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REVIEW

Sedentary lifestyle as a risk factor for low back pain: a systematic review

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Abstract
Objectives To review systematically studies examining the association between sedentary lifestyle and low back pain (LBP) using a comprehensive definition of sedentary behaviour including prolonged sitting both at work and during leisure time.
Methods Journal articles published between 1998 and 2006 were obtained by searching computerized bibliographical databases. Quality assessment of studies employing a cohort or case–control design was performed to assess the strength of the evidence.
Results Using pre-determined keywords, we identified 1,778 titles of which 1,391 were considered irrelevant. Then, 20 of the remaining 387 publications were scrutinized for full review after an examination of all the 387 abstracts. Finally, 15 studies (10 prospective cohorts and 5 case–controls) were included in the methodological quality assessment, of which 8 (6 cohorts and 2 case–controls; 53%) were classified as high-quality studies. One high-quality cohort study reported a positive association, between LBP and sitting at work only; all other studies reported no significant associations. Hence, there was limited evidence to demonstrate that sedentary behaviour is a risk factor for developing LBP.
Conclusions The present review confirms that sedentary lifestyle by itself is not associated with LBP.

Keywords Low back pain · Sedentary behaviour · Prolonged sitting · Risk factor

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Introduction

Low back pain (LBP) is a common musculoskeletal problem that affects most people at some point in their lifetime (Walker 2000). Slow recovery in some individuals with LBP can impact on the person's physical and psycho-social functions and increase the socio-economic burden (Katz 2006; Maniadakis and Gray 2000; Miedema et al. 1998). In contextual concepts of the International Classification of Functioning, Disability and Health (ICF) model, both environmental and individual factors affect the development of LBP. Lifestyle is a factor that could affect an individual's health (WHO 2001).

Sedentary lifestyle is associated with obesity, which in turn is linked to chronic health problems (Ford et al. 2005; Katzmarzyk et al. 2000; Martinez-Gonzalez et al. 1999; Sorensen 2000; Warburton et al. 2006). Modern living increases the tendency to have a more sedentary lifestyle that involves sitting (Egger et al. 2001; Jans et al. 2007). From a biomechanical perspective, sitting is an easy and more stable posture with low-energy consumption (Ainsworth et al. 2000), lower centre of mass and larger base of support (Zacharkow 1988). The disadvantages from prolonged sitting include increased intradiscal load (Nachemson 1966; Nachemson 1981), weakened posterior

lumbar structures (Beach et al. 2005; Corlett 2006; Hedman and Fernie 1997) and decreased metabolic exchange (McGill et al. 2000). Previous research suggested that prolonged sitting could be a risk factor for developing LBP (Corlett 2006; Pope et al. 2002).

No systematic review has examined the relationship between LBP and sitting at work and during leisure time simultaneously; previous reviews have only examined the association between sitting during working time and LBP (Hartvigsen et al. 2000; Lis et al. 2007). The main purpose of this review was therefore to conduct a systematic review of sedentary lifestyle for LBP using a more comprehensive definition of sedentary behaviour. We aimed to examine the degree of association between sedentary lifestyle and LBP as well as to assess the level of evidence. There are three major differences between the present and previous reviews: (i) this review included only cohort and case–control studies; (ii) sedentary occupational pattern was expanded to include leisure-time activity and (iii) comprehensive criteria were used to examine the assessment of LBP in the studies reviewed.

Methods

Search and screening strategy

Journal articles published between January 1998 and December 2006 were obtained by searching the bibliographical databases namely Medline, Embase and Web of Science. Other databases were searched using the EBSCOhost interface (e.g. Academic Search Premier, AMED (Alternative Medicine), CINAHL, Clinical Pharmacology, Clinical Reference Systems, Health Source—Consumer Edition, Health Source: Nursing/Academic Edition, Pre-CINAHL, PsycARTICLES, Psychology and Behavioural Sciences Collection, PsycINFO, SPORTDiscus). Key words used included: LBP, back pain, spinal pain, spine pain, lumbago, backache, lumbar spondylosis, sciatica; lifestyle, occupation, work, leisure time, physical activity; sitting, seat, sedentary, office worker, white-collar worker, computer worker, watching TV, television watching, playing computer game; epidemiology, risk factor, etiology, causality, predictor, determinant. Hand searching was also conducted and references quoted in all retrieved articles were screened. Two reviewers (SMC and MFL) conducted the search independently following the same procedures; differences in search outcomes were scrutinized and consensus for inclusion reached.

