studies suggest that the association may be dependent on age and gender. Therefore, all analyses were conducted separately for men and women, and for those aged 20–64 years and those aged 65 years or more. Specifically, the following research questions were raised:

(1) Is recreational exercise associated with a lower prevalence of chronic pain?
(2) If so, are the associations similar for frequency, duration, and intensity of exercise?

2. Materials and methods

2.1. Study design and subjects

All inhabitants aged 20 years or more in the county of Nord-Trøndelag in Norway have been invited to participate in three population-based health surveys: the Nord-Trøndelag Health Study (HUNT 1–3); http://www.ntnu.no/hunt/english. The first HUNT study was carried out in 1985–1987, the second in 1995–1997, and the third (HUNT 3) in 2006–2008. The population of Nord-Trøndelag is stable, with sex and age distributions similar to those of Norway as a whole, but with somewhat lower levels of education and income compared to national averages. The county is mostly rural and sparsely populated [23].

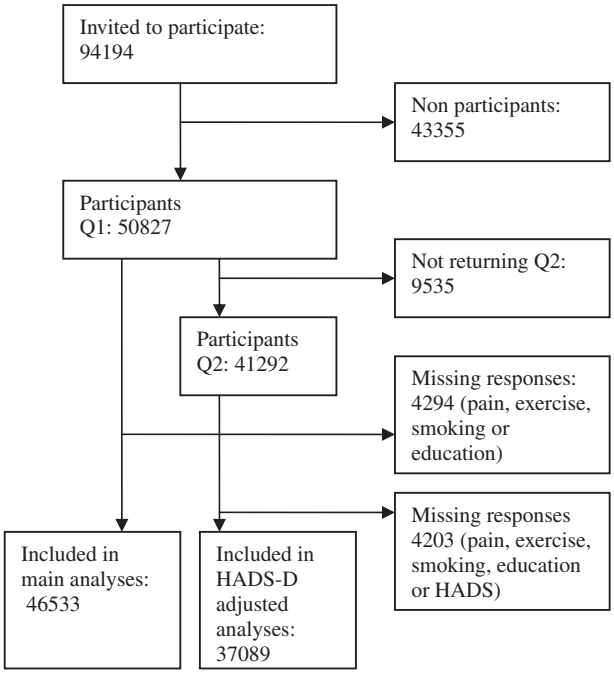

Fig. 1. Flow chart of participants included in analyses. Q1, questionnaire 1; Q2, questionnaire 2; HADS-D, Hospital Anxiety and Depression Scale-Depression.

In HUNT 3, a total of 94,194 individuals received a postal questionnaire together with an invitation to participate in the survey (Fig. 1), which also included physical examinations. Participants were asked to bring a questionnaire (Q1) when attending the physical examination. They also received a second questionnaire (Q2) at the examination, which they were asked to return by mail. A total of 50,827 (54%) returned Q1 and 41,292 returned Q2. Among the total of 50,827 participants, 4294 were excluded from analyses due to missing information on pain, exercise, smoking or education. After omitting these subjects, 46,533 (92%) respondents were included in the main analyses. Among these, 37,089 were included in the analyses adjusting for the Hospital Anxiety and Depression Scale (HADS) (Fig. 1).

The response rate was higher among women (58.5%) than men (49.8%) and lowest in the youngest age groups; 31% and 42% for the age groups 20–29 and 30–39 years, respectively, vs 71% for the age group 60–69 years, which had the highest participation.

HUNT 3 has been approved by the Norwegian Data Inspectorate and the Regional Committee for Ethics in Medical Research.

2.2. Questionnaires

Two questions regarding pain were included: Do you have bodily pain which has lasted for more than 6 months? and How much bodily pain have you had during the past month?, with the following response options: None, very mild, mild, moderate, severe, or very severe. This verbal pain rating scale has been extensively used, among others, in the various versions of the Short Form-36 health survey [52], which has been recommended as a global measurement of pain severity [49]. A division at the midpoint of the scale (no-to-mild vs moderate-to-very-severe pain) has been shown to be useful in identifying persons with pain of a more complex nature [28]. Case ascertainment of chronic pain was made based on the combination of reporting both pain lasting more than 6 months and moderate, severe, or very severe pain during the past month.

