Relationship between leisure time physical activity, weight, and the onset and persistence of non-specific neck pain: A systematic review

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Data sharing

All data relevant to the study are included in the article or are available as supplementary files.

Contributors

AL, FA, CD, LP designed the review. AL and FA developed and completed the search, determined eligible papers for inclusion, completed the quality appraisal of included papers and completed the data extraction. AL, FA, and GB completed the data analysis and synthesis. All authors contributed to the interpretation and discussion of the results, and to the writing of the final manuscript. All authors approved the final version of the manuscript.

Patient and Public Involvement

There was no patient or public involvement in the completion of this study.

Relationship between leisure time physical activity, weight, and the onset and persistence of non-specific neck pain: A systematic review

Objective: To study the relationships between weight, leisure time physical activity (PA), and the onset and persistence of neck pain in adults with non-specific neck pain (NSNP).

Design: Etiology and prognosis systematic review.

Literature search: Five databases (PubMed, Scopus, Embase, Cochrane Library, PsycINFO) were searched from January 2010 to November 2021.

Study selection criteria: Case-control or cohort studies assessing the relationship between the onset and the persistence of NSNP, weight, and leisure time PA in healthy adults or adults with NSNP at baseline.

Data synthesis: Use of the "vote counting based on direction of effects" and qualitative synthesis.

Results: Nine articles were included (20,350 participants, range 86-11,391), four on the onset and five on the persistence of NSNP. Methodological quality varied from poor to good according to the Newcastle-Ottawa Scale. For the onset and the persistence of NSNP, there was very low certainty evidence for modest associations suggesting a decreased risk with higher levels of leisure time PA and an increased risk in people with overweight and obesity.

Conclusion: The risk for onset and persistence of NSNP may be lower in more active people and higher in people with overweight and obesity. Results should be interpreted cautiously and should not be generalized to populations other than workers.

Key Words: Neck pain; Lifestyle; Physical activity; Weight

INTRODUCTION

Neck pain is one of the leading causes of global disability, and leads to direct and indirect societal and economic costs[20,31,37]. "Non-specific" neck pain (NSNP) is "neck pain occurring in the absence of trauma, signs or symptoms of major structural pathology, neurological signs or specific pathology"[7], without an identifiable source of pain[29]. Pain onset is associated with different biopsychosocial risk factors[6,7,28,45,47,60]. NSNP is also characterized by a poor prognosis[38] and frequent recurrence, both in the general population[15] and in the working population[16]. Almost half of patients with NSNP may develop persistent pain (> 3 months)[83]. Risk factors for persistent NSNP include a history of other musculoskeletal disorders, age, and psychosocial factors[6,21,66,82]. Some behavioral factors (e.g., physical activity [PA], weight, stress, sleep, and diet) that increase the risk of the onset or the persistence of NSNP are potentially modifiable and could be targeted by health care professionals[48].

PA can reduce morbidity and mortality in many chronic conditions[8,11,61], and can have an effect on pain in chronic pain populations[5,27] through different, although poorly-understood mechanisms[63,75]. PA is categorized as occupational (performed while one is working), transportation (to get from one place to another), household (done in or around one's home) and leisure time (not related to the other three; e.g., going for a walk and sports participation) activities[61]. Regular PA is consistently recommended for managing neck pain[21,46,50,60]. However, the association between PA and the onset or the persistence of NSNP is unclear. Several systematic reviews have analyzed the association between physical (in)activity and neck or neck/shoulder pain in the adult general and working populations[39,41,44,45,55,58,73], with inconsistent findings. Only two of them[55,73] specifically assessed the association with PA, but none exclusively focused on leisure time PA and on NSNP without any other associated painful areas (e.g., shoulder).

Weight is usually classified based on body mass index (BMI): underweight (BMI < 18.5 kg/m²), normal weight (BMI between 18.5 and 24.9 kg/m²), overweight (BMI between 25 and 29.9 kg/m²), and obesity (BMI greater than or equal to 30 kg/m²)[86]. Overweight and obesity are associated with the incidence of many comorbidities[30], including chronic pain[17,52,54] and musculoskeletal pain[84]. Similar to PA, systematic reviews analyzing the association between BMI and neck pain in adults[39,45] have inconsistent results. However, none specifically investigated the association between BMI and NSNP.

To date, the question "Are weight and leisure time PA associated with the onset or the persistence of NSNP?" remains unanswered, as previous systematic reviews have shown inconsistent results. This lack of evidence hinders health care professionals from treating patients with NSNP using a comprehensive biopsychosocial approach. Thus, the aim of this systematic review was to synthesize evidence on the relationship between weight, leisure time PA, and the onset or the persistence of neck pain in adults with NSNP.

METHODS

This systematic review was performed in accordance with the Cochrane Handbook recommendations[33] and reported according to the updated Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement[57]. A protocol was registered in PROSPERO prior to completion of the initial search (registration number: CRD42020215409).

Search strategy

Systematic searches were conducted in PubMed, Scopus, Cochrane Library, Embase, and PsycINFO to identify eligible studies published from January 2010 up until November 2020. An updated search was performed in November 2021. Comprehensive and exhaustive search equations were developed according to the PICO format and validated by an experienced librarian at the Université catholique de Louvain (UCLouvain, Belgium). Search terms were related to "neck pain", "physical activity", "weight", and their synonyms (chosen according to each database's syntax). Search equations are provided in **APPENDIX 1**. In addition, we screened the references list of each included study and similar reviews for any additional relevant papers that were missed in our search.

Study selection

Studies available in full text that met the eligibility criteria were included. These criteria were case-control or cohort design, including adults ($\geq$ 18 years) with NSNP and/or healthy participants, assessing the onset or the persistence of NSNP as outcomes, assessing leisure time PA or weight as exposures, including reported or extractable quantitative estimates of the risk of NSNP (onset or persistence), and published in French or English.

