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Risk and prognosis of inguinal hernia in relation to occupational mechanical exposures – a systematic review of the epidemiologic evidence

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ABSTRACT

Objective To evaluate the epidemiologic evidence for a causal effect of occupational mechanical exposures on incidence of inguinal hernia, and for a prognostic effect of such exposures on hernia recurrence and persistent pain after inguinal hernia repair.

Methods We performed a literature search in Medline, Embase and Web of Science until November 3 2011 to identify peer-reviewed papers on risk of inguinal hernia or prognosis after inguinal hernia repair in relation to occupation or occupational mechanical exposures. We also included studies on risk of inguinal hernia in relation to single strenuous events. Central information was extracted from included studies, and strengths and limitations were discussed.

Results All 23 included studies focussed on effects of (work) activities that were indicators of energy expenditure rather than they reflected specific occupational risk factors. Eight studies provided information on risk by occupation or occupational mechanical exposures. Increased risk was reported in six of the eight studies, but the risk estimates might well be inflated primarily by reporting bias. The negative findings in two studies might well be explained by bias towards the null due to crude exposure and/or outcome assessment. Three studies focussed on single strenuous events, but they primarily reflected patients' beliefs regarding risk factors. Information on prognosis with respect to recurrence was found in seven studies. Four reported an increased risk, but in general, the studies used crude exposure assessment, and three were also underpowered. Six studies on prognosis with respect to persistent pain (of which one study also concerned recurrence) were practically non-informative

for the purpose of the present review; major drawbacks were probable information bias, confounding and inadequate reporting of results.

Conclusion There is insufficient epidemiologic evidence (grade 0) to draw meaningful conclusions about the existence of causal associations between specific occupational mechanical exposures and the development of inguinal hernia and about the influence of these exposures on prognosis after inguinal hernia repair with respect to hernia recurrence and persistent pain. The limited epidemiologic literature does not rule out important associations.

Key terms

Occupational exposure, inguinal hernia, risk, prognosis

UDVIDET DANSK RESUME (EXTENDED DANISH SUMMARY)

Baggrund for problemstillingen

Denne gennemgang blev lavet i henhold til Arbejdsmiljøforskningsfondens opslag i december 2010 vedrørende udredninger om erhvervssygdomme, tema 2: Sammenhænge mellem lyskebrok (hernia inguinalis medialis et lateralis) og fysiske påvirkninger i arbejdslivet.

Lyskebrok

Ved et lyskebrok trænger bughinden og evt. en del af tarmen sig gennem bugvæggen lige over lyskebåndet. Lyskebrok deles op i det laterale eller indirekte (gennem lyskekanalen) og det mediale eller direkte (gennem bugvæggen). Lyskekanalen er skråt forløbende gennem bugens muskulatur og lukkes normalt af en slags klap-mekanisme. Et medfødt lyskebrok hos drenge er altid et lateralt lyskebrok. Det laterale lyskebrok udgør ca. 66% af alle lyskebrok hos voksne. Det mediale lyskebrok presses direkte gennem et svagt sted i lyskekanalens bagvæg og altså ikke gennem lyskekanalens indre åbning. Medialt lyskebrok ses hos personer med svækket bugvæg, og med alderen stiger andelen af mediale lyskebrok i forhold til andelen af laterale. I nogle tilfældene findes medialt og lateralt lyskebrok samtidigt, hvilket kaldes et saddelbrok. Lyskebrokket kan hos begge køn vise sig som en udbuling i lysken eller øverst på låret, hos mænd desuden i pungen. Nogle lyskebrok giver så godt som ingen gener. I mange tilfælde vil der dog være ubehag og smerter, fx ved fysisk arbejde. Der udføres årligt ca. 10.000 operationer for lyskebrok i Danmark. Lyskebrok optræder hyppigst hos mænd med en aldersjusteret hyppighed på 7-8 gange i forhold til kvinder.

Tunge løft og stående arbejde i længere perioder har været mistænkt som risikofaktorer for lyskebrok, og enkeltstående fysiske anstrengelser har været mistænkt for at kunne føre til en pludselig udvikling af et lyskebrok. Sygefravær og råd om tilbagevenden til arbejdet har sædvanligvis været begrundet med type af operation og forventede fysiske anstrengelser i arbejdet.

Formål

Det overordnede formål med denne udredning var at belyse, sammenfatte og vurdere holdepunkterne for eventuelle årsagssammenhænge mellem udvikling af medialt og lateralt lyskebrok og udsættelse for forskellige mekaniske påvirkninger i arbejdet. Endvidere var det formålet at undersøge mekaniske påvirkningers betydning for prognosen (forløbet) efter operation for lyskebrok med hensyn til gendannelse af brokket og langvarige smerter. Hensigten var at fokusere på arbejde med store samlede daglige løftemængder, gentagne tunge enkeltløft, personforflytninger og skub/træk samt langvarigt stående/gående arbejde. Udredningen skulle desuden omfatte en vurdering af kønnets eventuelle betydning.

Udredningens resultater er samlet i et referencedokument i henhold til retningslinjer udarbejdet af Arbejdsmiljøforskningsfonden. Udredningen bygger på en gennemgang af den epidemiologiske litteratur om sammenhænge mellem arbejdsrelaterede påvirkninger og udvikling af lyskebrok. Hvert studie er gennemgået systematisk, og der er udarbejdet tabeller for at sikre det nødvendige overblik. Det samlede materiale er gennemgået for mulige fejlkilder og ensartethed af resultaterne på tværs af de forskellige studier. Udredningen indeholder herudover afsnit om konkurrerende

årsager og mulige årsagsmekanismer. Referencedokumentet afsluttes med en konklusion i henhold til Arbejdsmiljøforskningsfondens kriterier.

Metoder

Der blev gennemført en litteratursøgning efter videnskabelige artikler i tre computeriserede databaser: Medline, Embase og Web of Science. Ved søgningen blev der brugt søgeord relateret til lyskebrok og erhvervseksponeringer (mekaniske påvirkninger, tunge løft, stående/gående arbejde). Artiklerne skulle være forfattet på engelsk, skandinavisk, fransk eller tysk samt være fra et tidsskrift med fagfællebedømmelse. Alle artikler, som blev identificeret ved søgningen, gennemgik en tretrins screeningsproces: 1) Artiklernes titler blev gennemgået for at finde undersøgelser, der kunne være relevante, 2) resumeer af muligt relevante artikler blev læst for at fravælge de undersøgelser, der ikke var relevante, og 3) de resterende artikler blev læst i deres fulde længde med henblik på at finde dem, der var velegnede til at indgå i dette dokument. Udvælgelse af artikler blev i første omgang foretaget af to forskere uafhængigt af hinanden. Den endelige udvælgelse skete efter konsensus i hele forskergruppen.

Resultater

Ved den indledende litteratursøgning fandtes 1771 artikler, hvor 1625 blev ekskluderet på baggrund af titel, og 125 blev fravalgt efter læsning af resume eller læsning af hele artiklen. To relevante artikler blev fundet via andre artikler, og dermed indgik 23 artikler i referencedokumentet. Sammenhængen mellem erhvervsmæssige mekaniske belastninger og risikoen for lyskebrok blev belyst i otte

artikler, tre artikler omhandlede lyskebrok efter enkeltstående belastninger, og 12 artikler omhandlede prognosen efter operation for lyskebrok.

Af de otte studier af sammenhængen mellem erhvervsmæssige mekaniske belastninger og udvikling af lyskebrok var tre tværsnitsundersøgelser, fire var case-kontrol undersøgelser, og et var et prospektivt kohortestudie. Samlet var studierne behæftet med mange mulige fejlkilder. Det samme gjorde sig gældende vedrørende enkeltstående belastninger og udviklingen af lyskebrok. Det største problem i undersøgelserne var målingen af de mekaniske eksponeringer, som i overvejende grad var baseret på selvrapporterede oplysninger eller stillingsbetegnelser. Andre problemer hidrørte fra mangelfulde analyser, mangelfuld confounderkontrol, og undersøgelser baseret på for få personer.

Information om prognose med hensyn til gendannelse af brokket efter operation fandtes i syv studier. Studiernes kvalitet var ringe i forhold til formålet med denne udredning. Seks undersøgelser om længerevarende smerter efter lyskebrokoperation indeholdt stort set ikke informationer, som var anvendelige i forhold til formålet med denne udredning.

Forskelle mellem mænd og kvinder

De fleste lyskebrokpatienter er mænd, og de fleste undersøgelser vedrører derfor også mænd. De få undersøgelser, som indbefatter resultater for kvinder, indeholder ikke resultater, som kan informere om forskel mellem kønnene med hensyn til betydningen af erhvervsmæssige mekaniske påvirkninger.

Konklusion

Der blev gennemført en omfattende litteratursøgning med det formål at udvælge undersøgelser, som belyste, hvorvidt personer med bestemte erhvervsmæssige mekaniske påvirkninger har en øget risiko for lyskebrok. På baggrund af i alt 1771 artikler blev 23 udvalgt som egnede og relevante for dette dokument. Litteraturgennemgangen bygger på studier udført i almenbefolkningen og inden for forskellige typer af erhverv. I langt de fleste tilfælde har der været tale om tværsnitsstudier eller case-kontrol studier, hvilket indebærer problemer med at fastslå den tidsmæssige karakter af eventuelle sammenhænge mellem de mekaniske eksponeringer og udviklingen af lyskebrok, og risiko for at studierne kan være behæftet med såvel informations- som selektionsbias. De fleste studier har ikke taget højde for muligheden for sammenblanding af effekter (confounding). Til vurdering af erhvervsmæssige mekaniske eksponeringer er der ofte anvendt selvrapporterede, grove skøn eller fagbetegnelser, og der eksisterer ikke undersøgelser, som har omfattet kvantitative opgørelser af samlede daglige løftemængder, frekvens af tunge løft eller daglig varighed af stående/gående arbejde.

Samlet er den epidemiologiske viden om erhvervsmæssige mekaniske påvirkninger og lyskebrok begrænset. Hvis man inddrager viden fra andre biomedicinske områder, er der forskning, som peger på mekanismer, der kan kæde mekaniske påvirkninger sammen med udvikling af lyskebrok. Det drejer sig bl.a. om målinger af trykket i bughulen, som antages at være en risikofaktor for lyskebrok. Trykket i bughulen er i eksperimentelle undersøgelser målt højere ved tunge løft, specielt ved løft, som udføres hurtigt.

- Den første konklusion er, at der er utilstrækkelig evidens [0] for en årsagssammenhæng mellem mekaniske påvirkninger i arbejdet og udviklingen af lyskebrok.
- Den anden konklusion er, at der er utilstrækkelig evidens [0] for en årsagssammenhæng mellem enkeltstående påvirkninger i arbejdet og udviklingen af lyskebrok.
- Den tredje konklusion er, at der er utilstrækkelig evidens [0] for en årsagssammenhæng mellem mekaniske belastninger i arbejdet og prognosen for af lyskebrok.

Forskningsbehov

Der er et stort behov for undersøgelser af en højere kvalitet vedrørende sammenhængen mellem erhvervsmæssige mekaniske påvirkninger og lyskebrok. Det gælder både bedre eksponeringsoplysninger og mulighederne for at skelne mellem det laterale og det mediale lyskebrok. Flere af forfatterne til dette referencedokument har i et samarbejde med Dansk Herniedatabase analyseret risikofaktorer for lyskebrok baseret på en jobeksponeringsmatrice. Der er endvidere planer om at anvende Den Muskuloskeletale Forskningsdatabase[1] ved Dansk Ramazzini Center til at undersøge risikofaktorer for lyskebrok. Der er også behov for at undersøge de erhvervsmæssige forholds betydning for reoperation og smerteforekomst efter operation.

