Sedentary behaviour and spinal pain in adolescents

Laura Rose Cooper Montgomery
BChiroSci MChiroprac

A thesis submitted in fulfilment of the requirements for the degree of
Master of Research

Department of Chiropractic, Faculty of Science and Engineering
Macquarie University, Sydney, Australia
13 February 2019

Abstract

Spinal pain in adolescents is a significant public health concern, and adolescent sedentary behaviour is a proposed modifiable risk factor for spinal pain. Whether sedentary behaviour recommendations in international public health guidelines are relevant for adolescent spinal pain is unknown. This thesis reports a systematic review exploring associations between sedentary behaviours and spinal pain in adolescents. It also reports a secondary cross-sectional analysis, of a population-based cohort of young adolescent Danes, to investigate the association between sedentary behaviour (as per public health guidelines) and non-trivial spinal pain. Cross-sectional multinominal logistic regression investigated associations between sedentary behaviour, by duration and type, and spinal pain, by region and triviality, adjusted for age and sex. The systematic review found there was no meaningful association between sedentary behaviour and adolescent spinal pain; however, the evidence base is inconsistent and at high risk of bias. The cross-sectional analysis demonstrated there was no association between exceeding two hours per day of sedentary behaviour and spinal pain. The collective thesis findings suggest that sedentary behaviour is not a meaningful risk factor for adolescent back pain. Therefore, challenge existing public and clinical beliefs that sedentary behaviour is causally associated with spinal pain in adolescents.

Statement of Originality

This statement of originality is to certify that to the best of my knowledge the intellectual content of this thesis is the product of my own work. This thesis contains no material previously published or written by another person except where due reference is made in the thesis itself. This work has not previously been submitted for any degree or another purpose in any university or institution.

Mrs Laura Montgomery *Signature removed* Date 22 October 2018

Ethics Approval

Macquarie University Human Research Ethics Committee, via the Science and Engineering Subcommittee, granted ethics approval on the 27th of July 2018 (Appendix A).
Ethics approval reference number: 520 183 146 351 9

Data Processor Agreement

A data processor agreement was drawn up for the use of the pre-existing anonymised data from the School site, Play-spot, Active transport, Club fitness and Environment study (Appendix B).

Supervisors Statement

As supervisors of Laura Montgomery's thesis work, we certify that we consider her thesis 'Sedentary behaviour and spinal pain in adolescents.' sufficiently well presented to be examined and does not exceed the prescribed page or word limit.

Primary Supervisor:

Mr Michael Swain *Signature removed* Date 22 October 2018

Lecturer in Chiropractic, Department of Chiropractic, Faculty of Science and Engineering, Macquarie University, Australia

Secondary Supervisor:

Dr Simon French *Signature removed* Date 22 October 2018

Professor of Musculoskeletal Disorders, Department of Chiropractic, Faculty of Science and Engineering, Macquarie University, Australia

Adjunct Supervisors:

Dr Steven Kamper *Signature removed* Date 22 October 2018

Associate Professor, Sydney School of Public Health, Faculty of Medicine and Health, The University of Sydney, Australia.

Dr Jan Hartvigsen *Signature removed* Date 22 October 2018

Professor, Head of Research Unit, Department of Sports and Clinical Biomechanics, University of Southern Denmark, Denmark

Acknowledgement

To my supervisors and colleagues – Michael Swain, your guidance and support this year has been invaluable. I will be forever grateful for your encouragement to start this journey and your ever steady and calm mentorship throughout. Professor Simon French, Associate Professor Steven Kamper and Professor Jan Hartvigsen, I am so grateful for the amazing opportunity I have had this year to work with each of you. Your knowledge and expertise have been limitless; I wish I had more time to learn from your counsel. Steve Sharp and Anika Young, thank you, you have both been a wonderful source of support this year.

To my family and friends – thank you for your practical advice and sharing in the celebration of my achievements. You have helped me to appreciate my hard work and not let it go unnoticed. Riley, thank you for your never-ending support and motivation. The dedication you show to your own work and passions inspires me to continue the pursuit of my own. I am so grateful to have you all in my life!

This Master of Research project would not have been possible were it not for the generous support of the Chiropractic & Osteopathic College of Australasia Research Pty Ltd (COCA), in partnership with the Australia and New Zealand Musculoskeletal Clinical Trials Network (ANZMUSC), and Chiropractic Australia (CA). This research was undertaken at Macquarie University while in an Australian Government Research Training Program (RTP) supported place.

Table of Contents

List of Figures

List of Tables

List of Abbreviations

ANZMUSC	Australia and New Zealand Musculoskeletal Clinical Trials Network
CA	Chiropractic Australia
COCA	Chiropractic & Osteopathic College of Australasia Research Pty Ltd
CSEP	Canadian Society for Exercise Physiology
FPS-R	Faces Pain Scale-Revised
HBSC	Health Behaviour in School-age Children
HRQoL	Health Related Quality of Life
LM	Laura Montgomery (MRes candidate)
MCaR	Little's Missing Completely at Random test
MeSH	Medical Subject Headings
MET	Metabolic equivalent
MS	Michael Swain (MRes primary supervisor)
NPRS	Numerical Pain Rating Scale
OR(95%CI)	Odds ratio with 95% confidence interval in parentheses
PRISMA	Preferred Reporting Items for Systematic reviews and Meta-Analysis
QUIPS	Quality in Prognostic Studies
RTP	Research Training Program
SBRN	Sedentary Behaviour Research Network
SF	Simon French (MRes secondary supervisor)
SPACE	School site, Play spot, Active transport, Club fitness and Environment study
STROBE	Strengthening the Reporting of Observational Studies In Epidemiology
WHO	World Health Organisation
YLD	Years lived with disability
YSQ	Young Spine Questionnaire

Chapter One. An introduction to sedentary behaviour and spinal pain in adolescents

1.1 Back pain in adolescents

Back pain is a common musculoskeletal disorder in adolescents that receives little attention from the public, clinicians and the research community.[1] Back pain in adolescents was previously thought to be infrequent and a red flag for serious pathology.[2-5] However, more recently, it has been determined that serious pathologies, including infection, malignancy or inflammatory joint disease are rare and only occur in 1-8% of adolescent back pain cases.[6,7] Adolescent back pain related to a specific diagnosis is also uncommon, such as Scheuermann's disease (1-8%[8]), spondylolisthesis (6-15%[7,8]), scoliosis (1-3%[8,9]), or disc herniation (3-5%[8]).[6,10] The bulk (50-95%[7,11]) of adolescent back pain episodes are non-specific, self-limiting, and mechanical disorders.[5-13] It is these seemingly benign episodes that are thought to contribute to the reoccurrence of back pain throughout the life course and into adulthood.[12,14] A greater understanding of the epidemiology for adolescent back pain is necessary to assist in the development of effective prevention and management strategies.[15]

1.1.1 Prevalence of back pain in adolescents

During adolescence, back pain prevalence rises sharply to approach adult rates by age eighteen.[5,16-18] The lifetime prevalence of low back pain at age seven is 1%, increasing to 12-40% by age 12, and almost doubling to 39-72% by age 15.[16-20] The wide variation in reported rates makes it difficult to comprehend precisely how many adolescents experience back pain, though it is becoming clear that it is more commonplace than previously understood.[20] Swain et al. showed in more than 400,000 11-15 year olds from 28 countries that a variation in mean monthly prevalence of low back pain exists, 28-51%. However, low back pain in adolescence is considered common worldwide.[21]

1.1.2 Impact of back pain in adolescence

The impact of adolescent back pain is multidimensional, creating a burden not only on the adolescent but also their family and society. The impacts of back pain in adolescents are still not well understood given the potentially far reaching nature of the consequences.[3-5,20] Up to 94% of adolescents with back pain report some level of impairment, which can be partly measured through a change in behaviour.[6,20,22-25] For example, in a German study of 749 children and adolescents with back pain, 57% sought medical attention, 16% took medication for their pain, 19% missed school, 21% postponed social activities, 42% altered their participation in sports or hobbies, 19% experienced a decrease in appetite and 52% noted that back pain affected their sleep.[23] Further, a study of 1,348 Danes reported 8% of 13-year-olds and 34% of 15-year-olds had sought medical care for back pain, suggesting a higher impact of back pain among older adolescents.[26]

1.1.3 Non-trivial adolescent back pain

The perception that back pain is always a trivial event during adolescence is likely one factor that hinders proper attention to, and awareness of, this musculoskeletal disorder.[1] Back pain episodes can be categorised as trivial or non-trivial based on characteristics of pain frequency, intensity, duration and impact.[12,17,22,27] Trivial pain is infrequent, of low pain intensity, and with minor impact on day-to-day activities.[26] While non-trivial pain is of higher frequency, experienced across multiple locations, and has a more significant impact on an individual and society.[6,17,27] Dissing et al. found in 1,465 Danes aged 8-16 that 40% of pain episodes were non-trivial.[12] Dissing et al. and Aartun et al. both reported the prevalence of non-trivial spinal pain increased as age increased.[12,26] Further, work by Hestbaek et al. found, from a study of 10,000 Danish twins, the risk of low back pain in adulthood increases with the presence of non-trivial low back pain in adolescence.[14] Particular attention needs to be paid to non-trivial adolescent back pain in future research.[1,28]

1.1.4 Adolescent back pain and comorbidities

Adolescents with non-trivial back pain are more likely to have co-morbid health conditions (physical or psychological).[1,7,12,20,29,30] Chronic musculoskeletal pain, including back pain, is often accompanied by obesity, substance misuse and poor mental health.[1,31] A Western Australian study of 17 year-olds found that low back pain commonly exists with neck and shoulder pain, anxiety and depression, and attention disorders.[32] Adolescents with comorbid back pain are also at greater risk of back pain in adulthood.[28,29] A study of 9,600 Danish twins aged 11-22 years found those with comorbid back pain (back pain with headache, or limb pain) were more likely to experience back pain into adulthood.[29]

1.1.5 Societal burden of adolescent back pain

An increase in back pain prevalence as age increases is of concern as it implies a cumulating societal burden of back pain prior to adulthood.[5,16-18] For adolescents aged 10-14, 15-19 and 20-24 years in 2013, low back and neck pain was ranked fifth, second and first respectively for years lived with disability (YLD), or productive years of life lost.[20,33,34] It is now well known that, by adulthood, low back pain is the leading cause of disability worldwide.[6,35,36] It is also well accepted that experiencing back pain in adolescence is predictive of adult back pain.[28] Adolescents with non-trivial back pain are more likely than adolescents with trivial back pain to add to this societal burden, and therefore should be prioritised within adolescent back pain public health initiatives, clinical care and future research.[28]

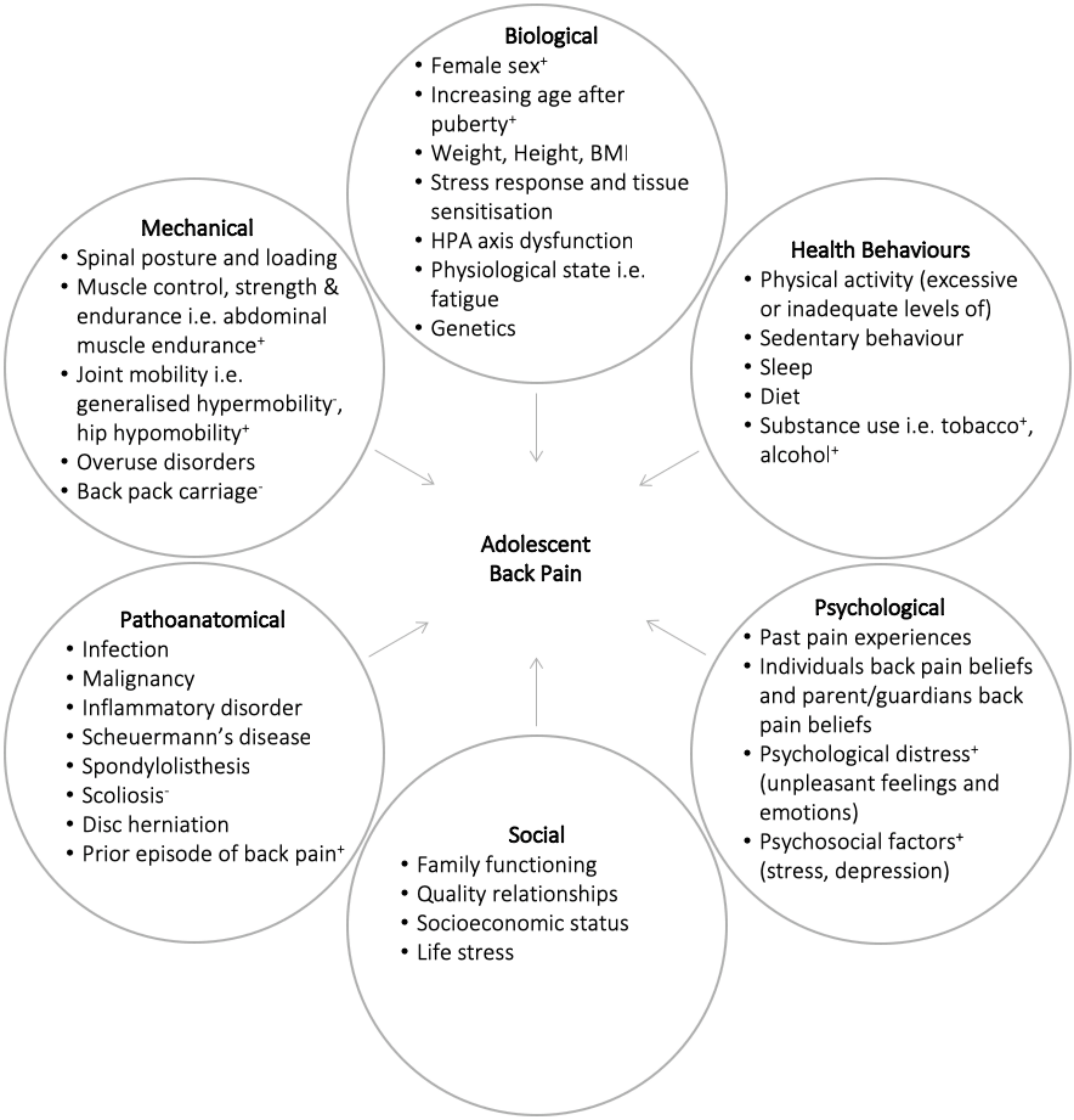
1.1.6 Economic burden of adolescent back pain

The impact and societal burden of adolescent back pain contribute to the economic cost for families, society and government.[24,32] A German study of 644,773 children and youths estimated the direct cost of adolescent back pain to be €100 million.[37] Increasing to a total estimated cost of €5.11 billion to the health care system for low back pain in adulthood.[28] In the United States, an estimated $19.5 billion is spent on adolescents with severe chronic pain, of which back and comorbid pains are predominant.[20,38] By adulthood, chronic pain, including back pain, is estimated to cost upwards of US$560 billion.[28] These significant figures are still conservative estimates, and in actuality, the total costs are likely to be higher.[20,37] Despite vast social and economic impacts, effective treatment options for back pain in adolescents, and adults, are limited.[15,20]

1.1.7 Risk factors for back pain in adolescence

There are many proposed risk factors for the development and persistence of adolescent back pain (Figure 1.1). Copious primary studies investigating individual or multiple discrete risk factors exist although often conclusions and risk estimates are conflicting.[20] This inconsistency is due to the wide variation in study design, interpretation, and reporting of adolescent back pain and risk factors. Of note is the social belief that all back pain is caused by either a single event or simple biomechanical factors such as backpacks, poor posture or sports participation.[1] A broader biopsychosocial approach is needed to understand the influence of particular health behaviours as risk factors for back pain, and how they interact over the life-course.[1,6,22,24,30,39]

In a recent umbrella review, Kamper et al. found consistent, high-quality evidence only exists for increasing age, after the onset of puberty, as a risk factor for adolescent back pain.[20] Other risk factors supported by high-quality, yet inconsistent, evidence are female sex, tobacco use, psychological distress (including unpleasant feelings and emotions) and psychosocial factors (for example, stress or depression).[20] Inconsistent and low-quality evidence exists for overweight/obesity, increased height, backpack use, hypermobility, muscle strength, posture, level of engagement in physical activity, and sedentary behaviour.[6,20,24]



Key: + High-quality evidence for a positive association with adolescent back pain. - High-quality evidence for no association with adolescent back pain. HPA Hypothalamic-Pituitary-Adrenal.

Figure 1.1 Risk factors for adolescent back pain[6,19,22,24,39], adapted from O'Sullivan et al. 2017[6]

1.2 Sedentary behaviour

Sedentary behaviour is defined as any activity using less than 1.5 metabolic equivalents (MET) while awake in a sitting, laying or reclining posture.[40] One MET is the resting metabolic rate while sitting quietly; this is approximately equal to 3.5 ml O^2/kg/min (1.2kcal/min) for a 70kg individual.[41] The above-agreed definition for sedentary behaviour was implemented following a Delphi study in 2013, and a terminology consensus project by the Sedentary Behaviour Research Network (SBRN) in

2017. Definitions for related terms, such as screen-time and physical inactivity, were also implemented.[40,42] This definition highlights some activities, though performed sitting or lying, are not classified as sedentary as their MET value is higher than 1.5 (for example, playing a musical instrument). There are also some activities with a MET value less than 1.5 but are also not classified as sedentary as they are performed standing (for example, watering the garden).[43-45] The nuances from earlier published work, before the acceptance of the above definition, made sedentary behaviour a nebulous concept within the literature. However, our understanding of sedentary behaviour is new and quickly evolving.

1.2.1 Adverse health outcomes associated with sedentary behaviour

Excessive sedentary behaviour is associated with adverse health outcomes including obesity, increased cardio-metabolic risk, increased all-cause mortality, lowered self-esteem and other psychological health impairments.[46,47] In children and adolescents excessive sedentary behaviour is additionally linked to delayed cognitive development, decreased academic achievement and behavioural misconduct.[46,48,49] Irrespective of physical activity participation excessive sedentary behaviour may lead to a decreased quality of life (HRQoL) in otherwise healthy adolescents.[46,50] Physical inactivity and sedentary behaviour are not one and the same. Physical inactivity is described as not meeting the recommended amount of daily physical activity. Therefore, adolescents who are adequately physically active, and meeting their physical activity quota, may also be excessively sedentary at other times during the day and thus still risk a decreased HRQoL.[42,44] Given this, several countries have added sedentary behaviour recommendations to their existing public health guidelines.[51,52]

1.2.2 Sedentary behaviour guidelines

Sedentary behaviour recommendations have been included in public health guidelines in an attempt to mitigate excessive sedentary behaviour and the associated negative health effects.[42] These recommendations are set on best evidence from multiple systematic literature reviews and meta-analysis by various international research groups.[51,53] The gold standard public health guidelines for children and young people were set by the Canadian Society for Exercise Physiology (CSEP) in 2011 and have since been adopted by both Australia and New Zealand.[51,52] These guidelines include a recommendation to limit recreational screen time to no more than two hours per day and to limit sedentary transport, extended sitting and day time spent indoors.[54] The United States of America have had sedentary behaviour recommendations, since 2001, to limit electronic media usage to no more than two hours per day.[51] While the United Kingdom included their specific sedentary behaviour recommendations in 2010, to limit extended periods of sitting and being sedentary.[51] Multiple other countries make a specific recommendation within their public health guidelines to limit time spent inactive to under two hours per day, including Austria, Iceland, Finland, Malta and Switzerland.[55]

Although the recommendation to limit additional sedentary behaviour to less than two hours per day has been explicitly included in multiple countries public health guidelines since 2011, the majority of children and adolescents do not meet these recommendations. A 2017 Canadian nationally representative study of 22,115 10-17 year-olds found only 8% met the two hours per day screen time recommendation, with boys meeting the recommendation less than girls.[56] Roman-Vinas et al. in 2016 found 39% of 6,128 9-s from 12 countries met the two hours per day limit for screen time, not including other sedentary behaviours, with the most adherence in India (62%) and the least in Brazil (24%).[57]

1.2.3 Sedentary behaviour as a risk factor for adolescent back pain

Sedentary behaviour is thought to be a possible risk factor for back pain in adolescence. Common theorised mechanisms of association are biomechanical. That is, poor posture may lead to a change in spinal curves, and muscle deconditioning may lead to reduced muscle endurance and abnormal movement patterns. Both of which may lead to dysfunctional or increased joint loading and in turn may cause mechanical back pain.[6,32] These hypothesised mechanisms of association are yet to be rigorously investigated. A strong understanding of the potential association between sedentary behaviour exposure and the development of spinal pain must be established first.

