# Physical activity and time spent sitting as a risk factor for low-back pain: longitudinal data from the HUNT study

**Torje Bragstad Venseth**

**Norwegian University of Science and Technology**

**Faculty of Medicine**

**Department of Neuroscience**

**BEV 3901 Master Thesis in Human Movement Science**

**Trondheim, spring 2014**

## Acknowledgements

I would like to thank my supervisors Tom Ivar Lund Nilsen and Paul Jarle Mork at the department of Human Movement Science, NTNU, for their guidance and valuable support throughout the process of writing my thesis. I would also like to thank my fellow students Mats Fjeld and Jørgen Danielsen for their help and support during the two last years. I am very grateful.

## Abstract

**Background**: Low back pain (LBP) is the most common pain condition with a lifetime prevalence of 70 %. One of the most investigated risk factor for LBP is sedentary lifestyle. This is of great interest as sitting is the more dominant occupational activity in today’s society. **Aim**: The aim of this study was to prospectively investigate if the risk of chronic LBP is associated with time spent sitting, leisure time physical activity, and occupational activity. We also examined the combined effect of time spent sitting and physical activity and also for the combined effect of physical leisure activity and work activity on the risk of chronic LBP. **Method:** Logistic regression was used to calculate odds ratio (OR) of LBP associated with the various activity measures. The precision of the estimates was assessed by 95 % confidence interval (Cl). **Results**: There was some evidence of an inverse association between time spent sitting and risk of chronic LBP, with a OR of 0.83 (0.71-0.97) among persons sitting more than eleven hours a day compared to persons sitting less than five hours a day. Hard physical labour increased the odds of chronic LBP (OR 1.19, 1.02-1.40) when compared to an occupation mostly involving sitting, whereas high levels of leisure time activity was associated with a OR of 0.79 (0.64 - 0.96) compared to being inactive. Combined analysis showed high level of leisure time physical activity to decrease the risk of chronic LBP regardless of occupation. The largest modification of leisure time physical activity on the risk of chronic LBP was found for persons having hard physical work demands. **Conclusion:**

In this population-based longitudinal study, time spent sitting and leisure time physical activity was inversely associated with chronic LBP, whereas heavy physical work, such as walking, lifting and heavy labour, increased the risk. Moreover, analyses of combined effects suggest that the lowest risk was among persons who reported high leisure time physical activity and much sitting.

# Introduction

Low back pain (LBP) is the most common disease with lifetime prevalence of 70 % (Hartvigsen et al 2000). A Danish cohort-study reported that 43% of 4866 Danish employees had experienced LBP during a 1-year period (Xu et al 1996). It is also the largest cause of disability among people under the age of 45 (Hartvigsen et al 2000; Lis et al 2007). Because of LBPs high prevalence it is the leading reason for physician visits, hospitalization and the use of other health care services, and in 1998 the total health care expenditure for LBP in the USA were 91 billion US dollars (Luo et al 2004). In western societies it is the largest reason for long-term sickness absence caused by musculoskeletal pain (Holtermann et al 2010).

There are great potential economic and social benefits to gain from reducing the public health problems concerning musculoskeletal pain, especially in the lower back. Therefore, several studies have investigated the causality and risk factors for LBP (Auvinen et al 2008; Hoogendoorn et al 2000; Holtermann et al 2014; Jacob et al 2004; Kopec et al 2004; Lee et al 1994; Levangie et al 1999; Nilsen et al 2011; Rotgolz et al 1992; Tissot et al 2009; Xu et al 1996; Xu et al 1997). Sedentary lifestyle is one of the most investigated risk factors for LBP. This is of great interest as sitting is the dominant occupational activity. A Danish study reported that one-third of Danish workers between the age 18-59 spend more than 75% of their work time in a seated position (Hartvigsen et al 2000). It is a common opinion that sitting is a risk factor for LBP. This is not supported by recent reviews, as they report no association with LBP and the time spent sitting at work (Chen et al 2009; Hartvigsen et al 2000; Lis et al 2007; Roffey et al 2010). However, they report that sitting combined with awkward positions and whole body vibrations may increase the risk. Early studies may have contributed to the perception that long periods of sitting may cause LBP. There have been reports of the seated position increasing the intradiscal pressure in the spine (Nachemson et al 1970; Andersson et al 1975). More recent study on the subject disagrees with the early reported findings (Sato et al 1999; Schultz et al 1982; Wilke et al 1999).

A great amount of research has been done in an attempt to decrease LBP with different sitting options. A review by O´Sullivan et al (2012) states that in the recent decades there has been a great focus on dynamic sitting. They reported of studies suggesting persons with LBP tend to assume a more static position while seated, and therefore chairs with the possibility to make small movements of the spine have become popular. The review, however, concludes that there is no association between dynamic sitting and a decreased risk of LBP.

Leisure time physical activity (LTPA) is often associated with good health and an important factor in the prevention of musculoskeletal dysfunctions, cardiovascular diseases, cancer and a positive effect on mental health (Batty et al 2000; Dunn et al 2005; Hildebrand et al 2000; Kohl 2001). LTPA has also been reported to have a positive effect on reducing non-specific LBP and a preventive effect on new occurrences of LBP (Hayden et al 2005; Holtermann et al 2010; Nilsen et al 2011;Vuoiri 2001). Different results have been reported. Two studies reported finding no association between LTPA and LBP (Hogendoorn et al 1999; Jacob et al 2004). Another study suggested that inactivity is associated with LBP (Hildebrandt et al 2000).