[1] Den Muskoloskeletale Forskningsdatabase indeholder data fra ni tidligere danske epidemiologiske undersøgelser om erhverv og muskelskeletlidelser, som er blevet samlet med økonomisk støtte fra Arbejdsmiljøforskningsfonden.

En arbejdsgruppe bestående af overlæge, ph.d. Susanne Wulff Svendsen, Arbejdsmedicinsk Klinik, Regionshospitalet Herning, overlæge, ph.d. Poul Frost, Arbejdsmedicinsk Klinik, Århus Sygehus, stud.med., MMSc Marie Vestergaard Vad og professor, overlæge, ph.d. Johan Hviid Andersen, Arbejdsmedicinsk Klinik, Regionshospitalet Herning har skrevet referencedokumentet. Dr.med. Morten Bay-Nielsen, Gastrokirurgisk afdeling, Hvidovre Hospital, Direktør Nils Fallentin, Center for Fysisk Ergonomi, Liberty Mutual Research Institute for Safety, Hopkinton, Massachusetts, USA, og overlæge, dr.med Sigurd Mikkelsen, Arbejds- og Miljømedicinsk Klinik, Bispebjerg har været eksterne bedømmere.
Bedømmerne har indsendt skriftlige kommentarer til en tidligere version af dokumentet. Dokumentet blev revideret, og efter et møde d. 8. december 2011 mellem arbejdsgruppen og bedømmerne, er referencedokumentet færdiggjort.

INTRODUCTION

Recently, the Danish Working Environment Research Fund commissioned us to undertake a systematic review of risk and prognosis of inguinal hernia in relation to occupational mechanical exposures. The Danish National Board of Industrial Injuries and the Occupational Diseases Committee requested the review for use in negotiations on the inclusion of new diseases in the list of occupational diseases and for adjusting the practice regarding recognition of unlisted diseases caused by the particular nature of the work. Existing Danish guidelines for recognizing hernias as unlisted diseases date back to 1997 (https://www.retsinformation.dk/Forms/R0710.aspx?id=84901).

An inguinal hernia is a protrusion of contents of the abdominal cavity through a defect in the lower abdominal wall above the inguinal ligament (1). Medial (or direct) hernias penetrate through a non-preformed gap, whereas lateral (or indirect) hernias pass through the inguinal canal. Lateral hernias may protrude within a patent processus vaginalis, which is an embryological evagination of the peritoneum. For both types of inguinal hernia, main symptoms are pain and discomfort due to groin swelling. The most important complication is incarceration of the hernia, which is a surgical emergency.

Inguinal hernia is far more common among men than among women, with a reported age-adjusted male female ratio of 7.5 to 1 (2). Among men aged 25 years and over, inguinal hernia in terms of a swelling observed at clinical examination or a previous repair occurred with a lifetime prevalence of 15% (3). The lifetime prevalence increased with age from 5% in the age group 25-34 years, through 10% in the age

group 35-44 years, 18% in the age group 45-54 years, 24% in the age group 55-64 years, and 31% in the age group 65-74 years, to 45% among men aged 75 years and over (3).

Except in case of serious comorbidity, surgical treatment of symptomatic inguinal hernias is recommended, whereas watchful waiting may be an acceptable option for asymptomatic or minimally symptomatic hernias (1;4). According to a register study from the United Kingdom, the all-ages annual incidence of inguinal hernia repairs was 13 per 10,000 in the period 1976 to 1986 (5), which probably underestimated the true incidence because surgery in private hospitals was not included (6). After the first year of life, the risk of inguinal hernia repair among males rose with age up to age 65 and declined slightly thereafter (5). In male patients aged 15-39 years, 78% of operated inguinal hernias (excluding pantaloon hernias and hernias with unknown type) were lateral (7). This percentage was 60% for the age group 40-59 years, and 55% for men aged 60 years or more (7). Around one fourth of all men can expect to have an inguinal hernia repair at some point in life (2;5), and men account for 90-95% of all inguinal hernia repairs (5;8;9).

Potential risk factors include a family history of inguinal hernia (10-12), comorbidity such as prostatic hypertrophy (3) and chronic obstructive pulmonary disease (11), ethnicity (2), and smoking (1), whereas a high body mass index seems to have a protective effect (2;3;12;13). Heavy physical workload (14;15) and standing for long periods at work (http://www.mayoclinic.com/health/inguinal-hernia/DS00364/DSECTION=risk%2Dfactors) have been implicated as risk factors. Potentially, a single strenuous event may also induce an inguinal hernia. Although

there may be little clinical merit in differentiating between medial and lateral hernias (1;16), the influence of occupational risk factors may differ.

Several surgical techniques are used that can be broadly categorized as open (sutured or mesh) or laparoscopic (17). Historically, open techniques were the first to be applied, whilst laparoscopic techniques did not gain a foothold until after around 1990. Open techniques are most commonly used. Hernia recurrence and persistent pain are considered the most important adverse outcomes after inguinal hernia repair. The question is, if generically or quantitatively different occupational mechanical exposures are related to different probabilities of these outcomes. In Denmark around the millennium, 17% of all inguinal hernia repairs were performed due to *recurrence* (18). The risk of recurrence depends on surgical technique (lower risk after mesh than non-mesh techniques) (19;20) and maybe also on defective collagen metabolism (21). *Persistent pain* for months or even years is a common symptom after inguinal hernia repair (22-26). In a Danish patient population, pain impairing daily activities was reported in about 17% one year after open inguinal hernia repair (27) and in 6% after 6.5 years (28). In addition to surgical technique (e.g. laparoscopic techniques seem to convey a lower risk than open techniques (24;25;29)), surgery for recurrence (24;25), young age, female gender, preoperative chronic pain, and acute pain in the early postoperative period have been identified as risk factors (22;30). Psychological factors may also play a role (30;31).

Another important prognostic outcome is *duration of postoperative sickness absence* that has considerable economic implications for society. In part, however, this outcome reflects advice on convalescence (32) that has traditionally depended on

surgery type (open or laparoscopic) and expected physical strain at work (33;34). Therefore, standardised recommendations on (early) return to work are a prerequisite for valid comparisons of patient groups with respect to how long time is necessary before they can resume work after inguinal hernia repair (35). Even when surgeons do provide standardised recommendations on early return to work, this may not be followed by the patients, e.g. due to advice to the contrary from general practitioners or employers. A priori, it therefore seems difficult to extract meaningful information on prognosis in relation to occupational mechanical exposures from studies that focus on duration of postoperative sickness absence as an outcome in its own right. In studies on risk of recurrence and persistent pain, prolonged postoperative sickness absence may be a protective factor, which should be taken into consideration. These arguments are reflected in the way we delineated the present review of the literature on prognosis.

Our overall objective was to produce a systematic review in the form of a reference document evaluating the epidemiologic evidence for 1) causal relations between occupational mechanical exposures and the development of lateral and medial inguinal hernia and 2) effects of occupational mechanical exposures on postoperative prognosis. Specific objectives were to present exposure-response patterns for associations that were likely to be causal, and to evaluate the risk of hernia recurrence and persistent postoperative pain in relation to early return to work characterised by different mechanical exposures. Part of the objective was to assess any impact of gender on these relationships. In case of insufficient evidence, a further objective was to outline major research needs.

METHODS

Literature search

We conducted a systematic search in Medline (last updated November 3 2011) using the terms (inguinal hernia OR hernia repair OR (inguinal hernia AND recurrence) OR (inguinal hernia AND reoperation) OR (inguinal hernia AND pain)) AND (convalescence OR work OR occupation OR strenuous OR occupational exposure OR lifting OR physical load OR standing OR walking OR work related OR occupational epidemiology OR risk factor*). Corresponding searches were performed in Embase and Web of Science. Moreover, we searched the reference lists of retrieved original papers and reviews for additional relevant material. Duplicates were excluded.

Selection of articles

First based on the title and second based on reading of the abstract, two researchers selected candidate papers to be retrieved in full text. Any differences of opinion were resolved in consensus. Included papers had to be in English, Scandinavian, French or German, to be published in a peer-reviewed journal, to describe results of an original study, and to comprise an analysis of risk or prognosis of inguinal hernia in relation to occupation or occupational mechanical exposures. In general, we excluded risk studies that did not include a control group. However, we made an exception from this criterion with respect to the potential impact of a single strenuous event where we included case series because we identified no other types of study. Case series that only considered compensation cases were excluded, and we did not include case reports. Prognostic studies with duration of sickness absence as the only outcome were excluded.

Article review

For each article on risk of inguinal hernia that we finally reviewed, we tabulated a standardised set of information on study design, population and completeness of participation, outcome assessment, exposure assessment and exposure contrasts, effect estimates (with confidence intervals or P-values), and confounder adjustment. For each article of prognosis with respect to recurrence, we tabulated study design, population and completeness of participation, type of hernia, surgical technique, assessment of recurrence, exposure assessment, effect estimates (with confidence intervals), and outcome probabilities given the exposure in combination with other predictors. Where counts or prevalence estimates were provided without any effect estimates, we calculated risk differences or odds ratios with exact 95% confidence intervals using STATA 11.2.

A brief description of each original study is provided below, together with an evaluation of the contribution of each study to knowledge. The evaluations are given in italics. The evaluations were based on a qualitative rating that considered limitations of design, potential for bias (inflationary or towards the null), adjustment for potential confounders (in studies of risk), inclusion of relevant potential predictors in multivariable models (in studies of prognosis), appropriateness of statistical analyses, and power to detect associations under study.

Grading of evidence for causal and prognostic relations

Across the individual articles on risk of inguinal hernias (or hernia repairs), we rated the degree of evidence for a causal association between a given exposure and a defined outcome according to the framework of the Scientific Committee of the

Danish Society of Occupational and Environmental Medicine that has been adopted by the Danish Working Environment Research Fund, appendix 1. We based the rating on the quality, consistency, and amount of evidence. The evidence for prognostic relations between occupational mechanical exposures and postoperative outcomes was evaluated according to the same framework, replacing the word causal with the word prognostic. We were interested in causal associations between risk factors and negative prognostic outcomes, rather than prediction per se (36;37). Therefore, we considered confounding relevant in prognostic studies.