To be included in the review, studies had to examine the association between exposure to sitting and LBP and be available in full text for the methodological quality assessment. Moreover, only studies employing a cohort (prospective or retrospective) or a case–control design were selected. Cross-sectional studies and those examining a specific spinal condition such as scoliosis, osteoporosis, herniated intervertebral disc disease or trauma were excluded.

Methodological quality assessment

Twenty-two criteria were used to assess the methodological quality of the studies. These criteria were modified from those used in previous reviews of musculoskeletal disorders (Borghouts et al. 1998; Hoogendoorn et al. 2000; Lievense et al. 2001). This study used a set of rigorous criteria to examine the assessment of LBP in the research. Studies received points if they clearly detailed the characteristics of LBP.

Due to different study designs, some items were used only for case–control studies, some only for cohort studies and some for both. Only items applicable to the study design contributed to the total score of that study, which was then used as an index to assess internal validity. The total score for each study was then standardized to a percentage. A study was rated as high quality when the standardized score was higher than 50%. All eligible articles were scored by two reviewers independently. Disagreements and discrepancies were discussed in an attempt to achieve consensus; a third reviewer (SKL) was consulted when a consensus was not reached.

Data extraction and analysis

For each article, the first author, year of publication, study population, the assessment of exposure, the assessment of LBP and the effect size (relative risk or odds ratio) were extracted and recorded.

Best evidence synthesis

Data from the studies were not pooled because of the heterogeneity in the study populations, the assessment of exposure and LBP (Hoogendoorn et al. 2000). Synthesis of the available information was used to assess the overall level of evidence (Slavin 1995). The levels of evidence defined were modified from Guyatt et al. (1995) and the Cochrane Collaboration Back Review Group (van Tulder et al. 2003), and had been used in previous studies (Lievense et al. 2001). Five levels of scientific evidence were derived from the study design, the number of studies and the methodological quality score:

1. *Strong evidence*: consistent findings at least 50% of high-quality cohort studies.
2. *Moderate evidence*: consistent findings in one high-quality cohort study and two or more high-quality case–control studies; or at least 50% of high-quality case–control studies.
3. *Limited evidence*: consistent findings in one high-quality cohort study or in two or more case–control studies.
4. *Conflicting evidence*: inconsistent findings among multiple studies.
5. *No evidence*: when one or less study (cohort or case–control) provided statistically significant data for or against an association.

Results

A total of 15 publications were selected and assessed for methodological quality (Fig. 1). The disagreement between the two reviewers on inclusion of studies was 11% (kappa 0.86, 95% CI 0.82–0.90); all were resolved after discussion.

Ten studies were prospective cohorts and five were case–control studies. For the cohort studies, the follow-up periods were more than 1 year except one that was only 3 months (Hestbaek et al. 2005). Of the five case–control studies, one was a retrospective nested case–control study (Thorbjornsson et al. 2000) and one was a study on twins (Hartvigsen et al. 2003).

The cohort studies investigated the general population (three studies), schoolchildren (three studies), military conscripts (one study) and three occupational studies. The case–control studies included the general population (one study), working population (one study), clinical patients (two studies) and the study on twins. Seven of the 15 studies used data from the same sample in more than one publication (Croft et al. 1999; Gunzburg et al. 1999; Jones and Macfarlane 2005; Jones et al. 2003; Levangie 1999a, b; Papageorgiou et al. 1995; Sjolie 2004a, b; Szpalski et al. 2002; Thorbjornsson et al. 1998, 2000; Yip 2001, 2004); the associated publications were found and related information extracted. The assessment of the methodological quality of any study was based on the information provided from all related reports using the same data set.