A large number of studies have looked at occupational sitting (Burdorf et al 1997; Hartvigsen et al 2000; Holtermann et al 1997; Lis et al 2007; Xu et al 1997), as this is valuable information that could be used in preventing occupational LBP. There is to our knowledge no study examining the effect of total time spent sitting on LBP and the combined effect of sedentary lifestyle and LTPA.

The aim of this study was to prospectively investigate if risk of chronic LBP is associated with total time spent sitting, leisure time physical activity, and occupational activity. We also examined the combined effect of time spent sitting and physical activity and also for the combined effect of physical-leisure activity and work activity on the risk of chronic LBP.

# Materials and methods

## Study population

The Nord-Trøndelag Health Study (HUNT) is a population-based health survey conducted in the Nord-Trøndelag County, Norway. It consists of three cross-sectional waves; HUNT 1 (1984-86), HUNT 2 (1995-97) and HUNT 3 (2006-08). HUNT 1 was primarily designed to determine the prevalence of hypertension, lung disease, diabetes and life quality. HUNT 2 and HUNT 3 were follow-ups to the original study, but several additional data has been added. They had a wider range of topics concerning diseases, urine samples and for some sub-groups clinical measurements e.g. spirometry and bone mineral density (Krogstad et al 2013). The population in Nord-Trøndelag County is a relatively stable and homogenous and therefore suitable for epidemiological studies (Krogstad et al 2013). It is also representative of Norway in terms of geography, economy, and industry, source of income, morbidity and mortality (Holmen et al 2003). Citizens aged 20 years or older were invited to participate in the study. In HUNT 1, 86.404 residents were invited to participate and 87% (n=77212) accepted. In HUNT 2, 93.898 were invited and 70% (n=65237) accepted. In HUNT 3, 93.860 were invited and 54% (n=50807) accepted. Information about a wide range of health and lifestyle related factors were obtained through questionnaires and interviews, whereas blood pressure and blood samples were obtained at a clinical examination by trained personnel using standardized procedures (Holmen et al 2003). A more detailed description of the HUNT study can be found at www.hunt.ntnu.no.

This current study is based on data from the last two waves of the HUNT study; HUNT 2 and HUNT 3. For the purpose of the present study, we selected 37.071 persons who had participated in both surveys. A total of 14.626 people reporting low back pain in HUNT 2 and were therefore excluded from the baseline study cohort. Thus, the prospective analysis of LBP were based on 10.658 men and 11.787 women (n=22445). The number included in each of the analyses varied somewhat due to missing data on each of the exposure variables. The study was approved by the Regional Committee for Ethics in Medical Research.

## Study variables

### Musculoskeletal pain in the lower back

To gather data on LBP, questions from the Standardized Nordic Questionnaire (Kurorinka et al 1987) were applied. In HUNT 2 and HUNT 3 the first question concerning musculoskeletal pain were; “During the last year, have you had pain and/or stiffness in your muscles and limbs that lasted for at least 3 consecutive months"? Response options were "yes" and "no". If the answer was yes, the participant was asked to specify the region of the chronic pain. Among 9 regions described by a body chart, one of the response options was "lower back", and these were defined as cases in the analyses.

**Time spent sitting**

In the HUNT 2 questionnaire, the participants were asked to report total hours spent sitting. "About how many hours do you sit during a normal day? (Include work hours and leisure time)". The participant responded by writing the total number of hours they spent seated a day. In the present study time spent sitting was divided into categories of; "<5 hours", "5-6 hours", "7-8 hours", "9-10 hours" and "11< hours" for the main analyses. However, for the combined analyses we categorized time spent sitting as "<6 hours", "7-10 hours" and ">11hours". The reason was having a significant amount of subjects in each category.

**Leisure time physical activity**

In the HUNT 2 questionnaire, participants were asked about their leisure time activity level. "How much of your leisure time have you been physically active in the last year? Weekly average for the year. Commute time counts". Physical activity was divided into low and vigorous physical activity. Low physical activity was defined as "no sweat, not out of breath". The definition of vigorous physical activity was "sweat, out of breath". The participant was asked to report the weekly amount for both low and vigorous activity. The response options were "none", "less than 1", "1-2" or "3 or more". For our analysis we renamed the categories from low and vigorous physical activity into light and hard physical activity. In the main analysis we examined the effect of only performing light activity. To investigate a general leisure time physical activity level, we combined light and hard activity into four categories based on the amount of hours; "inactivity" (none), "low activity" (<3 h light activity, and no hard activity), “moderate activity” (≥ 3 hours of light activity and/or <1 hour of hard activity) and “hard activity” (any hours of light activity and >1 hour of hard activity).

**Work activity**

The participants were asked to describe their physical work demands. “If you have/had paid or unpaid employment, how would you describe your job?” The response options were; “work that mostly involves sitting”, “work that requires much walking”, work that requires much walking and lifting” and “heavy physical labour”. Examples of work activity were given to explain each category.

