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The results of this study indicate that the effect of social position on sick leave was partly mediated through physical workload, even while accounting for childhood social position and personality. Our findings provide support that interventions aimed at reducing physical workload among those with lower social position could reduce sick leave risk.

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Adult social position and sick leave: the mediating effect of physical workload

by Karina Corbett, MPhil,¹ Jon Michael Gran, PhD,² Petter Kristensen, PhD,^{1,3} Ingrid Sivesind Mehlum, PhD¹

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Objective This study aimed to quantify how much of the adult social gradient in sick leave can be attributed to the mediating role of physical workload while accounting for the role of childhood and adolescent social position and neuroticism.

Methods Our sample consisted of 2099 women and 1229 men from a Norwegian birth cohort study (born 1967–1976) who participated in the Nord-Trøndelag Health Study (2006–2008) (HUNT3). Data on sick leave (defined as >16 calendar days; 2006–2009) and social position during childhood, adolescence, and adulthood were obtained from national registers. Study outcome was time-to-first sick leave spell. Physical workload and neuroticism were self-reported in HUNT3. Mediating effects through physical workload were estimated using a method based on the additive hazards survival model.

Results A hypothetical change from highest to lowest group in adult social position was, for women, associated with 51.6 [95% confidence interval (95% CI) 24.7–78.5] additional spells per 100 000 person-days at risk, in a model adjusted for childhood and adolescent social position and neuroticism. The corresponding rate increase for men was 41.1 (95% CI 21.4–60.8). Of these additional spells, the proportion mediated through physical workload was 24% (95% CI 10–49) and 30% (95% CI 10–63) for women and men, respectively.

Conclusions The effect of adult social position on sick leave was partly mediated through physical workload, even while accounting for earlier life course factors. Our findings provide support that interventions aimed at reducing physical workload among those with lower adult social position could reduce sick leave risk.

Key terms additive hazards model; cohort study; HUNT study; mediation analysis; Norway; occupational exposure; sickness absence; social inequality; socioeconomic status; survival analysis; work environment.

Sick leave is considered a measure of overall health (1) and is a predictor of mortality (2) among the working population. A persistent finding is that people with lower adult social position have higher levels of sick leave (3), and several longitudinal studies have suggested that working conditions could in part explain this link (4–10). Aspects of the working environment that have been identified as potentially harmful include psychosocial factors (4, 5, 7, 9, 10) and physical workload (5–10), with the latter appearing to be the most important factor explaining the social gradient (7, 9, 10). Despite the consistent pattern of these findings, the pathway link-

ing adult social position to sick leave through physical working conditions has not been clearly elucidated from a causal standpoint (11, 12).

Figure 1 presents the underlying causal diagram representing the relation between adult social position, physical workload, and sick leave. A causal pathway from adult social position to sick leave, via work, is compatible with the aforementioned findings. However, according to the indirect selection hypothesis (13), selection into adult social position is not random; the same early-life-course factors that are driving people into lower adult social positions could also be driving

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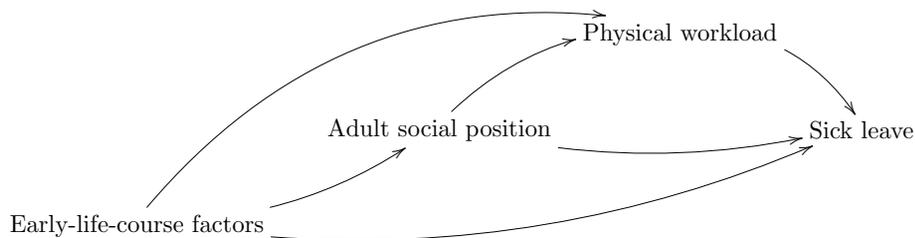


Figure 1. A causal diagram showing that the direct pathway between adult social position and sick leave, and the indirect pathway via working environment, is confounded by early life course factors.

them into jobs with higher physical workload, placing them at increased risk for sick leave. The link between adult social position and sick leave, and the mediating pathway of physical working conditions, could therefore in part be confounded by the contribution of early-life-course factors, and studies that do not control for these will be biased (11, 14). With the exception of the study by North et al (4), who considered the father's social class when examining the mediating effects of psychosocial work characteristics, none of the previous studies considered the role of early-life-course factors in the analyses.

We consider two early-life-course factors: childhood and adolescent social position and the personality trait "neuroticism". The rationale for considering these factors is drawn from two bodies of literature. The first is evidence from epidemiology showing that childhood and adolescent social position directly influences educational attainment (15) while also directly and independently influencing health outcomes, including morbidity (16) and work disability (17, 18). Childhood and adolescent social position could therefore be driving individuals into both lower adult social position and poor health, thereby confounding the relation between adult social position and sick leave. In addition, childhood and adolescent social position has an effect on occupational choice (19), and consequently the level of physical workload associated with a given occupation. Childhood and adolescent social position could thus also confound the indirect pathway from adult social position to sick leave, both by confounding the pathway between adult social position and physical workload, and between physical workload and sick leave.