Three questions addressed recreational exercise; the average number of times exercising per week (*never, less than once, once a week, 2–3 times per week, or almost every day*), the average minutes each time (*<15 minutes, 16–30 minutes, 30–60 minutes, or more than 60 minutes*), and average intensity each time (*easy, without breaking a sweat or losing breath, lose breath,* and *break into sweat or near exhaustion*). The questions were supported with examples of common types of exercise (e.g. going for a walk, skiing, swimming, or other sports). The questions have shown acceptable test–retest reliability, with kappa values ranging from 0.52 to 0.77, and significant correlations with VO_2 max (ranging from 0.31 for duration to 0.43 for frequency) in adult males [30]. In the present analyses, participants were categorized in a "non-exercise" category if they reported never exercising or exercising less than once a week on the frequency item, or <15 minutes on the duration item. The non-exercise category was thereby identical for each dimension of exercise. To reflect the average total time spent on exercise per week, the frequency categories were given the following scores; non-exercise = 0, once = 1, 2–3 times = 2.5, and nearly every day = 5. The duration categories were given the following scores: non-exercise = 0, 15–30 minutes = 0.38, 30–60 minutes = 0.75, and more than 60 minutes = 1 [30]. The frequency and duration scores were then multiplied and then divided into 4 categories: non-exercise, <1 hour per week, 1–2 hours per week, and more than 2 hours per week.

The HADS [53] was included in the second questionnaire. HADS is a 14-item self-administered questionnaire measuring depression (7 items) and anxiety (7 items) during the previous week. A cut-off set at $\geqslant 8$ has demonstrated a sensitivity and specificity at approximately 0.8 for both anxiety disorders and major depression [3].

Information on organ-specific diseases was obtained by the self-report of the following: myocardial infarction (heart attack), angina pectoris (chest pain), other heart disease, stroke/brain haemorrhage, kidney disease, asthma, chronic bronchitis, emphysema, or chronic obstructive pulmonary disease, diabetes, cancer, and epilepsy. Responses to these questions were categorized into no disease, 1 disease, and 2 or more diseases. Physical workload was assessed with the question: is your work so physically demanding that you are often physically worn out after a day's work? The response categories *nearly always, quite often, seldom,* and *almost never* were dichotomized with a cut-off between quite often and seldom.

Data on smoking were categorised as nonsmoker, previous smoker, or current smoker. The highest attained level of education for every participant was obtained from the National Education database, which includes individual data on education since 1970. All data are updated annually. For the current analyses, data from 2008 were used. Educational attainments were re-classified into 3 levels; compulsory education, upper secondary education, and higher level (tertiary) education (http://www.ssb.no/vis/english/magazine/art-2006-10-13-01-en.html).

Data on retirement pension, vocational rehabilitation allowance, and disability pension were obtained from Statistics Norway's history of event database, in which data from the Norwegian Labour and Welfare Organisation are provided.

2.3. Statistical analyses

Prevalence ratios adjusted for age, level of education, smoking, and co-morbidity (organ-specific disease and/or depression) for every level of frequency, duration, and intensity of exercise were calculated in separate analyses based on general linear models for the binomial families using the binreg function in Stata version 10.0 for Windows (Stata Corporation, College Station, TX). In these models, the non-exercise category was the reference category for each of the exercise dimensions. To evaluate the independence of each exercise dimensions' association with chronic pain, they were all included in one model. In this model, the reference category was the lowest level of exercise rather than the non-exercise category. Correlations among the 3 exercise dimensions were estimated among those exercising by calculation of Spearman's correlation coefficients.

Age was coded in 15-year categories; level of education as primary, secondary, or tertiary education; co-morbidity as none, 1, or 2 or more organ-specific diseases; depression as cut off $\geqslant 8$ on HADS-Depression (HADS-D); and smoking as never, previous, or current smoker. Analyses were carried out separately for each sex and for those who where between the ages of 20 and 64 years and those aged 65 years or more, respectively. For those aged 20–64 years who were not receiving retirement pension or disability pension, additional analyses were carried out with physical workload as a covariate. Interaction between exercise and gender and exercise and age category (20–64 years or 65 years or more) were carried out using likelihood ratio test.