There is a poor understanding of the link, if any, between adolescent back pain and excessive sedentary behaviour engagement. However, health professionals and popular media often publicise the negative health effects of sedentary behaviour and screen-time for musculoskeletal pain, including back pain, and poor posture.[1,58,59] Buzzwords used, such as 'Text Neck Syndrome' and 'iPosture', may generate confusion and even fear in the general community, which is unfortunate in the absence of a clear understanding of sedentary behaviour as a risk factor for adolescent back pain. Thus, a better understanding is needed to assist clinicians and the public in better understanding the implications of excessive sedentary behaviour for adolescent back pain.

1.3 Thesis rationale

Back pain in adolescents is a significant public health concern. Sedentary behaviour is a proposed modifiable risk factor for back pain in adolescence. Adverse health outcomes are frequently experienced by adolescents who engage in excessive sedentary behaviour. Due to this, multiple countries have added specific sedentary behaviour recommendations to their public health guidelines for children and young people in an attempt to reduce negative health outcomes. Whether these sedentary behaviour recommendations are relevant for back pain during adolescence is unknown.

There remain many research gaps in the field of back pain. To our knowledge, there are no systematic reviews which collectively appraise all available evidence for sedentary behaviour activities, screen-based and non-screen based, with spinal pain in adolescents. Also, to our knowledge, there are no primary studies that specifically investigate associations between exceeding the two hours per day sedentary behaviour guidelines and non-trivial spinal pain in adolescents.

1.4 Thesis objectives

1) To review and critically appraise the existing literature for associations between sedentary behaviours and spinal pain (neck, mid-back, and low back) in adolescents.
2) To investigate the association between sedentary behaviours exceeding the two hours per day international sedentary behaviour recommendations and non-trivial spinal pain in a Danish population-based cohort of young adolescents.

1.5 Thesis overview

This thesis consists of two linked projects about the central theme of the thesis which is sedentary behaviour and spinal pain in adolescents. This thesis includes a systematic review 'The relationship between sedentary behaviour and spinal pain in adolescents' (Chapter 2) and a cross-sectional analysis 'Association between sedentary behaviours and spinal pain in young adolescents' (Chapter 3 and 4). Both studies are presented in thesis format as per the requirements of the degree (Master of Research).

Chapter Two. The relationship between sedentary behaviour and spinal pain in adolescents: A systematic review

2.1 Systematic literature review rationale

Sedentary behaviour is a potentially modifiable risk factor for back pain in adolescents. No systematic review has comprehensively evaluated whether sedentary behaviours, screen-based and non-screen based, are associated with spinal pain in adolescents. Thus, a systematic review was designed to analyse and critically appraise the existing literature for associations between sedentary behaviours and spinal pain (neck, mid-back, and low back) in adolescents.

2.2 Methods

2.2.1 Information sources and search methods

This study followed the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA) 2015 statement.[60] A structured search of two electronic databases, PubMed and AMED, was performed on the 2nd of February 2018. The keyword search string was constructed in PubMed and modified for use in AMED (Appendix C). Limits were placed to return English only results. Results were exported to and managed in Endnote X8.

2.2.2 Eligibility criteria and screening of search results

Eligibility criteria set a priori defined study characteristics for inclusion based on study design, population, sedentary behaviour exposure, and spinal pain outcome. The eligibility criteria were applied independently by two review authors (LM, MS). Discrepancies were resolved by discussion with a third review author (SF). The eligibility criteria were:

- Study design: peer-reviewed observational cross-sectional, prospective or cohort studies.
- Study population: adolescents aged 10-19 years, as defined by the World Health Organisation (WHO).[61] Longitudinal studies were excluded if participants were older than 19 years at follow-up.
- Sedentary behaviour exposure: Sedentary behaviour as defined by the SBRN[40] measured quantitatively. For example, using a questionnaire, diary, interview, direct observation, accelerometer, or posture monitor.[62]
- Spinal pain outcome: Spinal pain either non-specified spine region (for example, spinal pain, back pain, backache), specific spine region (neck pain, mid back pain, low back pain) or combinations of the spine region with an adjacent anatomical region (for example, neck and shoulder pain). No

limits were placed on the duration, intensity or frequency of spinal pain. Studies were excluded if; 1. spinal pain was nested into a broader pain grouping (for example, musculoskeletal pain), or 2. if spinal pain was due to serious pathology (For example, infection, malignancy or inflammatory joint disease).

To increase the chance of inclusion of all relevant records reference and citation tracking were performed by one review author (LM) through the Scopus citation database up to and including the 15th of March 2018. All potential studies identified through the tracking process were screened for inclusion by a second review author (MS).

2.2.3 Data extraction

Two review authors (LM, MS) completed data extraction by tabulating data into a pre-developed data extraction table. This table was refined following data extraction from an initial five studies. Any difficulty in extraction, such as unclear data items, were cross-checked between the two review authors. Unreported items were sourced from article appendices or web-based supplementary materials. No study authors were contacted for additional data. The review authors were not blinded to any study information.

2.2.4 Risk of bias assessment

To assess the risk of bias within included studies a risk of bias assessment tool was developed by two review authors (LM, MS). The Quality in Prognostic Studies (QUIPS)[63] tool was modified to include five domains of potential bias with a yes/no response option. A study was scored one (yes) if it met the criterion, or zero (no) if it did not or if relevant information were not reported. A total score of five was possible; five of five equalled low risk, three to four of five equalled moderate risk, and zero to one equalled high risk. The five criteria were;

1) Study Participation: Was there random and representative sampling of study participants?
2) Study Attrition: Was the response/drop-out rate over 85%?
3) Exposure Measure: Was a valid tool used to measure sedentary behaviour? For example, accelerometer, direct observation, validated questionnaire, or if steps were taken to assess the reliability of the questionnaire used (for example, test-retest reliability).
4) Outcome Measure: Was a valid tool used to measure spinal pain? For example, the Nordic Musculoskeletal Questionnaire,[64] or if steps were taken to assess the reliability of the questionnaire used (for example, test-retest reliability).

5) Study Confounding: Were potential confounders adjusted for within the statistical analysis?

The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE)[65] quality of reporting tool was used as a guide to cross-check whether studies had appropriately included relevant information for the above five domains of bias.

2.2.5 Synthesis of data

Due to the vast differences in included studies, methodological and statistical, a meta-analysis was not possible, and a qualitative synthesis was performed. In order to evaluate all estimates of association from extracted studies, studies were initially divided by study design. Longitudinal study design allows more accurate estimate of causal mechanism, thus estimates of association extracted from longitudinal studies were presented separately from those extracted from cross-sectional studies. The remaining estimates of association were then grouped by outcome and exposure type. Back pain outcomes were grouped into four domains: spinal pain, neck pain, mid back pain and low back pain. Estimates calculated for a combined spine region with an adjacent anatomical region were grouped with the relevant spine region (For example, neck and shoulder pain were grouped with neck pain). Within the four outcome domains, association estimates were further grouped by sedentary behaviour exposure: TV, including video and DVD watching; computer, for homework, emailing and internet use; gaming, on electronic screen device, including computer or TV; mobile phone use; non-screen based activities; total screen time; and, total sedentary behaviour time. Summary statements were generated by study type and outcome domain.

Where multiple estimates of association were reported for the same combination of exposure and outcome in a study, the most adjusted association estimate available was extracted. That is, the estimate adjusted for by the greatest number of confounding variables in a multivariable estimate. The direction of each association was interpreted as “positive” when increased sedentary behaviour exposure significantly increased the likelihood of spinal pain, “negative” when increased sedentary behaviour exposure significantly decreased the likelihood of spinal pain, and “no association” when increased sedentary behaviour exposure neither increased or decreased the likelihood of spinal pain significantly. Level of significance was set at $P < 0.05$. A precise OR is defined, in this review, as an OR with narrow 95% confidence intervals where the upper and lower limit lie within one whole integer. Conversely, an imprecise OR is defined as an OR with wide 95% confidence intervals, larger than one whole integer.[66]

2.3 Findings

The searches returned 908 citations of which 10 were duplicates. Reference and citation tracking identified an additional 31 citations. All 929 citations were screened against the eligibility criteria with a final number of 45 citations included in this systematic review (Figure 2.1).

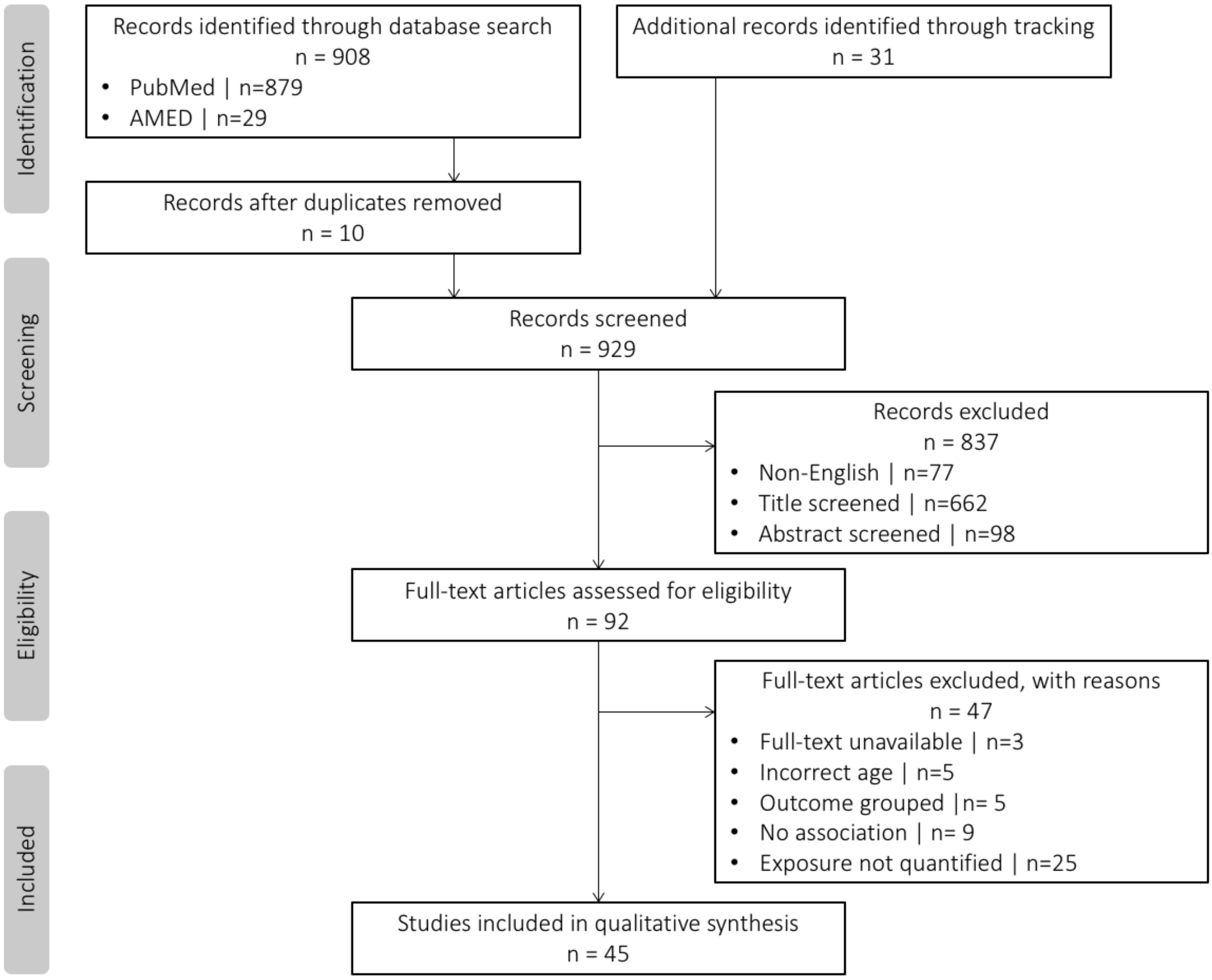


Figure 2.1 Flow of records through review screening process, modified from Liberati et al.[67]

2.3.1 Descriptive characteristics of included studies

Of the 45 included studies two were prospective longitudinal studies; one of six-month duration in South Africa with a sample size of 93, and the other of two years duration in Belgium with a sample size of 287 (Table 2.1).[68,69] The remainder of the included studies are cross-sectional from 35 unique samples including eight national databases. All studies included both sexes and sample sizes ranged from 88[70] to 31,022[71]. The included study samples represented many countries. There was one study included from each of Mozambique,[72] Ireland,[73] Taiwan,[74] and the United States.[74] There were two studies from each of China,[75,76] Iran,[77,78] and South Africa.[68,79] Four studies were from Australia,[80-83] nine from Brazil,[84-92] and 22 collectively from the European Union.[27,69-71,93-110]

Table 2.1 Characteristics of included studies

Study	Study Cohort, Country	Study Population	Exposure	Outcome
Longitudinal studies				
Brink et al., 2009[68]	Prospective, South Africa	School students, 15-17yrs, n=93, 48.4%F	Computer	UQMP
Szpalski et al., 2002[69]	Prospective, Belgium	School students, 9-12yrs, n=287, 50.9%F	TV, Computer, Gaming	LBP
Cross-sectional studies				
Auvinen et al., 2007[110]	Nationally representative, Finland	North Finland Birth Cohort 1986, 15-16yrs, n=5993, 53.1%F	TSB (TV, Reading (non-screen), Comp, Other SB)	NOP
Auvinen et al., 2008[109]	Nationally representative, Finland	North Finland Birth Cohort 1986, 15-16yrs, n=5999, 53%F	TSB (TV, Reading (non-screen), Computer , Other SB)	LBP
Balague et al., 1994[108]	Switzerland	School students, 8-16yrs, n=1716, 50.6%F	TV	LBP
Briggs et al., 2009[83]	Nationally representative, Australia	WA Pregnancy Cohort RAINE, 14yrs, n=643, 54.6%F	TV, Computer , Reading (non-screen), TST	NSP
Brindova et al., 2015[107]	Nationally representative, Slovakia	HBSC 2010, School students, 11-15yrs, n=8042, 51.4%F	TV, Computer	SP
Burke et al., 2002[111]	United States	School students, 5-18yrs, n=212, 51.9%F	Computer	NP, SP
Dianat et al., 2018[77]	Iran	School students, 11-14yrs, n=1611, 53.4%F	TV, Computer, Gaming	NP
Diepenmaat et al., 2006[106]	Netherlands	School students, 12-16yrs, n=3485, 50.5%F	TV, Computer	NSP, LBP
Fernandes et al., 2015[84]	Brazil	School students, 10-14yrs, n=1461, 48.4%F	TV, Computer	LBP
Grimmer et al., 2000[82]	Australia	School students, 12-18yrs, n=1269, NR	Time sitting after school	LBP
Hakala et al., 2006[105]	Nationally representative, Finland	AHLS2003, 14, 16, 18yrs, n=6003, 55.6%F	TV, Computer, Gaming, Internet Use, Mobile	NSP, LBP
Hakala et al., 2012[104]	Finland	School students, 12-13 & 15-16yrs, n=436, 53.7%F	Computer	NSP, LBP
Hulsegge et al., 2011[103]	Nationally representative, Netherlands	PIAMA Birth Cohort, 11yrs, n=2638, 49.8%F	TSB (TV + Computer after school)	SP
Keane et al., 2017[73]	Nationally representative, Ireland	School students, 10-17yrs, n=10474, 58.5%F	TST (TV, Gaming, Screen time, Homework, Social)	SP
Kristjansdottir et al., 2002[102]	Iceland	School students, 11-12 & 15-16yrs, n=2173, 49%F	TV, Computer (at home use), Homework	SP
Meziat-Filho et al., 2015[85]	Brazil	School students, 14-20yrs, n=1102, 53.3%F	TV, Computer, Gaming	LBP acute, LBP chronic
Meziat-Filho et al., 2017[86]	Brazil	School students, 14-20yrs, n=1102, 53.3%F	TV, Computer, Gaming	NP acute, NP chronic
Minghelli et al., 2014[101]	Portugal	School students, 10-16yrs, n=966, 54.8%F	TV, Computer/Gaming	LBP
Minghelli et al., 2016[100]	Portugal	School students, 10-16yrs, n=966, 54.8%F	TV, Computer/Gaming	LBP
Mohseni-Bandpei et al., 2007[78]	Iran	School students, 11-14yrs, n=4813, 52.3%F	TV, Computer, Homework	LBP
Myrtveit et al., 2014[99]	Nationally representative, Norway	Ung@hordaland, School students, 17-19yrs, n=10220, 53.7%F	TV, Computer, Other ST (after school)	NSP

Continued

Study	Study Cohort, Country	Study Population	Exposure	Outcome
Cross-sectional studies				
Noll et al., 2016[87]	Brazil	School students, 11-16yrs, n=1597, 46.4%F	TV, Computer	SP
Noll et al. (b), 2016[88]	Brazil	School athletes, 14-20yrs, n=251, 31.1%F	TV, Computer	SP
Noll et al., 2017[89]	Brazil	School athletes, 14-20yrs, n=251, 31.1%F	TV, Computer	SP
O'Sullivan et al., 2011[81]	Nationally representative, Australia	WA Pregnancy Cohort RAINE, 14yrs, n=1328, NR	TV, Computer	SP
Palm et al., 2007[98]	Sweden	School students, 16-18yrs, n=2826, 55.7%F	TV, Computer, Gaming	NSP
Picavet et al., 2016[97]	Nationally representative, Netherlands	PIAMA Birth Cohort, 11 & 14yrs, n=2517, 49.7%F	ST (Incl. TV, Computer, Gaming)	SP, UQMP
Prista et al., 2004[72]	Mozambique	School students, 11-16yrs, n=204, 53.9%F	TV	LBP
Rossi et al., 2016[96]	Finland	Youth sports clubs members, 14-16yrs, n=1637, 52.8%F	ST (TV, Computer, Gaming, Mobile, Tablet)	NSP, LBP
Shan et al., 2013[75]	China	School students, 15-19yrs, n=3016, 51.6%F	Computer, Tablet, Mobile	NSP, LBP
Shan et al., 2014[76]	China	School students, 15-19yrs, n=2842, 52%F	Computer, Sitting (time after class), Sitting (whole day)	NSP
Silva et al., 2016[91]	Brazil	School students, 14-19yrs, n=961, 61.6%F	ST (Incl. Computer + Gaming)	NP, TLP
Silva et al., 2017[90]	Brazil	School students, 13-19yrs, n=969, 51.8%F	TV, Computer, Gaming, Mobile	NP, TP, LBP
Sjolie, 2004[70]	Norway	School students, 14.1-16.1yrs, n=88, 43.2%F	TV, Computer, Reading	LBP
Skemiene et al., 2012[95]	Lithuania	School students, 13-18yrs, n=1730, 49.8%F	Computer	NSP, SP
Smith et al., 2009[79]	South Africa	School students, 14-18yrs, n=1073, 64.9%F	Computer	NP
Straker et al., 2018[80]	Nationally representative, Australia	WA Pregnancy Cohort RAINE,14yrs, n=884, 46.2%F	Computer	NSP
Torsheim et al., 2010[71]	Nationally representative, Scandinavian	HBSC 2005/6, School students, 11,13,15yrs, n=31022	TV, Computer, Gaming	SP
Turk et al., 2011[94]	Slovenia	School students, 11-15 & 17-18yrs, n=190, 49.5%F	TV, Computer	LBP
Wedderkopp et al., 2003[93]	Denmark	School students, 8-10 & 14-16yrs, n=806, 52%F	PI (Incl. TV before school + after school, Computer)	SP, TP, LBP
Wirth et al., 2015[27]	Switzerland	School students, 10-12yrs, 412, n=51.9%F	TV/Computer	SP
Yang et al., 2017[74]	Taiwan	School students, 16-19yrs, n=302, 39.7%F	Mobile	NP, TP, LBP
Zapata et al., 2006[92]	Brazil	School students, 10-18yrs, n=791, 52.5%F	Computer, Gaming	SP

Key: yrs, years; n=, sample size; %F, frequency of females in sample; TV, television, including watching video or DVD but not gaming; Computer, using a computer for any task other than gaming; Gaming, playing games on an electronic screen device, including computer or TV; ST, screen-time; TST, total screen-time; PI, physical inactivity; TSB, total sedentary behaviour; SP, spinal pain, including back pain and backache; LBP, low back pain; TLP, thoracolumbar pain; TP, thoracic pain, including mid back pain and upper back pain; NP, neck pain, including cervical pain; NOP, neck and occipital pain; NSP, neck and shoulder pain; UQMP, upper quarter musculoskeletal pain.