For the main analysis of this study work activity was coded as “sitting”, “walking”, “walking/lifting” and ”heavy labour”. For the combined analysis we combined the two categories “walking/lifting” and “heavy labour”.

**Other factors**

The height and weight of the participants were measured wearing light clothes and no shoes. Height was measured to the nearest 1.0 cm and weight to the nearest 0.5 kg. BMI was calculated as bodyweight in kilograms divided by the squared value of body height in meters ($kg/m^2$). The BMI values were recoded into four categorical scores; underweight: <18.5, normal weight: 18.6-24.9, overweight: 25.0-29.9 and obese: ≥30.

Psychosocial well-being was assessed by the question; “when you think about your life situation, are you generally satisfied or unsatisfied”. The response options were categorized by ”very satisfied”, “quite satisfied”, ”satisfied”, ”neither”, ”unsatisfied”, ”quite unsatisfied” and ”very unsatisfied”.

In our analysis we adjusted for education. There where four response options for the level of education; “high school”, “vocational school”, “college-degree”, “university degree less than 4 years” or “university degree more than 4 years”.

Based on info on smoking habits, persons were categorized as “never smoked”, “former smoker” and “current smoker”. In addition we adjusted for sex and continuous age.

### Statistical analysis

To analyse the characteristics of the study population, we used descriptive statistics presented as means and standard deviation, or in percentages. Logistic regression was applied to calculate odds ratio (OR) as estimate of relative risk for LBP associated with time spent sitting, only light activity, light and hard activity, and work activity. Furthermore, we investigated the combined effect of time spent sitting and “light and hard” activity and combined effect of work activity and “light and hard” activity on the risk of LBP. Analyses were adjusted for the following confounders: sex, age (continuous), BMI (categorical), well-being (categorical), education (categorical) and smoking (categorical). Precision of the associations was assessed by a 95% confidence interval (Cl). All statistical analyses were conducted using IBM SPSS statistics 2.0 for Mac OS X.

## Results

### Descriptive statistics of the population

During the 10 year period, 2.782 (12.4%) people reported LBP. Presented in Table 1 is the descriptive statistics of the population included in this study. Men: mean age 45.5, BMI 26.3 kg/m$^2$. Women: mean age 44.1, BMI 24.7 kg/m$^2$. 35.9% of the men were normal weight, and 12.3% obese. 50.2% of the women were normal weight and 13.5% were obese. Regarding LTPA, 5.4% of men were inactive and 3.3% of the women. A total of 30.2% of men and 23.6% of the women had an occupation that involved sitting, Only 19.5% of men and 2.3% of the women reported performing hard work activity.

Table 1 Descriptive statistics

| | Male | Female |
|---|---|---|
| Number of participants | 10658 | 11787 |
| Age, mean years (SD) | 45.5 (13.3) | 44.1 (13.9) |
| BMI, mean kg/m$^2$ | 26.3 (3.2) | 25.7 (4.2) |
| Leisure time physical activity | | |
| Inactive, n (%) | 554 (5.4) | 366 (3.3) |
| Low activity, n (%) | 2503 (24.4) | 3696 (33.3) |
| Moderate activity, n (%) | 3385 (33.0) | 4059 (36.6) |
| High activity, n (%) | 3823 (37.2) | 2971 (26.8) |
| Work activity | | |
| Sitting, n (%) | 3221 (30.2) | 2784 (23.6) |
| Heavy labour, n (%) | 2073 (19.5) | 269 (2.3) |
| BMI, kg/m$^2$ | | |
| Normal weight, n (%) | 3825 (35.9) | 5914 (50.2) |
| Obese, n (%) | 1308 (12.3) | 1595 (13.5) |

Abbrevations: N: number of participants, SD=standard deviation, BMI=body mass index.
*Leisure time physical activity*; "inactivity" (none), "low activity" (<3 h light activity, and no hard activity), "moderate activity" (≥3 hours of light activity and/or <1 hour of hard activity) and "hard activity" (any hours of light activity and >1 hour of hard activity). *BMI*: Normal weight (BMI 18.5-24.99), Obese (BMI ≥ 30).

## Time spent sitting, leisure time physical activity and work activity

The association between LBP, time spent sitting, LTPA and work activity is presented in Table 2. In the analysis of a possible association between odds ratio for LBP and time spent sitting there are tendencies towards a decrease of LBP with an increase of time spent sitting. Persons that sat for less than 5 hours were chosen as reference. Persons in the category 5-6 hours of time spent sitting showed no significant decrease of risk for LBP (OR 0.98) when adjusted for age, sex, BMI, smoking, wellness and education. The persons in the category of ”7-8” and ”9-10” hours of sitting did also not show any significant change. Only the category of >11 hours had a significant reduction of risk for LBP (OR 0.83, 0.71 - 0.97).

In the analysis of the association between LBP and performing only light activity, an increase of light activity showed to be associated with lower odds of LBP. Performing more than three hours of light LTPA decreased odds of LBP with 20% (0.80, 0.62-1.04) compared to doing none. A similar decrease was observed for both light and hard LTPA. A high level of LTPA decreased odds of LBP with 21% (0.79, 0.64-0.96).

The analysis of work activity showed the risk of LBP for different physical work demands. We observed that more sedentary work activity had a lower risk of LBP. Subject performing hard labour had a significant greater risk of LBP (OR 1.19, 1.02-1.40) than subjects sitting at work.