To evaluate possible selection bias introduced by missing data, we used additional information from the HUNT 3 study to impute missing data under the assumption of "missing at random" [43]. Twenty imputed data sets were obtained using the Imputation by Chained Equations (ICE) procedure in STATA. In the imputation we included all the variables used in the analyses as well as the following variables: self-perceived health (ordinal scale), body mass index (interval scale), hip circumference (interval scale), alcohol consumption (ordinal scale), impairment due to chronic disease (dichotomy), disability pension (dichotomy), income (interval scale), 4 questions on insomnia (ordinal scale), HADS anxiety (ordinal scale), type of physical activity in work (nominal scale), headache (dichotomy), musculoskeletal complaints (dichotomy), and back operations (dichotomy).

3. Results

3.1. Prevalence of chronic pain and nonexercise

Overall, 39% of the population reported pain that had lasted for 6 months or more. When combining pain for 6 months or more with at least moderate pain during the past month, the prevalence was 29%. As shown in Table 1, chronic pain was more prevalent among women (33%) than men (26%), and the prevalence increased with age. The prevalence of chronic pain was approximately 10 percentage points lower among those who never had smoked compared to current or former smokers. An almost 2-fold increase in the prevalence of chronic pain was seen among those who scored above the cut-off for depression (HADS-D $\geqslant 8$) and those with more than one organ-specific disease. The prevalence of chronic pain was also considerably higher among subjects with low educational attainment. The prevalence of non-exercise increased with age, smoking status, and with having one or more organ-specific diseases as well as depression. The prevalence of non-exercise decreased with level of attained education, and was higher among men (29%) than women (20%).

3.2. Associations between recreational exercise and chronic pain

Among subjects aged 20–64 years who exercised 2–3 times a week, the prevalence of chronic pain was 10% lower for women (prevalence ratio [PR] 0.90; 95% confidence interval [CI] 0.85–0.94) and 12% lower for men (PR 0.88; 95% CI 0.83–0.94) compared to those who did not exercise (Table 2). However, for both women and men exercising 4 times or more, the prevalence of chronic pain was similar to those not exercising. This indicates a U-shaped relation for frequency of exercise with chronic pain in this age group.

For older subjects who exercised 2–3 times a week, the prevalence of chronic pain was 27% lower for both women (PR 0.73; 95% CI 0.67–0.79) and men (PR 0.73; 95% CI 0.65–0.82) compared to those not exercising. In contrast to those aged 20–64 years, exercising 4 times or more was associated with an apparently larger or maintained reduction in chronic pain among the elderly (PR 0.66; 95% CI 0.60–0.72, and 0.79; 95% CI 0.70–0.89 for women and men, respectively).

A gradual reduction in chronic pain was seen with increasing duration and intensity of exercise, regardless of sex and age group. The associations were considerably stronger for those aged 65 years or more compared to those of their younger counterparts (all *P*-values for interactions between age groups and exercise <0.05). Among the older subjects, the associations were stronger for women than men (all *P*-values for interaction between exercise and gender were <0.001).

When investigating the association between exercise and chronic pain, several confounders were considered. Adjusting for age, education, and smoking reduced the association between exercise and chronic pain to approximately one half of what it was when adjusting for age only. Additional adjustment for organ-specific disease and depression did not change the associations (data not shown). Physical workload was considered a potential confounder for working participants, however, adjustment for physical workload did not lead to meaningful changes in the associations between exercise and chronic pain (data not shown).

Among those who exercised, we estimated the correlation between frequency and duration of exercise as 0.08, between frequency and intensity 0.34, and between duration and intensity

Table 1
Characteristics of study population, and prevalence of chronic pain[a] and non-exercise.[b]

	Women			Men		
	n (%)	Chronic pain (%)	Nonexercise (%)	n (%)	Chronic pain (%)	Nonexercise (%)
Age, years						
20–34	4085 (16)	15	18	2835 (13)	11	29
35–49	7443 (30)	28	17	6030 (28)	22	33
50–64	8249 (33)	41	17	7642 (36)	32	28
65–79	4351 (17)	41	22	4145 (19)	28	24
80+	996 (4)	43	42	757 (4)	30	36
Smoke						
Nonsmoker	11,447 (45)	27	16	9029(42)	19	24
Previous smoker	6187(25)	38	16	6468 (30)	30	27
Current smoker	7490 (30)	39	26	5912 (28)	30	39
Education						
Elementary	5214 (21)	45	28	4023 (19)	35	36
Secondary	12,203 (48)	36	19	12,456 (58)	27	31
Higher	7707(31)	21	13	4930 (23)	15	18
Organ disease*						
No	18,545 (74)	29	17	14,927 (70)	22	29
One	5030 (20)	40	22	4581 (21)	30	29
Two or more	1549 (6)	58	32	1901 (9)	41	31
HADS-D <8	19,094 (91)	32	17	14,929 (90)	24	26
HADS-D ⩾8	2817 (9)	53	30	1728 (10)	43	38
Total	25,124 (100)	33	19	21,409 (100)	26	29