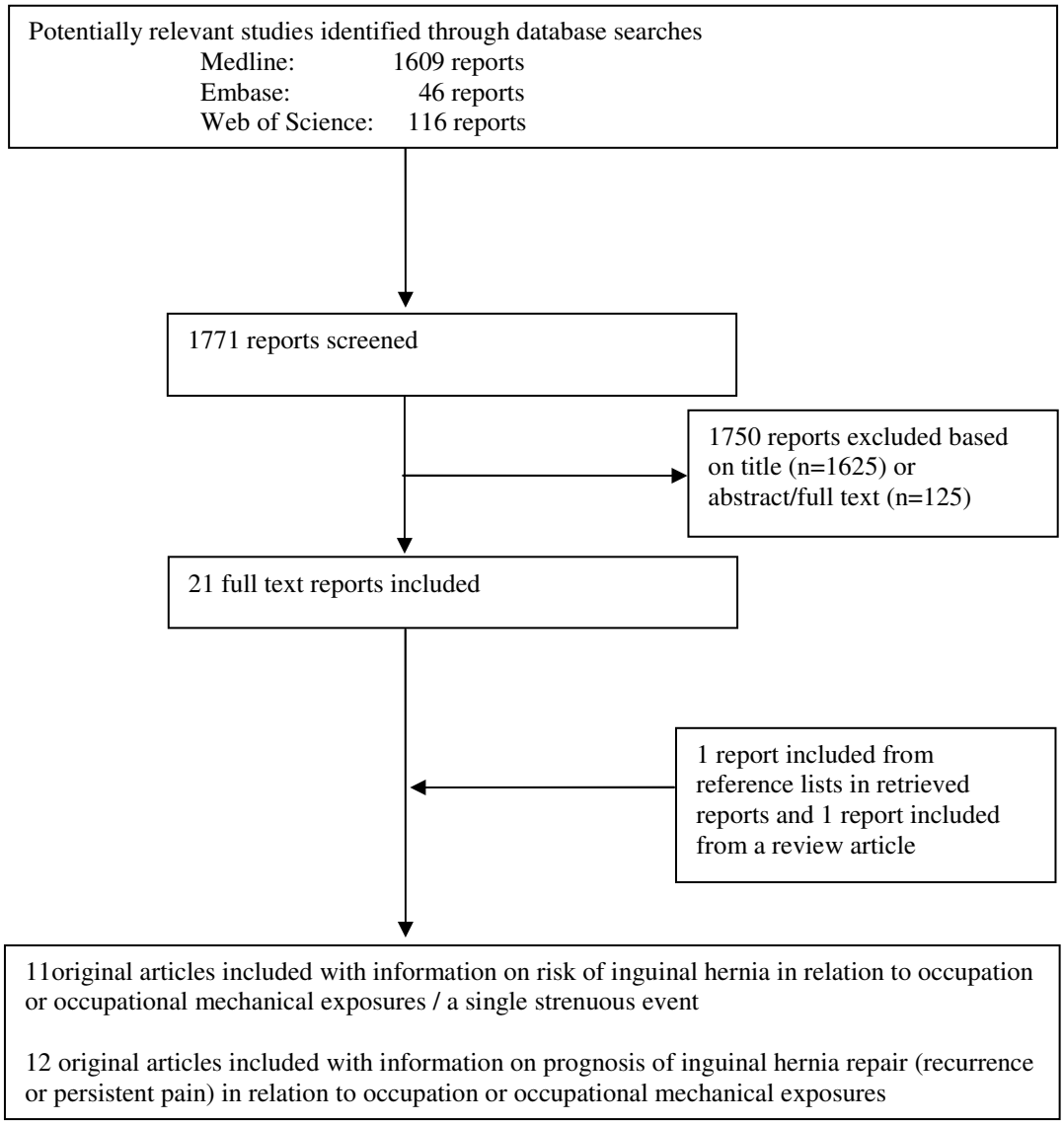
A note on terminology

In the surgical literature on inguinal hernias, the term 'primary' is used to designate a hernia that occurs for the first time or a first-time hernia repair. However, in other areas of surgical literature, the term 'primary' has other connotations: primary osteoarthritis means osteoarthritis of unknown aetiology as opposed to secondary osteoarthritis that occurs because of other disorders or trauma. We chose the term 'first-time' to designate first-time occurrences.

RESULTS

Figure 1 illustrates the literature search. The search revealed 1771 reports, of which 1625 were excluded based on title and 125 were excluded based on abstract or full text. A total of 23 original papers were included, including one (38) that was identified through the reference list in one of the other papers (39), and one (40) that was identified in a review (34). Eleven original papers on risk fell in two groups: eight that assessed the risk of inguinal hernia in relation to occupation or occupational mechanical exposures (2;3;11;12;38;39;41;42) and three that assessed the risk of inguinal hernia in relation to a single strenuous event (43-45). Of twelve original papers on postoperative prognosis, seven concerned recurrence (35;40;46-50) and six concerned persistent pain (49;51-55); one study provided results on both outcomes (49).

Figure 1. Flowchart on stages of identification, screening and selection of studies investigating risk and prognosis of inguinal hernia in relation to occupation or occupational mechanical exposures.



Risk of inguinal hernia by occupation or occupational mechanical exposures

Of the eight epidemiologic studies with information on risk of inguinal hernia in relation to occupation or occupational mechanical exposures, three were cross-sectional (3;38;39), four were case-control studies (11;12;41;42), and one was a prospective cohort study (2). Four studies included only men (3;11;38;39), two studies included around 80% men (41;42), one study included 40% men (2), and one study included only women (12). Two studies relied on self-reported outcomes (38;39), two studies were based on physician diagnoses (2;3) in part reported by the participants (2), and the four case-control studies focussed on hernia repair (11;12;41;42). Among the six studies that did not rely on self-reported outcomes, four studies focussed on inguinal hernias (2;3;11;12), and two studies included femoral hernias together with inguinal hernias (41;42). Only two studies were explicitly restricted to first-time inguinal hernias (2;11). Exposure assessment was based on self-reported work activity levels in four studies (2;3;11;12), a self-reported combined measure for work and leisure time activity levels in one study (41), job titles in two studies (38;39), and a job exposure matrix with three (3) or four (42) exposure categories in two studies. Two studies adjusted for potential confounders (2;3), but only one study presented adjusted risk estimates (2). The brief descriptions that follow are arranged first by year of publication, second alphabetically according to the first author's surname. In the same order, the eight studies are also presented in table 1.

Abramson et al (3) conducted a cross-sectional population study in Jerusalem. The study entailed clinical examination of 1883 men aged 25 years and over. The age-limit was motivated by younger age-groups being absent due to military service. Participation was 78%. Physical activity at work was assessed by a score based on the

reported performance of various activities, the reported frequency of lifting and carrying, and a three-level job exposure matrix, where the researchers classified all jobs as light (e.g. bus driver, clerk), active (e.g. postman, carpenter), or heavy (e.g. boilermaker, dock labourer) (56). In analyses adjusted for age, no significant associations were found between clinically diagnosed inguinal hernia and physical activity at work, but this statement was not substantiated by any risk estimates. *The particular strength of this study was that it was based on clinical examination of a population sample rather than relying on self-reported outcomes or being restricted to cases diagnosed at a hospital. A further strength was independent exposure assessment in addition to self-reported estimates. Unfortunately, physical activity at work was not included in multivariable models, and risk estimates were not presented.*

Flich et al (42) compared 128 cases who were surgically treated for inguinal or femoral hernia in 1986 with 174 controls that were sampled from the recruitment area of the same hospital. The method used for sampling the controls was not further described. Exclusion criteria for cases and controls differed in that controls were excluded if they had a clinical history of any kind of hernia or 'closely-related illnesses'. Participation was not described. Descriptive information was provided for medial and lateral inguinal hernias separately, but all hernia types were combined in the analyses, possibly also recurrent hernias. Exposure assessment was based on self-reported information on the job held longest combined with a job exposure matrix comprising the researchers' ratings of intensity of physical effort. Possible ratings were 1) no effort or sedentary work (e.g. night watchman, office worker), 2) light effort - standing work involving occasional lifting of not too heavy weights (e.g. waiter, shop assistant, electrician), 3) medium effort - more frequent lifting (e.g.

agricultural and construction workers, cleaners ('house maidens')), and 4) high effort - daily effort (e.g. quarry workers, manual warehouse workers). Duration of employment with these four effort intensities was also investigated. Findings suggested exposure response relations both for exposure intensity and for exposure duration, but the results were not adjusted for any confounders. *The main strength of this paper was the independent exposure assessment that minimised any risk of recall bias. However, the exposure characterization was limited, and no confounder control was made; the fact that cases and controls did not differ significantly with respect to mean age does not preclude this source of distortion of the risk estimates. Still, the risk associated with duration of exposure to physical effort was larger for years of high effort than for years of light/medium effort, and this difference may not be explained by age as a confounder.*

Mamtani & Cimino (38) compared retired sanitation workers with non-sanitation workers of whom 38.1% were retired. The study was cross-sectional and comprised men aged 25 years and over. Only around one third of the sanitation workers participated. The non-sanitation workers were addressed by a questionnaire that was sent to each sanitation worker asking him to pass it on to a brother or male first cousin. Thus, the proportion who participated among invited non-sanitation workers is unknown. The sanitation workers retired when they were quite young (7.9% were 25-44 years, 60.2% were 45-64 years), which seems to suggest that they stopped working because of ill health. The two groups of workers were compared with respect to 17 different illnesses, such as haemorrhoids, diabetes, and tuberculosis. Only one of the reported ORs was below 1 (the OR for stomach/gastric ulcer, which seems to be duplicated in the table presenting the results), and nine ORs were significantly larger

than 1. Outcome assessment was based on self-report. Among sanitation workers, the prevalence of inguinal hernia was 8.2% versus 4.7% among non-sanitation workers. It is not clear whether these percentages represented point or lifetime prevalence. No specific assessment of mechanical exposures was made, but according to occupational information on the non-sanitation workers (12.3% were employed in administration and 14.7% in service jobs), it seems likely that sanitation workers were more exposed to heavy lifting than non-sanitary workers were. On the other hand, some of the non-sanitation workers were probably also exposed to heavy lifting (11.4% were employed in craft and repair). Duration of employment was not considered. Even though potential confounding factors were not included in the analyses, the two groups seemed quite comparable. *This study had several limitations – low participation, cross-sectional design, self-reported outcome, weak exposure characterization, and multiple comparisons. Non-sanitation workers were exposed to some extent, and this may have led to lower risk estimates than if the comparison group had been "unexposed". On the other hand, only retired sanitation workers were included, whereas two thirds of the comparison group were not retired. Even if retired sanitation workers had not actually left the labour market, but just their trade, the restriction to former sanitation workers probably implied selection of unhealthy workers into this study group. The overrepresentation of a variety of illnesses among the sanitation workers agrees with the possibility of unhealthy worker selection. Low participation among sanitation workers may have further exaggerated this source of bias to the extent that symptomatic workers were more likely to participate. Thus, it seems likely that inflationary bias explained the increased risk for sanitation workers.*

Carbonell et al (41) performed a case-control study of 290 cases (79% men) who underwent inguinal or femoral hernia repair in the period 1987 to 1989, and 290 individually age and sex matched controls who were selected randomly from the population in the recruitment area of the hospital. The method used for sampling the controls was not further specified. Exclusion criteria for cases and controls differed in that controls were excluded if they had previously had surgery for any kind of hernia, not just the hernia types under study. Participation was not described. It is unclear if the study was restricted to first-time operations. Descriptive information was provided for medial and lateral inguinal hernias separately, but all hernia types were combined in the analyses. Among males, 9.6% (22/228) of the cases had a femoral hernia repair (the number of males in the case group is misprinted in table 1 of the paper). Among females, this percentage was 69% (43/62; the numbers of females with different hernia types are misprinted in table 4 of the paper). Thus, the results for females must be considered less relevant with respect to risk factors for inguinal hernias. Exposure assessment was based on an interview with subsequent calculation of an effort score (1-10) that reflected different aspects of physical activity during work and leisure time. The calculation of the score was inadequately described, e.g. cut points for dichotomization of the included variables were not stated. There also seems to be logical inconsistencies in the construction of the score: physical exertion only at work, physical exertion only during leisure time, and physical exertion both at work and during leisure time were all scored 1 for yes and 0 for no, implying that all participants would be allocated 1 score point for these three items. The score was calculated for the job held before the appearance of the hernia (it is unclear which year was chosen for the controls) and for up to three previous jobs, but the number of cases with information on more than one job was limited. The mean effort score