## Combined time spent sitting and level of leisure time physical activity

Table 3 shows the combined effect of sitting time and LTPA on odds of LBP. Persons being inactive and sitting less than 6 hours a day were used as reference. Overall, there was a tendency that an increased amount of sitting time reduces the odds of LBP in all four categories of activity. Of those four categories, an increased time spent sitting showed the largest effect among persons being inactive. Persons being inactive and sitting more than 11 hours a day had a great decrease of odds for LBP (OR 0.61, 0.32-1.14) compared to the reference group. Regardless of time spent sitting, an increased level of LTPA decreased of odds for LBP. The largest effect of high LTPA was observed among persons sitting less than 6 hours a day, with a OR of 0.69 (0.52-0.90) compared to the reference group. Additional analyses were done, adjusting for work activity. No significant difference was found.

## Combined leisure time physical activity and physical work demands

Odds ratios of low back pain with the combined effect of work activity and LTPA are presented in table 4. We observed that persons in the reference group with hard physical work demands and in addition being inactive had the highest odds of LBP. The lowest odds of LBP were observed with persons sitting at work that also had a high level of LTPA (OR 0.62, 0.45-0.85). The common trend is, regardless of physical work demands, that a higher level of LTPA will reduce odds of LBP. Our findings suggest a trend towards more sedentary work demands reducing the odds of LBP independent of the level of LTPA. The largest difference of work activity was observed with persons being inactive. Persons sitting at work had a 37% (0.63. 0.37-1.06) decrease on odds of LBP compared to persons with physical work demands involving walking, lifting or heavy labour. When comparing persons with a high level of LTPA, a smaller difference was observed. Persons with physical work demands involving walking, lifting or heavy labour had an odds for LBP of 0,76 (0.56-1.02), whereas persons sitting at work had an odds for LBP of 0,62 (0.45-0.85). Additional analyses were done, adjusting for time spent sitting. No significant difference was found.

Table 2 The association between LBP and time spent sitting, physical activity and work activity

| | Cases/no-cases | OR [1] | OR [2](95 % Cl) | P-trend |
|---|---|---|---|---|
| **Time spent sitting** | | | | |
| <5 | 770/4829 | 1.00 | Reference | |
| 5-6 | 615/3934 | 0.98 | 0.98 (0.87 - 1.09) | |
| 7-8 | 358/2604 | 0.86 | 0.90 (0.78 - 1.03) | |
| 9-10 | 369/2621 | 0.88 | 0.95 (0.83 - 1.09) | |
| 11< | 257/2148 | 0.75 | 0.83 (0.71 - 0.97) | 0.022 |
| **Only light activity** | | | | |
| None | 139/781 | 1.00 | Reference | |
| <1 | 203/1358 | 0.84 | 0.83 (0.65 - 1.05) | |
| 1-2 | 291/1767 | 0.93 | 0.91 (0.72 - 1.14) | |
| 3+ | 144/1010 | 0.80 | 0.80 (0.62 - 1.04) | 0.260 |
| **Light and hard activity** | | | | |
| Inactivity | 139/781 | 1.00 | Reference | |
| Low activity | 822/5377 | 0.86 | 0.84 (0.69 - 1.02) | |
| Moderate activity | 953/6491 | 0.83 | 0.86 (0.71 - 1.05) | |
| High activity | 742/6052 | 0.69 | 0.79 (0.64 - 0.96) | 0.060 |
| **Work activity** | | | | |
| Sitting | 650/5355 | 1.00 | Reference | |
| Walking | 781/5578 | 1.15 | 1.05 (0.94 - 1.18) | |
| Walking/lifting | 704/4211 | 1.38 | 1.22 (1.09 - 1.37) | |
| Heavy labour | 284/2058 | 1.14 | 1.19 (1.02 - 1.40) | 0.448 |

Abbreviations: OR: odds ratio, Cl; confidence interval

[1]: unadjusted. [2]: Adjusted for sex, age, bmi, smoking, education and psychosocial well being.

*Time spent sitting* categorized in total hours spent sitting a day. *Only light activity* categorized in hours per day. *Light and hard activity*; “inactivity” (none), “low activity” (<3 h light activity, and no hard activity), “moderate activity” (≥3 hours of light activity and/or <1 hour of hard activity) and “hard activity” (any hours of light activity and >1 hour of hard activity).

Table 3 Odds ratio (OR) for low back pain associated with the combined effect of time spent sitting and leisure time physical activity

| | Level of leisure time physical activity[a] | | | |
|---|---|---|---|---|
| | Inactivity | Low activity | Moderate activity | High activity |
| Time spent sitting | OR (95% Cl) | OR (95% Cl) | OR (95% Cl) | OR (95% Cl) |
| <6 hours | 1.00 | 0.73 (0.55 - 0.96) | 0.78 (0.60 - 1.03) | 0.69 (0.52 - 0.90) |
| 7-10 hours | 0.71 (0.44 - 1.15) | 0.70 (0.52 - 0.94) | 0.72 (0.54 - 0.96) | 0.64 (0.48 - 0.86) |
| >11 hours | 0.61 (0.32 - 1.14) | 0.66 (0.46 - 0.93) | 0.68 (0.49 - 0.95) | 0.54 (0.38 - 0.77) |

Abbreviations: OR: odds ratio, Cl; confidence interval

[a] *Level of leisure time physical activity*; “inactivity” (none), “low activity” (<3 h light activity, and no hard activity), “moderate activity” (≥3 hours of light activity and/or <1 hour of hard activity) and “hard activity” (any hours of light activity and >1 hour of hard activity). Adjusted for sex, age, bmi, smoking, education and psychosocial well being. OR: odds ratio Cl: confidence interval.