The second body of evidence is based on findings rooted in personality psychology. Neuroticism—a personality trait characterized by negative emotions in response to threat, frustration, or loss (20)—has been an area of wide interest in the work environment literature (21). Individuals high on neuroticism tend to report more adverse working conditions (21), including higher physical workload (22), and there has been a concern that this reporting pattern is the result of a bias, as opposed to an objective categorization of the work

environment (21). At the same time, neuroticism has a well-established link with overall health (23) and sick leave (24), as such, the pathway from physical workload to sick leave could be confounded by neuroticism, as shown in figure 1. Personality has also received some attention as a possible factor driving selection both into lower educational attainment and poor health outcomes (25) and mortality (26). Negative emotionality in particular, which is closely related to neuroticism, has in many studies been shown to be associated with both socioeconomic status and health (27). Given the aforementioned association neuroticism has with health and sick leave, the direct pathway between adult social position and sick leave could therefore be confounded by the contribution of neuroticism through its relation with adult social position, and sick leave, as shown in figure 1.

In the present study, we investigate how the effect of adult social position on sick leave is mediated through physical workload, while controlling for childhood and adolescent social position and neuroticism. Direct effects of adult social position and indirect effects through physical workload is estimated within a formal framework for causal inference suggested by Lange & Hansen (8), based on the additive hazards survival model (28).

Methods

Study population

The source population for this study is a national birth cohort initiated with the purpose of studying the impact of early conditions and events on health and employment outcomes later in life. The birth cohort includes all 626 928 live-born individuals (304 953 females and 321 975 males) registered in the Medical Birth Registry of Norway (29) between 1967 and 1976. Parental relationships have been obtained from the Medical Birth Registry, enabling us to identify the mother with certainty in all but six cases, and the father in all but 7.1% of cases. Demographic, educational, employment,

and sick leave data has been collected from national registers for both the individuals and their parents. For the current study, we limited the analysis to a subset of individuals from this birth cohort who also participated in the Nord-Trøndelag Health Study, 2006–2008 (HUNT3) (30). For HUNT3, all individuals residing in Nord-Trøndelag county aged 20 or older were invited to participate. Information on personality, life style factors, and work factors were collected by interview and two questionnaires. The first questionnaire was sent with the invitation to participate and was returned at the time of the interview. The second questionnaire was distributed at the interview and was completed at home and returned by mail. Overall, 93 860 individuals were invited to HUNT3, with 50 807 (52%) choosing to participate, and about 80% of these individuals returning the take-home questionnaire (30). A study of non-participants in HUNT3 suggests that individuals who had a lower social position, poorer health, and who received disability pension were less likely to participate (31).

Demographic data obtained from the database FD-Trygd (32) indicated that as of 2006, 15 053 (2.3%) individuals from the birth cohort that had not died or emigrated, were residing in Nord-Trøndelag, and were thus eligible to be recruited to the HUNT3 study; of these, 6913 (46%) individuals were linked to participants in the HUNT3 study. We further restricted participation to only include individuals who were employed at the time of the interview (excluding self-employed individuals), and who had valid responses in HUNT3 on occupation, physical workload (assessed both at the interview and in the take-home questionnaire), and neuroticism. In total, 5416 individuals, 3222 women and 2194 men reported being employed. Due to long lines at the interview site, 631 participants (12%) were randomly selected to be given a short version of the interview that did not include an item on physical workload; therefore, these individuals were also excluded. Of those completing the full interview, 3328 individuals, 2099 women and 1229 men, had completed the physical workload questions and the neuroticism scale in the take-home questionnaire and had an identifiable occupational group. This comprised our final study population. The selection process is shown in figure 2.

Sick leave data

Sick leave data was obtained from the event database FD-Trygd, which records all physician-diagnosed sick leave spells lasting >16 calendar days (32). Employees in Norwegian enterprises are fully paid by the employer during certified sick leave. The Norwegian Labor and Welfare Administration reimburse the employer after an absence >16 calendar days, therefore registration is considered to be complete for employees. We obtained

individual records on sick leave spells for the period 2006–2009. Diagnoses for each sick leave spell, coded according to the International Classification of Primary Care (ICPC-2) (33), were obtained from the Norwegian Labor and Welfare Administration. We did not consider sick leave spells that were pregnancy related (ICPC-2 code W).