(presumably in the most recent job) was significantly higher among cases than among controls (5.06 versus 3.21, p<0.001, table 1 in the paper). The effort score was then divided into four groups, but only one unadjusted OR of 2.92 (95% CI 2.11-4.04, table 5 in the paper) was reported in relation to the effort needed in the previous job, so it is unclear which comparison this OR represented. The authors reported an OR for sex of 0.98 as a result (table 5 in the paper), although this simply reflected the fact that cases and controls were matched by sex, and for the effort needed for the third job, the reported OR of 3.22 was classified as insignificant (p=0.71) even though the 95% CI ranged from 1.64 to 6.31. Results were not adjusted for potential confounders, and the statistical methods disregarded the matching. *This study had many limitations. The statistical analyses were not transparent and did not inspire confidence. Different outcomes were lumped together. Occupational exposures were poorly characterized and – most importantly – the effect measures may well be overestimated due to recall bias (cases may have been more likely to overestimate their exposures than controls) and confounding.*

Liem et al (12) conducted a case-control study among women who underwent inguinal hernia repair (cases) or surgery for benign skin tumours (controls) at one of six hospitals between 1994 and 1995. The analyses included 72 cases (participation 89%) of whom 76% underwent first-time inguinal hernia repair and 24% underwent surgery for a recurrent inguinal hernia, and 125 controls (participation 71%) who were individually matched to the cases by age and time of surgery. Lateral and medial hernias were combined in the analyses. Exposure assessment was based on questionnaire data, and present and past work activity intensities were scored 1-5 and 1-4, respectively. Furthermore, cumulative measures were calculated by multiplying

activity score and duration of employment (years); this was done separately for present and past activity. Selection of variables for inclusion in the final multivariable conditional regression analysis was guided by univariable unmatched significance testing of uneven distributions between cases and controls. In this way, occupational exposure variables were excluded from the final model. *A strength of the study was the sampling frame that probably ensured that the controls were included independently of occupational exposures and that the controls would have occurred as cases, had they developed an inguinal hernia. In addition to the relatively large proportion of recurrent hernias, major limitations were the small study size, and the method used to select variables for the final model, which meant that the study may well have overlooked any associations. Based on small numbers, it was noted that climbing stairs was protective, but this may be an example of reverse causation.*

Kang et al (39) reported results from a cross-sectional study of hernias (n= 30,791, primarily inguinal or unspecified) that employers identified as work-related in a survey conducted in 1994. The study was restricted to men. No distinction was made between first-time and recurrent hernias. One-year cumulative incidences were calculated by industry and occupation categories, and relative risks were presented using the incidence for the total population of 51,246,000 male workers in private industries, mines and railways as a reference. The estimates were not adjusted for age or other factors. The highest relative risks were found in occupations with strenuous, heavy manual labour. *By its focus on inguinal hernias that were judged to be work-related, this study reflected widespread beliefs regarding risk factors for inguinal hernias (which was also remarked by the authors) as well as compensation practices rather than true risks of inguinal hernias across industries and occupation. Thus, the*

results do not represent valid estimates of the risk of inguinal hernias in relation to occupational exposures.

Lau et al (11) conducted a case-control study among men aged 18 years or more (mean age 65 years). A total of 709 cases with a first-time hospital diagnosis of inguinal hernia were compared with 709 individually age-matched controls, who were sampled from the hospital's general surgical clinic and who had not had a hernia repair previously. The proportion who participated was not stated, and it was not described why the controls were seen at the clinic. Present work activity intensities were scored 1-5 by means of a questionnaire. Between cases and controls, a difference in mean work activity score of 0.1 was observed, and this was found to be statistically significant. No ORs were presented for the work activity index, which does not seem to have been considered for multivariable analysis. *There were several limitations. The appropriateness of the control group could not be judged (e.g. varicose veins may share risk factors with inguinal hernia (3) meaning that inclusion of patients with varicose veins in the control group would lead to underestimation of effects), and in particular, there was a potential for inflation of observed associations due to recall bias and confounding. Even if correct, it must be questioned if the small difference between cases and controls with respect to the work activity score was clinically important.*

Ruhl & Everhart (2) reported results from a prospective cohort study (NHANES I) that followed a sample of the US general population who were recruited between 1971 and 1975 when they were 25-74 years old. The study comprised 13,452 persons (93% of the original cohort), who were followed for a median of 18.2 years. Outcome

assessment was based on hospital/nursing home records and interview information from the participants on hernia diagnoses made by a physician (the last-mentioned diagnoses were added because hospital/nursing home records were only available for inpatients). For men, the analyses included baseline interview data on non-recreational (presumably physical) activity, classified as inactive (11.4% of the men), moderately active (44.5% of the men), and very active (44.1% of the men). Criteria for this classification were not stated. For women, the analyses included rural versus urban residence. It is unclear why urbanicity was not included in the analyses for men, and why the activity index was not included in the analyses for women. Cox proportional hazards analyses were performed, but since age-adjusted HRs for activity level were insignificant for men, this variable was not included in the final model. Rural residency was significantly related to the outcome among women. *This study benefitted from a longitudinal design, a large sample, a high participation at follow up, physician-based diagnoses, and consideration of several potential confounders. However, 44% of the population was classified as having a very active non-recreational activity level, which suggests that the exposure contrast between categories was limited. This may have caused underestimation of any association between a high physical exposure level and the outcome. It may also be questionable if the activity level at baseline represented the activity level throughout the whole period. Potentially, rural residence is as a proxy for high physical activity, but this assumption is not convincing. Hence, for the purpose of the present review, the exposure assessment was weak and exposure misclassification could easily have biased estimates of associations towards the null.*

Table 1. Main characteristics of eight epidemiologic studies on risk of inguinal hernia by occupation or occupational mechanical exposures. The studies are ordered first by publication year and second alphabetically according to the first author's surname.

Study	Design and population	Outcome	Exposure	Measure of risk, point estimate, 95% CI or p-value	Confounders considered
Abramson et al 1978 (3); Israel	Cross-sectional population study, men only, age 25+ years, n=1883, participation 78%	Clinical examination: a) obvious hernias – groin swellings and repaired hernias, b) palpable impulse only	A score based on self-reported performance of various activities Self-reported lifting or carrying A job exposure matrix with three activity levels based on the researchers' judgement	No significant relations were found between the measures of physical activity at work and the outcomes, but results were not shown	Adjustment for age Distributions of various risk factors across effort categories were not shown Multivariable analyses did not include physical activity at work
Flich et al 1992 (42); Spain	Case-control study, both men and women, mean age 50-51 years Cases, n=128, 83.6% men, participation unspecified	No specification regarding first-time surgery and surgery for recurrence Cases were treated for inguinal or femoral hernias in	Estimates of physical effort were allocated to each participant using a job exposure matrix with four activity levels based on the researchers' judgement combined with self-reported information on job	**Effort** / **OR** / **95% CI** No/light / 1 / - Medium / 1.84 / 0.95- 3.69 High / 6.39 / 2.66-15.57 [Our calculations based on table 5 in the paper]	Unadjusted analyses Descriptive data was provided on age, sex, weight, height, smoking, and alcohol consumption among cases and controls

Study	Design and population	Outcome	Exposure	Measure of risk, point estimate, 95% CI or p-value	Confounders considered
	Controls, n=174, 86.8% men, enrolled from the recruitment area of the hospital, participation unspecified	a surgical hospital department in 1986 Hernias were distributed with 57.8% lateral 26.6% medial 7.8% pantaloon (i.e. combined medial and lateral) 7.8% femoral	held longest Years of light/medium effort Years of high effort	 0 years 1.0 1-19 years 4.0 20-39 years 7.9 40-69 years 11.4 p≤0.001 0 years 1.0 1-19 years 13.6 20-39 years 65.0 P≤0.05	Distributions of these factors across effort categories were not shown
Mamtani & Cimino 1992 (38); United States	Cross-sectional, men only, age 25+ Sanitation workers retired after 1971 and alive in 1986, n=1933, participation 35.1% Non-sanitation workers (brothers and male first	Self-reported inguinal hernia Prevalence 8.2% Prevalence 4.7%	Comparison of job titles	OR 1.79 (1.24-2.58)	Unadjusted analyses The study was restricted to men. The two groups were similar with respect to age, weight, alcohol consumption, current smoking, and probably also ethnicity and socioeconomic status

Study	Design and population	Outcome	Exposure	Measure of risk, point estimate, 95% CI or p-value	Confounders considered
	cousins of the sanitation workers), predominantly blue collar workers – 38.1% were retired, n=801, participation unknown				
Carbonell et al 1993 (41); Spain	Case-control study, both men and women, mean age 59 years (range 21-90); cases and controls were individually matched by age and sex Cases, n=290, 79% men, participation unspecified Controls, n=290, from the background population, 79%	No specification regarding first-time surgery and surgery for recurrence Cases underwent inguinal or femoral hernia repair from 1987 to 1989	Self-reported physical effort during work and leisure time (a score, 1-10, divided into four categories)	**Effort** / **OR** / **95% CI** 0-<2.5 / 1 / - 2.5-<5 / 1.2 / 0.7-2.2 5-<7.5 / 3.2 / 1.9-5.4 7.5-10 / 3.5 / 0.8-17.4 [Our calculations based on table 2 in the paper that only allowed unconditional analyses. Thus, we treated the data as if cases and controls were frequency matched]	Unadjusted analyses Descriptive data was provided on education level, income, height and weight, coffee and alcohol consumption, smoking, chronic cough, frequency of defaecation and consistency of faeces Distributions of these factors across effort categories were not shown

Study	Design and population	Outcome	Exposure	Measure of risk, point estimate, 95% CI or p-value	Confounders considered
	men, participation unspecified				
Liem et al 1997 (12); The Netherlands	Case-control study, women only, age 20-80 years, cases and controls were individually matched by age and date of surgery Cases, n=72, participation 81% Controls, n=129, who had excision of benign tumours of the skin, participation 73%, (4 controls did not match a case and were excluded)	First-time inguinal hernia repair, n=55 (76%), or surgery for recurrence, n=17 (24%), from 1994 to 1995 Hernias were distributed with 54% lateral 42% medial 4% unclassified	Self-reported present physical work activity (a score, 1-5) Self-reported work activity in the past (sedentary, score 1; standing, score 2; labour, score 3; heavy labour, score 4)	Median work activity score Present physical work Cases 2.9 Controls 2.9 p=0.6 (Mann-Whitney U-test) Past physical work Cases 1 Controls 2 p=0.9 (Mann-Whitney U-test)	Unadjusted analyses with respect to work Descriptive data were provided on age, socioeconomic status, marital status, body mass index, smoking, abdominal operations, pregnancies, constipation, obstructive pulmonary disease, obstructive urinary tract disease, trauma, family history of inguinal hernia Distributions of these factors across effort categories were not shown
Kang et al 1999 (39);	Cross-sectional, men only	Primarily inguinal or unspecified	9 industries	Several risk estimates were presented as compared to the	Unadjusted analyses

