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工作者睡眠不足對下背部肌肉骨骼不適之影響

The Impacts of Sleep sufficiency on Low Back Pain

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The Impacts of Sleep Insufficiency on Low Back Pain

本論文係王韋筑君（R99841026）在國立臺灣大學職業醫學與工業衛生研究所完成之碩士學位論文，於民國 104 年 1 月 29 日承下列考試委員審查通過及口試及格，特此證明

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摘要

研究目的：下背肌肉骨骼不適是工作者之常見健康問題，工作之暴露已知對於下背肌肉骨骼不適有相當的貢獻。本研究目的在評估工作者之下背肌肉骨骼不適是否與睡眠不足有相關性，以及睡眠不足對於下背肌肉骨骼不適之貢獻度。

方法：本研究根據勞研所在2007年進行之『台灣地區受僱者工作環境安全衛生狀況認知調查』，其研究對象乃具代表性抽樣之台灣地區受僱者。以問卷評估受僱工作者下背痛情形，並以邏輯式迴歸評估這些不適與睡眠習慣（含工作日和假日的平均睡眠時數）的相關性，同時調整年齡、身體質量指數、運動習慣、與自覺工作環境中人因工程危害因子。並推算所有相關因子之影響和貢獻度。

結果：以28,716位受雇者為研究對象，填寫問卷進行分析，總共回收有效問卷24,509份。約11%的受僱者有會影響工作程度的下背痛。在調整年齡、身體質量指數、運動習慣、與自覺工作環境中人因工程危害因子的影響後，發現男性下背痛的危險因子包括體重過重、重體力勞動、震動暴露、工作日平均睡眠時數少於6小時 (aRR=1.1, 95% CI:1.1~1.2)、假日平均睡眠時數少於7小時 (aRR=1.1, 95% CI:1.0~1.2)。睡眠缺乏對下背痛的族群可歸因危險性為6.2%。女性下背痛的危險因子包括體重過重、重體力勞動、震動暴露、工作站作業、工作日平均睡眠時數6~7小時 (aRR=1.2, 95% CI:1.1~1.3)、工作日平均睡眠時數少於6小時 (aRR=1.3, 95% CI:1.2~1.4)。睡眠缺乏對下背痛的族群可歸因危險性為11.9%。

結論：下背痛在男女性工作者間有高盛行律。在調整各項風險因子之後，睡眠時數不足與下背痛仍有相關性。

關鍵字：睡眠時數、肌肉骨骼不適、下背痛、人因工程危害因子

Abstract

Objectives: Low back pain (LBP) is a common health problem in the working population worldwide. Insufficient sleep could be a potentially modifiable risk factor for LBP. The study aimed to evaluate whether insufficient sleep hours was associated with LBP among employed workers and to estimate the contribution of short sleep to LBP in the working population.

Methods: A nationwide survey of representative employed workers in Taiwan was conducted to estimate the prevalence of musculoskeletal discomforts in lower back, as well as duration of sleep on workdays and on holidays. Relationship between LBP and short sleep were determined by estimating relative risk using generalized linear modeling when adjusting for age, body mass index (BMI), exercise habit, and perceived exposure to ergonomic factors in the work environment. Population-attributable risk (PAR) was calculated by the prevalence of each predictive factor and the relative risk of that predictive factor.

Results: Among the candidates of 28,716 workers, 24,509 (85%) completed the questionnaire satisfactorily, including 14,772 men and 9,737 women. Approximately 11% complained of low back pain. For men, risk factors for LBP were overweight and obesity, heavy work, exposure to vibration, sleeping for less than 6 hr on workdays (aRR=1.1, 95% CI:1.1~1.2), and sleeping for less than 7 hr on weekends (aRR=1.1, 95% CI:1.0~1.2). The PAR for short sleeping time was 6.2%. For women, risk factors for LBP were overweight and obesity, heavy work, exposure to vibration, workstation exposure, sleeping for 6 to 7 hr on workdays (aRR=1.2, 95% CI:1.1~1.3), and less than 6 hr on workdays (aRR=1.3, 95% CI:1.2~1.4). The PAR for short sleeping time was 11.9%.

Conclusions: Based on a large representative sample of employed workers, we found rather high prevalence of LBP in both male and female workers. Short sleeping time contributed to LBP in addition to ergonomic factors, more among female than male workers.

Keywords: sleep sufficiency, lower back pain, ergonomics, musculoskeletal discomfort

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Chapter 1 Introduction

Low back pain (LBP) is one of the most common health problems worldwide [1, 2]. The global review of the prevalence of low back pain in the adult general population published in 2000 showed point prevalence of 12–33% and 1-year prevalence of 22–65% [3]. The most recent systematic review of the global prevalence of low back pain among the general population included a total of 165 studies from 54 countries published between 1980 and 2009, and showed point prevalence of 6-36% and 1-year prevalence of 14-65% [1].

The cost of treatment for patients with LBP is becoming a major economic problem globally [4-9]. In 2003, the estimated total health care costs of LBP and neck pain were 761 million Euros in the Netherlands [10]. In a study published in 2006, total costs associated with LBP exceed $100 billion per year in the United States [11]. A review study compared the studies about the direct or indirect costs of LBP published in English from 1997 to 2007 including Australia, Belgium, Japan, Korea, the Netherlands, Sweden, the UK, and the United States and found high direct cost for LBP spent on physical therapy (17%) and inpatient services (17%), followed by pharmacy (13%) and primary care (13%) [12].