Measure of adult social position

Our measure of adult social position was based on a combination of educational level and occupation grouped into three categories. We initially grouped educational level at the time of study inclusion – obtained from the National Education Database (34) – into five levels: (i) long tertiary; (ii) short tertiary; (iii) upper secondary complete; (iv) upper secondary basic; and (v) lower secondary or less. A description of current occupation was obtained during the HUNT3 interview and coded by Statistics Norway according to the 1998 version of the Norwegian Standard Classification of Occupations (35), based on The International Standard Classification of Occupations, ISCO-88, which identifies 10 main occupational groups (0–9) based on a combination of education and skill level. A large proportion of females clustered in few occupational groups. In addition, the distribution of physical workload and sick leave according to education and occupation differed for men and women. We therefore opted to group social position slightly differently for women and men. For women, the highest social position (I) included executive managers and military personnel (groups 0–1) and participants with long tertiary education. The middle group (II) included professionals (group 2), associate professionals (group 3), clerks and service workers (groups 4–5) and participants with a short tertiary education. The lowest social group (III) included manual laborers (groups 6–9) having upper secondary complete education or less. For men, however, associate professionals (group 2) were included in the highest social group (I) as opposed to the middle (II), while manual workers (groups 6–9) with upper secondary complete education were placed in the middle group (II) and not the lowest (I). A visual presentation of the categorization is presented in the supplementary material (supplementary figures A and B, www.sjweh.fi/data_repository.php).

Physical workload

Physical workload measures were obtained during the interview and in the take-home questionnaire using the following three questions: (i) “Are you exposed to heavy lifting?”; (ii) “Is your work so physically demanding that you are often worn out after a day’s work?”; and (iii) “If you have had paid or unpaid employment, how

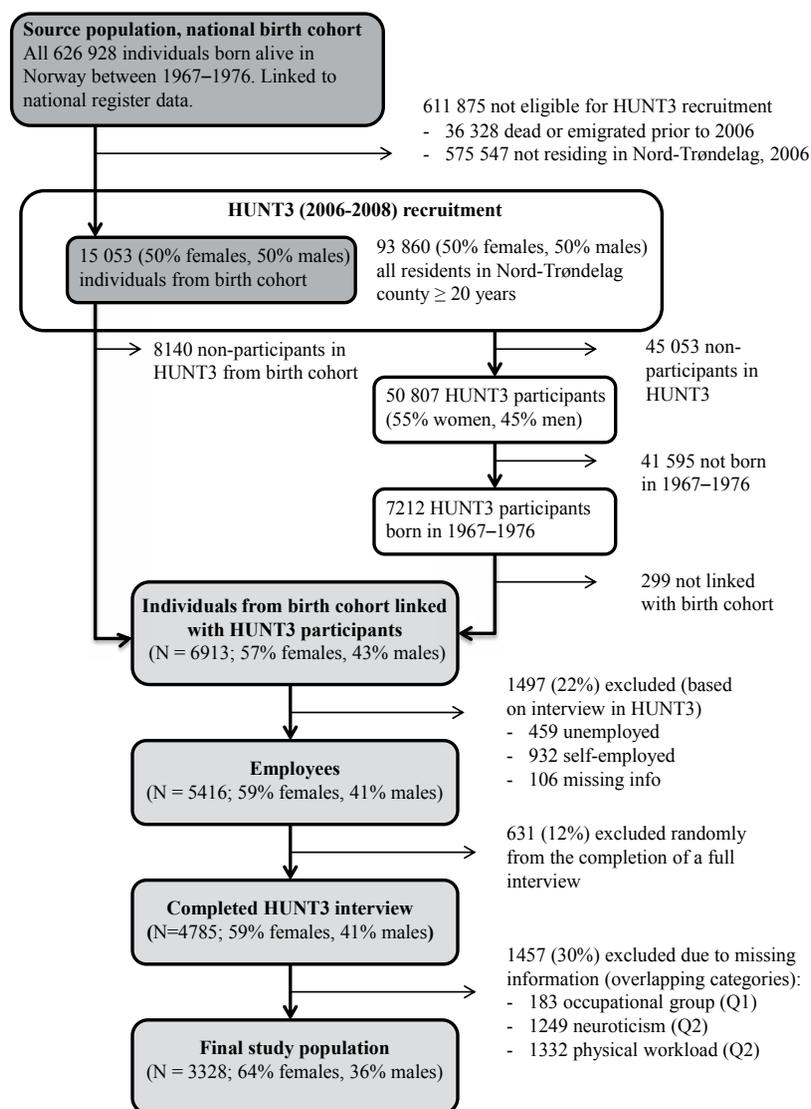


Figure 2. Flow chart showing selection into the study, starting with all individuals in a Norwegian birth cohort (born 1967–1976). Individuals who also participated in the Nord-Trøndelag Health Study 2006–2008 (HUNT3) were matched to this cohort, and provided the study base. Study participation was further restricted to those employed at the time of HUNT3 participation, and who had valid responses in HUNT3 on physical workload and neuroticism

would you describe your job?” Question (i) was rated on a 3-point scale from 0 (no) to 2 (often); question (ii) on a 4-point scale from 0 (yes, almost always) to 3 (never, or almost never); and question (iii) on a 4-point scale: 0 (work that mostly involves sitting), 1 (work that requires much walking), 2 (work that requires much walking and lifting), and 3 (heavy physical work). To account for question (i) being on a scale 1-point less than the other two questions, non-zero responses were weighted by one extra point, resulting in a 3-point scale with values 0, 2, and 3. The scores were then summed to create a physical workload index (and the sum score incremented by one, resulting in a 1–10 point index), with higher values indicating greater physical workload. There was a linear relation between adult social position and physical workload, and the variable appeared to be approximately normally distributed. A dichotomous physical workload variable was also created for descriptive purposes,

where a sum score below the median represented low physical workload.