To avoid missing any relevant studies, we used no specific definition of NSNP. However, the neck pain had to occur in the "absence of trauma, signs or symptoms of major structural pathology, neurological signs or specific pathology"[7]. Articles that reported NSNP in combination with pain in other body areas (e.g., shoulder or arm) were excluded, unless separate data related to neck pain were reported. Symptoms in the shoulder may be the result of injuries in the neck and/or shoulder regions and risk factors for neck and shoulder pain populations are not identical[23,78,81]. Therefore, studies investigating neck and shoulder symptoms as a single region (or a mixed population with inclusion of one or the other) were excluded.

Outcomes were the onset (new reported episode of neck pain/symptoms irrespective of the duration or severity of symptoms) and the persistence (episode for more than 3 months) of NSNP. There was no restriction on how these outcomes were assessed.

Only leisure time PA was evaluated in this review. Studies evaluating only occupational PA or a combination of occupational and leisure time PA without any subgroup analysis were not considered. There was no restriction on how these exposures were assessed.

We excluded studies of a mixed neck pain population (without subgroup analysis by type of neck pain) and/or studies that evaluated a combination of lifestyle factors.

Studies were selected according to the following process: import of citations in EndNote X9, removal of duplicates manually and via the EndNote process, screening on the basis of title and abstract, screening on the basis of full-text, and final inclusion in the review. All these steps were done independently by two reviewers (A.L. and F.A.). Disagreements were resolved through consensus. If not, a third reviewer (L.P.) made a final decision.

Data extraction

The following data of each primary study were extracted independently by two reviewers (A.L. and F.A.) in a standardized form: eligibility criteria, study methods, participants, intervention,

outcomes, results, and miscellaneous information. Details of extracted data are available in **APPENDIX 2**. In cases of missing data or a need to specify information about the study, authors were contacted via email.

Methodological quality assessment

Two reviewers (A.L. and F.A.) independently assessed methodological quality using the Newcastle-Ottawa Scale (NOS) for cohort and case-control studies[85]. Quality assessment tables are separated by exposure (leisure time PA and weight). The total score of NOS ranged from 0 to 9 based on three domains: selection (0-4 stars), comparability (0-2 stars), and outcome (0-3 stars). The NOS scoring system was applied; however, more weight was attributed for the "comparability" criterion (i.e., controlling for confounders), which better reflects the risk of bias in the included studies. Disagreements were resolved through consensus. Criteria used for the methodological quality assessment of included studies are presented in **APPENDIX 3**.

Data synthesis

A meta-analysis was precluded (see "differences between the protocol and review" section). Instead, we used the Synthesis Without Meta-analysis (SWiM) reporting guidelines for the synthesis of quantitative data[14]. Because narrative synthesis is characterized by a lack of transparency, making an assessment of the validity of its findings is difficult[13]. An alternative synthesis was chosen, when possible, as recommended by the SWiM guidelines. Our synthesis was based on the "vote counting based on direction of effects" method, which is considered acceptable when a meta-analysis could not be undertaken[51].

To undertake vote counting, we first created a standardized binary metric by categorizing each effect estimate based on direction ("showing benefit" vs. "showing harm")[51]. Regardless of statistical significance or effect size, we counted and compared the number of effect estimates showing benefit and those showing harm. We calculated an estimate of the proportion of effects favoring the exposure (leisure time PA or weight) as follows: proportion (p) = u/n, where u = number of effects favoring the exposure, and n = number of studies[51]. We also calculated a 95% confidence interval (CI) on this proportion using the Wilson interval method (in Stata version 17.0), as recommended by the Cochrane collaboration[51]. Because of the high heterogeneity (clinical and methodological diversities), a qualitative (narrative) synthesis was used for the persistence of NSNP.

Studies were grouped by outcome (onset and persistence) and exposure (leisure time PA and weight). Effect measures, retrieved from the primary studies, were odds ratio (OR) and hazard ratio. Each effect estimate was presented with its corresponding 95% CI in the results section. When necessary, the leisure time PA or weight subgroups used in the primary studies were specified in subscript with the corresponding OR. Studies were heterogeneous in the way they presented leisure time PA exposure. Some studied associations between NSNP and lower activity levels, while others studied associations between NSNP and higher activity levels. The same applied to the exposure weight (underweight, normal weight, and overweight). To make this clear, we presented the risk estimates of exposures into two categories for leisure time PA ("being less active" vs. "being more active") and for weight ("underweight or normal weight" vs. "overweight").

A positive or negative effect estimate was considered irrespective of the statistical significance. Automatic use of a binary "significant vs. non-significant" decision rule encourages raters to ignore potentially important observed differences[4]. Our approach avoids misinterpreting a moderate or large p-value (e.g., > 0.05) as evidence that the exposure has no effect on the

outcome[69]. Inclusion of non-significant findings allows for a more nuanced evaluation. However, we specified the significance of effect estimates for completeness. In the absence of a recommended threshold for an important difference, we specified a threshold including effect estimates in the region of 1 (between 0.95 and 1.05) to indicate little or no effect. Multivariable adjusted associations were preferred over univariable associations for data synthesis because they usually reduce the impact of confounding[32].

Certainty of evidence

The GRADE approach was used to assess the certainty of the synthesis findings for each outcome and each exposure[26,67]. The certainty of evidence for each outcome ranges from very low to high. According to the GRADE approach, because of the observational design, assessment started with a "low" certainty of evidence[67,68]. We downgraded certainty when the body of evidence for an outcome was judged to be affected by risk of bias, inconsistent results, indirectness of evidence, imprecision, or publication bias[67,68]. We upgraded certainty in case of large effects, dose-response associations, or residual confounding[67,68].

Differences between the protocol and review

Given the high heterogeneity between studies and the risk of bias, we did not conduct a meta-analysis[22]. Although subgroup analyses were planned for gender and age, they were not performed due to the paucity of studies. Data extraction was expanded to correspond to the Cochrane Handbook recommendations[49] by extracting more information about statistical analyses, methods used to prevent biases and to address missing data, as well as discussion information.