Table 4 Odds ratio (OR) for low back pain associated with the combined effect of work activity and leisure time physical activity

| | Level of leisure time physical activity[a] | | | |
|---|---|---|---|---|
| | Inactivity | Low activity | Moderate activity | High activity |
| Work activity | OR (95% Cl) | OR (95% Cl) | OR (95% Cl) | OR (95% Cl) |
| Walking/lifting/heavy | 1.00 | 0.76 (0.56 - 1.03) | 0.87 (0.65 - 1.17) | 0.76 (0.56 - 1.02) |
| Walking | 0.85 (0.53 - 1.35) | 0.65 (0.48 - 0.89) | 0.73 (0.54 - 0.99) | 0.67 (0.49 - 0.92) |
| Sitting | 0.63 (0.37 - 1.06) | 0.73 (0.54 - 1.00) | 0.63 (0.46 - 0.86) | 0.62 (0.45 - 0.85) |

Abbreviations: OR: odds ratio, Cl; confidence interval

[a] *Level of leisure time physical activity*; "inactivity" (none), "low activity" (<3 h light activity, and no hard activity), "moderate activity" (≥3 hours of light activity and/or <1 hour of hard activity) and "hard activity" (any hours of light activity and >1 hour of hard activity). Adjusted for sex, age, bmi, smoking, education and psychosocial well-being

# Discussion

## Main findings

In this prospective study using the population based HUNT-data from Nord-Trøndelag, Norway, we investigated the possible association between LBP and measures of physical activity in leisure time and at work, as well as with total time spent sitting. The main finding of this study was that time spent sitting did not increase the odds of LBP, but rather was weakly, but inversely associated with LBP. Heavy physical work demands showed to be a greater risk of LBP, compared to occupational sitting. Analyses show that LTPA was associated with lower odds of LBP, independent of occupational activity. However, the largest effect was found for persons with hard physical work demands.

## Comparison with current literature

We found sitting not to be associated with an increased risk of LBP. This corresponds with the latest reviews (Chen et al 2009; Hartvigsen et al 2000; Lis et al 2007; Roffey et al 2010). Moreover, we did not find occupational sitting to be a risk factor for LBP. Previous studies have reported similar findings (Burdorf et al 1997; Holtermann et al 2010; Xu et al 1996; Xu et al 1997). According to our results there may be tendencies of a protective effect of occupational sitting compared to harder word demands as a decreased odds of LBP is observed. There have been reported findings of LBP being associated with sitting (Lee et al 1997; Rotgoltz et al 1992). However, they report sitting to be a risk factor when combined with poor sitting habits, no freedom of movement or the activity done while sitting. Therefore, it is a question of definition as persons with “good-sitting-habits” and freedom to move while sitting does not seem to be associated with LBP (Tissot et al 2009). It is our opinion that studies proving sitting to be a risk factor for LBP are isolated to a specific occupation instead of research done on a general large population, similar to the present study. Specific terms of work conditions in smaller studies may be the reason for finding sitting to be associated with LBP. A typical example is whole-body vibration, which is a well-established risk factor for LBP (Chen et al 2009; Hartvigsen et al 2000; Lis et al 2007; Roffey et al 2010).

The widespread idea that sitting in general is associated with LBP has been described as a myth (Hartvigsen et al 2000). This is most likely caused by early studies reporting sitting to be damaging to the vertebral disc (Nachemson et al 1970; Andersson et al 1975). Reducing occupational LBP is of great importance both for the individual and the society. Studies have tried to identify the effect of ergonomic devices on LBP (Gregory et al 2006), but according to a recent review on dynamic sitting and LBP there was no evidence for a decrease of LBP (O´Sullivan et al 2012).

Heavy physical work demands such as prolonged standing, heavy lifting, bending or twisting are well-documented risk factors for LBP (Burdorf et al 1997; Hartvigsen et al 2000; Heneweer et al 2011; Hoogendoorn et al 1999; Lis et al 2007). The results of the present study correspond with the current literature. We found physical work demands to be associated with LBP, especially for persons with "walking/lifting" and "heavy labour" occupational activities. Macfarlane et al (1997) investigated physical work activities as predictors for new cases of LBP. They reported an increased risk for those having physical work demands involving lifting/pulling/pushing objects of at least 25 lbs., or whose jobs involved prolonged periods of standing or walking. There have also been suggestions of a dose-response for heavy lifting at work and LBP (Hoogendoorn et al 2000).