LBP not only leads to increased medical cost but also creates a substantial personal, and community burden due to sickness absence or disability claims [13-16]. Painful disorders of the back, neck and upper limb are major causes of work disability in western countries [17]. Lost work productivity represented a majority of overall costs associated with LBP [12]. The consequences and the costs of LBP are a huge burden to general societies and companies. Therefore, prevention of LBP is imperative.

Research on the prevalence of LBP among men and women had inconsistent results in previous studies. In one systematic review study, low back pain had the highest prevalence among female individuals and those aged 40-80 years [1]. In another survey, the attributable proportion of occupational LBP was higher for men than women [18].

Surveys among the working population in Taiwan showed that the one year prevalence of LBP is 18.3% for men and 19.7% for women [19]. High prevalence rates of LBP and the presence of the risk factors in the working population indicate the need for prevention at the workplace.

Due to the high prevalence and cost of musculoskeletal disorders, increasing interest has been directed in many countries to the development of methods to estimate and record musculoskeletal symptoms to help define the musculoskeletal problem and its relationship with occupational factors. Questionnaires have proved to be a good tool for obtaining the necessary data. The Nordic Musculoskeletal Questionnaire (NMQ) was developed from a project supported by the Nordic Council of Ministers [20]. The aim was to develop and test a standardized questionnaire allowing comparison of low back, neck, shoulder and general complaints for use in epidemiological studies. The questions of the questionnaire are forced choice variants and may be either self-administered or used in interviews. Previous studies concluded that concerning symptoms reporting for pain, the NMQ is repeatable, sensitive and useful as a screening and surveillance tool [21, 22].

Numerous studies intended to identify the cause of LBP. Both occupational and non-occupational risk factors were explored. LBP arising from ergonomic exposures at work is one of the important causes of disability. In a review study, estimation were made for each of 21 world regions and 187 countries, separately for 1990 and 2010 worldwide, LBP arising from ergonomic exposures at work was estimated to cause 21.7 million disability-adjusted life years (DALYs) [23]. The most frequently reported physical factors include manual materials handling, bending and twisting the trunk, whole-body vibration [24, 25], and cumulative low back load [26]. Personal factors include age, smoking habits, physical capacity, and body weight [27-31]. Psychosocial factors include stress, depression, social support, job satisfaction [32-36], high job demand and low job control [37]. Socio-economic factors has been explored and revealed a higher prevalence of LBP in countries where there is less poverty and more social support [17].

Recently, sleep problems have also been identified as common in patients with LBP, with 50–60% of patients with either acute or chronic LBP reporting problems with their sleep [38-40]. It is commonly assumed that pain induces poor or disturbed sleep, and this intuitive assumption is supported by several studies [41-43]. Patients with chronic pain often suffer from sleep disturbances concomitantly [44-47]. The increase in self-reported pain intensity is directly related to the degree of self-reported sleep disturbance [43]. Recent research, however, indicates that this relationship may be bidirectional [48-50]. Increasing evidence suggests a worsening cycle of pain and sleep. Pain can lead to poor sleep which in turn may result in increased next day pain, leading to disturbances in sleep the next night, as seen in other chronic pain conditions such as burns and fibromyalgia [51-54]. Recent evidence suggests that sleep can modulate the intensity of pain [55]. Experimental studies in healthy pain-free volunteers have demonstrated that induced sleep deprivation, via either a reduction in total sleep duration or disruption of sleep architecture, leads to the development of musculoskeletal pain [56] and decreased tolerance to noxious stimuli [57, 58]. Poor sleep quality has been reported to reduce pain thresholds and cognitive ability to manage pain [59]. In addition, the analgesic effect of recovery from sleep deprivation has been reported to be greater than the effect of common analgesic drugs [53]. Clinical studies have also found a significant relationship between improved sleep quality and decreased pain intensity in patients with musculoskeletal [60] or osteoarthritic pain [61] and comorbid insomnia.

Previous research also found a strong association between sleep disturbance and the development of musculoskeletal pain. Sleep deprivation in healthy individuals can cause temporary musculoskeletal and mood symptoms similar to those experienced by patients with chronic pain [62]. Salo et al found that sleep disturbances for 5-7 nights per week were associated with increased risk for subsequent disabling mental disorders and various physical illnesses. A single measurement of sleep disturbances was found to predict the outcome of work disability due to diseases of the musculoskeletal system [63]. In a prospective cohort study of more than 25,000 public sector employees, participants with stable severe sleep disturbances and increase in sleep disturbances were found to have increased risk of physician-certified sickness absence due to diseases of the musculoskeletal system [64]. A cohort-based, long-term follow-up study reported that individuals with sleep disturbances predicted hospitalizations for back disorders compared with those without sleep disturbances, although the results may have been confounded by occupational factors [65].

There is quantitative evidence that sleep disturbance is a common feature of LBP [38-40, 66, 67]. An important question to address is whether there is a causal relationship between pain and sleep disturbance in LBP and to ascertain the nature and direction of this relationship. This relationship may have significant implications for the treatment of LBP. Insufficient sleep could be a potentially modifiable risk factor for musculoskeletal discomfort. Intervention that has not been explored for reducing pain or disability is that targeted solely at improving sleep quality. Before implementation of such strategies, it is important to further explore the relationship of sleep to pain or disability.