Early-life-course factors

Childhood and adolescent social position. Childhood and adolescent social position was measured using three parental indicators: education, income, and disability pension. Parental education was defined as the educational level of the most educated parent (as measured when the participant was 16 years old) and grouped into four levels, combining the two tertiary groups (short and long) described previously, into one. Parental income was obtained from the Norwegian Labor and Welfare Organization for 1967–1994. The data provide annual pensionable income, reported in public pension base-rate units that are adjusted each year. To construct this variable, we averaged the mean of both parents’ income

during a 19-year period (when the participant was aged 0–18 years). If the father's identity was unknown, only the mother's income was used in this calculation. A dichotomous parental income variable was created for descriptive purposes, whereby a mean income in the lowest quartile represented low income. Data on whether parental disability pension before study participants had turned 18 was obtained from the Norwegian Labor and Welfare Administration.

Neuroticism. Neuroticism was assessed with a short version of the Eysenck Personality Questionnaire (36) administered as a take-home questionnaire in HUNT3. The following six questions had been selected for inclusion in the short form (37): (i) "Are you often worried?"; (ii) "Are your feelings easily hurt?"; (iii) "Do you often feel that you lose interest?"; (iv) "Do you have nervous problems?"; (v) "Do you often feel tired and indifferent/unmotivated without reason?"; and (vi) "Do you often worry that terrible things might happen?". A previous study has found that the sum scores from the full and the short form of the instrument had a correlation of 0.90 (37). The six questions were rated on a 2-point scale, either 0 (no) or 1 (yes). A neuroticism index was computed by summing the answers. Higher values on this index indicate that participants were higher on neuroticism. For descriptive purposes only, a dichotomous neuroticism variable was created based on the index, with low neuroticism representing a score below the median.

Other covariates

Age and marital status were considered as potential confounders. Age is strongly associated with sick leave risk (3), and there is some evidence that age is also associated with physical workload (38). The relation between marital status and sick leave does not seem to be conclusive (3), though there is evidence that an individual's situation outside work, including getting divorced, may lead to work overload and a higher risk of sick leave (39). Age was obtained from the Medical Birth Registry. Marital status was assessed by self-report in the HUNT3 questionnaire, and classified into: married, unmarried, and divorced, or other.

Statistical analysis

As a descriptive measure, we calculated the incidence rate of a first sick-leave spell per 100 000 person-years at risk, according to characteristics of the study population.

Time-to-first-sick-leave-spell from date of study participation in HUNT3 was analyzed using an additive hazards survival model (28), as suggested by Lange & Hansen (8). Using their approach to causal mediation analysis, we estimated the total effect of a hypothetical

change in adult social position, measured by the change in hazard rate for time-to-first-sick-leave-spell. This estimate can be directly interpreted as the rate difference (number of additional sick leave spells in a given group per person-time unit at risk, compared to the reference group). The method further allows this total effect to be decomposed into an indirect effect mediated through physical workload and a direct effect (8).

The mediation analysis involved two steps. In the first step, we estimated the effect of adult social position on physical workload (the mediator) in a linear regression model. Parameter estimates and standard errors from this model were used for the estimation of the indirect effect of adult social position on sick leave. We controlled for childhood and adolescent social position (parental education level, parental income and parental disability pension), neuroticism, age, and marital status.

In the second step, we estimated the direct effect of adult social position and physical workload on sick leave in an additive hazards survival model. The model controlled for physical workload, childhood and adolescent social position (parental education), neuroticism, and age. We considered marital status and parental income and disability pension as well, but their inclusion did not reduce the estimates substantially (<5% change) and were therefore not included. The model was tested for time-dependent effects, but none were present (all the P-values were >0.80) (40). We tested for interaction between adult social position and physical workload, and between neuroticism and physical workload, according to suggestions by Lange & Hansen (8, appendix: <http://links.lww.com/EDE/A476>). None of the interaction terms were statistically significant (P-values for interaction terms 0.10–0.90).

The total effect of adult social position on sick leave is given by the sum of the direct and indirect effects. The direct effect of adult social position on sick leave is obtained directly from the additive hazards survival model. The indirect effect is given by the product of the parameter estimates for the regression of physical workload on adult social position (linear model) and the parameter estimate of physical workload on sick leave (additive hazards survival model). The mediated proportion is given by the quotient of the indirect effect divided by the total effect. For the direct effect, 95% CI are available from the additive hazards survival model, whereas confidence limits for the indirect and total effects, as well as mediated proportion, were computed from the standard errors and covariances in line with Lange & Hansen (8). Analyses were done using the *timereg* package (40) in the open-source statistical software R, version 3.0.3 (41).