RESULTS

Study selection

The initial search yielded 10,199 references. After removing duplicates, we screened the titles and abstracts of 5610 articles. After applying the selection criteria, nine articles were included for qualitative synthesis. The updated search did not identify any new articles. Details are described in **FIGURE 1**.

Characteristics of included studies

Eight cohort studies and one case-control study were included in this systematic review, with a total of 20,350 participants (ranging from 86 to 11,391). Studies on the onset of NSNP included 1176 participants (**TABLE 1**), while studies of persistence included 19,174 participants (**TABLE 2**). Eight studies included workers (four studies[40,70-72] on white-collar workers, three studies[42,43,59] on mixed white-collar and blue-collar workers, one study[10] on blue-collar workers) and one study[62] included the general population of working age. Studies including mixed white-collar and blue-collar workers[42,43,59] included a majority of white-collar workers.

NSNP was self-reported in all studies, according to specific criteria decided by the authors (six studies) or by using the Standardized Nordic Questionnaire (three studies). Leisure time PA was assessed through self-reports in four studies, validated questionnaires in two studies (International Physical Activity Questionnaire and Baecke Physical Activity Index), and objectively via a pedometer in one study. Data for weight were self-reported in three studies and collected by an examiner in two studies.

Four studies investigated the association between exposures and the onset of NSNP (three on leisure time PA and two on weight), while five studies investigated the association between

exposures and the persistence of NSNP (four on leisure time PA and three on weight). Characteristics of the included studies are presented in **TABLE 1** and **TABLE 2**.

Methodological quality assessment

Six studies were judged to have "good" methodological quality (three for leisure time PA and three for weight), two were judged "fair" (two for leisure time PA), two were judged "poor to fair" (one for leisure time PA and one for weight), and two were judged "poor" (one for leisure time PA and one for weight). The most encountered limitations were the non-representativeness of the exposed cohorts (volunteers or convenience samples), the ascertainment of exposures (mostly self-reports), and the assessment of outcomes (mostly self-reports). Detailed risk of bias assessments can be found in **APPENDIX 4** (NOS for leisure time PA) and **APPENDIX 5** (NOS for weight).

Summary of results

Tabulation of the available effect estimates are shown in **TABLE 3** (onset of NSNP) and **TABLE 4** (persistence of NSNP). The GRADE assessment is shown in **TABLE 5**.

Association between leisure time PA and onset of NSNP

Three prospective cohort studies investigated the association between leisure time PA and the onset of NSNP. According to the vote counting based on direction of effects, two of three studies[40,72] (67% (95% CI: 21% to 94%); very low certainty evidence) found a decreased risk of NSNP with higher levels of activity (Jun et al. (2020)[40]: adjusted Hazard ratio [95%CI] = 0.72 [0.60-0.87]; Sitthipornvorakul et al. (2015)[72]: adjusted OR [95%CI] = 0.86 [0.74-1.00]).

Both studies were adjusted for some relevant confounders (e.g., confounders giving a star in the NOS assessment, being age, gender, previous neck or back pain, lifestyle factors, physical factors, or psychosocial factors). The third study[10] found little or no effect (unadjusted OR [95%CI] = 1.04 [0.69-1.57]) and was neither adjusted for relevant confounders nor statistically significant. One study[40], adjusted for relevant confounders, investigated the association between inactivity and the onset of NSNP and found a significant increased risk (adjusted Hazard ratio [95%CI] = 1.04 [1.03-1.06]). Because the effect size did not exceed our threshold for clinical relevance, we considered this to reflect little or no effect.

Association between weight and onset of NSNP

One cohort[10] and one case-control[43] study investigated the association between weight and the onset of NSNP. According to the vote counting based on direction of effects, both studies (100% (95% CI: 34% to 100%); very low certainty of evidence) found an increased risk of NSNP in overweight people. The case-control study[43] was adjusted for relevant confounders (e.g., age, gender, perception of job control, repetitive nature of work) and found a significant increased risk (adjusted OR [95%CI] = 2.44 [1.17-5.05]), whereas the effect estimate in the cohort study[10] was neither adjusted for relevant confounders nor statistically significant (unadjusted $OR_{25\text{-}27\ kg/m^2\ vs\ <25\ kg/m^2}$ [95%CI] = 1.19 [0.66-2.16]; unadjusted $OR_{>27\ kg/m^2\ vs\ <25\ kg/m^2}$ [95%CI] = 1.33 [0.71-2.48]).

Association between leisure time PA and persistence of NSNP

Four cohort studies investigated the association between leisure time PA and the persistence of NSNP (one of them[62] investigated recovery from persistent NSNP). Overall, based on multivariable effect estimates, there was a trend for a decreased risk of persistent NSNP in more

active people. Certainty of evidence was very low. Results are summarized qualitatively in **APPENDIX 6**.

Association between weight and persistence of NSNP

Three cohort studies investigated the association between weight and the persistence of NSNP (one of them[62] investigated recovery from persistent NSNP). Overall, based on multivariable effect estimates, there was a trend for an increased risk of persistent NSNP in overweight and obese people. Certainty of evidence was very low. Results are summarized qualitatively in **APPENDIX 6**.

DISCUSSION

We investigated the relationship between leisure time PA, weight, and NSNP (onset and persistence). There were modest associations, and overall, very low certainty evidence of a relationship between NSNP and both exposures.

For the onset of NSNP, two of two studies reported an increased risk in people with overweight or obesity, and two of three studies reported a decreased risk for more active people. For the persistence of NSNP, most studies' multivariable ORs reported a decreased risk with increased leisure time PA and an increased risk with overweight or obesity (with less consistent findings for men). Gender differences are well-known in neck pain[65], female sex being a risk factor for NSNP[7,44,58], which may explain the differences between men and women observed in this study. However, this needs to be investigated in future studies.