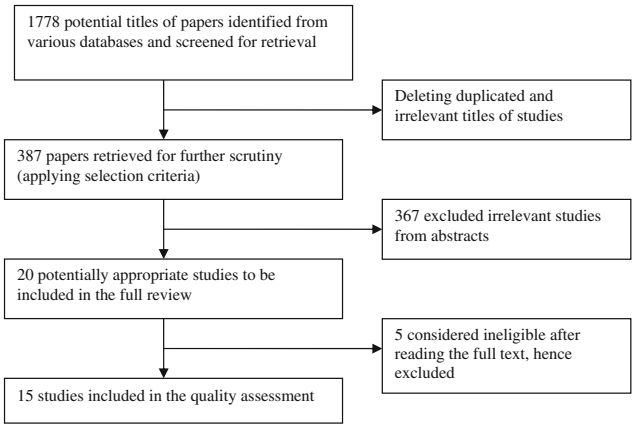

Fig. 1 Flow chart of the data screening process

Methodological quality assessment

The two reviewers had a disagreement rate of 12.9% (27/210) on cohort studies and 24.2% (23/95) on case–control studies, and <5% were resolved by involving a third reviewer (kappa 0.77, 95% CI 0.70–0.84). Six cohort studies (60%) and two case–control studies (40%) were classified as high-quality studies (Table 1).

Sensitivity analysis

When the cut-off point was changed to 40%, eight cohort studies (80%) and all the five case–control studies were classified as high-quality studies. Using a 60% cut-off point, five cohort studies (50%) and no case–control studies could be regarded as high-quality studies. There was no difference in the overall level of evidence for the effect of sedentary lifestyle on LBP with the use of different cut-off points. Therefore, in this report we will only describe the results when a 50% cut-point was used.

Assessment of LBP

Only five cohort studies included participants who had no LBP at baseline (Croft et al. 1999; Harkness et al. 2003; Jones et al. 2003; Kopec et al. 2004; Yip 2004), the remaining cohort studies included a population with LBP at baseline (Table 2). Only one cohort study had clearly defined and included only participants with non-specific LBP (NSLBP) and excluded other serious spinal diseases or conditions (Yip 2004). Most studies did not classify LBP clearly or exclude participants with serious low back pathology.

The definition of duration of LBP in participants varied between studies (Table 2). Some studies categorized the duration of pain (Hartvigsen et al. 2001, 2003; Hestbaek et al. 2005; Juul-Kristensen et al. 2004; Sjolie 2004b; Szpalski et al. 2002), others defined the duration of LBP (Croft et al. 1999; Harkness et al. 2003; Jones et al. 2003; Yip 2004) or had specific criteria for the duration of LBP (Kopec et al. 2004; Levangie 1999b; Nourbakhsh et al. 2001; Thorbjornsson et al. 2000). The recall period for LBP also varied among studies (Table 2), the range of recall period was from month to a lifetime.

Table 1 Methodological quality assessment of the 15 studies critically appraised

Item																							
References	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Total score	Score (%)
Hestbaek et al. (2005)	1	0	1	−1	1	0	NA	0.5	1	1	0	0	0	0.5	0	0	?	1	0	0	1	7	35
Juul-Kristensen et al. (2004)	1	0.5	0	−1	1	0	NA	0	1	1	0	0	0	1	1	0	?	0	0	1	1	7.5	38
Kopec et al. (2004)	1	1	1	0	1	1	NA	0.5	1	1	1	0	?	?	?	?	1	0	0	1	1	11.5	58
Sjolie (2004b)	1	1	1	−1	1	0	NA	1	1	1	0	0	1	?	?	1	0	1	1	1	1	12	60
Yip (2004)	1	0	1	−1	1	1	NA	0	1	1	1	0	1	1	1	1	1	1	1	1	1	15	75
Harkness et al. (2003)	1	1	1	−1	1	1	NA	1	1	1	1	0	?	1	1	0	0	1	0	1	1	13	65
Jones et al. (2003)	1	1	?	−1	1	1	NA	1	1	1	1	0	?	1	?	1	1	1	0	1	1	13	65
Szpalski et al. (2002)	1	0.5	0	−1	1	0	NA	1	1	1	0	0	1	0	0	1	1	0	0	1	1	9.5	48
Hartvigsen et al. (2001)	1	1	0	0	1	0	NA	0.5	1	1	0	0	0	1	0	0	0	0	0	1	1	8.5	43
Croft et al. (1999)	1	0	1	−1	1	1	NA	0	1	1	1	0	?	?	?	1	1	1	?	1	1	11	55
Hartvigsen et al. (2003)	NA	1	NA	0	1	1	1	?	NA	1	NA	0	0	1	0	0	0	0	0	NA	1	7	44
Nourbakhsh et al. (2001)	NA	?	NA	−1	1	1	1	?	NA	1	NA	0	0	1	0	1	1	1	0	NA	0	7	44
Thorbjornsson et al. (2000)	0	0	1	0	1	0	1	?	1	1	0	0	?	1	1	1	1	0	0	1	1	11	52
Vingard et al. (2000)	NA	?	NA	−1	1	1	1	?	NA	1	NA	0	?	1	1	1	1	0	0	NA	1	8	50
Levangie (1999b)	NA	1	NA	−1	1	1	1	?	NA	1	NA	0	0	?	0	?	1	1	0	NA	1	7	44