2.3.2 Risk of bias of included studies

No included study met all five risk of bias assessment criteria (Table 2.2). Just over half the studies (25) were at moderate risk of bias, the remainder (20) were at high risk of bias. Two studies met none of the risk of bias criteria; a cross-sectional by Straker et al.[80], and a longitudinal by Szpalski et al.[69] Of the individual criteria, 21 studies (47%) met the criterion for study participation. Twelve studies (27%) met the criterion for study attrition. The use of a validated measure tool for sedentary behaviour took place in 29 studies (53%), and for spinal pain in 23 studies (51%). Study confounding took place in 30 studies (67%).

2.3.3 Descriptive characteristics of associations

Included studies reported 150 estimates of association (Appendix D). No association between sedentary behaviour and spinal pain was reported in the majority of associations (63%). Positive associations were reported in 35%, where sedentary time increased the likelihood of spinal pain. Negative associations were reported in 2%, where sedentary time was protective of spinal pain. Potential confounders were adjusted for in 66% of associations. The most common confounders adjusted for were age, sex, school year, body mass index, smoking, level of physical activity and family history of spinal pain.

2.3.4 Summary of associations

2.3.4.1 Longitudinal studies

There were three estimates of association extracted from the two longitudinal studies. Brink et al.[68] found computer use greater than six hours per week (OR 1.6 [CI: 0.7-3.8]) or 105 minutes per day (OR 1.7 [CI: 0.7-4.2]) had no association with upper quadrant musculoskeletal pain over a six-month period. Brink et al.'s study was at moderate risk of bias. Szpalski et al.[69] reported daily computer use and gaming, of unreported duration, were not associated with low back pain (OR 1.53 [CI: 0.92-2.54]) over a two-year period. Spalski et al.'s study was at high risk of bias. Neither of the studies adjusted for confounders.

Table 2.2 Risk of bias assessment of included studies

Study	1. Study Participation	2. Study Attrition	3. Exposure Measure	4. Outcome Measure	5. Study Confounding	Total	Risk of Bias
Longitudinal studies							
Brink et al., 2009[68]	1	1	1	1	0	4	Moderate
Szpalski et al., 2002[69]	0	0	0	0	0	0	High
Cross-sectional studies							
Brindova et al., 2015[107]	0	1	1	1	1	4	Moderate
Minghelli et al., 2014[101]	1	0	1	1	1	4	Moderate
Minghelli et al., 2016[100]	1	0	1	1	1	4	Moderate
Mohseni-Bandpei et al., 2007[78]	1	1	1	1	0	4	Moderate
Noll et al., 2016[87]	1	0	1	1	1	4	Moderate
Prista et al., 2004[72]	1	0	1	1	1	4	Moderate
Shan et al., 2013[75]	0	1	1	1	1	4	Moderate
Shan et al., 2014[76]	0	1	1	1	1	4	Moderate
Torsheim et al., 2010[71]	0	1	1	1	1	4	Moderate
Auvinen et al., 2007[110]	0	0	1	1	1	3	Moderate
Briggs et al., 2009[83]	0	0	1	1	1	3	Moderate
Dianat et al., 2018[77]	1	1	0	0	1	3	Moderate
Fernandes et al., 2015[84]	1	1	1	0	0	3	Moderate
Hakala et al., 2006[105]	0	0	1	1	1	3	Moderate
Hulsegge et al., 2011[103]	1	0	1	1	0	3	Moderate
Keane et al., 2017[73]	1	0	1	0	1	3	Moderate
Meziat-Filho et al., 2015[85]	1	0	1	1	0	3	Moderate
Meziat-Filho et al., 2017[86]	1	0	1	1	0	3	Moderate
Noll et al. (b), 2016[88]	0	0	1	1	1	3	Moderate
Noll et al., 2017[89]	0	0	1	1	1	3	Moderate
O'Sullivan et al., 2011[81]	0	0	1	1	1	3	Moderate
Sjolie, 2004[70]	0	0	1	1	1	3	Moderate
Skemiene et al., 2012[95]	1	1	0	0	1	3	Moderate
Wedderkopp et al., 2003[93]	1	0	0	1	1	3	Moderate
Auvinen et al., 2008[109]	0	0	1	0	1	2	High
Balague et al., 1994[108]	1	0	0	0	1	2	High
Kristjansdottir et al., 2002[102]	1	1	0	0	0	2	High
Rossi et al., 2016[96]	0	0	0	1	1	2	High
Silva et al., 2016[91]	1	0	0	0	1	2	High
Smith et al., 2009[79]	0	0	1	0	1	2	High
Yang et al., 2017[74]	1	0	0	1	0	2	High
Burke et al., 2002[111]	1	0	0	0	0	1	High
Diepenmaat et al., 2006[106]	0	0	0	0	1	1	High
Grimmer et al., 2000[82]	0	1	0	0	0	1	High
Hakala et al., 2012[104]	0	0	0	0	1	1	High
Myrtveit et al., 2014[99]	0	0	0	0	1	1	High
Palm et al., 2007[98]	0	1	0	0	0	1	High
Picavet et al., 2016[97]	0	0	0	0	1	1	High
Silva et al., 2017[90]	0	0	0	0	1	1	High
Turk et al., 2011[94]	1	0	0	0	0	1	High
Wirth et al., 2015[27]	0	0	0	0	1	1	High
Zapata et al., 2006[92]	1	0	0	0	0	1	High
Straker et al., 2018[80]	0	0	0	0	0	0	High
Total	21(47%)	12(27%)	24(53%)	23(51%)	30(67%)		

Key: 1, met criterion; 0, did not meet criterion; High, total score 0-1; Moderate, total score 3-4; Low, total score 5.

2.3.4.2 Cross-sectional studies

2.3.4.2.1 Outcome domain one: Spinal pain

There were 31 association estimates, extracted from 15 cross-sectional studies, which quantified the relationship between sedentary behaviour and spinal pain (that is non-specified spine region pain, back pain and backache) in adolescents.[27,71,73,81,87-89,92,93,95,97,102,103,107,111] Cross-sectional evidence assessing the association between sedentary behaviour, of varying type and duration, and spinal pain in adolescents is conflicting. No association was reported in 39% of associations. Computer, gaming and television use weakly increased the likelihood of spinal pain in adolescents (ORs range: 1.00-2.5) in 61% of associations. There were no negative associations.

The link between computer use and spinal pain was reported in 14 estimates; 10 estimates found weak and precise positive associations (ORs range: 1.00-1.28), and four showed no association (ORs range: 0.98-1.09). The duration of computer use varied and estimates were adjusted for up to ten confounders. There was a weak positive association between gaming, of unreported duration, and spinal pain in two associations (OR 1.05[CI:1.01-1.10], OR 1.04 [CI:1.01-1.07]). These two associations were adjusted for age, country, socio-economic status, depressed mood, school stress and physical activity. The relationship between TV and spinal pain was reported in 12 estimates; six reported weak and precise positive associations (ORs range: 1.05-1.08), and six reported no association (ORs range: 0.98-1.08). The duration of TV time varied between two to four hours per day or was unreported. Of the 12 estimates, eight were adjusted for up to 13 confounders. Total screen time of more than two hours per day was associated with a weak increased likelihood of spinal pain (ORs range: 1.22-1.26) when adjusted for age, gender, social class, family structure and physical activity.[73]

2.3.4.2.2 Outcome domain two: Neck pain

There were 67 association estimates, from 19 cross-sectional studies, that assessed the relationship between sedentary behaviour and neck pain (including neck and occipital pain, neck and shoulder pain, and upper quadrant musculoskeletal pain) in adolescents.[74-77,79,80,83,86,91,95-99,104-106,110,111] Overall, there is inconsistent evidence to support an association between sedentary behaviour and neck pain in adolescents. There was no association between sedentary behaviour and neck pain reported in 67% of associations. A weak increased likelihood of neck pain with varying sedentary behaviour types and durations (ORs range: 1.05-2.5) was reported in 31% of associations. There were no negative associations.

There were 26 estimates of computer use associated with neck pain, nine of which stated a moderate increased likelihood of neck pain (ORs range: 1.29-2.5) and 17 reported no association (ORs range: 0.65-1.88). The duration of time spent using the computer varied between studies from more than 1.5 hours per day to 56 hours per week. Up to seven confounders were adjusted for and most commonly included age and sex. Hakala et al.[105] reported internet use for more than 14 hours per week was weakly associated with neck pain (OR 1.4 [CI: 1.0-2.0]). The association between gaming more than two to five hours per day and neck pain was investigated in eight associations; two reported a weak increased likelihood of experiencing neck pain (ORs range: 1.31-1.62). The other six reported no association (ORs range: 0-96-1.62). There was no association between mobile phone use of more than three or five hours per day and neck pain in five associations (ORs range: 0.69-2.20). Only one of nine estimates reported a small increased likelihood of neck pain with watching more than two hours of TV per day, compared to adolescents that watched less than two hours per day (OR 1.58 [CI:1.16-2.14]). The other eight estimates showed no increased likelihood of neck pain with TV time from more than two hours per day to more than 32 hours per week (ORs range: 0.66-1.3). These eight estimations of association were adjusted for up to seven confounding variables. Total sedentary behaviour time, of durations exceeding one hour per day through to 46 hours per week, were positively associated with neck pain in half of 14 estimates (ORs range: 1.05-1.89). All associations were adjusted for at least two confounders. Non-screen-based reading was assessed in four estimates of association, three reporting no association and one reporting a weak association in females that read more than two hours per day (OR 1.36 [CI: 1.02-1.80]).

2.3.4.2.3 Outcome domain three: Mid-back pain

There were seven associations from four cross-sectional studies assessing the relationship between sedentary behaviours and mid-back pain (including thoracic pain, upper back pain and thoracolumbar pain) in adolescents.[74,90,91,93] Only two estimates reported an increased likelihood of mid back pain; total screen time more than four hours per day (adjusted OR 1.33 [CI: 1.00-1.75]) and talking on a mobile phone more than three hours per day (unadjusted OR 4.34 [CI: 1.10-17.11]). The remaining five estimates reported no association of mobile phone use or physical inactivity with mid back pain. There were no negative associations. There is sparse evidence available to assess the association between sedentary behaviour and mid back pain.

2.3.4.2.4 Outcome domain four: Low back pain

There were 42 estimates of association, from 19 studies, assessing the association between sedentary behaviour and low back pain in adolescents.[70,72,74,75,78,82,84,85,90,93,94,96,100,101,104-106,108,109] No association between sedentary behaviour and low back pain was reported in 66% of associations. Only 26% of associations: of varying durations of computer use, watching TV, and total sedentary behaviour time, reported a weak increased likelihood of adolescents having low back pain (ORs range: 1.06-2.4). There were 8% of associations which reported a negative association.

Computer use, of varying durations, and low back pain was assessed in 11 associations. Three reported a weak positive association (ORs range: 1.7-2.4) and were adjusted for up to seven confounders. Gaming, over five hours per day, showed a weak increased likelihood of low back pain in one association adjusted for seven confounders (OR 2.0 [CI: 1.1-3.5]). No association was found between internet use over 14 hours per week (OR 0.9 [CI: 0.6-1.4]), or mobile phone use over three to five hours per day (ORs range: 0.79-2.31) and low back pain. The association between watching TV, for varying durations, and low back pain was reported in twelve associations. Three reported a weak increased likelihood of low back pain when adjusted for seven confounders (ORs range: 1.23-1.7). Two reported a negative association and seven reported no association (ORs range: 0.8-1.13). Four associations, adjusted for up to five confounders, showed a weak positive association between total sedentary time and low back pain (ORs range: 1.06-1.37), five reported no association. One association reported homework was protective for low back pain (OR 0.76 [CI: 0.61-0.94]).

2.3.5 Summary of findings

This systematic review investigated the epidemiological relationship between sedentary behaviour and spinal pain in adolescents. Research evidence is inconsistent, of low to moderate quality and predominantly cross-sectional(96%). The majority of associations (63%) report no association between sedentary behaviour and spinal pain in adolescents. A positive association, where sedentary behaviour increased the likelihood of having spinal pain, was found in 35% of estimates. Of the positive associations made between sedentary behaviour and spinal pain, adjusted estimates showed only a weak positive association (ORs range: 1.00-2.5) and unadjusted estimates show a weak to moderate increased likelihood of spinal pain (ORs range: 1.05-4.34). A negative association, where sedentary behaviour decreased the likelihood of spinal pain was found in 2% of estimates. From a comprehensive review of the literature, it is doubtful that sedentary behaviour is meaningfully associated with spinal pain in adolescents, if at all.

Chapter Three. Association between sedentary behaviours and spinal pain in young adolescents: Study methods

3.1 Study design and setting

This study is a secondary cross-sectional analysis of the baseline data collected for the School site, Play-spot, Active transport, Club fitness and Environment (SPACE) study in Southern Denmark in 2010.[112] The SPACE study was a population-based randomised controlled trial that took place from 2010 to 2012. Fourteen schools were randomised into control and intervention arms with the aim of reducing the age-related decline in physical activity via interventions to incentivise physical activity.

The 22 municipalities within the Southern Denmark region were invited to have their public schools partake in the SPACE study. Five municipalities accepted the invitation with a total of 28 schools that had 11-13 year old students enrolled. Five schools were excluded based on the following criteria: 1. The majority of students were non-native Danes, or 2. 25% of students lived more than two kilometres crow-flying distance from the school. Two schools withdrew their acceptance to participate. Of the remaining 21 schools, 14 were matched on the following criteria: 1. Crow-flying distance from home to school, 2. Area household income, 3. Area education level, 4. Area ethnicity distribution, 5. Urbanity, 6. Condition and characteristics of outdoor school areas, 7. School health policy, and 8. Active transport in the local area.[112,113] Further information on the SPACE study protocol and outcomes has been reported elsewhere.[112,113]

3.2 Participants and data collection

In April to June of 2010, 1,348 students aged 11-13 years from 14 schools participated in the SPACE baseline data collection. The Danish National Committee on Health Research Ethics judged formal ethical approval not necessary for the SPACE study and consent was approved on a passive opt-out approach. That is all children were included in the study unless a parent or guardian specifically withdrew consent. This passive consent approach is found to be ethically appropriate in low-risk research and assists in a high response rate.[113] Parents received information about passive informed consent explaining the study and that they could withdraw their child's participation at any stage.[112,113] No children were withdrawn from baseline data collection. Overall, 97.4% of eligible adolescents enrolled in the participating schools completed the baseline questionnaire. Baseline data collection included three separate electronic questionnaires (one each completed by the student, parent/s and school management). Students also underwent baseline anthropometric and physical fitness testing, kept a seven-day physical activity and sedentary behaviour dairy, and wore an MTI Actigraph accelerometer over the same seven consecutive days.[112,113] Only the student questionnaire data were analysed for this study.

3.3 Quantitative variables, data sources, and handling

3.3.1 Exposure variables: Sedentary behaviour

In the SPACE student baseline questionnaire, two questions collected data on sedentary behaviour exposure (Table 3.1). Current public health guidelines advise no more than two additional hours of sedentary behaviour for entertainment and leisure per day.[51,53] Therefore, each of the three sedentary behaviour response options, a. 'Watching tv or DVD? (Not just having it run in the background)?', b. 'Chatting or surfing the web, playing computer games, X-box or similar?' and c. 'Other, where you sit or lie, for example reading homework, being creative, playing music?', were dichotomised from the six-point ordinal scale to: 0. More than two hours, and 1. Less than or equal to two hours. The total time spent sedentary on weekdays outside school hours and on the weekend (from combining a., b., and c. response option answers) were also dichotomised to a binary variable as above.

Table 3.1 SPACE student baseline questionnaire sedentary behaviour questions

In everyday life, outside school hours, about how many hours do you usually spend a day...	0 hours	1 hour	2 hours	3 hours	4 hours	5+ hours
Watching tv or DVD? (Not just having it run in the background)	☐	☐	☐	☐	☐	☐
Chatting or surfing the web, playing computer games, x-box or similar?	☐	☐	☐	☐	☐	☐
Other, where you sit or lie, for example reading, homework, being creative, playing music?	☐	☐	☐	☐	☐	☐
On the weekend, about how many hours do you usually spend a day...	0 hours	1 hour	2 hours	3 hours	4 hours	5+ hours
Watching tv or DVD? (Not just having it run in the background)	☐	☐	☐	☐	☐	☐
Chatting or surfing the web, playing computer games, x-box or similar?	☐	☐	☐	☐	☐	☐
Other, where you sit or lie, for example reading, homework, being creative, playing music?	☐	☐	☐	☐	☐	☐

Note: Questionnaire was completed in Danish and has been translated to English for this study. There was no reference time-frame given to students to answer this question.

Previous research shows that the majority of adolescents exceed the recommended two hours per day of sedentary behaviour.[49,56,57] For sensitivity testing, a second sedentary behaviour binary variable was created by dichotomising the six-point ordinal scale at more than five hours per day.

For each sedentary behaviour type (a., b., and c.) and total sedentary behaviour time, on weekdays outside of school and weekend days. The binary variables created were: 0. More than five hours, and 1. Less than or equal to five hours.

3.3.2 Outcome variables: Spinal pain

The Young Spine Questionnaire (YSQ), within the SPACE student baseline questionnaire, collected data on spinal pain.[114] Four questions were asked separately for each of the three spinal regions (neck, mid back and low back) with diagrams provided in the questionnaire delineating the anatomical boundaries of each body region (Table 3.2).

Table 3.2 Neck pain portion of YSQ used in SPACE student baseline questionnaire

The neck is shown in the picture

How often have you had pain in the neck?

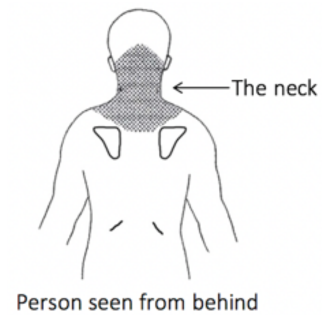
☐ Often ☐ Occasionally ☐ Once or twice ☐ Never

Have you had neck pain in the last week?

☐ Yes ☐ No

Have you had neck pain today?

☐ Yes ☐ No



The faces below show how much something can hurt. The pain ranges from ‘no pain’ to ‘very much pain’. Put a cross (X) on the face which shows how much pain you have had in the neck when it was worst.

No pain (1)	(2)	(3)	(4)	(5)	Very much pain (6)

Note: The Danish version of the YSQ was given to students. This is the translated English version.

Spinal pain in the last week was assessed by region using question b, pain in the last week, from the YSQ. The binary response options were: 0. No neck(/mid-back/low back) pain last week, and 1. Neck(/mid-back/low back) pain last week. Students who reported weekly pain from each of the three spinal regions (neck, mid back and low back) were combined to give the total number of spinal regions with pain in the last week. Thus, the variable for total number of regions of spinal pain in the last week were: 0. No pain, 1. One region, 2. Two regions, or 3. Three regions.

Given the primary emphasis to identify non-trivial episodes of spinal pain, spinal region pain in the last week (YSQ question b) was combined with spinal pain intensity (YSQ question d). The second face on the Faces Pain Scale-Revised (FPS-R), YSQ question d, represents lower pain intensity (two on a six-point scale). Trivial pain is of low intensity and low frequency. The second face on the FPS-R is considered a meaningful cut-point to delineate trivial and non-trivial pain experiences in this sample.[26] Thus, spinal pain intensity response options were dichotomised as 0. Trivial spinal pain (FPS-R faces one and two), and 1. Non-trivial spinal pain (FPS-R faces three to six). The final combined binary variable for non-trivial spinal pain by region in the last week was: 0. No or trivial (spinal region) pain in last week, and 1. Non-trivial (spinal region) pain in the last week. The combined variable for total number of regions of non-trivial spinal pain in the last week was: 0. No or trivial spinal pain, 1. One region, 2. Two regions, or 3. Three regions of non-trivial spinal pain.

3.3.3 Exploratory variables: Spinal pain frequency

For exploratory testing, variables were built to assess the frequency (YSQ question a) of non-trivial spinal pain by region and number of regions in the last week. The frequency of spinal pain was dichotomised to: 0. Infrequent spinal pain in the last week (Response options; once or twice, and never), and 1. Frequent spinal pain in the last week (Response options; often, and occasionally). This binary variable combined with the non-trivial binary variable became: 0. Infrequent, trivial or no spinal pain in the last week, and 1. Frequent non-trivial spinal pain in the last week.

3.3.4 Confounding variables: Age and sex

Older adolescents and females experience higher rates of spinal pain.[20] Therefore, age and sex were identified as important available confounders to use in the analysis of this dataset. Age was categorised into three age groups (11-, 12- and 13-years) for descriptive analyses and kept as a continuous scale variable for inferential analyses.