Leisure time PA seemed to protect against NSNP, which contradicts previous systematic reviews[55,73]. Sitthipornvorakul et al.[73] found limited evidence for no association between leisure time PA and neck pain in workers. However, their conclusion was based on one study including an adult working population with neck-shoulder symptoms[73]. Therefore, it may not generalize to a neck pain population. Øverås et al.[55] found that inactivity at work may protect against neck pain, while an increase in PA may increase the risk of neck pain. These findings are different to ours, and may reflect differences in the study population. Øverås et al.[55] mostly included blue-collar workers, who are usually more physically active at work than white-collar workers[55]. Also, because Øverås et al.[55] investigated both occupational and leisure time PA, a possible explanation for their findings is the PA paradox, which states that more occupational PA could be detrimental to health (effort of too low intensity or too long duration, elevation of 24-hour heart rate and blood pressure, no sufficient recovery time, low worker control, increased level of inflammation, prolonged postures or repetitive tasks)[18,19,34-36] and thus could

increase the risk of neck pain. Another explanation is that occupational and leisure time PA "elicit distinct biomechanical loadings and physiological responses which over time have differential impact on various health outcomes, including musculoskeletal health"[55]. Neither of these studies[55,73] investigated the persistence of NSNP. Based on these results, leisure time PA appears to be protective against the onset and persistence of NSNP, whereas occupational PA appears to promote NSNP. This is very important to consider when helping patients with NSNP, as the type of PA may have opposing effects and consequences on NSNP.

To date, two systematic reviews[39,45] on risk factors for NSNP have included studies that assessed weight and showed inconsistent results. Discrepancies between them and our review may be explained by the fact that we specifically focused on weight, whereas it was one of multiple risk factors in the other systematic reviews. Previous reviews did not investigate the persistence of NSNP. However, the link between overweight or obesity and NSNP would not be surprising, because obesity is associated with musculoskeletal disorders[84] and is considered a risk factor for low back pain[87].

A possible explanation for the inconsistent findings throughout the literature may be that only weight or leisure time PA is not sufficient to clearly influence the onset or the persistence of NSNP. Some recent reviews demonstrated the relationships between other lifestyle factors (e.g., smoking, stress, nutrition, sleep, and alcohol intake) and musculoskeletal pain[1,2,12,25,53,79,80]. When combined, lifestyle factors ("lifestyle behavior") may have a greater impact on NSNP. Indeed, two recent prospective cohort studies[9,74] suggest that adhering to a healthy lifestyle behavior decreases the risk of long-duration troublesome neck pain. However, the paucity of studies prevent firm conclusions and further research on the impact of a healthy lifestyle behavior on NSNP is needed.

Overall, our results reflect the current international guidelines promoting a healthy weight and regular leisure time PA to foster good health[11,24] and suggest that this also applies to NSNP.

Limitations

This is the first systematic review focusing on the relationship between these two exposures and the onset or the persistence of NSNP. Thanks to specific selection criteria, we could offer a better view of the association between leisure time PA, weight, and NSNP. Including mainly prospective cohort studies allowed to better assess the causation between exposures and NSNP[76]. To consider every effect estimate notwithstanding the statistical significance, as recommended by the Cochrane collaboration[51] to avoid ignoring potentially important observed differences, and interpreting effect estimates between 0.95 and 1.05 as null (not clinically relevant) allowed to better reflect the associations observed in primary studies. Using the Cochrane recommendations, the SWiM guidelines, and the GRADE approach, make this a rigorous systematic review.

Only English or French published articles were screened in some of the available databases, implying a risk for publication and language biases. The synthesis method used for the onset of NSNP is recommended when a meta-analysis cannot be undertaken[14,51], but it contains some disadvantages: no information on the magnitude of effects, does not account for differences in the relative sizes of the studies, and is less powerful than methods used to combine p-values[51]. The synthesis for the persistence of NSNP is also a limitation because descriptive (narrative) synthesis is characterized by a lack of transparency and makes the assessment of the validity of its findings difficult[13]. The presence of modest and sometimes inconsistent associations, as well as the paucity of studies and the specific population studied (white-collar and blue-collar workers), also represent limitations that decrease the generalizability of the findings and the certainty of the evidence.

Recommendations for future research

Most studies included workers (white-collar workers[40,70-72], mixed white-collar and blue-collar workers[42,43,59], blue-collar workers[10]), sometimes using a convenience sample, preventing the generalization of the results to a general population. Future studies should investigate these relationships in a general population.

To avoid biases induced by residual and unmeasured confounding[77], future studies should control for relevant confounders that are related to the onset or the persistence of NSNP, such as individual factors (e.g., age, gender, history of neck pain or other musculoskeletal disorders), psychosocial factors (e.g., anxiety, depression, high job demands, social or work support), and lifestyle factors (e.g., stress, sleep, smoking, occupational PA)[6,7,18,28,45,47,60].

Because studies with long-term follow-up could have recall bias, regular follow-ups are preferred. Self-reports of leisure time PA and weight could also introduce reporting bias due to over- or underestimation[3], so the use of validated objective measurements is recommended. BMI may not be sufficient to assess the risks associated with abdominal adiposity, so adding a measure of waist circumference should be performed[64] in future studies investigating weight as an exposure.

Several studies were subject to non-reporting and underreporting data due to non-significance, which implies totally or partially missing results[56]. Because missing results can lead to biases, authors recommend reporting and performing multivariable analyses for all results (significant or not).

Clinical implications

Leisure time PA and weight may play a role in the onset and persistence of NSNP, identifying these exposures as potential risk factors. Thus, clinicians may need to consider these factors when assessing and treating NSNP, to reduce the risk of new or persistent painful episodes.

This could prevent or reduce the burden and disability of their patients, as well as the costs associated with NSNP by avoiding recurrence or persistence of pain.

When assessing PA behavior, clinicians should take care to distinguish between occupational and leisure time PA, as they may have opposing effects on NSNP. Therefore, clinicians should investigate both aspects and make different recommendations depending on the type of PA (e.g., decrease occupational PA and/or increase leisure time PA).