Scoring rules: '1' if the item met the list of criteria; '0' if did not meet the criteria; '?' (and hence '0') if the description was not clear; '−1' if the condition didn't meet the criteria in item 5, otherwise it was scored '0'; '0.5' if the information provided by studies only met partially the criteria in items 3, 9 & 15. The first ten studies were cohort studies; the next 5 were case–control studies. Item 1 was the informative item and was not included in the scoring

NA not applicable

Sedentary work or prolonged sitting at work

Nine studies assessed sitting or sedentary time at work (Table 3). Only one high-quality cohort study reported a positive association between sitting at work and LBP among schoolchildren (OR 6.2, 95% CI 2.2–17.3) (Sjolie 2004b). The remaining studies reported no association between sedentary work or sitting at work and LBP. Therefore, this review has found limited evidence to support the hypothesis that sedentary work style or prolonged sitting at work is a risk factor for LBP.

Sedentary behaviour or prolonged sitting during leisure time

Five cohort studies assessed the risk of sedentary behaviour during leisure time (Table 4); only one nonhigh-quality study on schoolchildren reported a trend towards time spent playing computer games and LBP (OR 1.53, 95% CI 0.92–2.54) (Szpalski et al. 2002). There is no evidence to support that sedentary behaviour or prolonged sitting during leisure time is a risk factor for LBP.

Sedentary behaviour or prolonged sitting at work *and* during leisure time combined

Three studies assessed the association between sedentary behaviour or prolonged sitting at work and during leisure time and LBP (Table 5). Only one case–control study showed a trend towards prolonged sitting combined with work and leisure time and LBP (OR 1.98, 95% CI 0.98–4.0) (Nourbakhsh et al. 2001). There was no evidence to demonstrate that sitting or sedentary behaviour at work and during leisure time together is a risk factor of LBP.

Figure 2 shows the effect size reported in the studies appraised. A funnel plot is also presented (Fig. 3). No serious publication bias has been observed; only one relatively small study ($n = 85$) reported an odds ratio that was substantially bigger than the others.

Discussion

The present study reviewed 15 studies that examined the relationship between sedentary lifestyle at work and during leisure time and non-specific LBP.

Only one high-quality cohort study showed a significant positive relationship between sedentary behaviour or prolonged sitting (at work only) and LBP. Although the degree of association reported in the study was strong (OR 6.2), the 95% CI was wide (2.2–17.3), implying a high degree of uncertainty of the strength of association. No significant results were reported for the association between sedentary behaviour during leisure time and LBP or for sedentary behaviour or prolonged sitting at work and during leisure time combined and LBP. Therefore, little evidence exists