3.4 Validity of measures

The sedentary behaviour questions have been previously used in large international cohorts, including the Health Behaviour in School-age Children (HBSC).[112,113,115,116] The YSQ was specifically designed and tested for ease of understanding and validity in young adolescents.[22,114] The FPS-R, YSQ question d, has been validated against the Numerical Pain Rating Scale (NPRS) for measuring pain intensity.[22] The FPS-R has also been clinically validated in a cohort of 4-12 year old’s for a painful procedure (ear piercing) and for clinically relevant pain (requiring medical attention).[117]

3.5 Statistical methods

3.5.1 Data inspection and missing data analysis

Assessment of variables and missing data was performed before conducting statistical analyses. The shape of distributions and extent of missing data were assessed for all variables and individual cases. Little's Missing Completely at Random (MCaR) test was performed to assess whether the missing data followed a predictable pattern (i.e. random versus systematic error). Cases were censored that had non-response to all exposure and outcome variables. Where individual exposure and outcome items were missing at random, the proportion of missingness was reported following Listwise deletion. More comprehensive dataset cleaning and imputation were not required.

3.5.2 Descriptive statistics

Cross-tabulations (with chi-squared statistics) were used to report frequencies and associations of sedentary behaviour and spinal pain as counts and proportions categorised by age and sex. The weekly prevalence of spinal pain and non-trivial spinal pain were presented by spinal region (neck, mid-back, and low back) and the number of spinal regions.

3.5.3 Inferential statistics

Unadjusted and adjusted (age and sex) logistic and multinomial regression models were constructed to evaluate the association between adolescents exceeding the two hours per day sedentary behaviour recommendation and experiencing spinal pain. The primary analysis outcome was non-trivial spinal pain in the last week. The secondary analysis outcome was any spinal pain in the last week. Associations are expressed as odds ratios with 95% confidence intervals. The sedentary behaviour reference group were adolescents who met the recommendations (less than or equal to two hours per day). The spinal pain reference group for the primary analysis were students with no spinal pain or trivial spinal pain in the last week. For the secondary analysis the reference group were students with no spinal pain in the last week.

Sensitivity analyses were conducted to assess the association between exceeding five hours of sedentary time per day and experiencing spinal pain, non-trivial and trivial. Adjusted logistic regression models were constructed using the sedentary behaviour variables dichotomised at five hours per day. Exploratory analyses were conducted to evaluate associations between sedentary time and frequent episodes of non-trivial spinal pain. Adjusted logistic regression models were constructed using the spinal pain frequency variables. Sensitivity and exploratory analyses results were compared for similarity with the primary results.

Chapter Four. Association between sedentary behaviours and spinal pain in young adolescents: Study results

4.1 Study participants

Of the 1,348 participants entered into the SPACE study at baseline 1,303 (96.7%) were included in this study (Figure 4.1). There were 45 students excluded; 35 missed the baseline questionnaire in full, and 10 missed the YSQ in full. A further 13 students had data missing completely at random; these students have been included in all analyses, and the rate of missingness for each variable has been recorded.

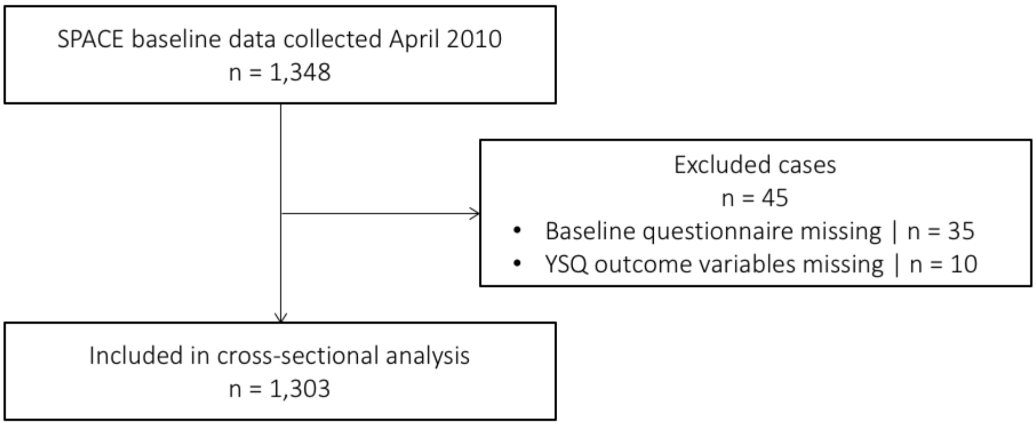


Figure 4.1 Flow of participants for inclusion in cross-sectional analysis.

4.2 Descriptive characteristics

The mean age of study participants was 12.5±0.6 years, ranging from 10.9 to 14.3 years, 48.7% were female. Regarding age-groups, 27.2% were 11-years (n=355), 51.7% were 12-years (n=673), and 21.1% were 13-years(n=275) (Table 4.1).

Overall, 89.9% (95%CI: 88.3%-91.5%) of adolescents exceeded sedentary behaviour recommendations during the week outside of school hours, and 89.9% (95%CI: 87.2%-90.6%) on the weekend. For all three sedentary behaviour types; option a. 'Watching tv or DVD? (Not just having it run in the background)?', b. 'Chatting or surfing the web, playing computer games, X-box or similar?' and c. 'Other, where you sit or lie, for example reading homework, being creative, playing music?', adolescents more frequently exceeded guideline recommendations on the weekend compared to during the week outside of school hours. 31.6% vs. 15.7% when watching TV or DVD; 35.2% vs. 22.2% when using the computer or gaming; and 15.2% (95%CI: 13.3%-17.1%) vs. 14.1% (95%CI: 12.2%-16.0%) when engaging in other sedentary behaviours.

Table 4.1 Descriptive characteristics of 11-13 year old Danish students

	Female	Male	11-years	12-years	13-years	Total	Missing
	634(48.7%)	*669(51.3%)*	*355(27.2%)*	*673(51.7%)*	*275(21.1%)*	*1303(100%)*	*0(0%)*
	12.42±0.62y	*12.50±0.63y*	*F186:M169*	*F328:M345*	*F120:M155*		
Sedentary behaviour on weekdays outside school hours							
TV/DVD >2h/d	105(16.6)	100(14.9)	43(12.1)	108(16.0)	54(19.6)	205(15.7)	0(0)
≤2h/d	529(83.4)	569(85.1)	312(87.9)	565(84.0)	221(80.4)	1098(84.3)	
Comp/Gaming	88(13.9)	201(30.0)	57(16.1)	153(22.7)	79(28.7)	289(22.2)	0(0)
≤2h/d	546(86.1)	468(70.0)	298(83.9)	520(77.3)	196(71.3)	1014(77.8)	
Other >2h/d	93(14.7)	91(13.6)	43(12.1)	99(14.7)	42(15.3)	184(14.1)	0(0)
≤2h/d	541(85.3)	578(86.4)	312(87.9)	574(85.3)	233(84.7)	1119(85.9)	
Total >2h/d	552(87.1)	607(90.7)	296(83.4)	603(89.6)	260(94.5)	1159(88.9)	0(0)
≤2h/d	82(12.9)	62(9.3)	59(16.6)	70(10.4)	15(5.5)	144(11.1)	
Sedentary behaviour on weekend days							
TV/DVD >2h/d	198(31.2)	214(32.0)	103(29.0)	210(31.2)	99(36.0)	412(31.6)	0(0)
≤2h/d	436(68.8)	455(68.0)	252(71.0)	463(68.8)	176(64.0)	891(68.4)	
Comp/Gaming	142(22.4)	317(47.4)	104(29.3)	242(36.0)	113(41.1)	459(35.2)	0(0)
≤2h/d	492(77.6)	352(52.6)	251(70.7)	431(64.0)	162(58.9)	844(64.8)	
Other >2h/d	105(16.6)	93(13.9)	47(13.2)	111(16.5)	40(14.5)	198(15.2)	0(0)
≤2h/d	529(83.4)	576(86.1)	308(86.8)	562(83.5)	235(85.5)	1105(84.8)	
Total >2h/d	559(88.2)	613(91.6)	305(85.9)	610(90.6)	257(93.5)	1172(89.9)	0(0)
≤2h/d	75(11.8)	56(8.4)	50(14.1)	63(9.4)	18(6.5)	131(10.1)	
Spinal pain by region							
NP	150(23.7)	151(22.6)	85(23.9)	148(22.0)	68(24.7)	301(23.1)	0(0)
No NP	484(76.3)	518(77.4)	270(76.1)	525(78.0)	207(75.3)	1002(76.9)	
MBP	106(16.7)	133(19.9)	56(15.8)	118(17.6)	65(23.6)	239(18.4)	2(0.2)
No MBP	527(83.3)	535(80.1)	298(84.2)	554(82.4)	210(76.4	1062(81.6)	
LBP	84(13.3)	67(10.0)	33(9.3)	86(12.8)	32(11.6)	151(11.6)	3(0.2)
No LBP	548(86.7)	601(90.0)	320(90.7)	586(87.2)	243(88.4)	1149(88.4	
Spinal pain by number of regions							
0 No pain	400(63.4)	432(64.7)	232(65.7)	441(65.7)	159(57.8)	832(64.0)	4(0.3)
1 Region	146(23.1)	148(22.2)	78(22.1)	139(20.7)	77(28.0)	294(22.6)	4(0.3)
2 Regions	61(9.7)	61(9.1)	33(9.3)	60(8.9)	29(10.5)	122(9.4)	4(0.3)
3 Regions	24(3.8)	27(4.0)	10(2.8)	31(4.6)	10(3.6)	51(3.9)	4(0.3)
Non-trivial spinal pain by region							
NP	95(15.0)	88(13.2)	48(13.6)	90(13.4)	45(16.4)	183(14.1)	1(0.1)
No NP	538(85)	581(86.8)	306(86.4)	583(86.6)	230(83.6)	1119(85.9)	
MBP	70(11.1)	74(11.1)	28(7.9)	81(12.1)	35(12.7)	144(11.1)	2(0.2)
No MBP	563(88.9)	594(88.9)	326(92.1)	591(87.9)	240(87.3)	1157(88.9)	
LBP	55(8.7)	37(5.5)	23(6.5)	50(7.4)	19(6.9)	92(7.1)	3(0.2)
No LBP	577(91.3)	631(94.5)	330(93.5)	622(92.6)	256(93.1)	1208(92.9)	
Non-trivial spinal pain by number of regions							
0 No/Trivial Pain	469(74.4)	527(78.9)	279(79.3)	521(77.6)	196(71.3)	996(76.7)	5(0.4)
1 Region	117(18.6)	96(14.4)	51(14.5)	99(14.8)	63(22.9)	213(16.4)	5(0.4)
2 Regions	29(4.6)	32(4.8)	18(5.1)	31(4.6)	12(4.4)	61(4.7)	5(0.4)
3 Regions	15(2.4)	13(1.9)	4(1.1)	20(3.0)	4(1.5)	28(2.2)	5(0.4)

Key: percent in parenthesis (%); h/d, hours per day; y, years; F:M ratio; NP, neck pain; MBP, mid back pain; LBP, low back pain; TV/DVD, actively watching TV/DVD; Comp/Gaming, chatting or surfing the web, playing computer games, X-box or something similar; Other, sitting or lying reading, doing homework, being creative, listening to music etc.

Older adolescents and males more frequently exceeded sedentary behaviour recommendations. During the week 83.4% of 11-year-olds, 89.6% of 12-year-olds and 94.5% of 13-year-olds; 87.1% of females and 90.7% of males exceeded two hours of sedentary time outside of school hours per day. On the weekend 85.9% of 11-year-olds, 90.6% 12-year-olds, and 93.5% of 13-year-olds; 88.2% of females and 91.6% of males exceeded two hours per day of sedentary time.

Non-trivial neck pain (14.1% [95%CI: 12.2%-16.0%]) was more prevalent that non-trivial mid-back (11.1% [95%CI: 9.4%-12.8%]) and non-trivial low back pain (7.1% [95%CI: 5.7%-8.5%]). One region of non-trivial spinal pain (16.4% [95%CI: 14.4%-18.4%]) was more prevalent that two (4.7% [95%CI: 3.5%-5.9%]) or three (2.2% [95%CI: 1.4%-3.0%]) regions of non-trivial pain. This same pattern was seen for any spinal pain in the last week by region and number of regions (Table 4.1).

4.3 Main results: Primary and secondary analyses

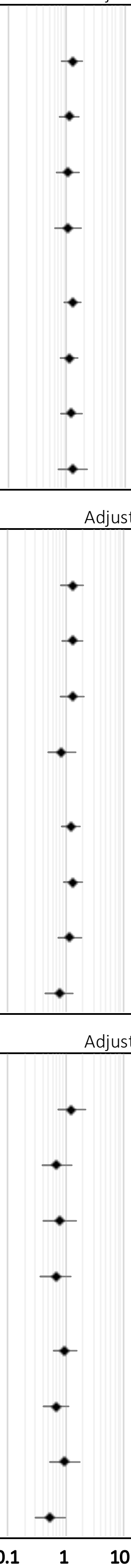
Overall, there was no association between exceeding two hours per day sedentary time and spinal pain in adolescents (Figure 4.2 and 4.3). There were a total of 48 primary analysis estimates of association, 46 adjusted estimates showed no association between sedentary behaviour and non-trivial neck pain (OR range: 1.04-1.26), mid-back pain (ORs range: 0.77-1.35), low back (ORs range: 0.55-1.28), one region of spinal pain (ORs range: 0.77-1.25), two regions of spinal pain (ORs range: 0.82-2.12), or three regions of spinal pain (ORs range: 0.43-1.42). The remaining two adjusted associations showed a moderate increased likelihood of exceeding two hours per day of sedentary behaviour and two regions of spinal pain (ORs range: 2.06-2.12). When associations were positive the unadjusted risk differences were also small, for example, adolescents that exceeded sedentary behaviour recommendations outside school on weekdays had a 4% greater risk of two regions of spinal pain than adolescents that met guideline recommendations.

Of the 48 secondary analysis associations, between sedentary behaviour and spinal pain (trivial and non-trivial) experienced in the last week, 45 adjusted estimates showed no association (ORs range: 0.39-1.47) (Figure 4.4-4.5). The remaining three adjusted estimates reported a small-moderate increased likelihood of experiencing neck pain or two regions of back pain when exceeding two hours per day of sedentary behaviour (ORs range:1.34-1.88).

Non-trivial neck pain		Risk (n/N)	Unadjusted OR	Adjusted OR
Weekday	TV/DVD			
	≤2 hours	14% (149/1097)		
	>2 hours	17% (34/205)	1.27 (0.84-1.9)	1.22 (0.81-1.84)
	Comp/Gaming			
	≤2 hours	14% (140/1013)		
	>2 hours	15% (43/289)	1.09 (0.75-1.58)	1.1 (0.75-1.61)
	Other			
	≤2 hours	14% (156/1118)		
	>2 hours	15% (27/184)	1.06 (0.68-1.65)	1.04 (0.67-1.62)
	Total			
	≤2 hours	13% (19/144)		
	>2 hours	14% (164/1158)	1.09 (0.65-1.81)	1.05 (0.63-1.76)
Weekend	TV/DVD			
	≤2 hours	13% (117/891)		
	>2 hours	16% (66/411)	1.27 (0.91-1.76)	1.25 (0.9-1.74)
	Comp/Gaming			
	≤2 hours	14% (116/844)		
	>2 hours	15% (67/459)	1.07 (0.77-1.48)	1.09 (0.78-1.53)
	Other			
	≤2 hours	14% (151/1105)		
	>2 hours	16% (32/197)	1.23 (0.81-1.86)	1.2 (0.79-1.82)
	Total			
	≤2 hours	11% (15/131)		
	>2 hours	14% (168/1171)	1.3 (0.74-2.27)	1.26 (0.72-2.23)

Non-trivial mid back pain		Risk (n/N)	Unadjusted OR	Adjusted OR
Weekday	TV/DVD			
	≤2 hours	11% (116/1096)		
	>2 hours	14% (28/205)	1.34 (0.86-2.08)	1.29 (0.83-2.01)
	Comp/Gaming			
	≤2 hours	10% (105/1012)		
	>2 hours	13% (39/289)	1.35 (0.91-2)	1.31 (0.88-1.97)
	Other			
	≤2 hours	11% (119/1118)		
	>2 hours	14% (25/183)	1.33 (0.84-2.11)	1.3 (0.82-2.07)
	Total			
	≤2 hours	12% (17/144)		
	>2 hours	11% (127/1157)	0.92 (0.54-1.58)	0.87 (0.5-1.49)
Weekend	TV/DVD			
	≤2 hours	10% (92/889)		
	>2 hours	13% (52/412)	1.25 (0.87-1.8)	1.23 (0.86-1.77)
	Comp/Gaming			
	≤2 hours	10% (84/843)		
	>2 hours	13% (60/458)	1.36 (0.96-1.94)	1.35 (0.93-1.95)
	Other			
	≤2 hours	11% (119/1104)		
	>2 hours	13% (25/197)	1.2 (0.76-1.91)	1.19 (0.75-1.89)
	Total			
	≤2 hours	13% (17/131)		
	>2 hours	11% (127/1171)	0.82 (0.47-1.4)	0.77 (0.45-1.34)

Non-trivial low back pain		Risk (n/N)	Unadjusted OR	Adjusted OR
Weekday	TV/DVD			
	≤2 hours	7% (74/1095)		
	>2 hours	9% (18/205)	1.33 (0.78-2.27)	1.28 (0.75-2.21)
	Comp/Gaming			
	≤2 hours	8% (77/1010)		
	>2 hours	5% (15/289)	0.66 (0.38-1.17)	0.71 (0.4-1.28)
	Other			
	≤2 hours	7% (81/1117)		
	>2 hours	6% (11/183)	0.82 (0.43-1.57)	0.8 (0.41-1.53)
	Total			
	≤2 hours	10% (14/144)		
	>2 hours	7% (78/1156)	0.67 (0.37-1.22)	0.67 (0.37-1.23)
Weekend	TV/DVD			
	≤2 hours	7% (63/889)		
	>2 hours	7% (29/412)	0.99 (0.63-1.56)	0.99 (0.62-1.56)
	Comp/Gaming			
	≤2 hours	8% (68/843)		
	>2 hours	5% (24/457)	0.63 (0.39-1.02)	0.69 (0.42-1.13)
	Other			
	≤2 hours	7% (78/1103)		
	>2 hours	7% (14/197)	1.01 (0.56-1.81)	0.97 (0.54-1.76)
	Total			
	≤2 hours	11% (15/131)		
	>2 hours	7% (77/1168)	0.55 (0.3-0.98)	0.55 (0.3-0.99)



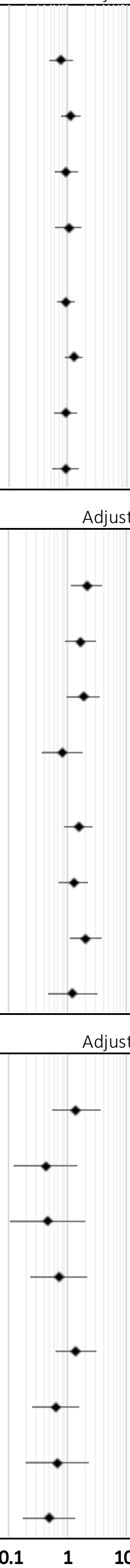
Key: Risk(n/N), prevalence with outcome over exposure in parentheses; Unadjusted OR, odds ratio with 95% confidence intervals; Adjusted OR, adjusted for age and sex.