Based on our findings, it does not seem that sedentary lifestyle is associated with increased risk of LBP. This is in accordance with previous reports (Chen et al 2009; Kopec et al 2004). We also found a favourable effect of LTPA on the odds of LBP. Participation in LTPA have previous been reported to have a positive effect in the prevention and treatment of LBP (Andersen et al 2010; Kujala et al 1999; Nilsen et al 2011). However, studies have also investigated LTPA as a risk factor for LBP. The results have been diverse. A longitudinal cohort study investigated risk factors for development of LBP. They reported LTPA not to increase risk of developing LBP (Kopec et al 2004). A cross-sectional study on adolescence (yrs 15-16) did in fact report an association with LTPA and LBP, and also for LBP and time spent sitting (Auvinen et al 2008). However, their definition of LBP was; "Have you had any pain or aching in your low back area during the past six months''? This is different from the definition of chronic LBP used in the current study and could explain the different result. A relation in form of a U-shaped curve has also been suggested, meaning that both inactivity and vigorous activity could have a negative effect on LBP. Heneweer et al (2009) investigated this hypothesis on a general population in the Netherlands. They concluded to have found some evidence of a U-shaped relation and that some activities may be preventive and that some may be a risk factor. Moreover, once LBP is established vigorous activity may contribute to increase the symptoms (Holtermann et al 2013; Jacob et al 2004).

It is a widespread idea that physical occupational activity can replace lack of LTPA. A study investigating occupation, hours worked and LTPA reported "blue collars" to be more inactive during leisure time than persons with a more sedentary occupation and higher level of education (Burton et al 2000). This could be explained by socioeconomic factors as they have been reported to affect people's level of health (Mehlum et al 2008). It is likely to assume that an occupation with high physical work demands will be more of a physical strain on the body. Our results indicate a protective effect from increased level of LTPA on the odds of developing LBP for persons with hard physical work demands. The same effect is observed with persons spending less time sitting.

## Possible mechanisms

Our results indicate that the longer time spent sitting, the lower the risk of LBP. An explanation could be persons in this category having an occupation that mainly involves sitting. Furthermore, less time spent sitting could imply that the persons have higher physical work demands. Walking, lifting and heavy work is associated with an increased risk of LBP compared to the seated occupation. Heavy-duty occupations will include working in odd posture and lifting heavier loads than the standards set by The Labour Inspection Authority (Xu et al 1997; Heneweer et al 2011; www.arbeidstilsynet.no). In a prospective cohort study by Hogendoorn et al (2000), they reported a dose-response relation between flexion and rotation of the trunk and lifting at work and LBP. The subjects reporting to lift loads at on at least 25 kg for more than 15 times a day had an 79% increased odds of LBP compared to subjects not lifting at all.

In the earlier mentioned study of Xu et al (1997), they collected data through interviews on Danish employees in the age group 19-59 years. They found an increased risk of LBP when sitting was combined with whole body vibrations and poor sitting posture (Xu et al 1997). These findings are also reported by other studies as a risk factor for LBP (Burdorf et al 1997; Lis et al 2007; Holtermann et al 2010; Hartvigsen et al 2000). The main impact of whole body vibration is its effect on the neuromuscular facilitation of the lumbar muscle and is often used as a training method (Wirth et al 2010). However, when a person is exposed to whole body vibration for a longer period of time, proprioception of the trunk will be affected and capability to support the lumbar posture will decrease (Li et al 2008).

Early studies have investigated sitting as a risk factor. One often cited study is Nachemson et al (1970); Intradiscal dynamic pressure in lumbar disc. They claim to prove that sitting will increase the hydrostatic pressure in the vertebral disc (IDP) compared to a neutral standing position. A study reported that standing would lead to only 35% of the IDP from sitting with lumbar flexion (Andersson et al 1975). This is however not supported by recent reviews (Hartvigsen et al 2000; Chen et al 2009; Lis et al 2007). More recent studies have reported lower or similar IDP measurements from sitting compared to standing (Schultz et al 1982; Wilke et al 1999; Sato et al 1999). Reasons for this contradicting reports in the more recent studies compared to earlier reports were explained in a review on sitting vs. standing IDP from development of new tools and methods to measure IDP (Claus et al 2008). They also concluded that if there in fact is an association between sitting and LBP it is unlikely raised by IDP.

## Strength and limitations

An important strength of this study is the sample. It consists of a large number of participants with varied age and occupation. This will decrease the possibility of selection bias. It also means that the results are comparable with populations of somewhat same culture, at least other Northern European populations (Krogstad et al 2013). In the HUNT study, data was collected by questionnaire with a wide range of information. This gave us the possibility to adjust for cofounding factors such as age, sex, BMI, education and well-being. In addition to investigate the association of LBP, time spent sitting, work activity and LTPA, we were also able to investigate the combined effects of time spent sitting and LTPA as well as work activity and LTPA. There is to our knowledge no other study examining these combined effects on odds of LBP.

Most studies concerning associations with LBP, occupation and LTPA are cross-sectional. In the current study we excluded people with LBP at baseline, and prospectively examined the risk of LBP. This increases the validity of the results in terms of possible causal associations. However, it should be noted that we used logistic regression to calculate OR as measure of relative risk, and these could be somewhat high due to high occurrence of LBP. Moreover, workers who have experienced low back pain may have changed jobs or work activities, it is therefore important to use longitudinal studies that define "exposures" before the onset of symptoms (Macfarlane et al 1997). However, as musculoskeletal pain is fluctuating, there is a chance of participants not reporting LBP based on their status the past year. Moreover, we do not know if a person’s activity level has changed from baseline to follow-up.