Table 2 Assessment of LBP

References	Study design (follow-up period)	LBP at baseline (yes/no)[a]	Measurement of LBP	Lasting duration of LBP	Recall period of LBP
Hestbaek et al. (2005)[a]	Prospective cohort (3 months)	Yes	Adapted Nordic questionnaire	Non-specific (category for no. of days)	During 3-month military service
Juul-Kristensen et al. (2004)[a]	Prospective cohort (21 months)	Yes	Adapted Nordic questionnaire	Non-specific (category for no. of days)	The past 12 months for an increase of days with symptoms The last 3 months for an increase of intensity with symptoms
Kopec et al. (2004)[a]	Prospective cohort (2 years)	No	Self-administrated questionnaire	More than 6 months	During the 2-year period of study
Sjolie (2004b)[a]	Prospective cohort (3 years)	Yes	Adapted Nordic questionnaire	Non-specific (category for no. of days)	The previous year
Yip (2004)[a]	Prospective cohort (1 year)	No	Adapted Aberdeen's scale	At least one day	The past 12 months
Harkness et al. (2003)[a]	Prospective cohort (1 & 2 years)	No	Self-administrated questionnaire	At least one day	The past month
Hartvigsen et al. (2003)	Twin-control	–	Standardized Nordic questionnaire	Non-specific (category for no. of days)	The past 12 months
Jones et al. (2003)[a]	Prospective cohort (1 year)	No	Self-administrated questionnaire	At least one day	The past month
Szpalski et al. (2002)[a]	Prospective cohort (2 years)	Yes	Self-administrated questionnaire Clinical examination	Non-specific (no. of days)	Lifetime
Hartvigsen et al. (2001)[a]	Prospective cohort (5 years)	Yes	Standardized Nordic questionnaire	Non-specific (category for no. of days)	The past 12 months
Nourbakhsh et al. (2001)	Case–control	–	Clinical diagnosis	More than 6 weeks or at least 1 week for each episode	The previous year
Thorbjornsson et al. (2000)	Retrospective nested case–control (24 years)	–	Interview and self-reported questionnaire	At least 7 days	The past 12 months
Vingard et al. (2000)	Case–control	–	Clinical examination	None	The past 6 months
Croft et al. (1999)[a]	Prospective cohort (1 year)	No	Self-administrated questionnaire Medical consultation	At least one day	The past month
Levangie (1999b)	Case–control	–	Clinical examination	<1 year	The past 12 months

[a] "LBP at baseline" was only applicable in cohort study

Table 3 Association between LBP and sedentary behaviour or prolonged sitting at work

References	Study design	Study population	Sample size	Effect size
Hestbaek et al. (2005)	Prospective cohort	Danish Military	982	Sedentary occupation: Leg pain originated from LB OR 0.87 (0.42–1.79)
Juul-Kristensen et al. (2004)	Prospective cohort	Office workers	1,963	Using computer at almost working hours: An increase of frequency of days with LBP OR 1.11 (0.61–2.02) An increase of intensity with LBP OR 1.25 (0.72–2.18)
Sjolie (2004b)	Prospective cohort	Schoolchildren	85	Sitting at school: OR 6.2 (2.2–17.3)
Yip (2004)	Prospective cohort	Nurses	144	Time spent sitting at work: $\geq$ 2 h vs. < 2 h RR 0.80 (0.50–1.25)
Harkness et al. (2003)	Prospective cohort	Newly employed workers	1,036	Time spent sitting at work: < 2 h OR 1.0 (0.6–1.7) $\geq$ 2 h OR 1.0 (0.6–1.7)
Hartvigsen et al. (2003)	Twin-control	Twin pairs	Case = 1,910 Control = 1,910	Sitting at work (completely sedentary work): OR 1.0 (referent) Sitting/walking at work (partially sedentary work): Short LBP ($\leq$ 30 d) OR 0.95 (0.80–1.14) Long LBP (> 30 d) OR 1.07 (0.79–1.44)
Hartvigsen et al. (2001)	Prospective cohort	General population	1,163	Sedentary workload compared to light workload: OR 0.75 (0.57–0.99)
Thorbjornsson et al. (2000)	Retrospective nested case–control	General population	Case = 222 Control = 262	Sedentary work (5 years before onset): Males, OR 1.7 (0.9–3.1) Females, OR 1.6 (0.9–2.8) Sedentary work (1 year before onset): Males, OR 1.6 (0.8–2.9) Females, OR 1.7 (1.0–3.1)
Vingard et al. (2000)	Case–control	Working population	Case = 695 Control = 1,423	Daily time spent sitting at work: > 5 h vs. < 1 h Males, RR 1.1 (0.7–1.7) Females, RR 0.7 (0.4–1.1)

Table 4 Association between LBP and sedentary behaviour or prolonged sitting during leisure time