Study	Design and population	Outcome	Exposure	Measure of risk, point estimate, 95% CI or p-value	Confounders considered
United States	A nationwide study representing 51,246,000 male workers	hernias, both first-time and recurrent, n= 30,791, resulting in at least one day away from work, corresponding to an overall annual incidence rate of 6.0 per 10,000 male workers The hernias were identified in a survey in 1994, asking the employers to report work-related cases	17 broad groups of occupations 40 major occupations	overall annual incidence. The top five high-risk occupations among 40 major occupations were: Non-construction labourers RR 4.5 (95% CI 4.0-5.0) Miscellaneous machine operators RR 2.8 (95% CI 2.4-3.3) Plumbers and pipefitters RR 2.7 (95% CI 2.2-3.2) Construction labourers RR 2.3 (95% CI 1.9-2.7) Freight, stock, and material handlers RR 2.2 (95% CI 1.9-2.6)	
Lau et al 2007 (11); Hong Kong	Case-control study, men only, mean age 65 years, cases and controls were individually matched by age	First-time hospital diagnosis of inguinal hernia Among cases who had surgery	Self-reported present physical work activity (a score, 1-5)	Comparison of mean work activity scores Cases: 2.8 (SD 0.5) Controls: 2.7 (SD 0.5) p=0.03 (Student t-test)	Unadjusted analyses with respect to work Separate analyses were performed for smoking, chronic obstructive

<table>
<tr><th>Study</th><th>Design and population</th><th>Outcome</th><th>Exposure</th><th>Measure of risk, point estimate, 95% CI or p-value</th><th>Confounders considered</th></tr>
<tr><td></td><td>Cases, n=709, participation unspecified

Controls, n=709, sampled from the general surgical clinic, participation unspecified</td><td>(n=554), hernias were distributed with

62% lateral
30% medial
8% combined</td><td>Self-reported total activity index (work, sport and leisure time)</td><td>In subanalyses, the total activity index was associated with medial as well as lateral hernias</td><td>pulmonary disease, other specified diseases, a family history of hernia, chronic cough, constipation, use of laxatives</td></tr>
<tr><td>Ruhl & Everhart 2007 (2); United States</td><td>Prospective cohort study, both men (40%) and women (60%)

A national sample of the general US population established 1971-1975

5316 men and 8136 women (93% of the original cohort) were followed up with a median follow-up period of</td><td>First-time physician diagnoses of inguinal hernia recorded in connection with overnight medical facility stays (60%) or first-time physician diagnoses of inguinal hernia reported by the participants (40%)

500 cases</td><td>Self-reported non-recreational physical activity (men)

Rural versus urban residence (women)</td><td><table><tr><th>Effort</th><th>HR*</th><th>95% CI</th></tr><tr><td>Low</td><td>1</td><td>-</td></tr><tr><td>Moderate</td><td>1.3</td><td>0.92-1.9</td></tr><tr><td>High</td><td>1.3</td><td>0.90-1.8</td></tr></table>* Age-adjusted

Urban: HR 1.0
Rural: HR 1.8 (95% CI 1.3-1.6)
Adjusted for age, height, chronic cough, and umbilical hernia</td><td>Analyses were stratified by sex and adjusted for age

Smoking, alcohol consumption, body mass index, ethnicity, education, recreational physical activity, hiatal or umbilical hernias, chronic cough, chronic bronchitis/emphysema, constipation, and bowel movement frequency were considered

Factors related to</td></tr>
</table>

Study	Design and population	Outcome	Exposure	Measure of risk, point estimate, 95% CI or p-value	Confounders considered
	18.2 years	occurred among men and 120 among women			inguinal hernia in age-adjusted models were evaluated in multivariable analyses

Risk of inguinal hernia in relation to a single strenuous event

The risk of inguinal hernia in relation to a single strenuous event was addressed in three case series that included a total of 582 surgical patients (43-45). Two studies were not restricted to first-time inguinal hernia, but included recurrent hernias (43;45) and other types of hernia (43). The proportion of patients who reported a sudden onset ranged from 7% and 11% to 43%, and patients with a sudden onset tended to relate their hernia to a specific strenuous event.

Smith et al (1996; United Kingdom) (45) reported results from a series of 129 patients (95% men) who were seen at a surgical department due to first-time or recurrent inguinal hernia over a six-month period (calendar year not specified). It is unclear if the data was collected by interview or questionnaire. Participation was not stated. None of the patients were engaged in claims for industrial injury compensation, but it is unclear whether this was an exclusion criterion. A sudden onset was reported by 7% of the patients (n=9), all of whom had a first-time hernia. Eight patients thought that their hernias were related to lifting strains at home or at work, and one patient remembered a fall. The sudden onset hernias were medial in five cases, lateral in three cases and unknown in one case, but for the gradual onset group, the numbers with lateral and medial hernias were not reported. *The study reflected beliefs regarding risk factors for hernias, rather than evaluating if anything unusual actually took place shortly before the onset.*

Pathak & Poston (2006; United Kingdom) (43) reported questionnaire-based results from a series of 133 patients with 135 inguinal (85%) or other abdominal hernias (15%), of which 19% were recurrent. The patients were seen at a general surgical

hospital clinic over a six-month period in 2003. Participation was 99%, the male female ratio was not reported. A sudden onset was reported by 11% of the patients (n=14), who thought that their hernia was caused by a single strenuous or traumatic event in terms of heavy lifting at work (n=1), strenuous exercise and stretching (n=3), coughing (n=2), or an unidentified activity (n=8). No distinction was made between medial and lateral hernias. *The study reflected beliefs regarding risk factors for hernias, rather than evaluating if anything unusual took place shortly before the onset.*

Sanjay & Woodward (2007; United Kingdom) (44) reported questionnaire-based results from a series of 320 patients who underwent inguinal hernia repair between 1995 and 2004. Only first-time hernias were included. Participation was 62% (320/520), the male female ratio was not reported. A sudden onset was reported by 43% (n=137). Lateral hernias were diagnosed in 74% of the patients with a sudden onset and in 57% of patients with a gradual onset ($p<0.05$). Heavy work was reported by 31% (42/137) in the group with a sudden onset and by 9% (14/163) in the group with a gradual onset (for heavy and manual work combined, the corresponding percentages were 46% and 17%, $p<0.05$). Patients with a sudden onset thought that their hernia was caused by a single strenuous or traumatic event in terms of one of four pre-specified response options: lifting (n=93), coughing (n=20), exercise (n=14), and gardening (n=10). *The study reflected beliefs regarding risk factors for inguinal hernias, rather than relations to unusual events that took place shortly before the onset. The long recall period of up to nine years and the pre-specified response options probably increased the risk that patients rationalized after the fact. The hernia may also have been present, but unnoticed by the patient before an event that*

provoked symptoms (57). However, these sources of error could not explain the finding that lateral hernias were more likely to have a sudden onset than medial hernias were, nor the increased occurrence of a sudden onset among patients with heavy work. If corroborated, these observations might suggest an injury mechanism where increased intraabdominal pressure makes the hernia protrude preferentially through the preformed canal.

Postoperative prognosis by occupation or occupational mechanical exposures

Of the twelve studies on prognosis, one study concerned patients treated laparoscopically (40), and three studies concerned patients who were treated either laparoscopically or by open surgery (49-51) – two of these studies presented results from the same trial (50;51). The remainder of the studies concerned patients who had open surgery (as judged from publication year, if not stated explicitly). Duration of postoperative sickness absence was considered in seven studies (35;46-48;50;51;53), but was not described in relation to occupational exposures in two of the studies (50;51). In three studies, part of the patients received standardised advise on short convalescence (35;46;48). The brief descriptions that follow are arranged first according to prognostic outcome (recurrence or persistent pain), second by year of publication, and third alphabetically according to the first author's surname. The seven studies on recurrence are also presented in table 2.

Prognosis with respect to recurrence

Ross (47) conducted a four-year follow up study of hernia recurrence among 260 adult male patients who underwent surgery for first-time or recurrent inguinal hernia. As judged from the publication year (1975), the study concerned open repair.

According to self-report, a total of 22 hernias (8.5%) recurred. No statistical analyses were performed. Results were presented by means of a figure showing the distribution of patients and recurrences according to number of weeks off work and occupational exposures classified as light work (e.g. office work), medium work (e.g. shop keepers, sales representatives), or heavy work (labourers, welders, butchers). Based on our readings from the figure, the median time until return to work was 5, 6, and 8 full weeks in the three exposure categories, respectively, and 75.7% (84/111), 52.6% (50/95), and 20.4% (11/54) of the patients in the three exposure categories had returned to work after 6 full weeks. Among patients with light work who returned to work before 6 full weeks, 4.8% had a recurrence, and among patients with light work who returned to work after 6 full weeks, 3.7% (1/27) had a recurrence. Among patients with medium or heavy work who returned to work before 6 full weeks, 11.5% (7/61) had a recurrence, and among patients with medium or heavy work who returned to work after 6 full weeks, 11.4% (10/88) had a recurrence. As stated by the author, early return to work (which we have interpreted as return to work before 6 full weeks after surgery) did not seem to increase the risk of hernia recurrence, and this applied whether the patients returned to light, medium, or heavy work. However, our readings and calculations showed that medium and heavy work was associated with a risk of recurrence of 11.4% (17/149) against 4.5% (5/111) for light work, yielding a univariable risk difference of 6.9% (95% CI 0.51%-13.3%, our calculation; the calculation was based on the assumption that all patients had the same follow up time – if recurrences occurred earlier in the exposed group, this assumption would lead to a conservative estimate of the risk ratio). *The study was observational, and patients may have adjusted their convalescence so that symptoms and workload were balanced in a way that minimised the risk of recurrence. Results may not be generalizable to*

situations where all patients are expected to return to work early. Medium and heavy work was associated with an increased risk of recurrence irrespective of time off work, which suggests that prolonged convalescence did not sufficiently protect against the increased risk.

Bourke et al (46) reported results of a randomised controlled trial comparing an intervention group who were advised to return to full activity as early as possible and a control group who received usual advice on convalescence. Male patients were enrolled in the study two to three weeks after an inguinal hernia repair that was performed between 1976 and 1981. As judged from the publication year, the study concerned open repair. After one year, 491 patients (95%) were followed up. In the intervention group 3.3% (8/246) had a recurrence as compared to 4.1% (10/245) in the control group; this difference was not significant. The intervention shortened the median convalescence from 65 to 48 days in comparisons restricted to workers (n=369). In the intervention group, patients with light (no lifting), intermediate (light lifting), and heavy work (heavy lifting) returned to work after a median of 42, 50, and 51 days, respectively. Among patients with heavy work, 3.5% (3/85) had a recurrence in the intervention group versus 1.1% (1/95) in the control group, and the corresponding univariable risk difference was 2.5% (95% CI -2.0%-6.9%; our calculation). *Overall, shorter convalescence was not significantly related to an increased risk of recurrence. Due to small numbers, it was not possible evaluate if earlier return to work was associated with a higher probability of recurrence among patients with heavy work.*

Taylor & Dewar (48) conducted two randomised controlled trials from 1978 to 1980 focussing on hernia recurrence in relation to duration of sickness absence and type of work. One trial comprised 96 presumably male naval and marine officers (mean age 30 years, range 17-54 years, participation 100%) who were ordered to resume full duties either 3 weeks or 3 months after an uncomplicated open inguinal hernia repair (the study received ethical approval, but it seems that the officers were not asked for consent to participate). The other trial comprised 119 male civilians (mean age 47 years, range 18-60 years, participation 91%) with unspecified jobs who underwent the same type of surgery and who were either advised to resume work after 3 weeks or received usual advice. In both trials, the patients' type of work was classified as heavy, light, or sedentary. Among the officers, 34% had heavy work, 49% had light work, and 17% had sedentary work. Among the civilians these percentages were 28%, 25%, and 47%. Recurrence within one year did not differ, but only two recurrences were observed altogether (both occurred among naval and marine officers who returned to full duties after 3 months). *The trials were underpowered to detect differences between the intervention and control groups with respect to recurrence.*