The objective of the present study was to investigate whether insufficient sleeping time is a risk factor for LBP in a large employed population. The hypothesis was that sleep deficiency is associated with self-reported musculoskeletal discomfort or pain in lower back. The objective of the current study is to estimate the contribution of short sleep to LBP in the working population.

To assess an objective scientific understanding of the contribution of short sleep to LBP in the working population, the population attributable risk percentage (PAR%) was calculated. PAR% may provide insight into the proportion of LBP would be preventable if the unhealthy effect of short sleep could be eliminated. This study quantified the impact of life style factors and physical factors along with short sleep on the prevalence of LBP in the working population in Taiwan. PAR% were computed for the following modifiable risk factors: body mass index, exercise habit, ergonomic work exposure, and short sleeping time. Findings from this study may indicate priorities for preventative strategies to reduce the burden of LBP in the working population.

Chapter 2 Materials and Methods

A. Study population and design

The Institute of Occupational Safety and Health, a research institute under the Council of Labor Affairs, conducted the Survey of Perceptions of Safety and Health in the Work Environment in Taiwan to characterize employees' perception of safety and health in the work environment. This was done every three to four years as a supplement to the Human Resources Survey organized by the Department of Statistics, who conduct large scaled nationwide surveys on a routine basis as references for policy setting. A representative sample of workers in the week of September 9, 2007 was obtained from a questionnaire survey using a two-stage stratified cluster sampling design. "Villages" and "Lis" (a unit of administrative district in urban areas, equivalent to "villages" in rural areas) were the primary sampling units, and were stratified into 23 strata according to the level of urbanization, industrial structure and educational attainment in the first stage. The numbers of villages and lis to be sampled from a certain stratum were determined according to the total numbers of villages and lis in the stratum. Households were the sampling units in the second stage, and were randomly selected from the villages and lis sampled in the first stage according to the resident registration data of each villages and lis. Within each household selected, subjects who were in employment during the study period were identified. A total of 28,716 workers were identified among the sampled households. All the adults in each sampled household met the inclusion criteria were asked to participate in the survey.

The questionnaire contained questions to obtain data on workers' demographic characteristics, lifestyle characteristics, perceived exposure to physical, chemical and ergonomic factors in the work environment, and musculoskeletal discomfort in different bodily parts. The study questionnaire was distributed by trained interviewers to the residents of the study candidates. All the interviewers had received a series of standard training and been given a standard procedure manual before the survey. The door-to-door questionnaire administration was conducted at different times and on different days of the week to accommodate the availability of the study candidates. Each sampled worker was asked to fill out the questionnaire, which was collected by the interviewer right after completion. If the participant was not able to complete the questionnaire or had any problem with answering, the interviewer would offer instant help. If the worker was not at home upon the visit of the interviewer, the questionnaire would be left and appointment wound be made for it to be collected after it was completed. The questionnaire was designed for the study subjects to complete in 15-20 minutes. Upon receiving the answered questionnaire, the interviewer would perform an error check to clarify confusions and correct possible errors immediately. Before visiting, a telephone call was made to make an appointment with the candidate. In addition, multiple attempts were made to reach the study candidate to ensure a high response rate. No monetary incentive was provided for participation.

B. Questionnaire

The interview was conducted by using a structured questionnaire containing only close-end questions. Two major sections were contained in the survey. In the first section, demographic data and employment information including age, gender, body weight, body height, average sleep hours on workdays and on holidays, work exposure, and exercise habit were inquired. The other section surveyed musculoskeletal discomfort symptoms. The musculoskeletal discomfort symptoms were collected using the Chinese version of the standardized Nordic Musculoskeletal Questionnaire (NMQ). The NMQ questionnaire asked whether the participants had suffered from musculoskeletal discomfort in any body part including pain or soreness during the past year. Those recalled having musculoskeletal discomfort were asked to answer which of the body part is involved (neck, upper back, lower back and waist, shoulder, elbow, hand and wrist, hip and thigh, knee, and ankle). An illustration of the human body was provided on the questionnaire to indicate the body parts. If there were any pain or soreness in any of the body parts reported, the degree of discomfort was then asked. The participants were inquired to place the discomfort into the following severity categories, namely, "caused no effect on work performance", "affected work performance without causing sickness absence", "caused sickness absence for less than four days", or "caused sickness absence for more than four days" in the past year were recorded. Those reported having musculoskeletal discomfort which "affected work performance without causing sickness absence" or more severe categories were considered to have positive outcomes.

C. Body mass index

Body mass index (BMI) was calculated from a person's weight and height. For adults 20 years old and older, BMI is interpreted using standard weight status categories that are the same for all ages and for both men and women. The standard weight status categories associated with BMI ranges for adults were divided into three groups according to the suggestion of Health Promotion Administration, Ministry of Health and Welfare, Taiwan: (1) less than 24 as normal, (2) 24 or more and less than 27 as overweight, and (3) more than 27 as obese.

D. Exercise habit

The questionnaire asked about workers' exercise habit falling into three categories: less than once per month (never), one to three times per month, and more than once per week.

E. Work exposure

Exposures to ergonomic factors included whole body vibration (vibration transmitted to the entire body from a vehicle seat or through the feet and legs from a vibrating), using vibrating hand tools (such as grinders, road breakers or drills), repetitive hand movement (such as typing, repetitive reaching or repetitive assembling work), using heavy hand tools, lifting heavy objects, awkward body postures (such as body twisting, long-term standing, walking, kneeling or squatting), speedy work pace (such as assembly line jobs), lengthy computer use, and inappropriate desk height (including tables or chairs). The questionnaire asked about the proportion of working time that was occupied by these activities, with three possible answers: never, sometimes, and often. Workers were considered having the above occupational physical exposure if he or she reported “often” exposed to questions related to any of the above factors. The results were analyzed with Factor Analysis in order to group the main factors that represent work exposure.