Results

The study population included 2099 women and 1229 men, with a mean age of 36 years (range 30–41) at the time of study inclusion. Baseline characteristics according to adult social position, physical workload, and sick leave are shown in table 1. Both for women and men there

was an overrepresentation in social group II (86% for women, and 68% for men). Lower adult social position was associated with higher levels of physical workload, lower childhood and adolescent social position (parental education level, parental income and parental disability benefits), and higher levels of neuroticism. For neuroticism, this gradient was especially pronounced for women.

Mean physical workload increased from 2.8 [stan-

Table 1. Descriptive characteristics by adult social position, physical workload, and sick leave: HUNT3 participants, 2006–2008.

	Adult social position ^a								Physical workload index	Sick leave	
	I		II		III		Total		Mean	N	Incidence rate per 100 000 person days
	N	%	N	%	N	%	N	%			
Women	166	8	1802	86	131	6	2099	100	4.1	992	72
Physical workload ^b											
Low physical workload	120	72	751	42	28	21	899	43	1.5	362	59
High physical workload	46	28	1051	58	103	79	1200	57	6.1	630	84
Parental education level											
Tertiary	59	36	325	18	4	3	388	19	3.5	162	65
Upper secondary, complete	23	14	258	14	17	13	298	14	4.1	142	75
Upper secondary, basic	69	42	949	53	80	61	1098	52	4.1	520	72
Lower secondary or less	15	9	268	15	30	23	313	15	4.6	167	85
Parental income ^c											
Low income	33	20	444	25	52	40	529	25	4.6	281	83
High income	133	80	1358	75	79	60	1570	75	3.9	711	69
Parental disability pension											
Not disabled	7	4	137	8	22	17	166	8	4.0	901	72
Disabled	159	96	1665	92	109	83	1933	92	4.8	91	90
Neuroticism ^d											
Low neuroticism	89	54	773	43	39	30	901	43	3.6	349	56
High neuroticism	77	46	1029	57	92	70	1198	57	4.5	643	87
Marital status											
Married	106	64	891	50	43	33	1040	50	3.8	467	68
Unmarried	49	30	753	42	72	55	874	42	4.3	414	73
Divorced and other	10	6	155	9	16	12	181	9	4.4	110	104
Men	272	22	834	68	123	10	1229	100	4.9	359	40
Physical workload ^b											
Low physical workload	225	83	295	35	15	12	535	44	1.4	115	29
High physical workload	47	17	539	65	108	88	694	56	7.7	244	141
Parental education level											
Tertiary, short and long	81	30	113	14	12	10	206	17	3.6	54	36
Upper secondary, complete	44	16	136	16	17	14	197	16	4.4	55	38
Upper secondary, basic	126	46	481	58	58	47	665	54	5.2	198	41
Lower secondary or less	21	8	103	12	36	29	160	13	6.1	52	46
Parental income ^c											
Low income	51	19	206	25	54	44	311	25	5.7	162	65
High income	221	81	628	75	69	56	918	75	4.7	162	65
Parental disability pension											
No disability	254	93	754	90	109	89	1117	91	4.8	319	40
Disability	18	7	80	10	14	11	112	9	5.6	40	49
Neuroticism ^d											
Low neuroticism	150	55	447	54	57	46	654	53	4.7	162	65
High neuroticism	122	45	387	46	66	54	575	47	5.2	162	65
Marital status											
Married	149	55	334	40	49	40	532	43	4.2	154	40
Unmarried	107	39	454	55	64	53	625	51	5.5	178	39
Divorced and other	16	6	45	5	9	7	70	6	4.7	26	55

^a From highest (I) to lowest (III), based on a combination of education and occupational group, grouped slightly differently for women and men.

^b Dichotomous indicator of physical workload, where a sum score on physical workload index below median represents low physical workload.

^c Low income = lowest quartile, combined maternal and paternal income.

^d Dichotomous indicator of neuroticism, where a sum score on the neuroticism index below median represents low neuroticism.

dard deviation (SD) 2.2] in social group I to 5.8 (SD 2.4) in group III for women, and from 2.2 (SD 1.6) to 6.6 (SD 2.3) for men. Individuals from a lower childhood and adolescent social position and with high neuroticism had higher levels of physical workload (table 1).

During the follow-up from date of participation in HUNT3 (2006–2008) through 2009, women and men contributed a total of 3725 and 2431 years of follow-up time, respectively. The mean number of follow-up years was 1.8 (SD 0.9) for women, and 2.0 (SD 0.8) for men. The number of women who had at least one sick leave spell was 992 (47%) compared to 359 men (29%). The incidence rate of a first-sick-leave-spell per 100 000 person-years at risk was 72 for women and 40 for men. Individuals with a lower adult social position had a higher incidence rate, increasing from 43 in group (I) to 109 in group (III) for women, and in corresponding groups, from 24 to 70 for men. High physical workload, lower childhood and adolescent social position, and high neuroticism were also associated with a higher incidence rate (table 1).