Le et al (40) conducted a follow-up study of 196 patients (98% men, mean age at follow-up 51 years, range 20-86 years). They were clinically examined on average 34 months (range 20-42 months) after laparoscopic repair of a first-time (89%) or recurrent (10%) inguinal hernia, or a femoral hernia (1%). Surgery was performed between 1996 and 1997. At follow-up, information was collected on "sustained physical activity"; it is not clear whether this information could be retrieved from clinical files or was obtained by a retrospective interview. No distinction was made between physical activity at work or during leisure time, and the timing of the

physical activity in relation to surgery was not specified. The duration of postoperative sickness absence was not described. Among patients with sustained physical activity, 30.3% (10/33) had a recurrence, whereas among patients without such activity, the percentage was 14.7% (24/163). Thus, the univariable risk difference was 15.6% (95% CI -1.0%-32.2%; our calculation assuming that all patients had the same follow up time, see above). Among patients with a recurrent hernia, 68% (23/34) were asymptomatic; this percentage was not specified according to physical activity. Multivariable analyses were not performed. *Results suggested that sustained physical activity is a risk factor for recurrence after laparoscopic hernia repair. However, recall bias may have inflated the risk difference, and the result is difficult to interpret because of the unspecified timing and character of the physical activity.*

Bay-Nielsen et al (35) advised 1059 men who underwent elective, open repair (with mesh) of a first-time inguinal hernia to return to work and daily activities on the day after surgery (participation 98% (1059/1084)). Among the 1059 men, 646 were employed or self-employed. In a preoperative questionnaire, they classified their occupational physical activities as “sedentary work” (22%), “walking, no heavy lifting” (28%), “intermittently strenuous work” (33%), or “constantly strenuous work” (14%). For the remainder, occupational physical activities were unspecified (5%). The median time off work ranged from 4.5 days to 14 days for patients in the lowest and highest occupational exposure categories, respectively. One month after surgery, 25% of the patients with constantly strenuous work were still sick-listed as compared with 10% of the patients with sedentary or walking work with no heavy lifting. Pain and wound problems were reported as the most common reasons for delayed resumption

of work. All 1059 men who received advice on resuming work early were compared with 1306 eligible patients who had surgery in the participating departments, but were not included in the study for administrative reasons, and with 8297 comparable patients who had surgery in other departments. The two comparison groups were not characterized with respect to age, physical strain at work, or time off work after surgery. Within up to two years of follow up (median follow-up time 16-17 months), reoperation rates (as a proxy for recurrence) did not differ between the three groups of patients. Reoperation rates were calculated as Kaplan-Meier estimates and compared with the log-rank test. *The study indicated that patients with physically strenuous work had a longer period of convalescence after inguinal hernia repair than patients whose work was not strenuous, even though standardised advice on early return to work was given. While in general reassuring with respect to hernia recurrence in relation to early return to work among patients treated by an open repair technique, the most highly exposed group was small, the comparisons across groups were not stratified by exposure category, and the longer periods off work among patients with physically strenuous work may have had a protective effect. Hence, the study may have overlooked an increased reoperation rate among patients with constantly strenuous work.*

Arvidsson et al (50) reported results of a randomised trial comparing two surgical techniques (laparoscopic repair versus open repair without mesh). From 1993 to 1996, 1068 male patients aged 30 to 70 years were enrolled in the trial in connection with first-time surgery for unilateral inguinal hernia. A total of 920 (86%) patients were followed up by an independent observer after five years or had developed a recurrence during follow-up. Recurrence was defined as a bulge in the operated groin when

standing and straining or as a positive herniography. At baseline, patients were categorized as occupied in a job with light (39%), moderate (20%), or heavy physical exposures (23%), or as unoccupied (4%), retired (12%), or having an unspecified occupational status (1%). Median sick-leave was 11 and 12 days in the two surgery groups, respectively. Duration of sick-leave was not described in relation to occupational physical exposures. In a nonlinear mixed model analysis, occupational exposure status was not a prognostic variable for recurrence after either type of surgery (it is unclear if the analysis was uni- or multivariable). *The result was reassuring, but exposure assessment was crude, which may have masked negative effects of specific exposures. To the extent that patients with heavy exposures had longer sick-leave, a protective effect of sick-leave would also tend to obscure any negative impact of occupational exposures on prognosis.*

Prognosis with respect to recurrence and persistent pain

Matthews et al (49) followed 1696 men (participation 86% (1696/1983)) for a minimum of two years after open (n=834) or laparoscopic (n=862) repair of a first-time or recurrent inguinal hernia. Information on physical activity level was collected by a preoperative questionnaire. Recurrences were identified by clinical examination or ultrasonography performed by an independent observer at follow-up appointments two weeks, three months, one year, and two years after surgery, or at the time of a reoperation. A higher preoperative activity level ('active' versus 'sedentary') during work or leisure-time predicted a higher risk of reoperation after a laparoscopic repair (adjusted OR 1.89, 95% CI 1.41-2.51; we calculated this result taking exp(x) of the values for beta and confidence limits reported in table 6 of the paper). Physical activity level did not predict reoperation after open repair. Patients who reported that

their highest physical activity level during work or leisure-time was moderate, heavy or very heavy had a lower risk of pain exceeding three months after a laparoscopic repair than patients who reported their activity level to be light (adjusted OR 0.52; 95% CI 0.30-0.89). Physical activity level did not predict long-term pain after open repair. Duration of postoperative sickness absence was not taken into account. *This study benefitted from prospective data collection and from separation of the two surgical procedures and the two postoperative outcomes. Results suggested that a higher than light activity level could be associated with a higher risk of reoperation, but a lower risk of persistent pain after a laparoscopic repair. Physical activity level did not predict reoperation or long-term pain after open repair. However, the crude assessment of physical activity levels was a weak point.*

Table 2. Main characteristics of six epidemiologic studies on prognosis with respect to recurrence after inguinal hernia repair by occupation or occupational mechanical exposures. The studies are ordered first by publication year and second alphabetically according to the first author's surname.

Study	Design and population	Type of hernia, surgical technique, and definition of recurrence	Exposure and – if applicable - intervention to shorten convalescence	Measure of risk, point estimate, 95% CI	Other predictors considered
Ross 1975 (47); United Kingdom	A four-year follow-up study of 260 adult men, participation not stated	First-time or recurrent inguinal hernia, open repair, calendar year(s) of surgery not stated Recurrence according to self-report	Light work Medium work Heavy work Exposure assessment according to researcher's judgement	Risk of recurrence: Light work 4.5% Medium/heavy work 11.4% Risk difference: 6.9% (0.51%-13.3%) Risk of recurrence according to exposure and duration of convalescence: Light work < 6 full weeks 4.8% ≥ 6 full weeks 3.7% Medium/heavy work < 6 full weeks 11.5% ≥ 6 full weeks 11.4% [Our calculations based on readings from the figure in the paper]	Duration of convalescence

Study	Design and population	Type of hernia, surgical technique, and definition of recurrence	Exposure and – if applicable - intervention to shorten convalescence	Measure of risk, point estimate, 95% CI	Other predictors considered
Bourke et al 1981 (46); United Kingdom	A randomised controlled study comprising 491 men, of whom 369 were workers, age not specified, participation 95% Follow up after one year	Unilateral inguinal hernias, no specification regarding first-time surgery and surgery for recurrence, open repair, 1976-1981 Recurrences were identified by clinical examination and defined in terms of need for reoperation or a truss	Light work Intermediate work Heavy work Exposure assessment according to researchers' judgement Advice on early return to full activity versus usual advice	Risk of recurrence: All types of work Intervention group 3.3% Control group 4.1% Heavy work Intervention group 3.5% Control group 1.1% Risk difference in the group with heavy work: 2.5% (-2.0%-6.9%) [Our calculation]	Duration of convalescence
Taylor & Dewar 1983 (48); United Kingdom	Two randomised controlled studies 1) Naval marine officers, n=96, mean age 30 years, participation 100%	Unilateral inguinal hernias, no specification regarding first-time surgery and surgery for recurrence of inguinal hernia, open repair (without mesh), 1978-1980	Naval and marine officers: 34% had heavy work, 49% light work, and 17% sedentary work Ordered to resume full activities after 3 weeks versus after 3 months	Only two recurrences occurred, both among naval/marine officers with long convalescence	Duration of convalescence

Study	Design and population	Type of hernia, surgical technique, and definition of recurrence	Exposure and – if applicable - intervention to shorten convalescence	Measure of risk, point estimate, 95% CI	Other predictors considered
	2) Male civilians, who had a job, n=119, mean age 47 years, participation 91%	Recurrences were identified by clinical examination and defined in terms of need for reoperation or a truss	Civilians: 28% had heavy work, 25% light work, and 47% sedentary work Advice to resume full activities after three weeks versus usual advice Both officers and civilians: Exposure assessment according to researchers' judgement		
Le et al 2001 (40); France	A follow-up study of 196 patients (98% men), mean follow-up time 34 months, mean age at follow up 51 years, participation not stated	First-time (89%) or recurrent (10%) inguinal hernia or femoral hernia (1%), laparoscopic repair, 1996-1997	Sustained physical activity at work or during leisure time according to interview or maybe clinical files	Risk of recurrence: Exposed 30.3% Non-exposed 14.7%	None

Study	Design and population	Type of hernia, surgical technique, and definition of recurrence	Exposure and – if applicable - intervention to shorten convalescence	Measure of risk, point estimate, 95% CI	Other predictors considered
		Recurrences were identified by clinical examination		Risk difference: 15.6% (-1.0%-32.2%) [Our calculation assuming that all patients had the same follow up time]	
Bay-Nielsen et al 2004 (35); Denmark	A prospective follow-up study of an intervention group that comprised 1059 adult men (participation 97.7%). They were followed for up to 24 months after surgery (median 16 months) Two comparison groups a) 1306 men from the same hospital department (median follow-up time 17 months), b) 8297 men from different hospital departments (median follow-up time 16 months)	First-time inguinal hernia, open repair (with mesh) Reoperation was used as a proxy for recurrence	Constantly strenuous work Intermittently strenuous work Walking, no heavy lifting Sedentary work Exposures were assessed by self-report Advice to return to work and daily activities on the day after surgery (intervention group) versus usual advice (the two comparison groups)	Risk of recurrence was not stated according to exposure or duration of convalescence (only duration of convalescence was stated according to exposure) At the median follow up time, the reoperation rates in the intervention group and in the two comparison groups were 0.7, 1.6, and 1.4, respectively. Employment status was not considered	Return to most strenuous leisure activity (separate analyses)