F. Sleep Hours

There were two indices referring to sleep quality in our study, namely, average sleep hours on workdays in the previous week, and average sleep hours on holidays in the previous week. The average duration of sleep per day on workdays and on holidays in the previous week were recorded in hours and minutes and were divided into three groups according to the average duration of sleep hours of men and women: (1) more than 7 hours, (2) more than 6, less than 7 hours, and (3) less than 6 for sleep hours on workdays, and (1) more than 8, (2) more than 7, less than 8, and (3) less than 7 for sleep hours on holidays.

G. Statistical analysis

The main aim of the study was to determine whether sleep hour predicted low back pain among male and female workers. The analysis included descriptive summary of demographics and exposure to ergonomic factors. Differences in prevalence were evaluated by chi-square tests (categorical covariates) or analysis of variance (continuous covariates: age, sleep hours on workdays, and sleep hours on holidays) at the two-tailed significant level of 0.05. Associations of discomfort outcomes with risk factors were characterized by odds ratios (OR) and associated 95% confidence intervals (95% CI), estimated by fitting logistic regression models. After an initial univariate analysis, only significant factors (at $P<0.05$) were included for the backward stepwise logistic regression to determine the order of entry of the independent variables into the regression analyses to construct a best-fitted multivariate model. Only significant predictors were retained in the final regression model. To stay in the model, variables were required to be significant at P value < 0.05. Generalized linear modeling was used to calculate the adjusted relative risk for the variables that were statistically significant in the logistic regression analyses.

Population attributable risks (PARs) were calculated to estimate the contribution of various risk factors to low back pain. The PAR for any risk factor represents the preventable proportion of low back pain cases if workers were not exposed to the specified factor. PAR was calculated using the formula $P(RR - 1)/ [P(RR - 1) + 1] \times 100$, with P representing the proportion exposed in the population and RR presenting the relative risk due to the exposure [68]. Although the OR is often used as an estimation of the RR, in our study this is not appropriate due to the high prevalence of LBP, which is against the rare disease assumption. Population-attributable risk (PAR) was calculated by the prevalence of each predictive factor and the relative risk of that predictive factor.

Statistics were performed by means of JMP software version 9.0 (SAS institute Inc., Cary, NC, USA.) for Mac.

Chapter 3 Results

A. Subject recruitment

Figure 1 shows the enrollment of the participants. A total of 28,716 workers in Taiwan were sampled as candidates of the study in 2007. Excluding 3,720 subjects who refused to participate or were unreachable at the time of survey, 24,996 subjects participated in the questionnaire survey. Among these participants, 487 were unemployed at the time of survey or did not completely answer the questionnaire, and were excluded, leaving 24,509 respondents for the final statistical analysis. Male respondents represented 60.3% (14,793) of all participants. Among male participants, 54.3% were 41 years or older, and 49.0% exercised less than once per month (Table 1). In female participants, 58.9% were 40 years or younger and 54.6% exercised less than once per month (Table 1).

B. Sleep hours

The average daily sleep time of male participants was 7.2 hours during workdays, and 8.2 hours on holidays (Table 1). The average daily sleep time of female participants was 7.2 hours during workdays, and 8.3 hours on holidays. Among male participants, 53.3% had less than 7 hours of sleep on workdays, and 64.6% had less than 8 hours of sleep on holidays. In female participants, 52.3% had less than 7 hours of sleep on workdays, and 60.8% had less than 8 hours of sleep on holidays.

C. Exposure to ergonomic factors

The most frequently reported workplace ergonomic factors in our participants were awkward working body posture (23.5%), followed by lifting heavy objects, lengthy computer use, using heavy hand tool, using vibrating hand tool, whole body vibration, and inappropriate work station height. in men, and lengthy computer use (25.3%), followed by awkward working body posture, lifting heavy objects, inappropriate work station height, using vibrating hand tool, using heavy hand tool and whole body vibration in women. Factor Analysis with Varimax rotation was used to group work exposures. Table 2 shows the factor loadings of each item. Three factors were identified accounting for 54.9% of total variance in all participants. They were named (1) Heavy work, (2) Exposure to vibration, and (3) Workstation exposure. The male participants were most frequently exposed to heavy work (32.4%), followed by workstation exposure and exposure to vibration. The female participants were most frequently exposed to workstation (26.8%), followed by heavy work and vibration.

D. Musculoskeletal discomfort

The prevalence of musculoskeletal discomfort among the participants was shown in Table 1. The body part in which the male participants reported to have discomfort the most was shoulder (33.6%), followed by neck, lower back and waist, and upper back. Among female participants, shoulder discomfort was reportedly the most (43.7%), followed by neck, lower back and waist, and upper back. Higher percentages of female workers reported discomforts in neck, shoulder, and upper back than male workers. The prevalence of musculoskeletal discomfort influencing work performance among the participants was shown in Table 1. The body part in which the male participants reported to have discomfort the most was shoulder (11.4%), followed by lower back and waist, neck, and upper back. Among female participants, shoulder discomfort was reportedly the most (14.9%), followed by neck, lower back and waist, and upper back. Higher percentages of female workers reported discomforts in neck, shoulder, and upper back than male workers.