HADS-D, Hospital Anxiety and Depression Scale-Depression.
* Based on self report of the following: myocardial infarction (heart attack), angina pectoris (chest pain), other heart disease, stroke/brain haemorrhage, kidney disease, diabetes, cancer, epilepsy, chronic bronchitis, emphysema, asthma or COPD (chronic obstructive pulmonary disease).
[a] Pain lasting more than 6 months and of at least moderate intensity during last month.
[b] Reports of no exercise or less than once a week or < 15 minutes duration.

Table 2
Prevalence ratios (PR) for chronic pain with 95% confidence intervals (CI) by frequency, duration, and intensity of exercise in the HUNT 3 study.

	20–64 years						65 years or more					
	Women			Men			Women			Men		
	n	PR*	95% CI	n	PR*	95% CI	n	PR*	95% CI	n	PR*	95% CI
Frequency												
Nonexercise[a]	3471	1	Ref	4982	1	Ref	1393	1	Ref	1267	1	Ref
1 time/week	4231	0.92	0.86–0.97	3811	0.90	0.84–0.97	817	0.76	0.69–0.84	748	0.90	0.79–0.95
2–3 times/week	8524	0.90	0.85–0.94	5643	0.88	0.83–0.94	1909	0.73	0.67–0.79	1680	0.73	065–0.82
⩾4 times/week	3551	1.00	0.94–1.07	2071	1.03	0.95–1.11	1228	0.66	0.60–0.72	1207	0.79	0.70–0.89
Duration												
Nonexercise[a]	3471	1	Ref	4982	1	Ref	1393	1	Ref	1267	1	Ref
15–30 minutes	2213	1.00	0.93–1.07	1618	0.98	0.90–1.07	961	0.79	0.72–0.86	713	0.95	0.83–1.08
30– 60 minutes	10,959	0.92	0.87–0.97	6584	0.90	0.85–0.96	2413	0.70	0.65–0.76	2017	0.75	0.68–0.84
⩾60 minutes	3134	0.87	0.81–0.93	3323	0.91	0.84–0.98	580	0.62	0.55–0.71	905	0.72	0.62–0.83
Intensity												
Nonexercise[a]	3471	1	Ref	4982	1	Ref	1393	1	Ref	1267	1	Ref
Light	5491	0.97	0.92–1.02	3031	0.99	0.92–1.06	2797	0.73	0.68–0.78	1882	0.85	0.77–0.94
Moderate	10,228	0.90	0.86–0.95	7529	0.89	0.84–0.94	1069	0.66	0.59–0.73	1691	0.69	0.61–0.78
Hard	473	0.68	0.55–0.84	904	0.77	0.65–0.91	18	0.54	0.25–1.12	29	0.89	0.50–1.60

* Adjusted for age (15-year categories), smoking (never, past, current), and education (primary, secondary, tertiary).
[a] Exercising less than once a week or for <15 minutes each time.

0.28. Frequency, duration, and intensity of exercise were all included as covariates in the same model to disentangle their role among those who exercised (Table 3). Similar patterns as those found in the simpler models were seen. For subjects aged 20-64 years, chronic pain was more prevalent among those exercising 4 times or more compared to those exercising once a week (PR 1.10; 95% CI 1.03–1.17 for women, and PR 1.15; 95% CI 1.05–1.25 for men). In general, chronic pain decreased with increasing duration and intensity of exercise. However, for men aged 20–64 years, no clear association was seen between exercise duration and chronic pain.

Frequency and duration were also combined into a measure reflecting the total time spent on exercise during an average week. For those aged 20–64 years, the total time spent on exercise showed similar but weaker associations with chronic pain as frequency of exercise (data not shown). Adjusting for intensity did not change this. For the older subjects, the associations between total time spent on exercise and prevalence of chronic pain were similar to the associations seen for frequency and duration.