Figure 4.2 Estimates of association between sedentary behaviour exceeding two hours per day and non-trivial spinal pain in the last week by region

One region non-trivial SP		Risk (n/N)	Unadjusted OR	Adjusted OR
Weekday	TV/DVD			
	≤2 hours	17% (185/1093)		
	>2 hours	14% (28/205)	0.83 (0.54-1.28)	0.77 (0.5-1.19)
	Comp/Gaming			
	≤2 hours	16% (163/1009)		
	>2 hours	17% (50/289)	1.1 (0.78-1.56)	1.12 (0.78-1.61)
	Other			
	≤2 hours	17% (184/1115)		
	>2 hours	16% (29/183)	0.98 (0.64-1.51)	0.94 (0.61-1.45)
	Total			
	≤2 hours	15% (22/144)		
	>2 hours	17% (191/1154)	1.08 (0.66-1.75)	1.01 (0.62-1.66)
Weekend	TV/DVD			
	≤2 hours	17% (149/887)		
	>2 hours	16% (64/411)	0.95 (0.69-1.31)	0.92 (0.67-1.28)
	Comp/Gaming			
	≤2 hours	16% (131/841)		
	>2 hours	18% (82/457)	1.19 (0.87-1.61)	1.25 (0.91-1.72)
	Other			
	≤2 hours	17% (183/1102)		
	>2 hours	15% (30/196)	0.95 (0.62-1.45)	0.91 (0.59-1.4)
	Total			
	≤2 hours	17% (22/131)		
	>2 hours	16% (191/1167)	0.96 (0.59-1.56)	0.91 (0.56-1.49)

Two regions non-trivial SP		Risk (n/N)	Unadjusted OR	Adjusted OR
Weekday	TV/DVD			
	≤2 hours	4% (44/1092)		
	>2 hours	8% (17/205)	2.11 (1.18-3.79)	**2.12 (1.18-3.82)**
	Comp/Gaming			
	≤2 hours	4% (42/1010)		
	>2 hours	7% (19/289)	1.62 (0.93-2.85)	1.67 (0.94-2.99)
	Other			
	≤2 hours	4% (47/1114)		
	>2 hours	8% (14/183)	1.85 (0.99-3.45)	1.85 (0.99-3.46)
	Total			
	≤2 hours	6% (8/144)		
	>2 hours	5% (53/1155)	0.82 (0.38-1.78)	0.82 (0.38-1.78)
Weekend	TV/DVD			
	≤2 hours	4% (37/911)		
	>2 hours	6% (25/411)	1.53 (0.9-2.59)	1.53 (0.9-2.59)
	Comp/Gaming			
	≤2 hours	4% (37/841)		
	>2 hours	5% (24/457)	1.23 (0.72-2.09)	1.26 (0.72-2.19)
	Other			
	≤2 hours	4% (45/1103)		
	>2 hours	8% (16/196)	2.05 (1.13-3.73)	**2.06 (1.13-3.74)**
	Total			
	≤2 hours	4% (5/131)		
	>2 hours	5% (56/1167)	1.24 (0.48-3.16)	1.24 (0.48-3.18)

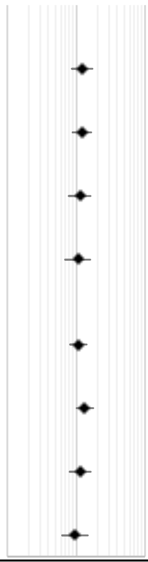
Three regions non-trivial SP		Risk (n/N)	Unadjusted OR	Adjusted OR
Weekday	TV/DVD			
	≤2 hours	2% (22/1095)		
	>2 hours	3% (6/205)	1.49 (0.59-3.74)	1.42 (0.57-3.59)
	Comp/Gaming			
	≤2 hours	2% (25/1008)		
	>2 hours	1% (3/288)	0.43 (0.13-1.44)	0.43 (0.13-1.45)
	Other			
	≤2 hours	2% (26/1116)		
	>2 hours	1% (2/183)	0.48 (0.11-2.04)	0.46 (0.11-1.98)
	Total			
	≤2 hours	3% (4/144)		
	>2 hours	2% (24/1154)	0.74 (0.25-2.19)	0.71 (0.24-2.12)
Weekend	TV/DVD			
	≤2 hours	2% (17/885)		
	>2 hours	3% (11/410)	1.43 (0.66-3.08)	1.41 (0.65-3.04)
	Comp/Gaming			
	≤2 hours	3% (21/840)		
	>2 hours	2% (7/458)	0.63 (0.27-1.5)	0.63 (0.26-1.55)
	Other			
	≤2 hours	2% (25/1101)		
	>2 hours	2% (3/196)	0.69 (0.21-2.32)	0.67 (0.2-2.26)
	Total			
	≤2 hours	4% (5/131)		
	>2 hours	2% (23/1168)	0.51 (0.19-1.37)	0.49 (0.18-1.32)



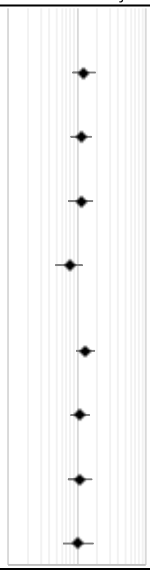
Key: Risk(n/N), prevalence with outcome over exposure in parentheses; Unadjusted OR, odds ratio with 95% confidence intervals; Adjusted OR, adjusted for age and sex; bold, positive association.

Figure 4.3 Estimates of association between sedentary behaviour exceeding two hours per day and non-trivial spinal pain in the last week by number of regions

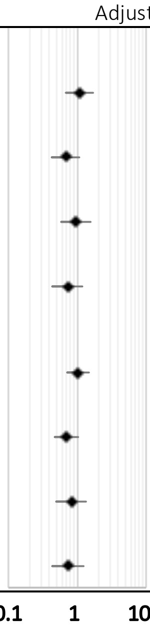
Neck Pain			Risk (n/N)	Unadjusted OR	Adjusted OR
Weekday	TV/DVD				
		≤2 hours	23% (247/1098)		
		>2 hours	26% (54/205)	1.23 (0.88-1.73)	1.22 (0.87-1.72)
	Comp/Gaming				
		≤2 hours	22% (227/1014)		
		>2 hours	26% (74/289)	1.19 (0.88-1.61)	1.21 (0.89-1.65)
	Other				
		≤2 hours	23% (255/1119)		
		>2 hours	25% (46/184)	1.13 (0.79-1.62)	1.12 (0.78-1.61)
	Total				
		≤2 hours	22% (32/144)		
		>2 hours	23% (269/1159)	1.06 (0.7-1.6)	1.05 (0.69-1.6)
Weekend	TV/DVD				
		≤2 hours	23% (202/891)		
		>2 hours	24% (99/412)	1.08 (0.82-1.42)	1.08 (0.82-1.42)
	Comp/Gaming				
		≤2 hours	21% (181/844)		
		>2 hours	26% (120/459)	1.3 (0.99-1.69)	**1.34 (1.02-1.77)**
	Other				
		≤2 hours	23% (251/1105)		
		>2 hours	25% (50/198)	1.15 (0.81-1.63)	1.14 (0.8-1.62)
	Total				
		≤2 hours	24% (31/131)		
		>2 hours	23% (270/1172)	0.97 (0.63-1.48)	0.96 (0.63-1.47)



Mid back pain			Risk (n/N)	Unadjusted OR	Adjusted OR
Weekday	TV/DVD				
		≤2 hours	18% (194/1096)		
		>2 hours	22% (45/205)	1.31 (0.91-1.88)	1.27 (0.88-1.84)
	Comp/Gaming				
		≤2 hours	18% (178/1012)		
		>2 hours	21% (61/289)	1.25 (0.91-1.74)	1.16 (0.83-1.62)
	Other				
		≤2 hours	18% (202/1118)		
		>2 hours	20% (37/183)	1.15 (0.78-1.7)	1.13 (0.77-1.68)
	Total				
		≤2 hours	21% (30/144)		
		>2 hours	18% (209/1157)	0.84 (0.55-1.29)	0.77 (0.5-1.19)
Weekend	TV/DVD				
		≤2 hours	17% (150/889)		
		>2 hours	22% (89/412)	1.36 (1.01-1.82)	1.34 (1-1.79)
	Comp/Gaming				
		≤2 hours	17% (146/843)		
		>2 hours	20% (93/458)	1.22 (0.91-1.62)	1.12 (0.83-1.52)
	Other				
		≤2 hours	18% (200/1104)		
		>2 hours	20% (39/197)	1.12 (0.76-1.64)	1.11 (0.76-1.63)
	Total				
		≤2 hours	17% (22/131)		
		>2 hours	19% (217/1170)	1.13 (0.7-1.83)	1.05 (0.65-1.71)



Low back pain			Risk (n/N)	Unadjusted OR	Adjusted OR
Weekday	TV/DVD				
		≤2 hours	11% (125/1095)		
		>2 hours	13% (26/205)	1.13 (0.72-1.77)	1.08 (0.68-1.7)
	Comp/Gaming				
		≤2 hours	12% (126/1011)		
		>2 hours	9% (25/289)	0.67 (0.42-1.04)	0.68 (0.43-1.07)
	Other				
		≤2 hours	12% (130/1117)		
		>2 hours	11% (21/183)	0.98 (0.6-1.61)	0.96 (0.58-1.56)
	Total				
		≤2 hours	15% (21/144)		
		>2 hours	11% (130/1156)	0.74 (0.45-1.22)	0.72 (0.43-1.19)
Weekend	TV/DVD				
		≤2 hours	11% (102/888)		
		>2 hours	12% (49/412)	1.04 (0.72-1.49)	1.03 (0.71-1.48)
	Comp/Gaming				
		≤2 hours	13% (109/843)		
		>2 hours	9% (42/457)	0.68 (0.47-0.99)	0.7 (0.47-1.03)
	Other				
		≤2 hours	12% (131/1103)		
		>2 hours	10% (20/197)	0.84 (0.51-1.38)	0.81 (0.49-1.34)
	Total				
		≤2 hours	15% (19/131)		
		>2 hours	11% (132/1169)	0.75 (0.45-1.26)	0.73 (0.43-1.24)



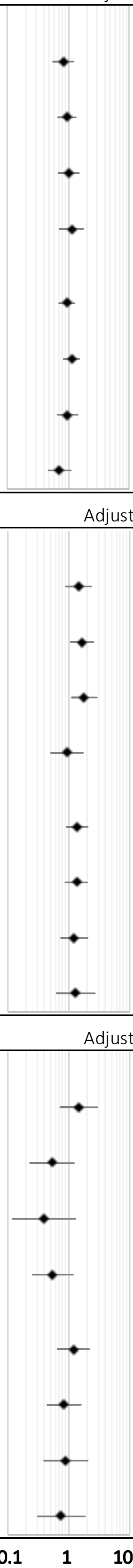
Key: Risk(n/N), prevalence with outcome over exposure in parentheses; Unadjusted OR, odds ratio with 95% confidence intervals; Adjusted OR, adjusted for age and sex; bold, positive association.

Figure 4.4 Estimates of association between sedentary behaviour exceeding two hours per day and spinal pain in the last week by region

One region spinal pain			Risk (n/N)	Unadjusted OR	Adjusted OR
Weekday	TV/DVD				
		≤2 hours	23% (254/1094)		
		>2 hours	20% (40/205)	0.87 (0.59-1.27)	0.83 (0.57-1.22)
	Comp/Gaming				
		≤2 hours	23% (231/1010)		
		>2 hours	22% (63/289)	0.98 (0.71-1.36)	0.96 (0.69-1.33)
	Other				
		≤2 hours	23% (253/1116)		
		>2 hours	22% (41/183)	1.04 (0.71-1.53)	1.02 (0.69-1.5)
	Total				
		≤2 hours	19% (28/144)		
		>2 hours	23% (266/1155)	1.2 (0.77-1.87)	1.14 (0.73-1.78)
Weekend	TV/DVD				
		≤2 hours	23% (205/887)		
		>2 hours	22% (89/412)	0.97 (0.72-1.29)	0.95 (0.71-1.27)
	Comp/Gaming				
		≤2 hours	22% (185/842)		
		>2 hours	24% (109/457)	1.14 (0.87-1.51)	1.14 (0.85-1.52)
	Other				
		≤2 hours	23% (250/1102)		
		>2 hours	22% (44/197)	1 (0.69-1.46)	0.99 (0.68-1.44)
	Total				
		≤2 hours	27% (36/131)		
		>2 hours	22% (258/1168)	0.76 (0.5-1.16)	0.73 (0.48-1.11)

Two regions spinal pain			Risk (n/N)	Unadjusted OR	Adjusted OR
Weekday	TV/DVD				
		≤2 hours	9% (96/1093)		
		>2 hours	13% (26/205)	1.49 (0.93-2.39)	1.45 (0.9-2.34)
	Comp/Gaming				
		≤2 hours	8% (84/1010)		
		>2 hours	13% (38/289)	1.63 (1.07-2.47)	**1.66 (1.08-2.55)**
	Other				
		≤2 hours	9% (95/1116)		
		>2 hours	15% (27/183)	1.83 (1.14-2.93)	**1.8 (1.12-2.89)**
	Total				
		≤2 hours	10% (14/144)		
		>2 hours	9% (108/1155)	0.97 (0.53-1.76)	0.94 (0.51-1.72)
Weekend	TV/DVD				
		≤2 hours	8% (75/887)		
		>2 hours	11% (47/412)	1.39 (0.94-2.07)	1.38 (0.93-2.05)
	Comp/Gaming				
		≤2 hours	9% (73/842)		
		>2 hours	11% (49/457)	1.3 (0.88-1.92)	1.33 (0.89-2)
	Other				
		≤2 hours	9% (100/1103)		
		>2 hours	11% (22/197)	1.26 (0.76-2.07)	1.24 (0.75-2.04)
	Total				
		≤2 hours	7% (9/131)		
		>2 hours	10% (113/1169)	1.34 (0.65-2.74)	1.3 (0.63-2.68)

Three regions spinal pain			Risk (n/N)	Unadjusted OR	Adjusted OR
Weekday	TV/DVD				
		≤2 hours	4% (40/1093)		
		>2 hours	5% (11/205)	1.51 (0.76-3.03)	1.47 (0.73-2.95)
	Comp/Gaming				
		≤2 hours	4% (44/1009)		
		>2 hours	2% (7/289)	0.57 (0.25-1.29)	0.53 (0.23-1.22)
	Other				
		≤2 hours	4% (48/1116)		
		>2 hours	2% (3/183)	0.4 (0.12-1.31)	0.39 (0.12-1.29)
	Total				
		≤2 hours	6% (9/144)		
		>2 hours	4% (42/1154)	0.59 (0.28-1.25)	0.55 (0.26-1.18)
Weekend	TV/DVD				
		≤2 hours	4% (33/887)		
		>2 hours	4% (18/412)	1.21 (0.67-2.2)	1.2 (0.66-2.17)
	Comp/Gaming				
		≤2 hours	4% (35/841)		
		>2 hours	4% (16/457)	0.89 (0.48-1.63)	0.84 (0.45-1.58)
	Other				
		≤2 hours	4% (44/1103)		
		>2 hours	4% (7/197)	0.91 (0.4-2.06)	0.9 (0.4-2.04)
	Total				
		≤2 hours	5% (6/131)		
		>2 hours	4% (45/1169)	0.8 (0.33-1.93)	0.76 (0.31-1.84)



Key: Risk(n/N), prevalence with outcome over exposure in parentheses; Unadjusted OR, odds ratio with 95% confidence intervals; Adjusted OR, adjusted for age and sex; bold, positive association.

Figure 4.5 Estimates of association between sedentary behaviour exceeding two hours per day and spinal pain in the last week by number of regions

4.4 Other results: Sensitivity and exploratory analyses

There were a total of 96 adjusted estimates of association from sensitivity analyses that assessed sedentary behaviour exceeding five hours per day and spinal pain (Table 4.2 and 4.3). Six associations reported a moderate increased likelihood of non-trivial neck pain, mid-back pain and two regions of spinal pain (ORs range: 1.73-4.09). Seven associations reported a moderate increased likelihood of any neck pain, mid-back pain, low back pain and two regions of spinal pain (ORs range: 1.62-2.95). The remaining 83 report no association (ORs range: 0.63-2.94).

Exploratory analyses investigated the association between sedentary behaviour exceeding either two hours per day or five hours per day of sedentary time and experiencing frequent non-trivial spinal (Table 4.4 and 4.5). There was one positive association, out of 48, showing a moderate likelihood of association when exceeding two hours per day of TV or DVD and frequent non-trivial two regions of spinal pain (OR 1.71 [95%CIs: 1.13-2.6]). The remaining 47 adjusted estimates showed no association (ORs range: 0.69-1.63). Of the 48 associations between exceeding five hours per day of sedentary behaviour and frequent non-trivial spinal pain; six showed a positive association (ORs range: 1.42-2.12) and 42 reported no association (ORs range: 0.21-4.27).

Table 4.2 Sensitivity analyses adjusted odds ratios with 95% confidence intervals for sedentary behaviour exceeding five hours per day non-trivial spinal pain in the last week.

	Non-trivial spinal pain in the last week by region			Non-trivial spinal pain in the last week by number of regions		
	Neck	Mid-back	Low back	One region	Two regions	Three regions
Sedentary behaviour on weekdays outside school hours						
TV/DVD >5h/d	1.82 (0.72-4.61)	1.38 (0.46-4.08)	1.84 (0.54-6.30)	0.99 (0.33-2.97)	2.84 (0.81-10.00)	1.97 (0.25-15.49)
≤5h/d	-	-	-	-	-	-
Comp/Gaming >5h/d	0.83 (0.38-1.78)	0.89 (0.39-2.01)	0.67 (0.20-2.22)	0.97 (0.49-1.92)	0.62 (0.15-2.65)	0.67 (0.09-5.15)
≤5h/d	-	-	-	-	-	-
Other >5h/d	**2.59 (1.30-5.16)**	**3.01 (1.47-6.14)**	1.05 (0.32-3.48)	1.49 (0.66-3.37)	**4.09(1.61-10.35)**	2.94(0.66-13.08)
≤5h/d	-	-	-	-	-	-
Total >5h/d	1.00 (0.73-1.37)	1.32 (0.93-1.87)	1.22 (0.79-1.87)	1.04 (0.77-1.41)	**1.73 (1.02-2.93)**	0.86 (0.4-1.86)
≤5h/d	-	-	-	-	-	-
Sedentary behaviour on weekend days						
TV/DVD >5h/d	1.32 (0.72-2.40)	1.27 (0.66-2.47)	1.33 (0.59-2.99)	0.76 (0.38-1.52)	**2.36 (1.07-5.21)**	1.20 (0.28-5.19)
≤5h/d	-	-	-	-	-	-
Comp/Gaming	1.20 (0.72-1.98)	1.58 (0.94-2.64)	0.93 (0.43-1.99)	1.09 (0.66-1.80)	**2.13 (1.05-4.32)**	0.73 (0.17-3.17)
≤5h/d	-	-	-	-	-	-
Other >5h/d	1.33 (0.58-3.06)	1.76 (0.76-4.06)	1.53 (0.53-4.40)	0.63 (0.22-1.82)	2.26 (0.77-6.64)	2.53 (0.57-11.16)
≤5h/d	-	-	-	-	-	-
Total >5h/d	1.31 (0.93-1.83)	1.00 (0.69-1.43)	0.87 (0.56-1.36)	1.21 (0.88-1.66)	1.51 (0.85-2.68)	0.61 (0.29-1.32)
≤5h/d	-	-	-	-	-	-

Key: h/d, hours per day; TV/DVD, actively watching TV/DVD; Comp/Gaming, chatting or surfing the web, playing computer games, X-box or something similar; Other, sitting or lying reading, doing homework, being creative, listening to music etc; bold, positive association.

Table 4.3 Sensitivity analyses adjusted odds ratios with 95% confidence intervals for sedentary behaviour exceeding five hours per day and spinal pain in the last week.

	Spinal pain in the last week by region			Spinal pain in the last week by number of regions		
	Neck	Mid-back	Low back	One region	Two regions	Three regions
Sedentary behaviour on weekdays outside school hours						
TV/DVD >5h/d	1.23 (0.51-2.96)	1.21 (0.48-3.05)	1.38 (0.47-4.11)	0.46 (0.13-1.60)	1.57 (0.52-4.79)	1.83 (0.41-8.23)
≤5h/d	-	-	-	-	-	-
Comp/Gaming >5h/d	1.09 (0.61-1.97)	1.30 (0.72-2.36)	0.77 (0.32-1.83)	0.93 (0.49-1.75)	1.55 (0.72-3.32)	0.74 (0.17-3.20)
≤5h/d	-	-	-	-	-	-
Other >5h/d	**1.90 (1.00-3.63)**	**2.02 (1.03-3.95)**	1.05 (0.41-2.73)	1.17 (0.53-2.57)	**2.95 (1.33-6.59)**	1.50 (0.34-6.56)
≤5h/d	-	-	-	-	-	-
Total >5h/d	0.99 (0.76-1.29)	1.16 (0.88-1.54)	1.23 (0.88-1.74)	1.02 (0.78-1.34)	1.38 (0.94-2.03)	0.95 (0.53-1.68)
≤5h/d	-	-	-	-	-	-
Sedentary behaviour on weekend days						
TV/DVD >5h/d	1.29 (0.77-2.14)	1.26 (0.73-2.17)	**1.87 (1.03-3.38)**	0.88 (0.48-1.61)	**2.15 (1.14-4.05)**	1.39 (0.48-4.03)
≤5h/d	-	-	-	-	-	-
Comp/Gaming	1.26 (0.83-1.91)	1.38 (0.89-2.13)	0.93 (0.52-1.69)	0.84 (0.52-1.36)	**2.11 (1.24-3.58)**	0.75 (0.26-2.18)
≤5h/d	-	-	-	-	-	-
Other >5h/d	0.83 (0.38-1.82)	1.11 (0.50-2.45)	0.86 (0.30-2.46)	0.60 (0.25-1.48)	0.98 (0.34-2.85)	1.18 (0.27-5.09)
≤5h/d	-	-	-	-	-	-
Total >5h/d	1.16 (0.89-1.53)	1.20 (0.88-1.62)	0.84 (0.59-1.20)	1.04 (0.78-1.37)	**1.62 (1.06-2.48)**	0.73 (0.41-1.30)
≤5h/d	-	-	-	-	-	-

Key: h/d, hours per day; TV/DVD, actively watching TV/DVD; Comp/Gaming, chatting or surfing the web, playing computer games, X-box or something similar; Other, sitting or lying reading, doing homework, being creative, listening to music etc; bold, positive association.