CONCLUSION

Modest and sometimes inconsistent associations suggest that the risk of NSNP (onset and persistence) may be lower in more active people and higher in people with overweight and obesity. However, the certainty of evidence is very low for all associations, which means that they may exist, but it is very uncertain. Also, due to the specific population studied, results should not be generalized to populations other than workers.

Key Points

Findings

- Leisure time physical activity tends to decrease the risk of the onset and the persistence of non-specific neck pain.
- Overweight and obesity tend to increase the risk of the onset and the persistence of non-specific neck pain.

Implications

- These findings synthesize the most recent evidence about the relationship between non-specific neck pain, weight, and leisure time physical activity. According to the findings, clinicians may need to consider their patients leisure time physical activity behavior and body mass index within a comprehensive assessment and management planning approach to non-specific neck pain.

Caution

- Due to the very low certainty of evidence and the specific population studied, results should be interpreted cautiously and should not be generalized to populations other than workers.

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FIGURE 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram for study selection.

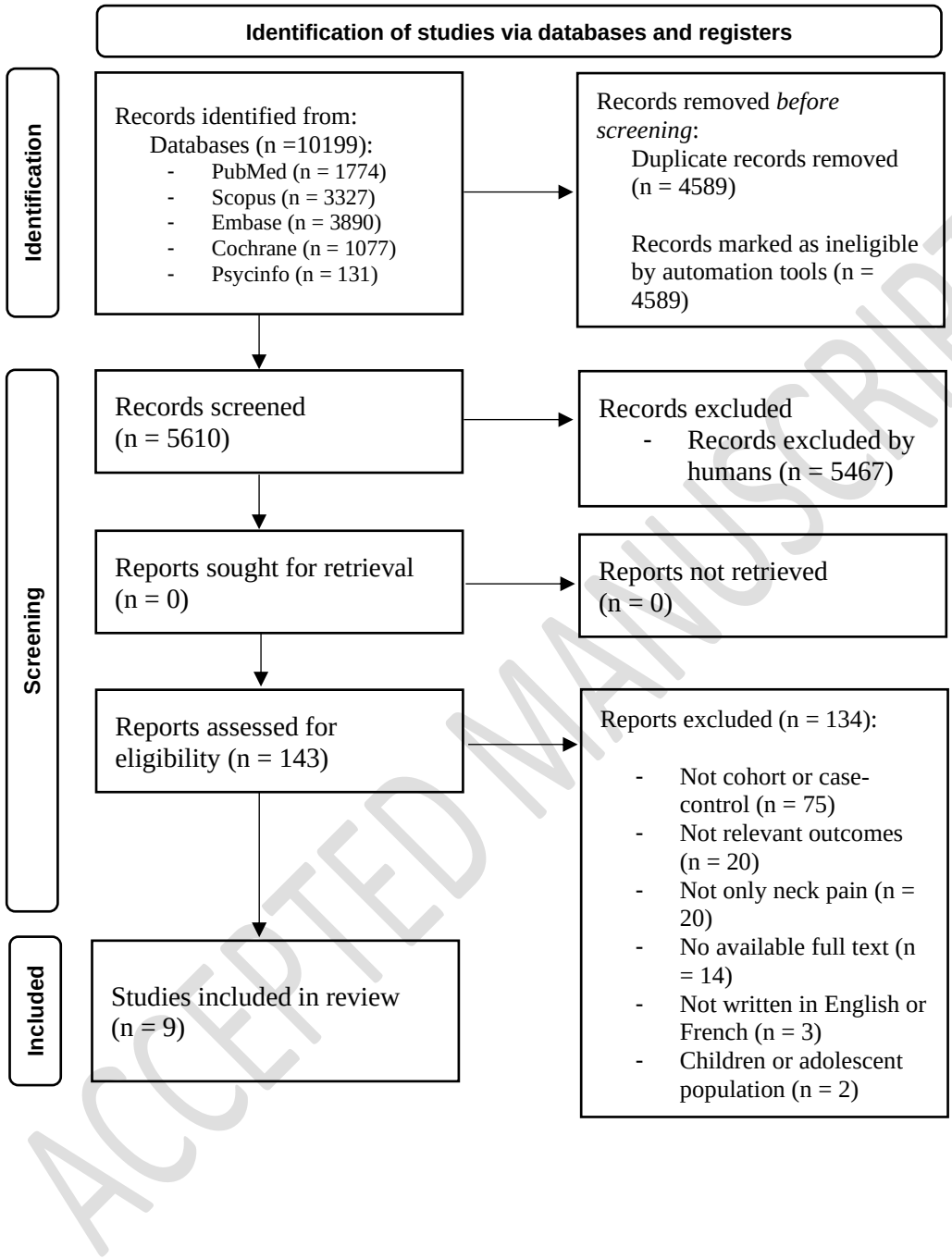

TABLE 1. Summary of studies assessing the onset of non-specific neck pain.

Authors	Study design	Study population	Sample size (N)	Follow-up duration Drop-out rate (%)	Exposure + Measurement tool or scale	Outcomes Outcome definition Measurement tool or scale	Statistical model, investigated covariates
Jun et al. (2020)	Prospective longitudinal cohort study	**Subjects:** Office workers from multiple organizations: universities, research center, management service, industrial-educational agency and health service institution. **Average age (SD):** 37.3 (9.9) years **Gender:** 55.1% female **Country:** Australia (Brisbane) and South Korea (Daegu)	Total included: (n=214): Brisbane (n=156) Daegu (n=58) 191 participants included in the final analysis (including risk factors between cultures)	**Follow-up:** 12 months **Drop-out rate:** 2.7% at follow-up and 13.2% at risk factor analysis	**Exposure:** Physical activity **Measurement tool:** -Brisbane: IPAQ-SF -Daegu: Korean version of the IPAQ-SF	**Outcome:** Onset of neck pain **Measurement tool:** Self-report (closed questions) **Definition:** A new development of interfering neck pain in the 12 months following the baseline assessment **Interfering neck pain** = Symptoms severe enough to (1) interfere with daily activities or (2) have taken sick leave or sought health care advice or self-management	Multivariate HR adjusted for age, gender, BMI, coping strategy, social support, muscular strength, and endurance
Kanagalakshmi et al. (2018)	Case-control study	**Subjects:** Support services staff including technicians, pharmacists, record keeping services and administrative staff in hospital **Average age (SD):** Cases: 39.14 (7.67) years Controls: 39.44 (7.80) years **Gender:** 40.7% female **Country:** India (Tamil Nadu)	Included in the risk factor analysis for BMI (n=86)	**Follow-up:** No follow-up **Drop-out rate:** Not applicable	**Exposure:** Weight (BMI) **Measurement tool:** Measured by a health care professional	**Outcome:** Onset of neck pain **Measurement tool:** Self-administered questionnaire + Evaluation of pain + Physical examination **Definition:** Pain, ache or discomfort in the neck and/or interscapular region between occiput and third thoracic vertebra in the last 3 months	Adjusted OR for age, gender, working more than 3 hours with computers, perception of job control, posture, repetitive nature of work