Table 2 shows the estimates obtained from the linear

Table 2. Parameter estimates with 95% confidence intervals (95% CI) from the linear regression analysis^a of physical workload on adult social position: HUNT3 participants, 2006–2008

	Women		Men	
	Estimate	95% CI	Estimate	95% CI
Adult social position ^b				
I	0	Reference	0	Reference
II	1.47	1.07–1.86	2.56	2.22–2.90
III	2.45	1.87–3.02	4.06	3.55–4.62

^a In a model adjusting for parental education level, parental income, parental disability, neuroticism (continuous), age, and marital status.

^b From highest (I) to lowest (III).

Table 3. Parameter estimates with 95% confidence intervals (95% CI) from the Aalen's additive hazard regression analysis of days to first sick leave spell: HUNT3, 2006–2008.

Covariate	Women		Men	
	Estimate × 10 ⁻⁵	95% CI	Estimate × 10 ⁻⁵	95% CI
Adult social position ^a				
I	0	Reference	0	Reference
II	17.6	4.7–30.5	9.3	-0.1–18.7
III	40.3	12.7–67.9	29.4	8.6–50.2
Physical workload	4.6	2.6–6.6	2.9	1.1–4.7
Parental education				
Tertiary, short and long	0	Reference	0	Reference
Upper secondary, complete	4.8	-10.9–20.5	0.6	-13.3–14.5
Upper secondary, basic	1.3	-10.7–13.3	-0.2	-11.5–11.2
Lower secondary or less	11.9	-4.6–28.4	-3.7	-19.8–12.4
Neuroticism	8.7	5.2–12.2	6.4	2.5–10.3
Age	2.8	1.0–4.6	-0.9	-2.4–0.6

^a From highest (I) to lowest (III).

regression analysis, where we regress physical workload on adult social position. In a model controlling for childhood and adolescent social position, neuroticism, age, and marital status, an increase in physical workload was observed with decreasing adult social position. Women in group III had, on average, a physical workload score 2.45 units higher than the women in group I. The corresponding number for men was 4.06 units. For women, the inclusion of childhood and adolescent social position and neuroticism reduced the estimates, compared to a model not adjusting for these variables, by 16% (2.45 versus 2.91) for group III and by 11% (1.47 versus 1.64) for group II. For men, the estimates were reduced by around 5% in both groups II and III. By including childhood and adolescent social position and neuroticism in the models separately (not shown), it became apparent that for women, the reduction was due to both these factors, with the former weighing slightly more heavily than the latter. For men, the slight reduction was attributable only to childhood and adolescent social position.

The direct effect of adult social position and physical workload on sick leave rate is derived from the additive hazards survival model and is presented in table 3. A change in social position from group I to group III for women, resulted in 40.3 (95% CI 12.7–67.9) additional spells per 100 000 person-days at risk. The corresponding rate increase for men was 29.4 (95% CI 8.6–50.2). For women, including childhood and adolescent social position and neuroticism in the model accounted for a 16% reduction (40.3 versus 47.9) of the estimates in group III and 9% reduction (17.6 versus 19.4) in group II. The reduction in the estimates was primarily due to neuroticism, though including childhood and adolescent social position reduced the estimates further. For men, the change in estimates was negligible when both childhood and adolescent social position and neuroticism were included simultaneously. However, neuroticism did reduce the effect estimates when included separately, but the effect was mitigated when childhood and adolescent social position was also included.

A 1-unit increase in physical workload resulted in a rate increase of 4.6 (95% CI 2.6–6.6) for women and 2.9 (95% CI 1.1–4.7) for men (table 3). When including childhood and adolescent social position and neuroticism, the physical workload estimates were reduced by around 17% for women (4.6 versus 5.4) and again the reduction was mostly attributable to the inclusion of neuroticism. For men the change was negligible.

The total (TE) and indirect effects (IE) are presented in table 4. For women, a hypothetical change in adult social position from highest to lowest social group would result in a total of 51.6 (95% CI 24.7–78.5) additional sick leave spells per 100 000 person-days at risk. For men, there would be 41.1 (95% CI 21.4–60.8) additional spells. For women, 24% (95% CI 10%–49%)

Table 4. Total effects (TE) of adult social position on sick leave and indirect effects (IE) through physical workload: HUNT3, 2006–2008. Note the direct effect can be found in table 3. [95% CI=95% confidence interval.]