Table 4.4 Adjusted odds ratios with 95% confidence intervals for sedentary behaviour exceeding two hours per day and frequent non-trivial spinal pain in the last week.

	Frequent non-trivial spinal pain by region			Frequent non-trivial spinal pain by number of regions		
	Neck	Mid-back	Low back	One region	Two regions	Three regions
Sedentary behaviour on weekdays outside school hours						
TV/DVD >2h/d	1.13 (0.78-1.63)	1.18 (0.78-1.79)	1.36 (0.82-2.26)	1.01 (0.69-1.50)	1.35 (0.80-2.28)	1.43 (0.57-3.59)
≤2h/d	-	-	-	-	-	-
Comp/Gaming >5h/d	1.25 (0.90-1.74)	1.28 (0.88-1.87)	0.77 (0.45-1.32)	1.24 (0.88-1.74)	1.35 (0.83-2.22)	0.78 (0.29-2.11)
≤2h/d	-	-	-	-	-	-
Other >2h/d	0.92 (0.61-1.37)	1.34 (0.87-2.04)	1.01 (0.57-1.80)	1.03 (0.68-1.54)	1.34 (0.78-2.31)	0.71 (0.21-2.40)
≤2h/d	-	-	-	-	-	-
Total >2h/d	1.12 (0.71-1.77)	1.02 (0.61-1.72)	0.94 (0.50-1.77)	0.99 (0.62-1.57)	1.33 (0.65-2.74)	0.78 (0.26-2.32)
≤2h/d	-	-	-	-	-	-
Sedentary behaviour on weekend days						
TV/DVD >2h/d	1.17 (0.87-1.57)	1.22 (0.87-1.70)	1.06 (0.69-1.63)	0.92 (0.67-1.25)	**1.71 (1.13-2.60)**	0.84 (0.37-1.92)
≤2h/d	-	-	-	-	-	-
Comp/Gaming	1.19 (0.88-1.61)	1.07 (0.76-1.51)	0.95 (0.60-1.48)	1.11 (0.81-1.51)	1.37 (0.88-2.13)	0.73 (0.31-1.71)
≤2h/d	-	-	-	-	-	-
Other >2h/d	1.13 (0.78-1.64)	1.20 (0.79-1.83)	1.54 (0.93-2.54)	1.12 (0.76-1.66)	1.63 (0.98-2.71)	0.95 (0.32-2.76)
≤2h/d	-	-	-	-	-	-
Total >2h/d	1.25 (0.76-2.04)	0.85 (0.51-1.41)	0.69 (0.38-1.26)	1.01 (0.62-1.64)	1.05 (0.52-2.09)	0.69 (0.23-2.05)
≤2h/d	-	-	-	-	-	-

Key: h/d, hours per day; TV/DVD, actively watching TV/DVD; Comp/Gaming, chatting or surfing the web, playing computer games, X-box or something similar; Other, sitting or lying reading, doing homework, being creative, listening to music etc; bold, positive association.

Table 4.5 Adjusted odds ratios with 95% confidence intervals for sedentary behaviour exceeding five hours per day and frequent non-trivial spinal pain in the last week.

	Frequent non-trivial spinal pain by region			Frequent non-trivial spinal pain by number of regions		
	Neck	Mid-back	Low back	One region	Two regions	Three regions
Sedentary behaviour on weekdays outside school hours						
TV/DVD >5h/d	1.85 (0.79-4.33)	1.16 (0.39-3.42)	**1.53 (1.02-2.31)**	1.35 (0.52-3.52)	1.22 (0.27-5.41)	4.27 (0.92-19.79)
≤5h/d	-	-	-	-	-	-
Comp/Gaming >5h/d	0.92 (0.48-1.77)	1.19 (0.59-2.4)	0.58 (0.18-1.91)	1.40 (0.77-2.52)	0.21 (0.03-1.56)	1.48 (0.33-6.62)
≤5h/d	-	-	-	-	-	-
Other >5h/d	1.74 (0.87-3.46)	1.81 (0.85-3.86)	0.59 (0.14-2.50)	1.92 (0.95-3.91)	1.56 (0.53-4.58)	1.32 (0.17-10.07)
≤5h/d	-	-	-	-	-	-
Total >5h/d	1.12 (0.85-1.48)	**1.42 (1.03-1.96)**	**1.53 (1.02-2.31)**	1.10 (0.82-1.47)	**1.92 (1.26-2.93)**	0.99 (0.47-2.10)
≤5h/d	-	-	-	-	-	-
Sedentary behaviour on weekend days						
TV/DVD >5h/d	1.14 (0.65-1.98)	1.39 (0.76-2.54)	1.36 (0.63-2.92)	0.64 (0.32-1.28)	1.74 (0.86-3.54)	1.77 (0.52-6.05)
≤5h/d	-	-	-	-	-	-
Comp/Gaming	1.11 (0.70-1.75)	1.47 (0.90-2.41)	0.80 (0.37-1.7)	1.27 (0.80-2.00)	1.15 (0.57-2.33)	1.12 (0.32-3.85)
≤5h/d	-	-	-	-	-	-
Other >5h/d	1.07 (0.48-2.35)	1.93 (0.90-4.12)	2.19 (0.89-5.37)	**2.12 (1.03-4.34)**	1.67 (0.56-4.93)	1.43 (0.19-10.97)
≤5h/d	-	-	-	-	-	-
Total >5h/d	**1.46 (1.08-1.97)**	1.11 (0.80-1.56)	1.12 (0.73-1.71)	1.31 (0.97-1.78)	1.55 (0.99-2.43)	0.92 (0.43-1.98)
≤5h/d	-	-	-	-	-	-

Key: h/d, hours per day; TV/DVD, actively watching TV/DVD; Comp/Gaming, chatting or surfing the web, playing computer games, X-box or something similar; Other, sitting or lying reading, doing homework, being creative, listening to music etc; bold, positive association.

Chapter Five. Discussion

5.1 Summary of main findings

The findings of the two projects within this thesis collectively challenge current clinical and public beliefs regarding sedentary behaviour as a risk factor for adolescent back pain. Results of the systematic review in Chapter two did not support a meaningful association between sedentary behaviour and spinal pain in adolescents, and the cross-sectional analysis in Chapters three and four found no association between exceeding two hours of sedentary time per day (as per international guidelines) and any definition of spinal pain in adolescents.

5.1.1 Summary of systematic review findings

The first aim of this thesis was to critically appraise the existing literature to investigate the epidemiological relationship between sedentary behaviour and spinal pain (neck, mid-back, and low back) in adolescents. The systematic review found that the majority of published estimates of association (63%) show no relationship exists between sedentary behaviour, of different types and varying durations, and adolescent spinal pain. There were 35% positive associations reported of which the unadjusted estimates were weak to moderate (ORs range: 1.05-4.34) and adjusted estimates weak (ORs range: 1.0-2.5). All positive associations were drawn from cross-sectional studies, and therefore the direction of the association was unknown. That is, it was unclear if sedentary behaviour increased the likelihood of spinal pain, or if spinal pain increased the likelihood of sedentary behaviour. The remaining 2% of published association estimates reported a negative relationship, namely that sedentary behaviour was protective for spinal pain. All negative association estimates were derived from unadjusted estimates in cross-sectional studies. These findings imply there is no strong evidence to support a positive association between engaging in sedentary behaviour and experiencing spinal pain in adolescents. However, much uncertainty remains as the available studies were methodologically and statistically heterogeneous, predominantly cross-sectional (96%), and of low to moderate quality.

5.1.2 Summary of cross-sectional analysis findings

The second aim of this thesis was to investigate whether exceeding two hours per day of sedentary time (per international recommendations) was associated with non-trivial spinal pain in a nationally representative population of 11-13 year old Danes.[51,113] The cross-sectional analysis found adolescents who spend more than two hours per day sedentary were not at a significantly higher likelihood of spinal pain (trivial or non-trivial) (ORs range: 0.39-2.12) compared to adolescents that met the sedentary behaviour guidelines (less than two hours per day). Further, sensitivity analyses found exceeding five hours per day of sedentary time was associated with a moderate increased likelihood of two regions (neck and mid-back) of spinal pain (trivial and non-trivial) (ORs range: 1.62-4.09). Of the three different sedentary behaviour types assessed (watching TV, using the computer or gaming, or other sedentary behaviours) 46% of these positive associations came from 'other' sedentary behaviours. These findings show a potential association might remain between longer engagement in sedentary behaviours and upper spinal pain (neck and mid back).

For 11-13 year old Danes, non-trivial neck pain (14.1% [95%CI: 12.2%-16.0%]) was more prevalent that non-trivial mid-back pain (11.1% [95%CI: 9.4%-12.8%]) and non-trivial low back pain (7.1% [95%CI: 5.7%-8.5%]). The higher prevalence of non-trivial upper back pain (neck and mid back) compared to non-trivial low back pain in this age group may be an important new finding as back pain research highlights the higher prevalence of low back pain in the adult population. The higher frequency of upper back pain in young adolescents may represent that spinal pain starts here and changes location by adulthood.

5.2 Implications of findings

5.2.1 Implications for clinicians

The collective findings of this thesis can be implemented in evidence-based clinical management strategies for spinal pain in adolescents. For example, O'Sullivan et al. provide a clinical framework for the triage, profiling, and targeted management of spinal pain in adolescents.[6] In all cases of spinal pain, trivial and non-trivial, the authors advocate that clinicians explain the factors associated with spinal pain. For non-trivial cases of spinal pain, the authors advocate clinicians first address issues relating to incorrect beliefs and behaviours for spinal pain, such as inadequate activity and lifestyle factors. Recent research shows obesity, backpacks, hypermobility and sports participation are inconsistently, and at best minimally, linked with spinal pain.[6,20,24] Sedentary behaviour may now fall in with these other risk factors that have all been shown unlikely to have a causal relationship with spinal pain. Incorrect beliefs surrounding the perceived causal relationship between sedentary behaviour and spinal pain are typically hypothesised via a mechanistic association. This belief may negatively influence both adolescent and carer perceptions around spine resilience.[6,32] Educating adolescents, and carers, about health and lifestyle behaviours as risk factors for spinal pain, aligns with a more contemporary evidence-based model of care.[1,31] Clinicians may need to step away from dated mechanical, and pain focused, beliefs and instead highlight social factors (for example, substance use, physical activity engagement) and psychological factors (for example, stress, depression, poor coping) that are more strongly linked to non-trivial adolescent spinal pain.[31] In a study by Batley et al, using the same SPACE dataset as our study, psychological factors were found to be positively associated with substantial spinal pain males (OR1.82[95%CI1.02-3.26] as was loneliness with substantial spinal pain in females (OR1.70[05%CI1.02-2.86]).[118]

Mechanical and self-limiting spinal pain in adolescence is common.[7,11] Recent research suggests non-trivial spinal pain may warrant more attention as prevalence increases with age.[12,26] In the cross-sectional analysis non-trivial spinal pain was present in almost one quarter (23%) of 11-13 year old Danes. Work by Aartun et al. and Dissing et al. speak to the necessity in demarcating trivial adolescent spinal pain from non-trivial.[12,26] Trivial episodes of spinal pain are fleeting and non-impactful while non-trivial episodes increase the risk of back pain later in life.[12,14,26] Thus, there is a compelling argument that trivial spinal pain events should be skilfully overlooked by clinicians, in the best interest of the adolescent, in an endeavour to reduce over-medicalising trivial everyday aches and pains.[1]

5.2.2 Implications for public health policy

The collective findings of this thesis suggest public health policy may better emphasise the more prominent social and psychological risk factors, mentioned above, that are more strongly linked to adolescent back pain rather than sedentary behaviour.[31] Our cross-sectional analysis has highlighted that two hours per day of sedentary time is not related to adolescent spinal pain. Notwithstanding, sedentary behaviour recommendations in public health guidelines are not explicitly set for spinal pain, but general health. The findings of this thesis suggest end users, such as policymakers and clinicians, can inform adolescents, or their carers, that there is insufficient evidence that exceeding sedentary behaviour recommendations is not directly linked to spinal pain. Commonly promoted colloquial spine pain terms such as 'iPosture' and 'Text Neck' attribute sedentary behaviour as the cause. However, these notions promoted by the media and other sources are not congruent with current evidence.

The cross-sectional analysis reported that during the week, outside school hours, 89.9% (95%CI: 88.3%-91.5%) of adolescent Danes exceeded the two hours per day sedentary recommendation and 89.9% (95%CI: 87.2%-90.6%) exceeded the recommendation on the weekend. These findings are comparable with a 2017 Canadian study that found 91% of 22,115 10-17 year-olds exceeded the two-hour per day screen-time recommendation.[56] The cross-sectional sensitivity analyses also showed a potential association might remain between longer duration of sedentary behaviour and upper spinal pain (neck and mid back). This is a common postulation in the field. Costigan et al. (2013) concluded that a positive association might exist between longer sedentary behaviour duration and musculoskeletal pain.[119] Kuo et al. (2012) concluded increased duration of computer use was likely associated with neck pain.[120] Toh et al. (2017) concluding aspects of the use of touchscreen devices (duration of use, awkward posture, screen size, and task) might be associated with musculoskeletal symptoms.[121] Thus, public awareness via dissemination of the public health sedentary behaviour guidelines may aid in developing appropriate behaviour around the duration of sedentary engagement.

5.3 Strengths and limitations

5.3.1 Systematic literature review strengths and limitations

The findings from this thesis align with a recent (2018) systematic review by Calvo-Munoz et al., on the risk factors for low back pain in childhood and adolescence.[18] This study found that most of the included studies support the notion that sitting was not a significant determinant of low back pain in children and adolescents. Although previous systematic reviews have covered various relationships between multiple risk factors for musculoskeletal pain (including back pain) across varied age ranges, these reviews draw conflicting conclusions. Inconsistencies in conclusions may be related to the heterogeneity that exists between included studies. Another possibility is that broad systematic reviews may fail to capture all available studies for a specific risk factor, such as sedentary behaviour. For example, Huguet et al., in 2016, published a systematic review with a meta-analysis that included 65 risk and prognostic factors for musculoskeletal pain, including back pain, in children and adolescents.[24] Neither sedentary behaviour nor screen time were discussed in this review. To date, no systematic review has addressed the association between sedentary behaviour and spinal pain in adolescents explicitly. The systematic review (Chapter two) is the first to comprehensively evaluate all relevant epidemiological studies assessing the association between sedentary behaviour and spinal pain in adolescents. Only the most adjusted associations were extracted to best account for all potential confounding factors. However, a meta-analysis was not possible, but an in-depth qualitative synthesis highlighted the lack of any consistent association between sedentary behaviour and adolescent spinal pain and revealed methodological shortcomings in the field.

The systematic review conformed to the PRISMA guidelines ensuring thorough, robust and explicit methods to allow for the transparent analysis of the available evidence.[67] However, there are two main limitations in the systematic review methodology. First, there are no gold standard quality appraisal tools to accurately assess the quality and risk of bias in epidemiological studies. Instead, a risk of bias tool was developed, modified from the QUIPS tool.[63] Five criteria were generated to assess sampling, selection, reporting and confounding bias. Despite being justifiable risk of bias domains, the methods were superficial with minimal steering frameworks for each domain and equal weighting of one point given to each of those criteria. The use of this modified non-validated QUIPS quality appraisal tool in Chapter two remains a limitation of this systematic review. Second, only two electronic databases were searched, PubMed and AMED. The inclusion of more databases, such as EMBASE, Medline, PsycINFO and CINAHL, may have increased the pool of potentially eligible studies for this review. Notwithstanding, a thorough citation and reference tracking were completed through the Scopus citation database in an attempt to include all relevant studies.

5.3.2 Cross-sectional analysis strengths and limitations

The cross-sectional analysis was the first that specifically investigated the association between two-hours per day of sedentary behaviour (per international guidelines) and non-trivial spinal pain in adolescents. The primary aim was to describe the effects of guideline level thresholds, rather than dose-response relationships of sedentary behaviour, on adolescent spinal pain. The SPACE study dataset was optimally designed to assess this research question due to the similarity of primary aim, suitability of exposure and outcome measures, large sample size and high response rate. Sedentary time was dichotomised to align with and emphasise guideline recommendations of no more than two hours per day of additional sedentary behaviour for adolescents.[51,52] It is recognised, however, both the guidelines and exposure measured in the SPACE study did not include time spent sedentary during the school day, which limits insight to the effect of actual sedentary time spent by adolescents on spinal pain. To account for this, sensitivity analyses were run that dichotomised sedentary time at more than five hours per day. The arbitrary threshold of five hours per day was chosen as it represents greater than two-fold increase in the two hours per day recommendations made in international public health guidelines.

The use of previously validated measurement tools allows better suitability for comparison between previous and future research. The measurement tools used to assess sedentary behaviour and spinal pain in the SPACE study, although they have been previously validated, may introduce recall and reporting bias.[22,112-114] This was a limitation recognised within the cross-sectional analysis; therefore, in an attempt to reduce the influence of recall bias, spinal pain variables were limited to the last week. Spinal pain experiences in the last week were explicitly asked in the YSQ, although the last week timeline was not mentioned in the sedentary behaviour questions. This study assumes time-based consistency between exposure and outcome variables, whereby adolescents would answer based on their most recent engagement with sedentary behaviours over the last week.

However, pain is a subjective experience influenced by many lifestyle and socioenvironmental factors and is complicated by physical and psychological health interactions.[31] Thus, it is difficult to capture and communicate pain appropriately.[22] The cross-sectional analysis drew on a large nationally representative population of Danes aged 11-13 years who answered spinal pain questions in Danish via the subjective YSQ in the SPACE study. Given that pain needs to be contextualised to sociodemographic and cultural norms, caution needs to be applied when generalising the findings of this cross-sectional analysis to other geographical regions and other age groups.

5.4 Future research directions

While the two projects in this thesis assist in advancing understanding, there remain many knowledge gaps in the field of spinal pain in adolescents. In particular, there is a need for high-quality longitudinal research to investigate causal mechanisms, methodological and statistical homogeneity in the field to allow for meta-analyses, and a better understanding of non-trivial spinal pain in adolescents.

To appropriately assess the causal relationship between sedentary behaviour and adolescent spinal pain high-quality longitudinal research is needed. There is a large body of low and moderate quality cross-sectional analyses assessing the association between sedentary behaviour and back pain in adolescents. However, we are currently unable to identify causal mechanisms due to the lack of longitudinal studies. The bigger picture suggests that spinal pain, particularly non-trivial spinal pain, is a lifelong condition with increasing risk as age increases.[7,8,30,122] Long-term epidemiological studies are needed to assess potential risk factors, mechanisms and protective approaches to spinal pain over the life course.[20,123,124] To adequately assess whether sedentary behaviour habits in adolescence are predictive of back pain in adults high-quality, long-term prospective longitudinal studies are required.

The field would benefit from future research that increases methodological and statistical homogeneity allowing for comparable findings and pooling of data. Heterogeneity was noted across studies included in the systematic review and is not an uncommon finding in the wider field of research.[20,125-127] Thus, the need for methodological homogeneity from consistent definitions and measurement tools used for both sedentary behaviour and spinal pain in future research. One example would be the use of accelerometers to objectively measure sedentary behaviour reducing recall bias. Previous barriers to the use of these devices are being overcome as accelerometers are now cheaper, smaller, easier to use and integrated into personal portable devices (for example, smartphone, Fitbit, and Apple watch). Statistical homogeneity in future research could be improved with the appropriate selection and use of confounders to assess causal association. Under adjustment, unnecessary adjustment and over adjustment of confounders can all add bias and decrease the precision of association estimates.[128,129]

Few previous studies assess non-trivial spinal pain.[12,26] The cross-sectional analysis is one of the first to investigate non-trivial spinal pain in adolescents. The spinal pain measurement tool used allows for the suitable calculation of non-trivial spinal pain due to its coverage of spinal pain frequency and intensity. Replication is needed in this area to build a research base and assist in the future development of effective back pain prevention and management strategies.