Sitthipornvorakul et al. (2015)	Prospective cohort study	**Subjects:** Office workers from 4 large-scale enterprises (1 university and 3 ministry's head offices) **Average age (% sample):** 20–29 years (24.3%) 30–39 years (49.1%) 40–45 years (26.6%) **Gender:** 76.2% female **Country:** Thailand (Bangkok)	N = 387 (baseline) N = 367 (12-month follow-up) N = 362 (final analysis)	**Follow-up:** 12 months **Drop-out rate:** 5.2% at 12-month follow-up and 6.5% at final analysis	**Exposure:** Physical activity (daily walking steps) **Measurement tool:** - Digi-walker Pedometer CW700s	**Outcome:** Onset of neck pain **Measurement tool:** Standardized Nordic Questionnaire **Definition:** Pain lasting for more than 1 day in the last month with intensity greater than 30 mm on a 100-mm visual analog scale, and no weakness or numbness in the upper or lower limbs	Adjusted OR for age, gender, history of neck pain, chair adjustability, physical job demands
Bovenzi et al. (2015)	Prospective cohort study	**Subjects:** Male professional drivers employed in several industries (marble quarries, marble laboratories, dockyards, paper mills) and public utilities (garbage services, public transport) located in various Provinces of Italy **Average age (SD):** 41 (8.1) years **Gender:** 100% male **Country:** Italy	N = 598 (baseline) N = 537 (analyzed): 317 did the 2 follow-ups, 220 only did one.	**Follow-up:** 3 years **Drop-out rate:**10.2% at one-year follow-up	**Exposures:** Physical activity and Weight **Measurement tool:** -Physical activity: self-report (questionnaire) -Weight (BMI): self-report (questionnaire)	**Outcome:** Onset of neck pain **Measurement tool:** Modified version of the Nordic questionnaire on musculoskeletal symptoms **Definition:** At least one episode of pain lasting one day or more in the neck anatomical area	Univariate OR adjusted for time-effect

BMI, Body Mass Index; HR, Hazard Ratio; IPAQ-SF, International Physical Activity Questionnaire – Short Form; OR, Odds Ratio; SD, Standard Deviation

TABLE 2. Summary of studies assessing the persistence of non-specific neck pain.

Authors	Study design	Study population	Sample size (N)	Follow-up duration Drop-out rate (%)	Exposure + Measurement tool or scale	Outcomes Outcome definition Measurement tool or scale	Statistical model, investigated covariates
Kääriä et al. (2012)	Prospective cohort study	**Subjects:** Middle-aged employees of the City of Helsinki (more than 200 different occupations) **Age (% sample):** 40 years (20.9%) 45 years (21.6%) 50 years (21.2%) 55 years (24.3%) 60 years (12%) **Gender:** 80% female **Country:** Finland (Helsinki)	N = 5277	**Follow-up:**5-7 years **Drop-out rate:** 17%	**Exposure:** Physical activity and Weight **Measurement tool:** -Physical activity: Self-report (opened question) -Weight (BMI): Self-report of weight and height	**Outcome:** New onset of chronic neck pain **Measurement tool:** Self-report (closed question) **Definition:** Incident chronic neck pain (duration > 3 months) was defined as not having had chronic neck pain at the baseline but reporting it at the follow-up	Adjusted OR for age
Palmlöf et al. (2016)	Prospective cohort study 2 sub-cohorts *Cohort 1* = risk cohort *Cohort 2* = prognostic cohort	**Subjects:** Swedish residents (18-65 years) from 24 out of 26 municipalities in Stockholm County *Cohort 1*: Individuals with no neck pain at baseline (during the last 6 months) *Cohort 2:* Individuals with occasional neck pain at baseline **Average age (SD):** *Cohort 1:* 44 (11) years *Cohort 2:* 42 (11) years **Gender:** *Cohort 1:* 40.3% female *Cohort 2:* 57.7% female	N= 11391 (analyzed) *Cohort 1:* n= 4639 *Cohort 2:* n= *6752*	**Follow-up:** 5 years **Drop-out rate:** 20.4%	**Exposure:** Physical activity **Measurement tool:** Self-report (multiple choice question)	**Outcome:** Long duration troublesome neck pain **Measurement tool:** Self-report (closed question) **Definition**: Neck pain for at least three consecutive months in the last five years that is considerably bothering	**Cohort 1**: Adjusted OR for age, alcohol consumption, smoking, immigrant status, work under knee level, computer work, work above shoulder level **Cohort 2**: Adjusted OR for age, immigrant status, smoking, work over shoulder level and computer work