Study	Design and population	Type of hernia, surgical technique, and definition of recurrence	Exposure and – if applicable - intervention to shorten convalescence	Measure of risk, point estimate, 95% CI	Other predictors considered
Arvidsson et al 2005 (50); Sweden	A randomised controlled study comparing two surgical techniques 920 men with five years of follow-up or development of a recurrence during the study period	First-time inguinal hernia treated by laparoscopic (n= 454) or open (without mesh) repair (n=466) Recurrence was defined as a bulge in the operated groin when standing and straining or a positive herniography	Light physical work Moderate physical work Heavy physical work Unoccupied Retired (It is unclear if the exposures were classified by the patients or by the researchers)	Occupational physical exposures were not associated with recurrence after laparoscopic or open (without mesh) repair (It is unclear if this was based on uni- or multivariable analysis)	American Association of Anaesthesiology grade, age, smoking, hernia size, operating time, com-plications, sick leave, and complaints at three months
Matthews et al 2007 (49); United States	A randomised controlled study comparing two surgical techniques 1696 men with at least two years of follow-up (participation 86%)	First-time or recurrent inguinal hernia treated by laparoscopic (n=862) or open (with mesh) repair (n=834) Recurrence identified by clinical examination, ultrasonography, or reoperation	Activity level during work or leisure time Active versus sedentary (It is unclear if the exposures were classified by the patients or by the researchers)	Laparoscopic repair: OR 1.89 (1.41-2.51) Open repair: Activity level not included in final model	The model included BMI, surgeon experience, and American Association of Anaesthesiology grade Several other demographic, comorbid, hernia

Study	Design and population	Type of hernia, surgical technique, and definition of recurrence	Exposure and – if applicable - intervention to shorten convalescence	Measure of risk, point estimate, 95% CI	Other predictors considered
					and surgical factors were considered

Prognosis with respect to persistent pain

Salcedo-Wasicek & Thirlby (1995; United States) (53) conducted a follow up study of 44 male patients with a mean age of 46 years who underwent first-time inguinal hernia repair in 1992, using an open technique (the study is not a matched case-control study, although the authors stated so; all participants underwent inguinal hernia surgery). The outcomes were number of days to pain-free status and number of days until return to work according to a telephone interview. The number of days off work was higher among patients with workers' compensation than among patients with a commercial insurance. Standardised advice on early return to work was not given. Both type of insurance coverage (workers' compensation versus a commercial insurance) and self-reported work level (sedentary, moderate, or heavy lifting) were among the variables that were included in a multivariable Cox proportional hazards regression analysis. Type of insurance coverage was reported as the only significant prognostic factor with respect to duration of pain. However, type of insurance coverage and work level correlated. Among patients with a workers' compensation, 4% had sedentary work, 32% had a moderate work level, and 64% performed heavy lifting. Among patients with a commercial insurance the corresponding percentages were 64%, 18% and 18%. Unadjusted, partly adjusted, and fully adjusted HRs were not reported. Incidentally, the percentage with lateral hernias was 73% among patients with a workers' compensation against 55% among patients with a commercial insurance. *It is a challenge to interpret results of multivariable analyses that include highly correlated variables, and the study could not disentangle effects of workers' compensation and heavy work. The results may suggest that preoperative heavy work was associated with postoperative pain. Alternatively, the results may suggest that attempts to return to heavy work aggravated or perpetuated postoperative pain, or*

that the patients omitted early return to work because they expected aggravated symptoms or hernia recurrence. Therefore, the study is hardly informative for the purpose of the present review.

Poobalan et al (2001; United Kingdom) (55) conducted a follow-up study among 226 patients (participation 64%, mean age 61 years, unspecified gender distribution) who had undergone open surgery (with or without mesh) for first-time or recurrent inguinal hernias between 1995 and 1997, i.e. 21 to 57 months previously. They were asked to recall pain lasting more than three months after the operation, and to state their employment status; it is not clear whether this meant their present employment status or their employment status at the time of surgery. Type of work was not specified. Patients who were working (full or part time) had a 35% (35/101) risk of pain against a risk of 14% (14/97) for those who had retired. Thus, the univariable risk difference was 20% (98% CI 8.6%-31.8%; our calculation based on table 1, assuming that all patients had the same follow up time, see above). The comparison was not adjusted for any potential confounders, and duration of postoperative sickness absence was not taken into account. Increasing age was associated with less chronic pain. *Risk associated with employment status without any indication of occupational exposures is difficult to interpret, and age probably confounded the comparison. Therefore, the study is hardly informative for the purpose of the present review.*

Nienhuijs et al (2005; the Netherlands) (52) conducted a prognostic study based on a randomised trial that compared three types of open hernia repair (with mesh). From 2001 to 2003, 334 patients (97% men (58)) were enrolled in the trial and 96% were followed up after a median of 15.4 months. For patients who were employed versus

patients who were not employed, the univariable risk difference for persistent pain at follow up was 12.3% (95% CI 1.4%-23.2%; our calculation based on data in table 2 of the paper, assuming that all patients had the same follow up time, see above): 48% (90/186) of the employed and 36% (48/133) of the unemployed patients had persistent pain. Duration of postoperative sickness absence was not taken into account. Age was the only predictor that remained significant in a multivariable analysis that also included body mass index, hernia characteristics, surgeon experience, operating time, and type of anaesthesia. With increasing age, less chronic pain was reported, and the majority of the elderly were unemployed. *The study did not consider type of employment, and the multivariable analysis suggested that age explained the association between employment and persistent pain.*

Berndsen et al (2007; Sweden) (51) reported results of a randomised trial comparing two surgical techniques (laparoscopic repair versus open repair without mesh); Arvidsson et al (2005) (50) reported results of the same trial with respect to recurrence, see above. From 1993 to 1996, 1068 male patients aged 30 to 70 years were enrolled in the trial when they had first-time surgery for unilateral inguinal hernia. After five years, 867 (81%) were followed up by an independent observer with respect to "discomfort"; patients were excluded in case of hernia recurrence. At baseline, patients were categorized as occupied in a job with slight (39%), moderate (21%), or heavy exposures (23%), or as unoccupied (4%), retired (12%), or having an unspecified occupational status (1%). Median sick-leave was 10 and 14 days in the two surgery groups, respectively. Duration of sick-leave was not described in relation to occupational exposure status. In univariable logistic regression analysis, occupational exposure status was not a prognostic variable for long-term discomfort

for either type of surgery; multivariable analyses were not conducted. *The result was reassuring, but exposure assessment was crude, which may have masked negative effects of specific exposures. To the extent that patients with heavy exposures had longer sick-leave, a protective effect of sick-leave would also tend to obscure any negative impact of occupational exposures on prognosis.*

Staal et al (2008; the Netherlands) (54) conducted a prognostic study based on a randomised trial that compared two types of open hernia repair (both with mesh) among patients with a first-time inguinal hernia. From 2004 to 2005, 172 patients were enrolled in the trial, and 88% (of whom 99% men) were followed for three months with respect to pain-related disability as measured by the Pain Disability Index (PDI). The PDI contains seven subscales of activities of daily living and the index ranges from 0 (best) to 70 (worst). Preoperatively, 41.8% of the patients assessed their employment as light, 29.5% assessed their employment as heavy, and the remaining 28.8% were unemployed or retired. Results showed that light work tended to be associated with a lower PDI preoperatively than heavy work was (12.07 versus 16.65, p= 0.06). The difference was statistically significant when assessed two weeks after surgery (14.23 versus 20.14, p=0.04). Three months after surgery, the difference had disappeared (p=0.57). It was not stated, which proportions who had resumed work at these points in time. *Results suggested that pain-related disability assessed preoperatively and 14 days postoperatively was more pronounced for patients who rated their work as heavy than for patients who rated their work as light, but the clinical importance of the difference may be limited; this was not discussed. Pain lasting for only 14 days may not qualify as persistent pain. The prospective design was a strength. However, preoperative pain is in general considered a*

predictor of postoperative pain (30). To the extent that patients with pain overestimated their exposures at the preoperative assessment, information bias may be an explanation of the observed differences.

Gender differences

Men have a constitutional predisposition for both medial and lateral inguinal hernia, cf. the introduction. Only two risk studies provided results specifically for women (2;12). Self-reported physical work activity was not related to inguinal hernia repair in one of these studies (12). In the other, rural residency was a risk factor first-time inguinal hernias among women, but the assumption that rural residence is as a proxy for high physical activity is weak (2). Results with respect to rural residency were not reported for men (2). Women are more likely to report prolonged postoperative pain than men are (22;30). The potential influence of work on postoperative prognosis has hardly been explored among women.

DISCUSSION

We aimed to make a comprehensive literature search, but we may have missed publications, e.g. in languages other than English. We did not include abstracts and unpublished results, and we did not contact authors for original data. However, we feel confident that important high-quality studies were not overlooked by our search strategy. In order to be able to retrieve the study (40) that was only identified through a review paper, we revised our search string and succeeded in retrieving the study by adding the search term "physical activity". Using the revised search string, we identified 80 new references, but except for the study that we specifically looked for, none of them fulfilled our criteria for inclusion in the present review. Publication bias was hardly a major problem considering the diverse results. The most important limitation of this review was the poor quality of the reports that we identified regarding risk and prognosis of inguinal hernia in relation to occupational exposures. In particular, the estimated physical efforts or physical (work) activities were indicators of energy expenditure that at the most only indirectly reflected specific occupational risk factors for inguinal hernia or prognostic factors for inguinal hernia repair. Please note that the quality assessment is relative to the focus of the review - some of the reports contained important information with respect to other research questions.

Risk of inguinal hernia by occupation or occupational mechanical exposures

Indications of an increasing risk with increasing physical effort at work were found in one small study that was based on independent exposure assessment, but neglected adjustment for confounders including age (42). Positive associations in three other studies might well be explained by inflationary bias (38;39;41), and the negative

findings for men in the only prospective study might well be explained by exposure misclassification (2). Two studies reported simple comparisons of cases and controls with respect to average physical work activity, and the average hardly differed between groups (11;12).

The only prospective study used self-reported crude estimates of physical activity during work (2). The remainder of the studies were based on cross-sectional or retrospective data. The scores used for exposure assessment tended to obscure the nature of the studied exposures even more than would have been the case if job titles had been used per se. None of the studies on occupations or occupational exposures investigated effects of generic occupational exposures such as total daily load lifted, frequency of lifting loads weighing more than a specified number of kilograms, time per day spent standing/walking etc.

In general, outcome assessment was unspecific. First-time and recurrent hernias were often combined so that risk factors and prognostic factors were mixed up. Except for subanalyses in one study (11), none of the studies analysed lateral and medial hernias separately, and sometimes femoral hernias and even other abdominal hernias were included. The lumping together of different hernia types may have masked relations between exposures and specific outcomes. Among the studies that did not rely on self-reported outcomes, the majority considered hernia repair. Hernia repair may be regarded as a proxy for hernia formation, but since asymptomatic hernias may remain unnoticed, and since asymptomatic and minimally symptomatic hernias may not require surgery, it is impossible to distinguish between risk factors for hernia formation and factors that provoke or aggravate symptoms from a pre-existing hernia

in studies focussing on hernia repair. Studies that entail clinical examination (cf. (3)) and maybe ultrasonography of men representing contrasting occupational mechanical exposures could help disentangle these possibilities. However, it may be argued that the distinction is somewhat academic because the heart of the problem is risk factors for symptoms and for becoming a patient. When compared to the deficiencies in exposure and outcome assessment, potential lack of blinding of examiners to exposure status seemed a minor problem.

In the four included case-control studies (11;12;41;42), cases and controls were compared with respect to potential confounders, and non-significant differences were implicitly taken as reassurance that results would not be confounded. This is a fallacy, however, because a potential confounding factor may still be associated with the exposure under study in the population that gave rise to the cases. Only two studies controlled for important potential confounders such as age (2;3).