To investigate the effect of the severity of pain on the associations between exercise and chronic pain, the data were reanalysed using different cut-points for pain when ascertaining cases. Selecting 3 (mild) as a cut-point rather than 4 (moderate) resulted in only marginal changes in the associations. Selecting 5 (severe) as a cut-point resulted in lower prevalence ratios but wider confidence intervals. For men aged 20–64 years, the widening of the

Table 3
Multivariable analyses of the association between frequency, duration, and intensity (mutually adjusted) of exercise and chronic pain among those who exercised in the HUNT 3 study.

	20–64 years				65 years and older			
	Women		Men		Women		Men	
	PR*	95% CI	PR*	95% CI	PR*	95% CI	PR*	95% CI
Frequency[a]								
1 times/week	1	Ref	1	Ref	1	Ref	1	Ref
2–3 times/week	0.99	0.92–1.07	1.00	0.93–1.08	1.00	0.90–1.11	0.87	0.76–1.00
≥4 times/week	1.10	1.03–1.17	1.15	1.05–1.25	0.89	0.79–0.99	0.93	0.81–1.08
Duration[b]								
15–30 minutes	1	Ref	1	Ref	1	Ref	1	Ref
30–60 minutes	0.94	0.88–1.00	0.95	0.87–1.04	0.91	0.83–1.00	0.83	0.73–0.95
≥60 minutes	0.89	0.83–0.97	0.97	0.87–1.07	0.83	0.72–0.96	0.81	0.69–0.96
Intensity[c]								
Light	1	Ref	1	Ref	1	Ref	1	Ref
Moderate	0.95	0.90–0.99	0.91	0.85–0.98	0.93	0.84–1.02	0.85	0.75–0.95
Hard	0.72	0.59–0.89	0.79	0.66–0.94	0.76	0.36–1.60	1.08	0.60–1.94

PR, prevalence ratio; CI, confidence interval.
* Adjusted for age (15-year categories), smoking (never, past, current), and education (primary, secondary, tertiary).
[a] Additional adjustment for exercise duration and intensity.
[b] Additional adjustment for exercise frequency and intensity.
[c] Additional adjustment for exercise frequency and duration.

confidence intervals made most of the associations nonsignificant (data not shown).

To check for loss of precision or bias due to incomplete responses, a multiple imputation procedure was performed. Comparing the associations obtained from the multiple imputations procedure and complete case analyses revealed similar results, indicating high reliability of the complete case analyses.

4. Discussion

This study documents a consistent association between frequency, duration, and intensity of recreational exercise and prevalence of chronic pain in the general population. For participants aged 65 years or more, a linear association was seen for every dimension of exercise, and the association was considerable also for the lowest loads. For those aged 20–64 years, the exercise frequency showed a U-shaped relationship with chronic pain, while exercise bouts of more than 30 minutes duration or moderate intensity were needed to show a lower prevalence of chronic pain.

Overall, 29% of the population reported moderate to severe chronic pain. These figures are in accordance with previous studies. The prevalence of chronic pain estimated in seven studies following the International Association for the Study of Pain definition of chronic pain [36] ranged from 11.5% to 55.2%, with a weighted mean of 35.5% [38], and in a pan-European survey, 19% of all adult Europeans, and 30% of the Norwegians reported moderate-to-severe chronic pain [6]. Furthermore, associations with previously well-known risk factors such as gender, age, education, and depression were confirmed.

To our knowledge, this is the first study that investigates the association between frequency, duration, and intensity of recreational exercise and chronic pain of at least moderate intensity in the general population. The findings raise new awareness of the potential benefits of exercise on chronic pain. Several mechanisms may explain a higher prevalence of chronic pain among those not exercising. Physical deconditioning, including reduced cardiovascular capacity, muscular endurance, strength, and motor control may create excessive strain, increased fatigue, and development of micro-injuries [48]. However, there is little evidence that these factors explain chronic pain [5,16,42]. Other mechanisms by which physical activity may operate, such as increased mood, reduced hypervigilance, and anxiety, have received little attention. However, recreational exercise has shown positive effects on both pain and psychological distress, suggesting a common pathway between recreational exercise and positive mood and pain relief [22,26].