Self-reported information will always raise the possibility of misclassification and information bias. People may misunderstand the difference between the two categories both in relations to amount and intensity (Shepard 2003). However, keeping in mind that we have a relative large sample size the categorization of physical activity has showed to be valid (Shepard 2003). Furthermore, the method in the questionnaire used to collect data on levels of physical activity has been validated through objective measurements of physical activity, cardiorespiratory fitness and energy expenditure in a random sample (Kurtze et al 2008). In the present study, questions from the Standardised Nordic Questionnaire were applied for assessing information on musculoskeletal pain and physical activity. The reliability of this questionnaire has been shown to be acceptable (Kuorinka et al 1987).

## Conclusion

In this population-based longitudinal study, total time spent sitting was weakly and inversely associated with LBP. In relation to physical work demands, walking, lifting and heavy labour was positively associated with the risk of LBP compared to people having sedentary work. In addition, leisure time physical activity was associated with decreased odds of developing LBP. Moreover, analyses of combined effects suggest that the lowest risk was among persons who reported high leisure time physical activity and much sitting. This could be of importance for further research.

## Literature


Auvinen J, Tammelin T, Taimela S, Zitting P, Karppinen J. Association of physical activity and inactivity with low back pain in adolescents, Scand J Med Sci Sports. 2008;(2):188-94.

Andersen LL, Christensen KB, Holtermann A, Poulsen OM, Sjøgaard G, Pedersen MT, Hansen EA. Effect of physical exercise interventions on musculoskeletal pain in all body regions among office workers: a one-year randomized controlled trial, Man Ther. 2010;15(1):100-4.

Andersson BJ, Ortegren R, Nachemson AL, Elfstrom G, Broman H. The sitting posture: an electromyographic and discometric study. Orthop Clin North Am. 1975;6(1):105-20.

Batty D, Thune I. Does physical activity prevent cancer? Evidence suggests protection against colon cancer and probably breast cancer. BMJ. 2000;321(7274):1424-5.

Burdorf A, Sorock G. Positive and negative evidence of risk factors for back disorders, Scand J Work Environ Health. 1997;23(4):243-56.

Burton NW, Turrell G. Occupation, hours worked and leisure-time physical activity. Prev Med. 2000;31(6):673-81.

Claus A, Hides J, Moseley GL, Hodges P. Sitting versus standing: Does the intradiscal pressure cause disc degeneration or low back pain?, J Electromyogr Kinesiol. 2008;18(4):550-8.

Chen SM, Mei-Fang L, Cook J, Bass S, Lo SK. Sedentary lifestyle as a risk factor for low back pain: a systematic review. Int Ach Occup Environ Health. 2009;82(7):797-806.

Dunn AL, Trivedi MH, Kampert JB, Clark CG, Chambliss HO. Exercise treatment for depression: efficacy and dose response. Am J Prev Med. 2005;28(1):1-8.

Gregory DE, Dunk NM, Callaghan JP. Stability ball versus office chair: comparison of muscle activation and lumbar spine posture during prolonged sitting, Hum Factors. 2006;48(1):142-53.

Hartvigsen J, Leboeuf-Yde C, Lings S, Corder EH. Is sitting-while-at-work associated with low back pain? A systematic, critical literature review. Scand J Public Health. 2000;28(3):230-39.

Hayden J, van Tulder MW, Malmivaara A, Koes BW. Exercise therapy for treatment of non-spesific low back pain. Cochrane Database Syst Rev. 2005;20;(3).

Heneweer H, Vanhees L, Picavet SJ. Physical activity and low back pain: A U-shaped relation? Pain. 2009;143(1-2):21-5.

Heneweer H, Staes F, Aufdemkampe G. Physical activity and low back pain: a systematic review of recent literature, Eur Spine J, 2011;20(6):826-45.

Hoogendoorn WE, van Poppel MNM, Bongers PM, Koes BW, Bouter LM, (1999) Physical load during work and leisure time as risk factors for back pain, Scand J Work Environ Health. 1999;25(5):387-403.

Hoohendoorn WE, Bongers PM, de Vet HCW, Douwes M, Koes BW, Miedema MC, Ariëns GAM, Bouter LM. Flexion and rotation of the trunk and lifting at work are risk factors for low back pain: results of a prospective Cohort Study, Spine (Phila Pa 1976). 2000;25(23):3087-92.

Hildebrandt VH, Bongers PM, Dul J, van Dijk FJ, Kemper HC. The relationship between leisure time, physical activities and muskuloskeletal symptoms and disability in worker population, Int Arch Occup Environ Health. 2000;73(8):507-18.

Holmen J, Midthjell K, Krüger Ø, Langhammer A, Holmen TL, Bratberg GH, Vatten L, Lund-Larsen PG. The Nord-Trøndelag Health Study 1995-97 (HUNT 2): Objectives, contents, methods and participation, Nor Epidemiol. 2003;13:19-32.

Holtermann A, Clausen T, Jørgensen MB, Mork PJ, Andersen LL. Should physical activity recommendation depend on state of low back pain?, Eur J Pain. 2014;18(4):575-81.

Holtermann, A, Hansen JV, Burr H, Søgaard K. Prognostic factors for long-term sickness absence among employees with neck-shoulder and low back pain. Scand J Work Environ Health. 2010;36(1):34-41.