		Country: Sweden (Stockholm)					
Rasmussen et al. (2013)	Prospective cohort study	**Subjects:** Residents (18 to 65 years) of Stockholm County, from each of 43 strata comprising 25 municipalities and 18 sub-regions of the municipality **Average age:** Not reported **Gender:** 71.4% female **Country:** Sweden (Stockholm)	N = 1730	**Follow-up:** 5 years **Drop-out rate:** 5.36%	**Exposure:** Physical activity and Weight **Measurement tool:** -PA: Self-report (multiple choice question) -Weight (BMI): Self-report of weight and height	**Outcome:** Recovery from persistent neck pain **Measurement tool:** Self-report (closed questions) **Definition:** -Persistent neck pain= Pain in the neck or upper back, every day during the previous 6 months -Recovery from neck pain = No neck pain during the past 5-year period for at least 3 consecutive months (or at least 7 consecutive days but less than 3 consecutive months) that was considerably bothering	Adjusted OR for age, smoking, alcohol, back pain the previous 6 months, chronic illness or handicap, socioeconomic class, current occupation, marital status, country of birth, time with housework per day, main physical workload the previous 12 months, sick leave the last 12 months, time spent at computer per day, psychological well-being and BMI
Shahidi et al. (2015)	Prospective cohort study	**Subjects:** Office workers (18-65 years) from Denver metropolitan area **Average age:** 30 years **Gender:** 79.5% female **Country:** United States of America (Denver)	N = 167	**Follow-up:** 12 months **Drop-out rate:** 2.3%	**Exposure:** Physical activity **Measurement tool:** Baecke Physical Activity (BPA) Index	**Outcome**: Chronic interfering neck pain **Measurement tool:** Self-report **Definition:** Either persistent (≥3 consecutive months) or episodic (≥3 non-consecutive months) interfering pain at any point during the 12-month follow up	Adjusted OR for age, gender, BMI
Sihawong et al. (2016)	Prospective cohort study	**Subjects:** Office workers from 9 large-scale enterprises in Bangkok **Average age (SD):** 35.7 (8.3) years **Gender:** 74.9% female **Country:** Thailand (Bangkok)	N = 669 (baseline) N = 609 (analysis)	**Follow-up:** 12 months **Drop-out rate:** 9%	**Exposure:** Weight (BMI) **Measurement tools:** -Body weight: Electronic digital scale -Body height: Wall-mounted stadiometer -Waist circumference: tape measure	**Outcome**: Chronic neck pain **Measurement tool:** Standardized Nordic questionnaire **Definition:** -Incident neck pain = Neck pain lasting >24h in the past month, intensity >30 mm on a 100-mm VAS and no weakness or numbness in the upper or lower limbs	Adjusted OR for age, gender, initial pain intensity, and initial disability level

						-Chronic neck pain = Incident neck pain for at least 3 months in any 6 months during the 1-year follow up	

BMI, Body Mass Index; OR, Odds Ratio; SD, Standard Deviation; VAS, Visual Analogue Scale

TABLE 3. Effect of leisure time physical activity and weight on the onset of non-specific neck pain (results and vote-counting).

Authors (NOS assessment)	**Exposure**	**Outcomes**	**Results**	**Being less active**	**Being more active**
Jun et al. 2020 ("Fair" quality)	**Leisure time physical activity** (total METs/week derived from the IPAQ) **Inactivity** (per hour of sitting during weekdays, according to the IPAQ)	**Onset of interfering neck pain**	Adjusted* HR: 0.72 (0.60-0.87) Adjusted* HR: 1.04 (1.03-1.06)	 0	-*
Sitthipornvorakul et al. 2015 ("Good" quality)	**Leisure time physical activity** (per 1000 daily walking steps, measured by a pedometer)	**Onset of neck pain**	Adjusted* OR: 0.86 (0.74-1.00)		-
Bovenzi et al. 2015 ("Poor" quality)	**Leisure time physical activity** (self-reported weekly frequency) → **< 3 times a week vs. ≥ 3 times a week**	At least one episode of **neck pain**	Unadjusted OR: 1.04 (0.69-1.57)		0
				Underweight or normal weight	**Overweight**
Kanagalakshmi et al. 2018 ("Good" quality)	**Overweight** (BMI **≤ 25 vs. > 25kg/m²**)	**Onset of neck pain**	Adjusted* OR: 2.44 (1.17-5.05)		+*
Bovenzi et al. 2015 ("Poor" quality)	**BMI** (calculated based on self-reported height and weight) → **BMI 25-27 vs. <25kg/m² // BMI > 27 vs. <25 kg/m²**	At least one episode of **neck pain**	Unadjusted $OR_{25\text{-}27 \text{ vs } <25}$: 1.19 (0.66-2.16) Unadjusted $OR_{>27 \text{ vs } <25}$: 1.33 (0.71-2.48)		+ +

BMI, Body Mass Index; HR, Hazard Ratio; MET, Metabolic Equivalent Task; NOS, Newcastle-Ottawa Scale; OR, Odds Ratio

***** Adjusted for at least age and gender

-*: significant decreased risk / +*: significant increased risk / -: non-significant decreased risk / +: non-significant increased risk

TABLE 4. Effect of leisure time physical activity and weight on the persistence of non-specific neck pain (results and vote-counting).

Authors **(NOS assessment)**	**Exposure**	**Outcomes**	**Results**	**Being less active**	**Being more active**
Kääriä et al. 2012 (“Poor to fair” quality)	**Leisure time physical activity** (four grades of intensity exemplified with common activities that people often do) → **Classification into 4 groups based on METs hours/week (inactive, moderate, vigorous, conditioning)**	**Chronic neck pain**	Unadjusted OR **Men (n = 1057)**: **Vigorous vs. Conditioning**: 0.84 (0.44-1.60) **Moderate vs. Conditioning**: 1.18 (0.64-2.20) **Inactive vs. Conditioning**: 1.05 (0.55-2.00) Unadjusted OR **Women (n = 4220):** **Vigorous vs. Conditioning**: 1.05 (0.76-1.46) **Moderate vs. Conditioning**: 1.26 (0.94-1.69) **Inactive vs. Conditioning**: 0.98 (0.71-1.36)	**Men** - + 0 **Women** 0 + 0	
Palmlöf et al. 2016 (“Good” quality)	**Leisure time physical activity** (“How much have you been physically active in your leisure time during the past twelve months?”) → **Sedentary, moderate physical activity, moderate regular physical activity, high regular physical activity**	**Cohort 1: Onset of long-duration troublesome neck pain** (healthy participants at baseline)	**Both sexes** Adjusted* OR **Moderate level vs. Sedentary**: 0.7 (0.4-1.0) **Moderate or high regular level vs. Sedentary**: 0.6 (0.4-0.9) **Men (n = 2772)** Adjusted* OR **Moderate level vs. Sedentary**: 0.8 (0.4-1.6) **Moderate or high regular level vs. Sedentary**: 0.6 (0.3-1.2)		**Both sexes** **-** **-*** **Men** - -