E. Sleep hours and musculoskeletal discomfort

Table 3 shows the factors for lower back discomfort in male participants. Significant crude odds ratios were found for older age, body mass index of 27 or higher, exercise habit, heavy work, exposure to vibration, workstation exposure, average sleep time of less than six hr on workdays, and average sleep time of less than seven on holidays. Adjusted odds ratios were significant for older age, heavy work, exposure to vibration, workstation exposure, average sleep time of less than six hr on workdays, and average sleep time of less than seven hr on holidays. Adjusted relative risk were significant for age of 41 or older, heavy work, exposure to vibration, workstation exposure, average sleep time of less than six hr on workdays, and average sleep time of less than seven hr on holidays. The population-attributable risks for older age, overweight and obesity, ergonomic work exposure, and short sleep were 10.1%, 8.0%, 24.3%, and 6.2% respectively.

Table 4 shows the factors for lower back discomfort in female participants. Significant crude odds ratios were found for older age, body mass index of 24 or higher, exercise 1 to 3 times per month, heavy work, exposure to vibration, workstation exposure, average sleep time of less than seven hr on workdays, and average sleep time of less than seven on holidays. Adjusted odds ratios were significant for age between 31 to 40, age of 51 or older, body mass index more than 24, heavy work, exposure to vibration, workstation exposure, and average sleep time of less than seven hr on workdays. Adjusted relative risk were significant for age of 51 or older, body mass index between 24 to 27, heavy work, exposure to vibration, workstation exposure, and average sleep time of less than seven hr on workdays. The population-attributable risk for older age, overweight and obesity, ergonomic work exposure, and short sleep were 8.3%, 3.3%, 24.2%, and 11.9% respectively.

Chapter 4 Discussion

Based on a large representative sample of employed workers, we found rather high prevalence of musculoskeletal discomfort in both male and female workers, including low back pain. After adjusting for other important factors, short sleeping time was associated with increased risk of low back discomforts in both working men and women. In the working population, short sleeping time contributed to 6.2% of LBP in men and to 11.9% in women. Exposure to workplace ergonomic factors contributed to 24.3% of LBP in men and 24.3% in women.

In our study, we found that factors and contribution to LBP were different between working men and women. Heavy work and exposure to vibration had a higher PAR in men (21.0% vs. 16.2%) while workstation exposure had a PAR in women only (6.9%). This might be related to higher exposure to heavy works in men than women. As for the ergonomic factors, working men were more frequently exposed to heavy work, but women were to workstation. Only relatively small percent of workers were exposed to vibration, i.e., 1.8% in women and 9.0 % in men.

Total PAR of 48.6% and 47.8% were found in men and women for risk factors of LBP. Some risk factors may not have been taken into account in this study. Smoking was considered to be a risk factor for LBP in some studies [31, 69]. Trunk muscle strength [70], former history of low back injury [71], cumulative low back load [26, 72, 73], depression [32], and occupational driving [74] were found to be risk factors of LBP in previous studies but not included as confounders in our study. Investigations on attributable risk to LBP have been relatively rare. In the meantime, the proportions of attributable risks were generally lower than 50% [18, 37], indicating lacking of complete knowledge on the contributing factors to LBP in human studies.

A lot of previous studies attempted to determine occupational predictors of LBP or back pain. Physical workload, sum of heavy lifting, awkward postures, and whole-body vibration predicted low-back pain among those younger than 50 years old [75]. Our study found positive association between workstation exposure and heavy work including awkward body posture and LBP, which is partly different from the findings of a systematic review study of 18 studies which concluded that sitting, prolonged standing or walking were not associated with low back pain, while evidence for associations in whole body vibration, heavy physical work, and working with ones trunk in bent and/or twisted position and low back pain was conflicting [72].

Some studies supported that higher BMI was associated with LBP among both men and women. In one study, asymptomatic workers had a higher risk of low back pain the next year if they had a BMI over 30 [76]. A recent prospective cohort following 25,540 people found that both overweight and obese subjects without low back pain at enrollment had weak risks of having chronic low back pain at 11-year follow up [77]. Other studies had controversial results. Mirtz et al concluded from a review of the literature that the data for a link between obesity and low back pain appears to be controversial due to lack of evidence for body weight to be considered a true cause of LBP and there exists conflicting views of obesity and low back pain-related conditions such as spondylosis, decreased physical activities and discal herniation [78]. In the present study, body mass index over 24 was a risk factor for low back discomfort in women with PAR 3.3% but similar result was not found in men.

Exercise habit was not found to associate with LBP in this current study. Levels of leisure-time physical were not strongly associated with subsequent new onset LBP in a 12-month follow up for men [79]. Strenuous physical activity at least once a week was found to be protective for incident LBP in the elderly [80]. Gardening or yard work was found to have negative association with LBP [81]. No statistically significant relationship was found between exercise and LBP in other studies [75, 82]. According to the physiological point of view, the musculoskeletal system of the spine weakens from overuse or disuse [83], which indicated that both physical activity and physical inactivity may induce spinal weakening. Exercise behavior and leisure activities may not associate with LBP but physical inactivity may be worth further investigation.