Risk of inguinal hernia in relation to a single strenuous event

Effects of single strenuous events were merely studied in case series (43-45). The proportion of hernias that was reported to have a sudden onset varied considerably from study to study, which maybe reflected the way questions on onset were asked. Case-crossover designs were not employed although these designs have been developed to evaluate if anything unusual took place shortly before the sudden onset of an event/health outcome (59). Admittedly, a case-crossover study of patients with sudden onset hernias would be an immense challenge, just considering the efforts needed to identify new cases and contact patients shortly after the onset; hernias may

even have been present, but unnoticed by the patient before an event that provoked symptoms.

Contributory evidence with respect to risk of hernia formation

Injury mechanisms may involve increased intra-abdominal pressure leading to herniation of the tissues through the inguinal canal or a through a weak point in the abdominal muscles/aponeuroses (http://www.mayoclinic.com/health/inguinal-hernia/DS00364/DSECTION=causes) or the transversalis fascia. Increased intra-abdominal pressure has been hypothesised to be an important stimulus for hernia formation (60). Significant increases in intra-abdominal pressure have been observed during a variety of occupational activities. In 20 healthy young people, 10 men and 10 women, measured mean pressures while sitting, standing, and walking up a flight of stairs were 17 mmHg, 20 mmHg, and 69 mmHg, respectively, while jumping in place generated the highest pressure of 171 mmHg (61). Intra-abdominal pressure increased with the speed of walking/running up to a mean of 38 mmHg, and intra-abdominal pressures above 100 mmHg were often measured in relation to a jump down from a height of 0.4 m (62). A gradual increase in intra-abdominal pressure has been found during sustained lifting, reaching levels around 20 mmHg when the subjects were exhausted after around eight minutes (63). Intra-abdominal pressures above 100 mmHg have been measured during heavy lifting in a stooping position, especially during rapid lifts (64), and intra-abdominal pressures around 120 mmHg have been measured during lifting for a few seconds using maximal force (65). Sudden trunk loading during simulated patient handling situations where the patient fell resulted in peak intra-abdominal pressures of 153 mmHg among well-trained men and 120 mmHg among well-trained women (66). These findings suggest that specific

occupational mechanical exposures may be associated with increased intraabdominal pressures and that detailed exposure assessment may be needed in future studies of risk of inguinal hernia in order to reflect this potential injury mechanism.

In childhood, lateral inguinal hernias arise from incomplete obliteration of the processus vaginalis. In a study based on laparoscopy, a patent processus vaginalis was found in 30.9% (29/94) of men and in 9.5% (23 /242) of women who were on average 50 years old and had not previously undergone inguinal hernia repair (67). During a mean follow-up period of 5.5 years, an inguinal hernia was diagnosed in 11.5% of the patients who had a patent processus vaginalis (at least four of these six hernias were lateral) and in 3% of the others. The authors concluded that a patent processus vaginalis was a risk factor for lateral inguinal hernias in adults. Although gender stratified analyses would be necessary to reach this conclusion because men have an increased risk of both inguinal hernia and patent processus vaginalis, the study did illustrate that part of the working age male population may be particularly vulnerable to exposures that increase intraabdominal pressures or otherwise widen the pre-existing opening. The observations by Sanjay & Woodward (44) seem to be consistent with this potential mechanism in that lateral hernias were more likely to have a sudden onset than medial hernias were and that a sudden onset was more likely among patients with heavy work. Also in the study by Salcedo-Wasicek & Thirlby (53) lateral hernias were associated with heavy lifting. Individual vulnerability does not preclude the work-relatedness of disorders that have a multifactorial aetiology, as long as occupational exposures contribute to an increased risk.

Among 53 male athletes (mainly soccer players, mean age 26) with unclear groin pain and no palpable hernia, 4 lateral and 8 medial hernias were diagnosed by means of herniography, i.e. X-ray examination after injection of a contrast medium into the peritoneal cavity (68). It was noted that the prevalence of medial hernias was remarkably high, considering the young age of the athletes (68). If corroborated, this observation could generate the hypothesis that peak forces during sports and work may traumatise the transversalis fascia and increase the risk of especially medial herniation. Maybe mechanical exposures can also act through a mechanism involving gradual degradation and weakening of the transversalis fascia (60;68-70) leading to accelerated age-induced degeneration, cf. the increasing ratio of medial to lateral hernias with age (7). In accordance with this, connective tissue alterations have been reported to be more pronounced in patients with a medial inguinal hernia than in patients with a lateral inguinal hernia (71). Hernia formation has been related to increased elasticity of the transversalis fascia (72) and to weak collagen structure and/or defects in collagen (73-75) and elastic fibre (76) metabolism. However, we are not aware of any studies that have related mechanical exposures to pathologic connective tissue alterations in the inguinal region.

Postoperative prognosis by occupation or occupational mechanical exposures

After open repair, one study of older date suggested that medium and heavy work was associated with an increased risk of recurrence (our calculations) (47), one study, which was underpowered, also suggested an increased risk of recurrence in relation to occupational exposures (46), one clearly underpowered study was uninformative (48), two studies suggested no increase in risk in relation to occupational exposures (49;50), and one study suggested that early return to work did not increase the risk of

recurrence (35). We identified three studies on risk of recurrence after laparoscopic repair; two of these studies indicated an increased risk of recurrence among patients in the exposed groups (40;49), whilst the third study did not (50). Across the included studies on recurrence, convalescence tended to increase with occupational exposure intensities, which may have had a protective effect. Convalescence has been shortened considerably since the 1970ies without an increasing trend in risk of recurrence. This may in part be explained by increasing use of mesh-based instead of conventional open techniques (77) and in part be related to the fact that the most heavily exposed patients have not shortened their convalescence to the same degree as less exposed patients - they still tend to be on sick-leave for 14 days after surgery even when advised to return to work early (35). Taken together, the studies on postoperative pain in relation to occupational mechanical exposures did not suggest substantial associations, but crude exposure assessment may have masked negative effects of specific exposures, and a protective effect of sick-leave may also have obscured any negative impact of occupational exposures on prognosis with respect to persistence of postoperative pain.

Gender differences

Inguinal hernia is primarily a disorder that affects men. The potential influence of occupational mechanical exposures on risk and prognosis among women has hardly been studied.

Comparison with other reviews of the literature and clinical guidelines

One review found that the literature did not give a clear answer to the question if physical stresses or events are causally associated with hernias, and did not find any study focussing on the association between early return to work and risk of hernia relapse (34). Another review stated that activity level seemed to be both protective and detrimental depending on the study in focus, but did not provide references to substantiate the statement (15). A third review concluded that the sparse literature did not support a relation between herniation and single or recurrent strenuous events and did not support a relation between early return to work and reoperation (78). The European Hernia Society has graded the evidence of long-term heavy work as a risk factor for inguinal hernias to level 3, i.e. based on studies of low quality. Thus, our conclusions agree quite well with those of the wider literature. According to the European Hernia Society's guidelines, heavy weight lifting (probably referring to a sports activity) should be banned for 2-3 weeks following surgery, whereas other limitations are not warranted (1). Danish clinical guidelines state that patients can be active immediately after surgery when this is not hindered by pain (4). However, prolonged reaction time due to pain has been reported with respect to driving, and this may be the case for operating other machines as well (79).

Evidence synthesis

On the basis of this review, we find that there is insufficient epidemiologic evidence (grade 0) to draw meaningful conclusions about the existence of a causal association between specific occupational mechanical exposures and the development of medial and lateral inguinal hernia. The limited epidemiologic literature, on the other hand, does not rule out important associations, and the contributory evidence with respect to

intraabdominal pressures, a patent processus vaginalis, and – to a lesser extent - connective tissue alterations, points to mechanisms that may link mechanical exposures to inguinal hernia formation.

We also find that there is insufficient epidemiologic evidence (grade 0) to draw meaningful conclusions about the existence of a prognostic association between specific occupational mechanical exposures and negative postoperative outcomes in terms of hernia recurrence and persistent pain. There is no evidence supporting prolonged convalescence in order to avoid recurrence and persistent postoperative pain, but on the other hand, it remains to be shown that patients with high occupational mechanical exposures can safely return to work immediately after surgery.

Research needs

There is a need for high-quality studies of occupational risk factors for lateral and medial inguinal hernia formation in order to corroborate or exclude causal relations. The Danish Hernia Database distinguishes between medial and lateral hernias, which the Danish National Patient Register does not. In collaboration with a researcher from the Danish Hernia Database, three of the authors of this reference document are currently conducting a nationwide male cohort study focussing on quantitative exposure-response relations. Exposure assessment is based on individual job histories according to the Employment Classification Module in Statistics Denmark (80) combined with a Job exposure matrix based on occupational physicians' quantitative assessments of generic mechanical exposures (81). The plan is to continue this line of research using data from the Musculoskeletal Research Database at the Danish

Ramazzini Centre, which will allow us to take important potential confounders into account. Maybe inguinal hernias occur at a younger age in highly exposed jobs, and it would be interesting to explore this hypothesis of risk acceleration (82;83). The influence of occupational exposures on reoperation rates and prolonged postoperative pain warrants further study.

CONCLUDING REMARKS

Inguinal hernia is a common disorder, especially among men, and inguinal hernia repair is one of the most common operations in general surgery. Based on this review, we find that there is insufficient epidemiologic evidence (grade 0) to draw meaningful conclusions about the existence of a causal association between specific occupational mechanical exposures and the development of medial and lateral inguinal hernia. However, contributory evidence points to mechanisms that may link mechanical exposures to inguinal hernia formation. We also find that there is insufficient epidemiologic evidence (grade 0) to draw meaningful conclusions about the existence of a prognostic association between specific occupational mechanical exposures and outcomes after inguinal hernia repair. The limited epidemiologic literature does not rule out important associations. This review revealed several research needs in order to determine if the disorder can be prevented and if the postoperative prognosis can be improved by reducing occupational mechanical exposures.

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APPENDIX 1 Grading of evidence

Framework for assessing the evidence of a *causal* association between an exposure to a specific risk factor and a specific outcome according to the Scientific Committee of the Danish Society of Occupational and Environmental Medicine.

For assessing the evidence of a *prognostic* association, we used an adjusted version of this framework, where we replaced the word "causal" with the word "prognostic". With a view to potential prevention, we were interested in causal associations between risk factors and negative prognostic outcomes, rather than prediction per se (36;37).

Strong evidence of a causal association (+++): A causal relationship is very likely. A positive relationship between exposure to the risk factor and the outcome has been observed in several epidemiological studies. It can be ruled out with reasonable confidence that this relationship is explained by chance, bias, or confounding.

Moderate evidence of a causal association (++): A causal relationship is likely. A positive relationship between exposure to the risk factor and the outcome has been observed in several epidemiological studies. It cannot be ruled out with reasonable confidence that this relationship can be explained by chance, bias, or confounding, although this is not a very likely explanation.

Limited evidence of a causal association(+): A causal relationship is possible. A positive relationship between exposure to the risk factor and the outcome has been observed in several epidemiological studies. It is not unlikely that this relationship can be explained by chance, bias, or confounding.

Insufficient evidence of a causal association (0): The available studies are of insufficient quality, consistency, or statistical power to permit a conclusion regarding the presence or absence of a causal association.

Evidence suggesting lack of a causal association (-): Several studies of sufficient quality, consistency and statistical power indicate that the specific risk factor is not causally related to the specific outcome.

Comments

The classification does not include a category for which a causal relation is considered as established beyond any doubt. The key criterion is the epidemiological evidence.

The likelihood that chance, bias, and confounding may explain observed associations is a criterion that encompasses criteria such as consistency and number of “high quality” studies.

Biological plausibility and contributory information may add to the evidence of a causal association.

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