In the working-age population, the prevalence of chronic pain was similar for those not exercising and for those exercising almost every day, whereas it was lower for those exercising 1 to 3 times a week. The reason for this U-shaped relationship is not completely understood. Exercise is generally regarded as a protective factor for health and functioning. However, it has been supposed that both inactivity and excessive activity exerts deleterious effects on general health and compromises musculoskeletal function [1]. A similar U-shaped association between total amount of physical activity and chronic low back pain has been reported previously [20]. The authors noted that individuals engage in a whole range of different activities, some of which may be risk activities and some protective activities of pain. We know little about how exercise may interact with other activities in terms of increasing or reducing the risk for developing chronic pain. However, exercising almost every day may add to the total amount of activity in such a way that the total load of activities increases the risk of chronic pain. On the other hand, we should also bear in mind that many subjects use exercise as a strategy to manage their pain [46]. Accordingly, the U-shape may reflect that a large proportion of those with chronic pain exercise frequently because it eases their pain.

The U-shaped relationship between exercise frequency and chronic pain was not observed for older participants. This difference between the age groups may be attributed to a lower total amount of physical activity among older individuals compared to those of working age [32]. Older individuals generally have lower levels of physical work activities and daily routine activities, and daily exercise may not exceed the total load of physical activity, increasing the risk for chronic pain. To gain insight into this potential interaction between exercise and other types of physical activity, further studies are needed.

Another interesting difference between the age groups was the more distinct association between exercise and chronic pain among the older individuals. Older age is associated with decreasing reserve capacity of musculoskeletal fitness due to physiological ageing and general declines in total activity levels [10,51]. Therefore, the effect of exercise on pain may increase. Also, those who exercise in old age may have done so for a long time, and the payback with reference to chronic pain may require many years

of regular exercise. On the other hand, those who are more likely to maintain exercising in older age may also be more likely to have an innate high pain threshold and therefore report less pain.

Interestingly, among the older adults, the associations were consistently stronger among women than men. This has also been shown previously [7]. The mechanisms underlying this gender difference are not known but should be addressed in future studies.

The analysis including all 3 dimensions of exercise in the same multivariable model showed essentially similar associations as the univariable analyses. This indicates that all 3 dimensions of exercise are of importance for chronic pain, and that mutual adjustment does not change this impression. However, as the 3 dimensions of exercise are correlated and may suffer from different degrees of measurement error, their "independent" associations with chronic pain should be interpreted with some caution [40].

Some limitations of the study need to be addressed. First, the response rate of 54% may reduce the external validity of the results. However, in the previous HUNT surveys, nonparticipation was only minimally dependent on health status [23]. Furthermore, analyses based on the complete response dataset and the multiple imputation dataset were practically identical, indicating high reliability of the analyses based on complete responses. Second, the time frame of the questions measuring exercise was a normal week during the past year. This measure is potentially affected by both a recall bias and a social desirability bias. Interpretation of the responses as the actual extent of exercise should therefore be done with caution. Third, data on comorbidity were obtained by self-report. An underestimation of the prevalence of comorbid conditions would have caused some residual confounding. Moreover, the statistical model failed to converge when entering age, comorbidity, education, and smoking together with exercise. This was solved by including age as a rather broad categorical variable (15-year categories). This could cause residual confounding in the model. However, including age as either a continuous or a 15-year categorical variable in the partly adjusted models revealed minimal differences in the associations. Finally, the cross-sectional nature of the presented data does not allow for any inference about causality between exercise and chronic pain. The causal pathways are likely to be complex and bidirectional. That is, activity level might influence and might be influenced by pain in several ways. The study serves as an exploration of associations, and should indicate which factors are important when investigating the causal links between leisure-time physical activity and pain.

The current study has several major strengths. The use of data from a large population-based health survey made it possible to detect associations even when they were small, and to stratify analyses according to both age and gender without losing statistical power. Furthermore, we were able to control for the effect of a wide range of confounders with extensive data on a variety of health measures and socioeconomic factors. Finally, we used clear case definitions, sensitive to both the duration and severity aspects of chronic pain.

4.1. Conclusion

This study shows that frequency, duration, and intensity of recreational exercise are all associated with a lower prevalence of chronic pain, and that the associations are stronger for older subjects, especially for women. Communicating a potential positive effect of recreational exercise on chronic pain in older age may be of importance as an aging population brings about increasing strain on health care resources. Even though one cannot conclude that exercise may prevent chronic pain based on the current cross-sectional data, benefits of exercise on several disease outcomes have been documented in a large amount of prospective observational studies [19]. As exercise also has shown an effect on the treatment of chronic pain from randomised controlled trials [1], one may argue that the current results should have implications for the recommendation of physical activity to the general public.

Conflict of interest statement

The authors declare no conflict of interest.

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