Sleep disturbances were reported to be associated with increased musculoskeletal discomforts in neck or back (6 hours or less sleep per day, OR 1.59; 95% CI 1.39-1.81 in men; OR 1.83; 95% CI 1.6-2.08 in women) [84], and in lower back (hazard ratio 1.44; 95% CI 1.27-1.64) [64]. Mild or severe sleep disturbances in workers over 50 were statistically significantly associated with LBP (OR 2.0; 95% CI 1.3-3.0; OR 2.1; 95% CI 1.0-4.6) [75]. Sleep disturbances strongly predicted low back pain in a group of active Finnish firefighters (adjusted OR 2.4; 95 % CI 1.2-4.7) [85]. Other studies reported that sleep disturbance predicts the outcome of work disability due to musculoskeletal disorders [63, 64]. Night shifts had been shown to be connected with reduced sleeping time and subjective sleep quality [86]. One study reported a positive relationship between night shifts and LBP and supported the hypothesis of an independent association between night shifts and LBP among female nursing personnel [87]. Another study considered working night shifts and found a weak association between working night shifts and sick leave greater than 14 days attributed to LBP (OR 1.64; 95% CI 1.09-2.49) but no association with intense LBP or sick leave during the first 3 months was found [88]. Sleep quality was found to be an independent predictor of disability along with pain in patients with spinal pathology in a recent study [89].

In our study, short sleeping time was found to be a risk factor for LBP in both men and women with different contribution. In men, PAR of 6.1% for short sleep was found while 11.6% was found in women. Other confounders not included in this study may associated more in men with low back discomfort than in women due to lifestyle difference and thus the contribution of short sleep was more obvious in women.

The odds ratios describing the relationships between insufficient sleep and low back discomfort were relatively high, which strengthened the possibility of causality between these variables. Several plausible mechanisms may explain an association between insufficient sleep and low back discomforts. Sleep disturbance was hypothesized to increased muscle tension that contributes to pain in the low back [90]. One hypothesis is that insufficient sleep causes musculoskeletal disorders by a pathophysiological pathway. Insufficient sleep was found to increase the concentration of cytokines and inflammatory mediators [91, 92]. Subsequent activation of inflammatory mediators via cortisol and cytokine networks has been suggested as one of the possible mechanisms for sleep disturbances to predicted hospitalization for back disorders [65]. A modest amount of sleep loss also alters molecular processes that drive cellular immune activation and induce inflammatory cytokines [93]. Restricting time in bed to four hours per night over 12 days in a laboratory setting has been shown to increase inflammatory markers interleukin-6 and C-reactive protein and self-reported levels of pain among healthy volunteers [94].

Sleep loss also alters metabolism. Short-term sleep deprivation alters hormonal regulation and causes perturbations in the regulation of energy metabolism, which may lead to musculoskeletal symptoms via the hampering of tissue rebuilding and adaptation [95]. Sleep restriction induces a reduction in insulin sensitivity and causes impairment of glucose tolerance [96] and may cause problems in tissue recovery.

Some previous studies demonstrated that pain intensity and sleep disturbance have a bidirectional relationship, where a night of poor sleep quality was followed by a day with higher pain intensity. Likewise a day with high pain intensity was followed by a decrease in the subsequent night's sleep quality [50, 97, 98]. Other studies have reported different findings. Tang et al [99] and Lewandowski et al [100] investigated the pain-sleep relationship in diverse samples of patients with chronic pain and did not find daytime pain to be a significant predictor of subsequent poor sleep. Raymond et al [52] who studied the pain-sleep relationship in patients with acute burn-related pain did not find pain during the day to be a reliable predictor of subsequent poor sleep. Poor sleep was found, however, to result in subsequent higher daytime pain intensity. Lack of sleep may also increase sensitivity to pain and may increase pain. Loss of 4 hours of sleep and specific loss if rapid eye movement sleep are hyperalgesic the following day [101]. The mechanism remained unclear, and several possibly related explanations included the alternation of neurotransmission in the central nervous system and subsequent nociception.

This study has several limitations. First, the assessment of sleep sufficiency was by self-report. LBP was defined on the basis of the occurrence of subjective soreness and pain and degree without clinical assessments. However, we collected sleep sufficiency according to self-report average sleep hours, which is an objective assessment of sleep quality and the NMQ questionnaire used is an instrument useful as a screening and surveillance tool for musculoskeletal pain in epidemiological studies. Second, our cross-sectional study did not collect information about the duration and nature of the subjects' pain, a past history of LBP, previous therapeutic interventions, or sleep hygiene practices. These data would have enriched our understanding of the study population and improved analyses by capturing important covariates. Third, the ergonomic factors were qualitative, not quantitative and that cumulative exposure assessment was not feasible. Finally, this cross-sectional study does not allow for causal inference. Thus, we can only postulate as to how the association between short sleeping time and LBP is established. Nevertheless, this increases the applicability of our results and underlines the strength of the relationship between short sleep and LBP regardless of the specific etiology. Despite it being intuitive that sleep disorder will be present in patients with spinal problem resulting in back or leg pain, insufficient sleep was still correlated to LBP in our study after adjusting for other important confounders.

This study has several strengths. The large representative working population and high response rate were allowed us to apply to the general working population in Taiwan. Random sampling was applied and the representativeness of the sample was ensured. Second, the current study is one of the very few that are able to provide reliable estimates of the prevalence of LBP in the general working population. Third, other risk factors, mainly including ergonomic factors were carefully adjusted. Some of the high-risk ergonomic factors were similar to previous findings, while some were seldom evaluated in the literature. Fourth, our study not only evaluated the relationship between sleep and LBP using total sleeping time on workdays and holidays, but also identified the attributable risk for lack of sleep, along with other factors, suggesting that almost 50% of LBP among the working population could be decreased if risk factors were reduced.