	IE	95% CI × 10 ⁻⁵	TE	95% CI × 10 ⁻⁵	IE/TE	95% CI
Women						
I->II	6.7	3.5–10.4	24.3	11.1–37.5	0.31	0.13–0.64
I->III	11.2	6.0–17.1	51.6	24.7–78.5	0.24	0.10–0.49
Men						
I->II	7.4	2.8–12.1	17.1	8.4–25.8	0.48	0.16–1.00
I->III	11.7	4.5–19.2	41.1	21.4–60.8	0.30	0.10–0.63

of these extra spells could be attributed to the mediating pathway of physical workload, while for men the corresponding figure was 30% (95% CI 10%–63%). That is, an intervention that could have reduced the physical workload of group III so that it was at the same level as group I would have reduced the number of sick leave spells by 24% for women and 30% for men. The total effect of adult social position on sick leave was reduced when childhood and adolescent social position and neuroticism were included in the model; for women in group III, the number of extra spells was reduced by 20% (51.6 versus 63.7), and for those in group II, by 14% (24.3 versus 28.2). For men, the reduction in total effect was substantially lower: 1% and 5% in group II and III, respectively. For men and women, both childhood and adolescent social position and neuroticism accounted for the reduction in effect estimates, though with neuroticism accounting for the largest reduction. The indirect effect estimates were similarly reduced when childhood and adolescent social position and neuroticism were included in the model; 24% (6.7 versus 8.8) for women in the middle group and 29% (11.2 versus 15.7) for women in the lowest group. For men, the reduction was around 5% in both middle and lowest group. Finally, the estimates of proportion mediated were slightly reduced for women, by 6% (0.31 versus 0.33) and 8% (0.24 versus 0.26) in the middle and lowest social group, respectively, when childhood and adolescent social position and neuroticism were included in the model. For men, the proportion mediated was reduced by 4% for the middle social group, and remained unchanged in the lowest social group.

Discussion

This study of a Norwegian working population indicates that an intervention that could reduce the physical workload of social group III to the level of group I has the potential of reducing the number of sick leave episodes attributable to adult social position by 24% among

women and 30% among men. Similarly, improving the physical workload conditions of group II to the level of group I could reduce 31% of the number of sick leave episodes attributable to adult social position amongst women, and 48% amongst men.

Advantages of our study are that we were able to take into account childhood and adolescent social position and neuroticism in our analysis; that we had complete, register-based sick leave data; and that we used an analytic approach that enables a causal interpretation. However, several limitations to our study are apparent. First, the causal interpretation of our findings rests on the assumptions of the mediation analysis not being violated (8). The assumption of no confounding on the direct and indirect pathway is threatened by our lack of indicators of childhood and adolescent health, as early health is associated with adult health (42) and educational attainment in adulthood (15); as a result, the association between adult social position on sick leave, via physical workload, could still be somewhat overestimated. We did have data on overall health measured at the time of study inclusion in HUNT3, but, in our opinion, poor health measured at this time point could have been the result of ongoing exposure to high physical workload rather than a cause of it. Thus, by adjusting for this variable, we could be blocking a pathway from physical workload (experienced prior to HUNT3 participation) to sick leave. A clear advantage would have been to have repeated measurements of physical workload, employment status and health, ideally from the start of employment history, which would enable us to disentangle the complex relation between health and physical workload over time. Furthermore, the expression for indirect and direct effect developed in Lange & Hansen focuses on situations in which the exposure and mediator do not interact (8). We assessed for interaction between the exposure and mediator, though since our study sample was relatively small, we may not have had adequate power to detect a possible interaction.

Second, our measure of physical workload was based on just three self-report questions that to our knowledge have not been validated. Further, in order to accommodate the mediation analysis, which has so far only been defined for a continuous variable, we created a sum score based on these three items. However, the physical workload items were arguably on an ordinal scale. Additionally, the questions appeared to assess slightly different aspects of physical workload (eg, the degree of heavy physical workload as opposed to perceived exhaustion from said workload). As a result, the interpretation of what a 1-unit increase on the physical workload scale means in terms of real-life physical work exposure remains unclear. Additionally, objective measurements of work exposure, such as direct measurements of mechanical exposure, would be more optimal. However, a review study suggests that self-report mea-

asures tend to underestimate the effect mediated through work, compared to more objective measures (12), which suggests that, if anything, the mediating role of physical workload would be somewhat underestimated in our study.

Third, our study assumes that personality traits measured in adulthood are representative of personality in childhood and adolescence, which is consistent with the tendency to view personality as relatively fixed (20). Recent advances have challenged this perspective by demonstrating personality changes across the lifespan (43). Moreover, these personality changes have been linked to environmental influences (44), including adverse experiences at the workplace (45). As such, personality could in part be a result of adverse conditions throughout the life course, rather than the ultimate cause of them. If this is the case, then including neuroticism might tend to underestimate the role of adult social position and physical workload on sick leave. Another challenging aspect regarding neuroticism is that it is strongly linked to depression (46). If depression is in part a result of high physical workload, then by controlling for neuroticism, we could in part be blocking a causal pathway from physical workload to sick leave which would lead to an underestimation of the true effect of physical workload.