			Women (n = 1867) Adjusted* OR **Moderate level vs. Sedentary**: 0.5 (0.2-1.0) **Moderate or high regular level vs. Sedentary**: 0.6 (0.3-1.1)		**Women** - -
	Leisure time physical activity ("How much have you been physically active in your leisure time during the past twelve months?") → **Sedentary, moderate physical activity, moderate regular physical activity, high regular physical activity**	**Cohort 2**: **Onset of chronic neck pain** (occasional neck pain participants at baseline)	**Both sexes** Adjusted* OR **Moderate level vs. Sedentary**: 1.0 (0.8-1.3) **Moderate or high regular level vs. Sedentary**: 0.9 (0.7-1.1) **Men (n = 2924)** Adjusted* OR **Moderate level vs. Sedentary**: 1.2 (0.8-1.7) **Moderate or high regular level vs. Sedentary**: 0.8 (0.5-1.1) **Women (n = 3891)** Adjusted* OR **Moderate level vs. Sedentary**: 0.9 (0.6-1.2) **Moderate or high regular level vs. Sedentary**: 0.9 (0.7-1.2)		**Both sexes** 0 - **Men** + - **Women** - -
Rasmussen et al. 2013 ("Good" quality)	**Leisure time physical activity level (PAL)** ("During the previous 12 months, how physically active have you been during leisure time? If your activity differs between, e.g., summer and winter, please estimate the average activity") → **Sedentary, low, moderate, high**	**Recovery from persistent neck pain**	**Men (n = 495)** Adjusted* OR **Active PAL vs. Sedentary**: 0.9 (0.6-1.5) **Women (n = 1235)** Adjusted* OR **Active PAL vs. Sedentary**: 1.5 (1.0-2.4)		**Men** - **Women** +

Shahidi et al. 2015 ("Fair" quality)	**Leisure time physical activity** (Baecke Physical Activity (BPA) Index - Leisure)	**Chronic interfering neck pain**	Adjusted* OR: 0.79 (0.46-1.37)		-
				Underweight or normal weight	**Overweight or obese**
Kääriä et al. 2012 ("Poor to fair" quality)	**BMI** (kg/m², calculated based on self-reported height and weight) → **Normal weight, overweight, obese**	**Chronic neck pain**	**Men (n = 1057)**: Unadjusted OR **Overweight vs. Normal weight**: 0.60 (0.38-0.96) **Obese vs. Normal weight**: 1.11 (0.61-2.02) **Women (n = 4220)**: Adjusted* OR **Overweight vs. Normal weight**: 1.22 (1.00-1.48) **Obese vs. Normal weight**: 1.39 (1.08-1.80)		**Men** **-*** **+** **Women** **+** **+***
Rasmussen et al. 2013 ("Good" quality)	**BMI** (kg/m², calculated based on self-reported height and weight) → **Underweight, normal weight, overweight**	**Recovery from persistent neck pain**	**Men (n = 495)** Adjusted* OR **18-24.9 vs. <18 and >25**: 1.2 (0.7-1.9) **Women (n = 1235)** Adjusted* OR **18-24.9 vs. <18 and >25**: 1.0 (0.8-1.3)		**Men** **+** **Women** 0

Sihawong et al. 2016 ("Good" quality)	**BMI** (kg/m², calculated based on weight (digital scale) and height (wall-mounted stadiometer))	**Chronic neck pain**	Adjusted* OR: 1.10 (1.02-1.19)		**+***

BMI, Body Mass Index; MET, Metabolic Equivalent Task; NOS, Newcastle-Ottawa Scale; OR, Odds Ratio; PA, Physical Activity; PAL, Physical Activity Level

***** Adjusted for at least age and gender

-*: significant decreased risk / +*: significant increased risk / -: non-significant decreased risk / +: non-significant increased risk

TABLE 5. Grading of Recommendations Assessment, Development and Evaluation (GRADE) summary of findings.

Number of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Publication bias	Certainty of evidence
Leisure time physical activity on onset of neck pain							
3	Observational studies	Not serious	Not serious	Serious[a]	Not serious	Likely[b]	**Very low** ⊕◯◯◯
Weight on onset of neck pain							
2	Observational studies	Some concerns[c]	Not serious	Serious[d]	Serious[e]	Likely[b]	**Very low** ⊕◯◯◯
Leisure time physical activity on persistence of neck pain							
4	Observational studies	Not serious	Not serious	Serious[f]	Serious[g]	Likely[b]	**Very low** ⊕◯◯◯
Weight on persistence of neck pain							
3	Observational studies	Not serious	Not serious	Serious[f]	Serious[g]	Likely[b]	**Very low** ⊕◯◯◯

[a] One study did not use a validated assessment of leisure time PA and most studies included specific populations

[b] Some studies tended to report and analyze only significant factors / The search strategy did not cover every database and unpublished literature, thus relevant studies with different effect estimates may have been missed

[c] Limitations may lower confidence in the estimate of effect (one "good" quality study and one "poor" quality study)

[d] Subjective assessment of weight and various populations

[e] Low number of events (< 400 events), large confidence intervals (crossing 1.0) for one study

[f] Most studies used self-reports, one study investigated recovery rather than chronicity, mixed populations investigated

[g] Most effect estimates crossing 1.0