Chapter 5 Conclusion

The present findings suggest that sleep insufficiency may be an independent risk factor for low back pain in both male and female workers. The potential mechanisms behind the effect of sleep insufficiency on low back pain were highly speculative and required further research. In addition, interventional studies should be carried out to evaluate whether improving sleep quantity is effective in preventing or improving LBP.

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Tables

Table 1. Characteristics of study participants

Characteristic	**Questionnaire (n = 24,509)**		**P value †**
	Men	**Women**	
	No. (%)		
Total	14,772 (60.3)	9,737(39.7)	
Age			<0.0001
≤ 30	3,008 (20.4)	2,974 (30.5)	
31-40	3,743 (25.3)	2,761 (28.4)	
41-50	4,207 (28.5)	2,524 (25.9)	
≥ 51	3,814 (25.8)	1,478 (15.2)	
BMI			<0.0001
BMI < 24	8,010 (54.2)	7,734 (79.4)	
24 ≤ BMI < 27	4,582 (31.0)	1,395 (14.3)	
BMI ≥ 27	2,180 (14.8)	608 (6.2)	
Exercise habit			<0.0001
< Once per month	7,235 (49.0)	5,321 (54.7)	
1-3times/month	3,038 (20.6)	1,946 (20.0)	
> Once per week	4,499 (30.5)	2,470 (25.4)	
Musculoskeletal discomfort			
Neck	4,063 (27.5)	3,421 (35.1)	<0.0001
Shoulder	4,964 (33.6)	4,257 (43.7)	<0.0001
Upper back	2,511 (17.0)	1,982 (20.4)	<0.0001
Lower back	3,893 (26.4)	2,801 (28.8)	<0.0001
Musculoskeletal discomfort influencing work performance			
Neck	1,362 (9.2)	1,200 (12.3)	<0.0001
Shoulder	1,682 (11.4)	1,455 (14.9)	<0.0001
Upper back	988 (6.7)	798 (8.2)	<0.0001
Lower back	1,651 (11.2)	1,072 (11.0)	0.684

Characteristic	**Men**	**Women**	**P value †**
	No. (%)		
Exposure to ergonomic factors			
Whole body vibration	578 (3.9)	87 (0.9)	<0.0001
Vibrating hand tool	1,050 (7.1)	122 (1.3)	<0.0001
Heavy hand tool	1,264 (8.5)	174 (1.8)	<0.0001
Lifting heavy objects	2,575 (17.4)	540 (5.5)	<0.0001
Awkward body posture	3,475 (23.5)	2,370 (24.3)	0.153
Lengthy computer use	1,944 (13.1)	2,469 (25.3)	<0.0001
Inappropriate desk height	330 (2.2)	407 (4.2)	<0.0001
Sleep hr on workday			0.357
Sleep hr > 7	6,903 (46.8)	4,644 (47.7)	
6 < Sleep hr ≤ 7	5,243 (35.5)	3,389 (34.8)	
Sleep hr ≤ 6	2,626 (17.8)	1,704 (17.5)	
Sleep hr on holiday			<0.0001
Sleep hr > 8	5,234 (35.4)	3,812 (39.2)	
7 < Sleep hr ≤ 8	5,989 (40.5)	3,908 (40.1)	
Sleep hr ≤ 7	3,549 (24.0)	2,017 (20.7)	
	Mean (SD)		
Age	42.1 (12.0)	38.1 (11.3)	
BMI	24.0 (3.1)	21.7 (3.1)	
Sleep hr on workday	7.2 (1.0)	7.2 (1.0)	
Sleep hr on holiday	8.2 (1.3)	8.3 (1.3)	

† P-value were derived from chi-square test for categorical variables and t test for continuous variables

Table 2. Factor analysis for ergonomic work exposure factors

Eigen value	2.7219	1.2960	0.9395
Exposure items	Factor loading		
Inappropriate desk height	0.9669	0.1006	0.2344
Lengthy computer use	0.3529	-0.1034	-0.1764
Vibrating hand tool	-0.0454	0.8077	0.2347
Whole body vibration	-0.0174	0.5907	0.2192
Lifting heavy objects	-0.0995	0.2212	0.8013
Heavy hand tool	-0.0528	0.4753	0.6029
Awkward body posture	0.0569	0.1721	0.4952
Factor named	Workstation exposure	Exposure to vibration	Heavy work
% of male workers exposed	14.3	9.0	32.4
% of female workers exposed	26.8	1.8	26.6