Last, there were a fairly high number of non-participants in the HUNT3 study, and 30% of those who participated in the first part of the study and completed the full interview either did not return or had incomplete responses on the second questionnaire (as shown in figure 2). A recent study showed that individuals with low social position, poor health, and higher rates of disability were less likely to participate in HUNT3 (31). Participation in our study is thus in part determined by adult childhood position and also most likely sick leave, suggesting that the observed association between these variables could in part be induced by selective study participation. Furthermore, our study participants were restricted to people living in the county of Nord-Trøndelag, so our findings may not be generalizable to other populations. On a more general level, sick leave rates vary within geographical region, according to economic changes and according to the welfare system (39).

Despite these limitations, our study provides support that physical workload is an important mediator between adult social position and sick leave. Our study replicates findings from other research showing that the social gradient in sick leave is reduced when factoring in the role of the physical exposures at work (6–10). Direct comparison with these studies is difficult, due to the different analytic approaches in measuring mediation. The paper by Lange & Hansen (8) is the only other study we are aware of that estimates the mediating effect of physical work environment in a survival context with a

causal interpretation. In their study, they found that the proportion mediated via physical work environment ranged from 24–48% for men and 26–71% for women, which is slightly higher than what we found. However, direct comparison is difficult due to the use of different measures of adult social position and physical work environment. Another aspect of our study that makes direct comparison with other studies difficult is that most of them included other aspects of the working environment and a host of lifestyle factors, including smoking, alcohol use, and physical activity, in their model. The relation between working conditions and other life-course factors could quite likely be the result of a complex causal chain, whereby working conditions may be prohibitive of a healthy lifestyle, and reduced health resulting from a poor lifestyle may influence the ability to handle physical workload. Therefore, while several life-course factors were assessed in the HUNT3 study, we chose not to control for them because they could in part be a result of coping with high physical workload, rather than a pathway operating directly from adult social position to sick leave.

Our study makes a unique contribution in that we were able to include childhood and adolescent social position and neuroticism in assessing the mediating role of physical workload on sick leave. The total number of extra sick leave spells attributable to adult social position became lower when these factors were included, and the reduction was more prominent for women (24–29%) than men (5%). For women, the reduction in number of extra spells was accounted for by a reduction both in number of extra spells attributable to the indirect pathway through physical workload and the direct pathway from adult social position to sick leave. For men, there was only a reduction in the number of extra spells attributable to the indirect pathway through physical workload.

The finding that the total number of extra spells in group III compared to group I are reduced when factoring in childhood and adolescent social position and neuroticism is compatible with a life-course perspective, whereby adult social position and health is influenced by earlier factors in life. This interpretation is in line with several studies showing that social position early in life is important for health (47) and sick leave (48), even while accounting for adult social position. Fewer studies have investigated the role of personality as an early life-course factor accounting for the attainment of adult social position and health outcomes, but there is evidence from a study by Hampson et al that personality traits can in part explain the social gradient in self-reported health through its influence on both education and health-promoting behaviors (25). Our study suggests that childhood and adolescent social position and neuroticism are important confounders between adult social

position and sick leave, and by taking into account these early factors, we get a more conservative estimate of the rate increase attributable to physical workload. Future research would therefore benefit from considering these variables when studying adult social position and sick leave, in particular there is still a need to elucidate to what extent early-life conditions could be influencing the development of personality over time and vice versa.

The implications of these findings should also be considered. Sick leave is a large problem both in terms of its cost to society and employers, but also the individual. Unlike adult social position, which would be very difficult to modify, it is possible to intervene at workplaces in order to reduce exposure to hazardous physical working conditions. Such interventions could be based on requirements and recommendations set up in national regulations and guidelines. While our study provides an estimate of the maximum number of sick leave episodes that could be removed under an intervention in which the physical workload of group II and III were reduced to that of group I – arguably a target that is difficult to meet in real life – this finding is nonetheless informative in that it quantifies how much of the social gradient in adult social position could possibly be removed by such an intervention. The pathway through physical workload represents one of many possible targets for an intervention, and the finding that a substantial gradient persists after taking into account the role of physical workload suggest that other causal pathways, such as through psychosocial work factors and the range of lifestyle factors, are also linking adult social position and sick leave. These pathways could be separate and distinct, but might also be interacting with one another in complex ways over time. Recent developments in mediation analysis rooted in a causal framework have made advances that enables the analysis of multiple mediating pathways and interactions (49). Future studies would benefit from applying these methods to datasets that include repeated measurements of life-course factors over time in order to disentangle the complex relation between social position, work exposures, and sick leave.

In summary, the present study quantifies the mediating effect of physical workload in explaining the social gradient in sick leave while taking into account the contribution from personality and social position earlier in life. It also shows that neuroticism and early life-course factors contribute to the total effect of social position on sick leave.

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