5.5 Concluding statement

In conclusion, this thesis advances understanding in the field of sedentary behaviour and spinal pain in adolescents. The combined thesis findings suggest that sedentary behaviour, as measured in this thesis, is not a meaningful risk factor for adolescent back pain. The systematic review found no consistent association between sedentary behaviour and adolescent spinal pain. The cross-sectional analysis found no significant association between exceeding two hours per day of sedentary behaviour (as per international recommendations) and spinal pain, trivial or non-trivial, in young adolescent Danes.

These findings challenge existing public and clinical beliefs that sedentary behaviour is a considerable risk factor for adolescent spinal pain. Clinicians and policymakers need to move away from mechanical pain focused beliefs surrounding spinal pain and focus on social and psychological factors that are more strongly linked to non-trivial adolescent spinal pain. High-quality longitudinal studies are needed in future research to assess the potential causal relationship between sedentary behaviour of longer duration and non-trivial spinal pain development over the life-course.

References

1. Kamper S.J., Williams C.M. Musculoskeletal Pain in Children and Adolescents: A Way Forward. Journal of Orthopaedic & Sports Physical Therapy 2017;47(10):702-04.

2. Balague F., Troussier B., Salminen J.J. Non-specific low back pain in children and adolescents: risk factors. Eur Spine J 1999;8(6):429-38.

3. Jones G.T., Macfarlane G.J. Epidemiology of low back pain in children and adolescents. Arch Dis Child 2005;90(3):312-16.

4. Leboeuf-Yde C., Kyvik K.O. At what age does low back pain become a common problem? A study of 29,424 individuals aged 12-41 years. Spine (Phila Pa 1976) 1998;23(2):228-34.

5. MacDonald J., Stuart E., Rodenberg R. Musculoskeletal Low Back Pain in School-aged Children: A Review. JAMA Pediatr 2017;171(3):280-87.

6. O'Sullivan P., Smith A., Beales D., et al. Understanding Adolescent Low Back Pain From a Multidimensional Perspective: Implications for Management. J Orthop Sports Phys Ther 2017;47(10):741-51.

7. Kim H.J., Green D.W. Adolescent back pain. Curr Opin Pediatr 2008;20(1):37-45.

8. Houghton K.M. Review for the generalist: evaluation of low back pain in children and adolescents. Pediatr Rheumatol 2010;8

9. Calloni S.F., Huisman T.A.G.M., Poretti A., et al. Back pain and scoliosis in children: When to image, what to consider. Neuroradiol J 2017;30(5):393-404.

10. Ryder C., Harrison K., Johnson K. Back pain in children and adolescents. Paediatr Child Health 2015;25(12):549-54.

11. Gennari J.M., Themar-Noel C., Panuel M., et al. Adolescent spinal pain: The pediatric orthopedist's point of view. Orthop Traumatol Surg Res 2015;101(6):S247-S50.

12. Dissing K.B., Hestbæk L., Hartvigsen J., et al. Spinal pain in Danish school children – how often and how long? The CHAMPS Study-DK. BMC Musculoskelet Disord 2017;18(1):67.

13. Bernstein R.M., Cozen H. Evaluation of back pain in children and adolescents. Am Fam Physician 2007;76(11):1669-76.

14. Hestbaek L., Leboeuf-Yde C., Kyvik K.O., et al. The course of low back pain from adolescence to adulthood: eight-year follow-up of 9600 twins. Spine (Phila Pa 1976) 2006;31(4):468-72.

15. Coenen P., Smith A., Paananen M., et al. Trajectories of Low Back Pain From Adolescence to Young Adulthood. Arthritis Care & Research 2017;69(3):403-12.

16. Calvo-Munoz I., Gomez-Conesa A., Sanchez-Meca J. Prevalence of low back pain in children and adolescents: a meta-analysis. BMC Pediatr 2013;13(1):14.

17. Kamper S.J., Henschke N., Hestbaek L., et al. Musculoskeletal pain in children and adolescents. Braz J Phys Ther 2016;20(3):275-84.

18. Calvo-Munoz I., Kovacs F.M., Roque M., et al. Risk Factors for Low Back Pain in Childhood and Adolescence: A Systematic Review. Clin J Pain 2018;34(5):468-84.

19. Jones M.A., Stratton G., Reilly T., et al. Biological risk indicators for recurrent non-specific low back pain in adolescents. Br J Sports Med 2005;39(3):137-40.

20. Kamper S.J., Yamato T.P., Williams C.M. The prevalence, risk factors, prognosis and treatment for back pain in children and adolescents: An overview of systematic reviews. Best Pract Res Clin Rheumatol 2016;30(6):1021-36.

21. Swain M.S., Henschke N., Kamper S.J., et al. An international survey of pain in adolescents. BMC Public Health 2014;14:447.

22. Michaleff Z., Kamper S., N. Stinson J., et al. Measuring Musculoskeletal Pain in Infants, Children, and Adolescents2017.

23. Roth-Isigkeit A., Thyen U., Stoven H., et al. Pain among children and adolescents: restrictions in daily living and triggering factors. Pediatrics 2005;115(2):e152-62.

24. Huguet A., Tougas M.E., Hayden J., et al. Systematic review with meta-analysis of childhood and adolescent risk and prognostic factors for musculoskeletal pain. Pain 2016;157(12):2640-56.

25. Watson K.D., Papageorgiou A.C., Jones G.T., et al. Low back pain in schoolchildren: occurrence and characteristics. Pain 2002;97(1-2):87-92.

26. Aartun E., Hartvigsen J., Wedderkopp N., et al. Spinal pain in adolescents: prevalence, incidence, and course: a school-based two-year prospective cohort study in 1,300 Danes aged 11-13. BMC Musculoskelet Disord 2014;15:187.

27. Wirth B., Humphreys B.K. Pain characteristics of adolescent spinal pain. BMC Pediatr 2015;15(1):42.

28. Henschke N., Kamper S.J., Maher C.G. The epidemiology and economic consequences of pain. Mayo Clin Proc 2015;90(1):139-47.

29. Hestbaek L., Leboeuf-Yde C., Kyvik K.O. Is comorbidity in adolescence a predictor for adult low back pain? A prospective study of a young population. BMC Musculoskelet Disord 2006;7:29.

30. Dunn K.M., Hestbaek L., Cassidy J.D. Low back pain across the life course. Best Pract Res Clin Rheumatol 2013;27(5):591-600.

31. Williams C.M., Kamper S.J. A Broader Perspective of Musculoskeletal Conditions in Children. Journal of Orthopaedic & Sports Physical Therapy 2017;47(10):699-701.

32. Beales D.J., Smith A.J., O'Sullivan P.B., et al. Low back pain and comorbidity clusters at 17 years of age: a cross-sectional examination of health-related quality of life and specific low back pain impacts. J Adolesc Health 2012;50(5):509-16.

33. GBD Compare Data Visualization Seattle, WA:IHME: University of Washington; 2016 [Available from: http://vizhub.healthdata.org/gbd-compare]. accessed 10th February 2018.

34. Mokdad A.H., Forouzanfar M.H., Daoud F., et al. Global burden of diseases, injuries, and risk factors for young people's health during 1990-2013: a systematic analysis for the Global Burden of Disease Study 2013. Lancet 2016;387(10036):2383-401.

35. Vos T., Abajobir A.A., Abate K.H., et al. Global, regional, and national incidence, prevalence, and years lived with disability for 328 diseases and injuries for 195 countries, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. The Lancet 2017;390(10100):1211-59.

36. Hartvigsen J., Hancock M.J., Kongsted A., et al. What low back pain is and why we need to pay attention. Lancet 2018;391(10137):2356-67.

37. Ochsmann E.B., Escobar Pinzon C.L., Letzel S., et al. Prevalence of diagnosis and direct treatment costs of back disorders in 644,773 children and youths in Germany. BMC Musculoskelet Disord 2010;11:193.

38. Groenewald C.B., Essner B.S., Wright D., et al. The Economic Costs of Chronic Pain Among a Cohort of Treatment-Seeking Adolescents in the United States. J Pain 2014;15(9):925-33.

39. Kamper SJ M.Z., Campbell P, Dunn KM, Yamato TP, Hodder RK, Wiggers J, Williams CM. Back pain, mental health and substance use are associated in adolescents. J Public Health 2018

40. Tremblay M.S., Aubert S., Barnes J.D., et al. Sedentary Behavior Research Network (SBRN) - Terminology Consensus Project process and outcome. Int J Behav Nutr Phys Act 2017;14(1):75.

41. Jette M., Sidney K., Blumchen G. Metabolic equivalents (METS) in exercise testing, exercise prescription, and evaluation of functional capacity. Clin Cardiol 1990;13(8):555-65.

42. Chastin S.F., Schwarz U., Skelton D.A. Development of a consensus taxonomy of sedentary behaviors (SIT): report of Delphi Round 1. PloS One 2013;8(12):e82313.

43. Ainsworth B.E., Haskell W.L., Whitt M.C., et al. Compendium of physical activities: an update of activity codes and MET intensities. Med Sci Sports Exerc 2000;32(9 Suppl):S498-504.

44. Mansoubi M., Pearson N., Clemes S.A., et al. Energy expenditure during common sitting and standing tasks: examining the 1.5 MET definition of sedentary behaviour. BMC Public Health 2015;15:516.

45. Stamatakis E., Ekelund U., Ding D., et al. Is the time right for quantitative public health guidelines on sitting? A narrative review of sedentary behaviour research paradigms and findings. Br J Sports Med 2018

46. Wu X.Y., Han L.H., Zhang J.H., et al. The influence of physical activity, sedentary behavior on health-related quality of life among the general population of children and adolescents: A systematic review. PloS One 2017;12(11):e0187668.

47. Carson V., Hunter S., Kuzik N., et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth: an update. Appl Physiol Nutr Metab 2016;41(6):240-65.

48. de Rezende L.F., Rodrigues Lopes M., Rey-Lopez J.P., et al. Sedentary behavior and health outcomes: an overview of systematic reviews. PloS One 2014;9(8):e105620.

49. Roberts K.C., Yao X., Carson V., et al. Meeting the Canadian 24-Hour Movement Guidelines for Children and Youth. Health Rep 2017;28(10):3-7.

50. Tremblay M.S., LeBlanc A.G., Kho M.E., et al. Systematic review of sedentary behaviour and health indicators in school-aged children and youth. Int J Behav Nutr Phys Act 2011;8:98.

51. Okely A., Salmon J., Vella S., et al. A Systematic Review to inform the Australian Sedentary Behaviour Guidelines for Children and Young People. 2012

52. Tremblay M.S., Carson V., Chaput J.P. Introduction to the Canadian 24-Hour Movement Guidelines for Children and Youth: An Integration of Physical Activity, Sedentary Behaviour, and Sleep. Applied Physiology Nutrition and Metabolism 2016;41(6):Iii-Iv.

53. Tremblay M.S., LeBlanc A.G., Janssen I., et al. Canadian Sedentary Behaviour Guidelines for Children and Youth. Appl Physiol Nutr Metab 2011;36(1):59-64.

54. Tremblay M.S., Carson V., Chaput J.P., et al. Canadian 24-Hour Movement Guidelines for Children and Youth: An Integration of Physical Activity, Sedentary Behaviour, and Sleep. Appl Physiol Nutr Metab 2016;41(6 Suppl 3):S311-27.

55. Kahlmeier S., Wijnhoven T.M., Alpiger P., et al. National physical activity recommendations: systematic overview and analysis of the situation in European countries. BMC Public Health 2015;15:133.

56. Janssen I., Roberts K.C., Thompson W. Adherence to the 24-Hour Movement Guidelines among 10- to 17-year-old Canadians. Health Promot Chronic Dis Prev Can 2017;37(11):369-75.

57. Roman-Vinas B., Chaput J.P., Katzmarzyk P.T., et al. Proportion of children meeting recommendations for 24-hour movement guidelines and associations with adiposity in a 12-country study. Int J Behav Nutr Phys Act 2016;13(1):123.

58. CAA. 'Text Neck' a growing pain for Aussies [Media Release]. NSW, Australia: Chiropractic Association of Australia; 2017 [updated 10.04.2017. Available from: http://www.chiropractorsnsw.asn.au/assets/pdf/Media-Releases/170410_CAANSW_Story_Text_Neck_a_growing_pain.pdf accessed 07.03.2018 2018.

59. Screen time blamed for back pain in young people. Community practitioner : the journal of the Community Practitioners' & Health Visitors' Association. 88 ed. England, 2015:5.

60. Moher D., Shamseer L., Clarke M., et al. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. Syst Rev 2015;4:1.

61. Dick B., Ferguson B.J. Health for the world's adolescents: a second chance in the second decade. J Adolesc Health 2015;56(1):3-6.

62. Atkin A.J., Gorely T., Clemes S.A., et al. Methods of Measurement in epidemiology: sedentary Behaviour. Int J Epidemiol 2012;41(5):1460-71.

63. Hayden J.A., van der Windt D.A., Cartwright J.L., et al. Assessing bias in studies of prognostic factors. Ann Intern Med 2013;158(4):280-6.

64. Barros E.N.C.D., Alexandre N.M.C. Cross-cultural adaptation of the Nordic musculoskeletal questionnaire. Int Nurs Rev 2003;50(2):101-08.

65. Vandenbroucke J.P., von Elm E., Altman D.G., et al. Strengthening the Reporting of Observational Studies in Epidemiology (STROBE): explanation and elaboration. Int J Surg 2014;12(12):1500-24.

66. Levangie P.K. Application and interpretation of simple odds ratios in physical therapy-related research. J Orthop Sports Phys Ther 2001;31(9):496-503.

67. Liberati A., Altman D.G., Tetzlaff J., et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: explanation and elaboration. BMJ 2009;339

68. Brink Y., Crous L.C., Louw Q.A., et al. The association between postural alignment and psychosocial factors to upper quadrant pain in high school students: a prospective study. Man Ther 2009;14(6):647-53.

69. Szpalski M., Gunzburg R., Balague F., et al. A 2-year prospective longitudinal study on low back pain in primary school children. Eur Spine J 2002;11(5):459-64.

70. Sjolie A.N. Associations between activities and low back pain in adolescents. Scand J Med Sci Sports 2004;14(6):352-9.

71. Torsheim T., Eriksson L., Schnohr C.W., et al. Screen-based activities and physical complaints among adolescents from the Nordic countries. BMC Public Health 2010;10:324.

72. Prista A., Balague F., Nordin M., et al. Low back pain in Mozambican adolescents. Eur Spine J 2004;13(4):341-5.

73. Keane E., Kelly C., Molcho M., et al. Physical activity, screen time and the risk of subjective health complaints in school-aged children. Prev Med 2017;96:21-27.

74. Yang S.Y., Chen M.D., Huang Y.C., et al. Association Between Smartphone Use and Musculoskeletal Discomfort in Adolescent Students. J Community Health 2017;42(3):423-30.

75. Shan Z., Deng G., Li J., et al. Correlational analysis of neck/shoulder pain and low back pain with the use of digital products, physical activity and psychological status among adolescents in Shanghai. PloS One 2013;8(10):e78109.

76. Shan Z., Deng G., Li J., et al. How schooling and lifestyle factors effect neck and shoulder pain? A cross-sectional survey of adolescents in China. Spine (Phila Pa 1976) 2014;39(4):E276-83.

77. Dianat I., Alipour A., Jafarabadi M.A. Risk factors for neck and shoulder pain among schoolchildren and adolescents. J Paediatr Child Health 2018;54(1):20-27.

78. Mohseni-Bandpei M.A., Bagheri-Nesami M., Shayesteh-Azar M. Nonspecific low back pain in 5000 Iranian school-age children. J Pediatr Orthop 2007;27(2):126-9.

79. Smith L., Louw Q., Crous L., et al. Prevalence of neck pain and headaches: impact of computer use and other associative factors. Cephalalgia 2009;29(2):250-7.

80. Straker L., O'Sullivan P., Kendall G., et al. IT kids: exposure to computers and adolescents' neck posture and pain2018.

81. O'Sullivan P.B., Smith A.J., Beales D.J., et al. Association of biopsychosocial factors with degree of slump in sitting posture and self-report of back pain in adolescents: a cross-sectional study. Phys Ther 2011;91(4):470-83.

82. Grimmer K., Williams M. Gender-age environmental associates of adolescent low back pain. Appl Ergon 2000;31(4):343-60.

83. Briggs A.M., Straker L.M., Bear N.L., et al. Neck/shoulder pain in adolescents is not related to the level or nature of self-reported physical activity or type of sedentary activity in an Australian pregnancy cohort. BMC Musculoskelet Disord 2009;10:87.

84. Fernandes J.A., Genebra C.V., Maciel N.M., et al. Low Back Pain in Schoolchildren: A Cross-Sectional Study in a Western City of Sao Paulo State, Brazil. Acta Ortop Bras 2015;23(5):235-8.

85. Meziat Filho N., Coutinho E.S., Azevedo e Silva G. Association between home posture habits and low back pain in high school adolescents. Eur Spine J 2015;24(3):425-33.

86. Meziat-Filho N., Azevedo E.S.G., Coutinho E.S., et al. Association between home posture habits and neck pain in High School adolescents. J Back Musculoskelet Rehabil 2017;30(3):467-75.

87. Noll M., Candotti C.T., Rosa B.N., et al. Back pain prevalence and associated factors in children and adolescents: an epidemiological population study. Revista de saude publica 2016;50

88. Noll M., de Avelar I.S., Lehnen G.C., et al. Back Pain Prevalence and Its Associated Factors in Brazilian Athletes from Public High Schools: A Cross-Sectional Study. PloS One 2016;11(3):e0150542.

89. Noll M., Silveira E.A., Avelar I.S. Evaluation of factors associated with severe and frequent back pain in high school athletes. PloS One 2017;12(2):e0171978.

90. Silva A.G., Sa-Couto P., Queiros A., et al. Pain, pain intensity and pain disability in high school students are differently associated with physical activity, screening hours and sleep. BMC Musculoskelet Disord 2017;18(1):194.

91. Silva G.R., Pitangui A.C., Xavier M.K., et al. Prevalence of musculoskeletal pain in adolescents and association with computer and videogame use. J Pediatr (Rio J) 2016;92(2):188-96.

92. Zapata A.L., Moraes A.J., Leone C., et al. Pain and musculoskeletal pain syndromes related to computer and video game use in adolescents. Eur J Pediatr 2006;165(6):408-14.

93. Wedderkopp N., Leboeuf-Yde C., Bo Andersen L., et al. Back pain in children: no association with objectively measured level of physical activity. Spine 2003;28(17):2019-24.

94. Turk Z., Vauhnik R., Micetic-Turk D. Prevalence of nonspecific low back pain in schoolchildren in north-eastern Slovenia. Coll Antropol 2011;35(4):1031-5.

95. Skemiene L., Ustinaviciene R., Luksiene D., et al. Computer use and musculoskeletal complaints in the Lithuanian adolescent population. Cent Eur J Med 2012;7(2):203-08.

96. Rossi M., Pasanen K., Kokko S., et al. Low back and neck and shoulder pain in members and non-members of adolescents' sports clubs: the Finnish Health Promoting Sports Club (FHPSC) study. BMC Musculoskelet Disord 2016;17:263.

97. Picavet H.S., Berentzen N., Scheuer N., et al. Musculoskeletal complaints while growing up from age 11 to age 14: the PIAMA birth cohort study. Pain 2016;157(12):2826-33.

98. Palm P., Risberg E.H., Mortimer M., et al. Computer use, neck and upper-extremity symptoms, eyestrain and headache among female and male upper secondary school students. SJWEH Supplements 2007(3):33-41.

99. Myrtveit S.M., Sivertsen B., Skogen J.C., et al. Adolescent neck and shoulder pain--the association with depression, physical activity, screen-based activities, and use of health care services. J Adolesc Health 2014;55(3):366-72.

100. Minghelli B., Oliveira R., Nunes C. Postural habits and weight of backpacks of Portuguese adolescents: Are they associated with scoliosis and low back pain? Work 2016;54(1):197-208.

101. Minghelli B., Oliveira R., Nunes C. Non-specific low back pain in adolescents from the south of Portugal: prevalence and associated factors. J Orthop Sci 2014;19(6):883-92.

102. Kristjansdottir G., Rhee H. Risk factors of back pain frequency in schoolchildren: a search for explanations to a public health problem. Acta Paediatr 2002;91(7):849-54.

103. Hulsegge G., van Oostrom S.H., Picavet H.S., et al. Musculoskeletal complaints among 11-year-old children and associated factors: the PIAMA birth cohort study. Am J Epidemiol 2011;174(8):877-84.