Table 3. The risk factors of lower back discomfort in male participants

Variables	With condition/total (%)	Lower back MSD (N= 1,651)			
		OR (95% CI)	aOR (95% CI)	aRR (95% CI)	adjusted AR
Age*					10.1
≤ 30	268/3008 (8.9)	1	1	1	
31-40	395/3743 (10.6)	1.2 (1.0-1.4)*	1.2 (1.0-1.4)*	1.1 (1.0-1.2)*	
41-50	514/4207 (12.2)	1.4 (1.2-1.7)***	1.4 (1.2-1.7)***	1.1 (1.1-1.2)***	
≥ 51	474/3814 (12.4)	1.5 (1.2-1.7)***	1.5 (1.2-1.7)***	1.2 (1.1-1.3)***	
BMI					8.0
BMI < 24	844/8010 (10.5)	1	1	1	
24 ≤ BMI < 27	521/4582 (11.4)	1.1 (1.0-1.2)	1.1 (0.9-1.2)	1.0 (1.0-1.1)	
BMI ≥ 27	286/2180 (13.1)	1.3 (1.1-1.5)**	1.2 (1.0-1.4)*	1.1 (1.0-1.1)*	
Exercise habit					-
< Once per month	877/7235 (12.1)	1	-	-	
1-3times/month	305/3038 (10.0)	0.8 (0.7-0.9)**	-	-	
Once per week	469/4499 (10.4)	0.8 (0.7-0.9)**	-	-	
Work exposure					
Heavy work***	935/4779 (19.6)	3.2 (2.8-3.5)***	2.9 (2.6-3.3)***	1.6 (1.5-1.7)***	21.0
Exposure to vibration***	294/1326 (22.2)	2.5 (2.2-2.9)***	1.7 (1.5-2.0)***	1.2 (1.2-1.3) ***	3.3
Workstation exposure	246/2116 (11.6)	1.1 (0.9-1.2)	-	-	-

Sleep hr on workday * **					3.0
Sleep hr > 7	684/6903 (9.9)	1	1	1	
6 < Sleep hr ≤ 7	572/5243 (10.9)	1.1 (1.0-1.3)	1.0 (0.9-1.2)	1.0 (1.0-1.1)	
Sleep hr ≤ 6	395/2626 (15.0)	1.6 (1.4-1.8)***	1.4 (1.2-1.6)***	1.1 (1.1-1.2)**	
Sleep hr on holiday***					3.1
Sleep hr > 8	530/5234 (10.1)	1	1	1	
7 < Sleep hr ≤ 8	616/5989 (10.3)	1.0 (0.9-1.2)	1.0 (0.9-1.1)	1.0 (1.0-1.1)	
Sleep hr ≤ 7	505/3549 (14.2)	1.5 (1.3-1.7)***	1.3 (1.1-1.5)**	1.1 (1.0-1.2)**	

aOR = Adjusted odds ratio using backward stepwise logistic regression

aRR = Adjusted relative risk using generalized linear model

adjusted AR = adjusted attributable risk

MSD : musculoskeletal discomfort

*P < 0.05

**P < 0.01

***P < 0.0001

Table 4. The risk factors of lower back discomfort in female participants

Variables	With condition/total (%)	Lower back MSD (N= 1,072)			
		OR	aOR	aRR (95% CI)	adjusted AR
Age* **					8.3
≤ 30	269/2974 (9.1)	1	1	1	
31-40	307/2761 (11.1)	1.3 (1.1-1.5)**	1.3 (1.1-1.5)**	1.1 (1.0-1.2)*	
41-50	289/2524 (11.5)	1.3 (1.1-1.5)**	1.3 (1.1-1.5)*	1.1 (1.0-1.2)*	
≥ 51	207/1478 (14.0)	1.6 (1.3-2.0)***	1.7 (1.3-2.0)***	1.2 (1.1-1.3)***	
BMI* **					3.3
BMI < 24	775/7734 (10.0)	1	1	1	
24 ≤ BMI < 27	207/1395 (14.8)	1.6 (1.3-1.8)***	1.4 (1.2-1.6)**	1.1 (1.1-1.2)**	
BMI ≥ 27	90/608 (14.8)	1.6 (1.2-2.0)**	1.4 (1.1-1.8)**	1.1 (1.0-1.2)*	
Exercise habit*					-
< Once per month	628/5321 (11.8)	1	-	-	
1-3times/month	183/1946 (9.4)	0.8 (0.6-0.9)**	-	-	
Once per week	261/2470 (10.6)	0.9 (0.8-1.0)	-	-	
Work exposure					
Heavy work***	499/2587 (19.3)	2.7 (2.4-3.1)***	2.7 (2.4-3.1)***	1.5 (1.5-1.6)***	16.2
Exposure to vibration***	52/175 (29.7)	3.5 (2.5-4.9)***	2.4 (1.7-3.4)***	1.3 (1.2-1.4)***	1.1
Workstation exposure***	364/2611 (13.9)	1.5 (1.3-1.7)***	1.8 (1.6-2.1)***	1.3 (1.2-1.3)***	6.9

Sleep hr on workday ***					11.9
Sleep hr > 7	382/4644 (8.2)	1	1	1	
6 < Sleep hr ≤ 7	406/3389 (12.0)	1.5 (1.3-1.8)***	1.4 (1.2-1.7)***	1.2 (1.1-1.3)***	
Sleep hr ≤ 6	284/1704 (16.7)	2.2 (1.9-2.6)***	1.9 (1.6-2.3)***	1.3 (1.2-1.4)***	
Sleep hr on holiday***			-		-
Sleep hr > 8	377/3812 (9.9)	1	-	-	
7 < Sleep hr ≤ 8	411/3908 (10.5)	1.1 (0.9-1.2)	-	-	
Sleep hr ≤ 7	284/2017 (14.1)	1.5 (1.3-1.8)***	-	-	

aOR = Adjusted odds ratio using backward stepwise logistic regression

aRR = Adjusted relative risk using generalized linear model

adjusted AR = adjusted attributable risk

MSD : musculoskeletal discomfort

*P < 0.05

**P < 0.01

***P < 0.0001

Figures

Figure 1. Study enrollment.