Jacob T, Baras M, Zeev A, Epstein L. Physical activities and low back pain: a community-based study, Med. Sci. Sports Exerc. 2004;36(1):9-15.

Kohl HW. Physical activity and cardiovascular disease; evidence for a dose-respons, Med Sci Sports Exerc. 2001;33(6):472-83.

Kopec JA, Sayre EC, Esdaile JM. Predictors of back pain in a general population cohort. Spine (Phila Pa 1976). 2004;29(1):70-7.

Krogstad S, Langhammer A, Hveem K, Holmen TL, Midthjell K, Stene TR, Bratberg G, Heggland J, Holmen J. Cohort Profile: The HUNT Study, Norway, Int J Epidem. 2013;42(4):968-77.

Kujala UM, Taimela S, Viljanen T. Leisure physical activity and various pain symptoms among adolescents, Br J Sports Med. 1999;33(5):325-8.

Kurorinka I, Jonsson B, Kilborn A, Vinterberg H, Biering-Sørensen F, Andersson G, Jørgensen K. (1987) Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms, Appl Ergon. 1987; 18(3):233-7.

Kurtze, N., Rangul, V., & Hustvedt, B. E. (2008). Reliability and validity of the international physical activity questionnaire in the Nord-Trondelag health study (HUNT) population of men. BMC Med Res Methodol. 2008;8:63.

Lee YH, Chiou WK. Risk factors for low back pain, and patient handling capasity of nursing personnel. J Safety Res. 1994;25:135-45.

Levangie PK. Association of low back pain with self-reported risk factors among patiens seeking physical therapy service, Phys Ther. 1999;79(8):757-66.

Li L, Lamis F, Wilson SE. Whole-body vibration alters proprioception in the trunk, Int J Ind Ergon. 2008;38(9-10):792-800.

Lis AM, Black KM, Korn H, Nordin M. Association between sitting and occupational LBP, Eur Spine J. 2007;16(2):283-98.

Luo X, Pietrobon R, Sun SX, Liu GG, Hey L. Estimates and patterns of direct health care expenditures among individuals with back pain in the United States, Spine (Phila Pa 1976). 2004;29(1):79-86.

Macfarlane GJ, Thomas E, Papageorgiou AC, Croft PR, Jayson MI, Silman AJ. Employment and physical work activities as predictors of future low back pain. Spine (Phila Pa 1976). 1997;22(10):1143-9.

Mehlum IS, Kristensen P, Kjuus H, Wergeland E. Are occupational factors important determinants of socioeconomic inequalities in musculoskeletal pain?, Scand J Work Environ Health. 2008;34(4), 250-9.

Nachemson A, Elfström G. Intravital dynamic pressure measurments in lumbar disc, Scand J Rehabil Med Suppl. 1970;1:1-40.

Nilsen, TI, Holtermann A, Mork PJ. Physical exercise, body mass index, and risk of chronic pain in the low back and neck/shoulder; longitudinal data from the Nord-Trøndelag Health Study, AM J Epidemiol. 2011;174(3):267-73.

Roffey DM, Wai EK, Bishop P, Kwon BK, Dagenais S. Causal assessment of occupational sitting and low back pain: results of a systematic review, Spine J. 2010;10(3):252-61.

Rotgoltz J, Derazne E, Froom P, Grushecky E, Ribak J. Prevalence of low back pain in employees of a pharmaceutical company, Isr J Med Sci.1992;28(8-9):615-8.

Sato K, Kikuchi S, Yonezawa T. In vito intradiscal pressure measurments in healthy individuals and in patients with ongoing back problems, Spine (Phila Pa 1976). 1999;24(23):2468-74.

Schultz A, Andersson G, Ortegren, Haderspeck K, Nachemson A. Loads in lumbar spine. Validation of a biomechanical analysis by measurments of intradiscal pressures and myoelectric signals, J Bone Joint Surg Am. 1982;64(5):713-20.

Shephard, RJ. Limits to the measurement of habitual physical activity by questionnaires. Br J Sports Med. 2003;37(3):97-206.

The Labour Investigation Authority of Norway: www.arbeidstilsynet.no

Tissot F, Messing K, Stock S. Studying the relationship between low back pain and working postures among those who stand and those who sit most of the working day, Ergonomics, 52(11):1402-18.

Vuori I. M. Dose-respons of physical activity and low back pain, osteoarthritis and osteoporosis, Med Sci Sports Exerc. 2001;33(6 Suppl);551-86.

Wilke HJ, Neef P, Caimi M, Hoogland T, Claes LE. New in vivo measurments off pressure in the intervertebral disc in daily life, Spine (Phila Pa 1976). 1999;24(8):755-62.

Wirth B, Zurfluh S, Müller R. Acute effect of whole-body vibration on trunk muscles in young healthy adults, J Electromyogr Kinesiol. 2011; 21(21);450-57.

Xu U, Bach E, Ørhede E. Occupation and risk for the occurrence of low back pain (LBP) in Danish employees. Occup. Med (Lond). 1996;46(2):131-6.

Xu U, Bach E, Ørhede E. Work environment and low back pain: the influence of occupational activities. Occup. Environ Med. 1997;54(10):741-5.