References	Study design	Study population	Sample size	Effect size
Sjolie (2004b)	Prospective cohort	Schoolchildren	85	Time spent on TV and playing computer games: OR 0.7 (0.2–2.6)
Yip (2004)	Prospective cohort	Nurses	144	Sedentary leisure-time activity vs. active leisure-time activity: RR 0.74 (0.48–1.14)
Jones et al. (2003)	Prospective cohort	Schoolchildren	809	Time spent watching TV or playing computer games: <120 min RR 1.0, 70–180 min RR 0.9 (0.6–1.5), 125–183 min RR 1.0 (0.6–1.6), 183–270 min RR 1.2 (0.7–1.9), >275 min RR 1.0 (0.6–1.8)
Szpalski et al. (2002)	Prospective cohort	Schoolchildren	287	Daily time spent playing computer games OR 1.53 (0.92–2.54)
Croft et al. (1999)	Prospective cohort	General population	1,649	Daily time spent watching TV: $\leq$ 3 h RR 1.0 (reference) >3 h RR 1.0 (0.8–1.3) Males RR 1.0 (0.8–1.2) Females

Table 5 Association between LBP and sedentary behaviour or prolonged sitting for work and leisure time combined

References	Study design	Study population	Sample size	Effect size
Kopec et al. (2004)	Prospective cohort	General population	885	Usual daily activity in sitting (males only) OR 1.0 (referent)
Nourbakhsh et al. (2001)	Case–control	Hospital patients	Case = 121 Control = 105	Sitting at work and no exercise compared to sitting at work and regular exercise: OR 1.98 (0.98–4.0)
Levangie (1999b)	Case–control	Clinical outpatients	Case = 150 Control = 138	Weekly time spent sitting: ≤4 h OR 1.0 (referent) >4 h ≤ 6 h OR 1.54 (0.81–2.91) >6 h ≤ 8 h OR 0.71 (0.37–1.35) ≥9 h OR 1.42 (0.73–2.78)

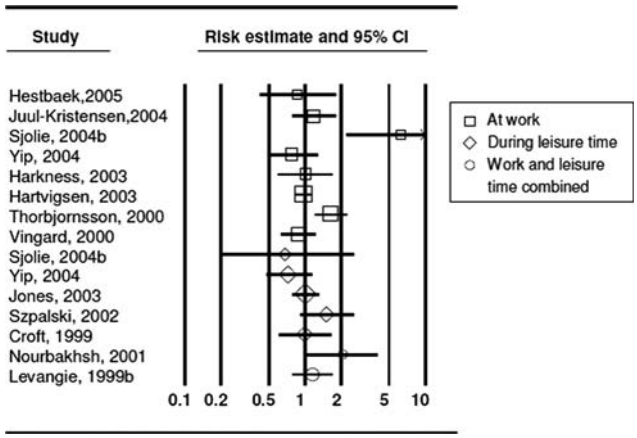

Fig. 2 Forest plot showing the effect size of sedentary behaviour or prolonged sitting and combination of work with leisure time as a risk factor for LBP. *Note*: no effect size reported in two studies as prolonged sitting was used as the reference group; risk estimate could be relative risk or odds ratio; see Tables 3–5 for details

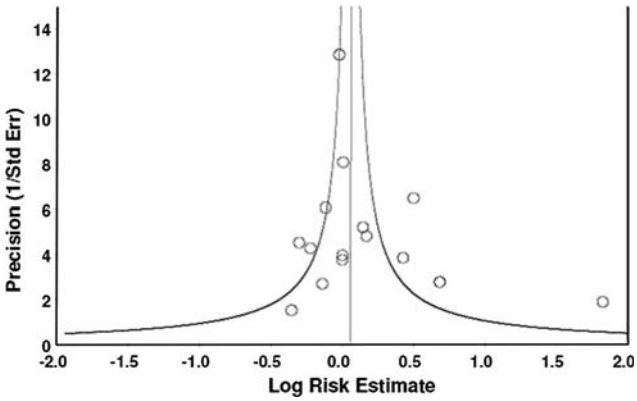

Fig. 3 Funnel plot of the studies critically appraised

that sedentary behaviour or prolonged sitting at work and during leisure time is related to LBP, confirming the conclusions of previous reviews (Hartvigsen et al. 2000; Lis et al. 2007).

Studies in this review also confirmed no dose-related response (Croft et al. 1999; Harkness et al. 2003; Jones et al. 2003; Levangie 1999b; Vingard et al. 2000; Yip 2004); sitting longer is not worse for LBP. There was no significant increase in risk on the time spent watching TV or playing computer games for <2 h (RR 1.0) or more than 4.5 h (RR 1.0, 95% CI 0.6–1.8) (Jones et al. 2003) or for the weekly time spent sitting for <4 h (OR 1.0) or more than 9 h (OR 1.42, 95% CI 0.73–2.78) (Levangie 1999b).

There were four differences between the studies included in the present review and previous reviews (Hartvigsen et al. 2000; Lis et al. 2007). First, according to the exposure-effect model, some physical load (e.g. seated work) may increase the risk for developing LBP if the duration of cumulative exposure is long (Winkel and Mathiassen 1994). This review included more studies (the absolute number and the proportion of studies reviewed) with a prospective design (10/15; 67%) and excluded all studies employing a cross-sectional design that measured exposure and outcome at the same time. One of the previous two reviews had only 11% (4/35) cohort studies; the rest were cross-sectional studies (Hartvigsen et al. 2000). The other review had 42% (10/24) cohort studies but also assessed 11 cross-sectional studies (Lis et al. 2007). Second, this review excluded some occupations (e.g. transit drivers) that a previous review had included (Lis et al. 2007). The Lis et al. review (2007) had 8 of the 24 reports that assessed sitting only with the remaining 16 studies assessed driving as well. It means that the risk exposure included not only sitting but also vibration. Whole body vibration has been shown to have negative effects on the intervertebral disc, the connected nervous system and the supporting musculature (Bernard 1997; Bovenzi and Hulshof 1999; Magnusson et al. 1996). Third, the present review included both occupational groups and school children as study populations. This was because the lifetime prevalence of LBP in children and adolescents has been demonstrated to be as high as adults and may predispose to future onset in adult life (Jones and Macfarlane 2005; Kovacs et al. 2003). Finally, we included work and leisure time. Previous reviews had investigated working time (Hartvigsen et al. 2000; Lis et al. 2007). Although Hildebrandt et al. (2000) concluded that

workers who participated in sedentary activity during leisure time had a tendency to have higher prevalence of LBP and sick leave due to their LBP, this review showed that the evidence was not strong enough to claim prolonged sitting or sedentary behaviour during leisure time is a risk factor for developing LBP.

Limitations of the review and suggestions for future studies

Previous injury is the biggest risk factor for further injury in most musculoskeletal disorders, and LBP appears to be no different (Hootman et al. 2002). For example, Burdorf et al. (1996) reported that previous LBP was associated with a higher risk (RR 9.8) for recurrent back pain during 1-year follow-up. Another study reported the 12-month recurrence rate was as high as 73% (Pengel et al. 2003). In the present review, a few studies reported that previous episodes of LBP were strongly linked with further LBP (Sjolie 2004b; Szpalski et al. 2002). Future studies should evaluate previous LBP.

Most epidemiological studies define cases based on symptoms (Smedley et al. 2005). Most observational studies in this review did not explicitly establish if the study subjects had serious underlying diseases or conditions (e.g. spinal tumour, inflammatory diseases) that could have strong mediating effects. We therefore suggest that future studies should specifically exclude these participants.

It is believed that cumulated exposure to physical load for a period of time could increase the risk of LBP (Winkel and Mathiassen 1994). In particular, sitting may reach a threshold for major injury during lifetime cumulated exposure. However, there was a lack of the measurement of the duration of exposure to physical load in all studies included in the present review (item 13 in Table 1). Future studies should therefore take lifetime cumulated exposure into consideration.

The possibility of publication and selection bias cannot be ruled out as only full text papers written in English were included. In terms of the criteria of methodological quality assessment, sedentary exposure was one of the physical loads and was usually measured together with other physical loads (e.g. manual material handling, lifting and carrying). Hence, the present review could only assess the total physical load rather than sitting as a single risk factor for the methodological quality assessment.

In conclusion, there was insufficient evidence to demonstrate that sedentary behaviour is a risk factor for developing LBP. Hence, the present review confirms that sedentary lifestyle combined work and leisure time is not associated with LBP.

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