104. Hakala P.T., Saarni L.A., Punamaki R.L., et al. Musculoskeletal symptoms and computer use among Finnish adolescents--pain intensity and inconvenience to everyday life: a cross-sectional study. BMC Musculoskelet Disord 2012;13:41.

105. Hakala P.T., Rimpela A.H., Saarni L.A., et al. Frequent computer-related activities increase the risk of neck-shoulder and low back pain in adolescents. Eur J Public Health 2006;16(5):536-41.

106. Diepenmaat A.C., van der Wal M.F., de Vet H.C., et al. Neck/shoulder, low back, and arm pain in relation to computer use, physical activity, stress, and depression among Dutch adolescents. Pediatrics 2006;117(2):412-6.

107. Brindova D., Veselska Z.D., Klein D., et al. Is the association between screen-based behaviour and health complaints among adolescents moderated by physical activity? Int J Public Health 2015;60(2):139-45.

108. Balague F., Nordin M., Skovron M.L., et al. Non-specific low-back pain among schoolchildren: a field survey with analysis of some associated factors. J Spinal Disord 1994;7(5):374-9.

109. Auvinen J., Tammelin T., Taimela S., et al. Associations of physical activity and inactivity with low back pain in adolescents. Scand J Med Sci Sports 2008;18(2):188-94.

110. Auvinen J., Tammelin T., Taimela S., et al. Neck and Shoulder Pains in Relation to Physical Activity and Sedentary Activities in Adolescence. Spine 2007;32(8):1038-44.

111. Burke A., Peper E. Cumulative trauma disorder risk for children using computer products: results of a pilot investigation with a student convenience sample. Public Health Rep 2002;117(4):350-57.

112. Toftager M., Christiansen L.B., Kristensen P.L., et al. SPACE for physical activity--a multicomponent intervention study: study design and baseline findings from a cluster randomized controlled trial. BMC Public Health 2011;11(1):777.

113. Toftager M., Christiansen L.B., Ersboll A.K., et al. Intervention effects on adolescent physical activity in the multicomponent SPACE study: a cluster randomized controlled trial. PloS One 2014;9(6):e99369.

114. Lauridsen H.H., Hestbaek L. Development of the young spine questionnaire. BMC Musculoskelet Disord 2013;14:185.

115. White I.R., Horton N.J., Carpenter J., et al. Strategy for intention to treat analysis in randomised trials with missing outcome data. BMJ 2011;342:d40.

116. Hidding L.M., Altenburg T.M., Mokkink L.B., et al. Systematic Review of Childhood Sedentary Behavior Questionnaires: What do We Know and What is Next? Sports Med 2017;47(4):677-99.

117. Hicks C.L., von Baeyer C.L., Spafford P.A., et al. The Faces Pain Scale-Revised: toward a common metric in pediatric pain measurement. Pain 2001;93(2):173-83.

118. Batley S., Aartun E., Boyle E., et al. The association between psychological and social factors and spinal pain in adolescents. Eur J Pediatr 2018

119. Costigan S.A., Barnett L., Plotnikoff R.C., et al. The health indicators associated with screen-based sedentary behavior among adolescent girls: a systematic review. J Adolesc Health 2013;52(4):382-92.

120. Kuo Y.L., Lee L.L. Prevalence and risk factors associated with spinal pain in adolescent computer users: a systematic review. JBI Database System Rev Implement Rep 2012;10(45):2906-43.

121. Toh S.H., Coenen P., Howie E.K., et al. The associations of mobile touch screen device use with musculoskeletal symptoms and exposures: A systematic review. PloS One 2017;12(8):e0181220.

122. Sawyer S.M., Afifi R.A., Bearinger L.H., et al. Adolescence: a foundation for future health. Lancet 2012;379(9826):1630-40.

123. Kuh D. Life course epidemiology. Journal of Epidemiology & Community Health 2003;57(10):778-83.

124. Michaleff Z.A., Kamper S.J., Maher C.G., et al. Low back pain in children and adolescents: a systematic review and meta-analysis evaluating the effectiveness of conservative interventions. Eur Spine J 2014;23(10):2046-58.

125. Hill J.J., Keating J.L. Risk factors for the first episode of low back pain in children are infrequently validated across samples and conditions: a systematic review. J Physiother 2010;56(4):237-44.

126. Trevelyan F.C., Legg S.J. Back pain in school children--where to from here? Appl Ergon 2006;37(1):45-54.

127. Smith D.L., P. Back Pain in the Young: A Review of Studies Conducted Among School Children and University Students. Curr Pediatr Rev 2007;3(1):69-77.

128. Xie Y., Szeto G., Dai J. Prevalence and risk factors associated with musculoskeletal complaints among users of mobile handheld devices: A systematic review. Appl Ergon 2017;59(Pt A):132-42.

129. Schisterman E.F., Cole S.R., Platt R.W. Overadjustment bias and unnecessary adjustment in epidemiologic studies. Epidemiology (Cambridge, Mass) 2009;20(4):488-95.

Appendix A. Ethics approval

Science & Engineering Subcommittee
Macquarie University, North Ryde
NSW 2109, Australia

MACQUARIE University

27/07/2018

Dear Mr Swain,

Reference No: 5201831463519
Project ID: 3146
Title: Is sedentary behaviour and screen time associated with spinal pain in adolescents? A cross-sectional epidemiological study.

Thank you for submitting the above application for ethical review. The Science & Engineering Subcommittee have considered your application.

I am pleased to advise that ethical approval has been granted for this project to be conducted by Mr Michael Swain, Mrs Laura Montgomery, Prof Simon French.

This research meets the requirements set out in the National Statement on Ethical Conduct in Human Research 2007 (Updated July 2018).

Standard Conditions of Approval:

1. Continuing compliance with the requirements of the National Statement, available from the following website: https://www.nhmrc.gov.au/_files_nhmrc/file/publications/national-statement-2018.pdf.
2. This approval is valid for five (5) years, subject to the submission of annual reports. Please submit your reports on the anniversary of the approval for this protocol. You will be sent an automatic reminder email one week from the due date to remind you of your reporting responsibilities.
3. All adverse events, including unforeseen events, which might affect the continued ethical acceptability of the project, must be reported to the subcommittee within 72 hours.
4. All proposed changes to the project and associated documents must be submitted to the subcommittee for review and approval before implementation. Changes can be made via the Human Research Ethics Management System.

The HREC Terms of Reference and Standard Operating Procedures are available from the Research Services website: https://www.mq.edu.au/research/ethics-integrity-and-policies/ethics/human-ethics

It is the responsibility of the Chief Investigator to retain a copy of all documentation related to this project and to forward a copy of this approval letter to all personnel listed on the project.

Should you have any queries regarding your project, please contact the Faculty Ethics Officer.

The Science & Engineering Subcommittee wishes you every success in your research.

Yours sincerely,

Dr Peter Busch

Chair, Science & Engineering Subcommittee

The Faculty Ethics Subcommittees at Macquarie University operate in accordance with the National Statement on Ethical Conduct in Human Research (2007), [Section 5.2.22].

Appendix B. Data processor agreement

Data Processor Agreement

between
Center for Applied Research in Health Promotion and Prevention, Dept. of Sports and Clinical Biomechanics, University of Southern Denmark, Campusvej 55, 5230 Odense M, Denmark
Data controller

and
Dept. of Chiropractic, Level 3 C5C West, Macquarie University, NSW 2109, Australia
Data processor

Intention of the agreement and processor's obligation
The agreement concerns the processor's use of data on behalf of the controller and shall ensure that information relating to the data subjects is not used unlawfully or comes into the hands of a third party. When processing personal data on behalf of the controller, the processor shall follow the routines and instructions stipulated by the controller at any given time.
The processor is obliged to give the controller access to his written technical and organizational security measures and to provide assistance to that the controller can fulfil his responsibilities.
The processor must observe professional secrecy in regard to the documentation and personal data to which access has been given in accordance with this agreement. This provision also applies after the agreement has been discontinued.

Data specification
In relation to data analysis Processor will get access to research data from:
Project name: "SPACE for physical activity" (Danish Data Protection Agency file no. 2010-41-5147).
Sensitivity of data: Data will be available in anonymized form

Project
Processor is only allowed to use the data for the project stated below:
Title of project: "Is sedentary behavior and screen time associated with spinal pain in adolescents? A cross-sectional epidemiological study"
Project staff: MRes student: Laura Montgomery (Macquarie University), MRes supervisors: Michael Swain (Macquarie University), Simon French (Macquarie University).
Expected time and duration of data processing: 1 July 2018 – 31 December 2019

Date Signature

4th July 2018

Dept. of Chiropractic
Macquarie University

Date Signature

2nd July 2018

Dept. of Sports and Clinical Biomechanics
University of Southern Denmark

Appendix C. Systematic literature review search strings

PubMed search string 02.02.2018

((Adolescent[Mesh]) AND ((("Low Back Pain"[Mesh]) OR "Back pain"[Mesh]) OR "Neck pain"[Mesh])) AND (((((((((((((("Sedentary Lifestyle"[Mesh]) OR Television[Mesh]) OR Computer[Mesh]) OR "Computers, Handheld"[Mesh]) OR "Cell phone use"[Mesh]) OR "cell phone"[Mesh]) OR Movement[Mesh]) OR Internet[Mesh]) OR MP3-player[Mesh]) OR "Physical inactivity") OR "Sedentary behaviour") OR "Sedentary behavior") OR Inactivity) OR Sedentary activity) OR Sitting) OR screen*)

AMED search string 02.02.2018

22. 1 and 20 and 21

21. 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19

20. 2 or 3 or 4

19. screen*.mp. [mp=abstract, heading words, title]

18 sitting.mp. [mp=abstract, heading words, title]

17. sedentary activity.mp. [mp=abstract, heading words, title]

16. inactivity.mp. [mp=abstract, heading words, title]

15. sedentary behavior.mp. [mp=abstract, heading words, title]

14. sedentary behaviour.mp. [mp=abstract, heading words, title]

13. physical inactivity.mp. [mp=abstract, heading words, title]

12. mp3-player.mp. [mp=abstract, heading words, title]

11. internet.mp. [mp=abstract, heading words, title]

10 movement.mp. [mp=abstract, heading words, title]

9. cell phone.mp. [mp=abstract, heading words, title]

8. computers, handheld.mp. [mp=abstract, heading words, title]

7. computer.mp. [mp=abstract, heading words, title]

6. television.mp. [mp=abstract, heading words, title]

5. sedentary lifestyle.mp. [mp=abstract, heading words, title]

4. neck pain.mp. [mp=abstract, heading words, title]

3. back pain.mp. [mp=abstract, heading words, title]

2. Low back pain.mp. [mp=abstract, heading words, title]

1. Adolescent.mp. [mp=abstract, heading words

Appendix D. Data extraction table and summary of association estimates

Study	Exposure	Outcome	Estimate	Confounders	Finding
Longitudinal studies					
Brink et al., 2009	Computer >6h/wk	UQMP (6mth)	OR 1.6 (0.7-3.8)		No association
Brink et al., 2009	Computer >105m/d	UQMP (6mth)	OR 1.7 (0.7-4.2)		No association
Szpalski et al., 2002	Computer/Gaming daily total	LBP (2yrs)	OR 1.53 (0.92-2.54)		No association
Cross-sectional studies					
Auvinen et al., 2007	Computer <2h/d vs. >2h/d	NOP	* F OR 1.27 (0.83-1.96)		No association
Auvinen et al., 2007	SB Other <1h/d vs. >1h/d	NOP	* F OR 1.07(0.89-1.29)		No association
Auvinen et al., 2007	Read(Non-Screen) <2h vs. >2h/d	NOP	* M OR 1.16 (0.80-1.70)		No association
Auvinen et al., 2007	TV <4h/d vs. >4h/d	NOP	* F OR 1.25 (0.97-1.62)		No association
Auvinen et al., 2007	TV <4h/d vs. >4h/d	NOP	* M OR 1.30 (0.98-1.71)		No association
Auvinen et al., 2007	Computer <2h/d vs. >2h/d	NOP	* M OR 1.29 (1.01-1.65)	BMI, Smoking, Physical Activity Level, Total screen time	Positive
Auvinen et al., 2007	SB Other <1h/d vs. >1h/d	NOP	* M OR 1.31 (1.09-1.58)		Positive
Auvinen et al., 2007	Read(Non-Screen) <2h vs. >2h/d	NOP	* F OR 1.36 (1.02-1.80)		Positive
Auvinen et al., 2007	TSB <4h/d vs. >4h/d	NOP	* F OR 1.21 (1.02-1.44)		Positive
Auvinen et al., 2007	TSB <4h/d vs. >4h/d	NOP	* M OR 1.34 (1.08-1.65)		Positive
Auvinen et al., 2008	TSB <8h/d vs. >8h/d	LBP	* M OR 0.97 (0.78-1.21)		No association
Auvinen et al., 2008	TSB <8h/d vs. >8h/d	LBP	* F OR 1.37 (1.13-1.66)		Positive
Balague et al., 1994	TV (h/wk in preceding week)	LBP	* OR 1.23 (1.0-1.52)	Age, Sex, Parental History Of LBP treatment, Competitive Sports Activity, TV Time	Positive
Briggs et al., 2009	Computer <12h/wk vs. >12h/wk	NSP	* F OR 1.35 (0.57-3.19)		No association
Briggs et al., 2009	Computer <12h/wk vs. >12h/wk	NSP	* M OR 0.65 (0.23-1.83)		No association
Briggs et al., 2009	Read(Non-Screen) <4 vs. >4h/wk	NSP	* M OR 1.61 (0.27-9.48)		No association
Briggs et al., 2009	Read (Non-Screen) <4 vs. >4h/wk	NSP	* F OR 1.52 (0.24-9.80)	BMI, Smoking	No association
Briggs et al., 2009	TST <46h/wk vs. >46h/wk	NSP	* F OR 0.52 (0.10-2.73)		No association
Briggs et al., 2009	TST <46h/wk vs. >46h/wk	NSP	* M OR 1.28 (0.31-5.35)		No association
Briggs et al., 2009	TV <32h/wk vs. >32h/wk	NSP	* F OR 0.66 (0.23-1.87)		No association
Briggs et al., 2009	TV <32h/wk vs. >32h/wk	NSP	* M OR 0.72 (0.22-2.33)		No association
Brindova et al., 2015	TV <3h/d vs. >3h/d	SP	* OR 1.07 (0.91-1.26)	Age, Sex	No association
Brindova et al., 2015	Computer <3h/d vs. >3h/d	SP	* OR 1.28 (1.10-1.49)		Positive
Burke et al., 2002	Computer	NP	Low Use 0.13±0.35 vs. High Use 0.29±0.46		No association
Burke et al., 2002	Computer	SP	Low Use 0±0 vs. High Use 0.34±0.48		Positive
Continued					

Study	Exposure	Outcome	Estimate	Confounders	Finding
Cross-sectional studies					
Dianat et al., 2018	Computer <4h/wk vs. >4h/wk	NP	OR 0.99 (0.75-1.31)		No association
Dianat et al., 2018	Gaming <2h/wk vs. >2h/wk	NP	OR 1.07 (0.83-1.38)		No association
Dianat et al., 2018	TV <12h/wk vs. >12h/wk	NP	OR 0.78 (0.60-1.02)		No association
Diepenmaat et al., 2006	Computer <3h/d vs. >3 H/D	LBP	OR 0.9 (0.6-1.3)		No association
Diepenmaat et al., 2006	Computer <3h/d vs. >3 H/D	NSP	OR 1.2 (0.8-1.6)		No association
Diepenmaat et al., 2006	TV <4h/d vs. >4h/d	NSP	OR 1.0 (0.8-1.4)		No association
Diepenmaat et al., 2006	TV <4h/d vs. >4h/d	LBP	OR 0.8 (0.6-1.2)		No association
Fernandes et al., 2015	TV (h/d and times/wk)	LBP	* OR 1.53 (1.04-2.27)	Age, Gender	Positive
Grimer et al., 2000	Sitting (after school)	LBP	F(Yr9) OR 2.1 (0.2-24.8)		No association
Grimmer et al., 2000	Sitting (after school)	LBP	M(Yr8) OR 15.5 (0.7-35)		No association
Hakala et al., 2006	Internet <14h/wk vs. >14h/wk	LBP	* OR 0.9 (0.6-1.4)	Age, Sex, Parents Education Level, Adolescent School Success, Timing Of Puberty, Efficiency Of Physical Activity, Stress Symptoms	No association
Hakala et al., 2006	Mobile <5h/d vs. >5h/d	LBP	* OR 1.0 (0.5-2.3)		No association
Hakala et al., 2006	Computer <5h/d vs. >5h/d	NSP	* OR 1.4 (0.7-3.0)		No association
Hakala et al., 2006	Gaming <5h/d vs. >5h/d	NSP	* OR 1.4 (0.8-2.4)		No association
Hakala et al., 2006	Mobile <5h/d vs. >5h/d	NSP	* OR 1.7 (0.9-3.2)		No association
Hakala et al., 2006	TV <5h/d vs. >5h/d	NSP	* OR 0.8 (0.4-1.4)		No association
Hakala et al., 2006	TV <5h/d vs. >5h/d	LBP	* OR 1.3 (0.7-2.3)		No association
Hakala et al., 2006	Computer <42h/wk vs. >42h/wk	LBP	* OR 1.7 (1.0-3.1)		Positive
Hakala et al., 2006	Computer <5h/d vs. >5h/d	LBP	* OR 2.0 (1.0-4.2)		Positive
Hakala et al., 2006	Gaming <5h/d vs. >5h/d	LBP	* OR 2.0 (1.1-3.5)		Positive
Hakala et al., 2006	Computer <42h/wk vs. >42h/wk	NSP	* OR 2.5 (1.5-4.3)		Positive
Hakala et al., 2006	Internet <14h/wk vs. >14h/wk	NSP	* OR 1.4 (1.0-2.0)		Positive
Hakala et al., 2012	Computer <3.6h/wk vs. >3.6h/wk	NSP	* OR 1.6 (0.9-2.9)	Sex, School Grade	No association
Hakala et al., 2012	Computer <3.6h/wk vs. >3.6h/wk	LBP	* OR 2.4 (1.2-4.8)		Positive
Hulsegge et al., 2011	TV/Computer <2h/d vs. >2h/d	SP	OR 1.08 (0.66-1.75)	Age, Sex	No association
Keane et al., 2017	TST <2h/d vs. >2h/d	SP	* OR 1.36 (1.20-1.55)	Age(Group), Gender, Social Class, Family Structure, Physical Activity, Total Screen Time	Positive
Kristjansdottir et al, 2002	TV	SP	R=0.075		Positive
Kristjansdottir et al, 2002	TV (Video)	SP	R=0.082		Positive
Meziat-Filho et al., 2015	Computer <2h/d vs. >2h/d	LBP (Chronic)	18.9% (16.3-21.5%)		No association
Meziat-Filho et al., 2015	Computer <2h/d vs. >2h/d	LBP (Acute)	29.1%(26.1-32.1%)		No association
Meziat-Filho et al., 2015	Gaming <2h/d vs. >2h/d	LBP (Chronic)	15.4% (10.9-19.9%)		No association
Meziat-Filho et al., 2015	Gaming <2h/d vs. >2h/d	LBP (Acute)	25.9%(20.4-31.4%)		No association
Continued					

Study	Exposure	Outcome	Estimate	Confounders	Finding
Cross-sectional studies					
Meziat-Filho et al., 2015	TV <2h/d vs. >2h/d	LBP (Chronic)	17.8% (15.2-20.4%)		No association
Meziat-Filho et al., 2015	TV <2h/d vs. >2h/d	LBP (Acute)	28.8% (25.1-32.5%)		No association
Meziat-Filho et al., 2017	Computer <2h/d vs. >2h/d	NP (Chronic)	16.3% (13.9-18.7%)		No association
Meziat-Filho et al., 2017	Computer <2h/d vs. >2h/d	NP (Acute)	33.2% (30.1-36.3%)		No association
Meziat-Filho et al., 2017	Gaming <2h/d vs. >2h/d	NP (Chronic)	13.5% (9.2-17.8%)		No association
Meziat-Filho et al., 2017	Gaming <2h/d vs. >2h/d	NP (Acute)	31.0% (25.2-36.8%)		No association
Meziat-Filho et al., 2017	TV <2h/d vs. >2h/d	NP (Chronic)	15.0% (12.6-17.4%)		No association
Meziat-Filho et al., 2017	TV <2h/d vs. >2h/d	NP (Acute)	35.4% (32.1-38.7%)		Positive
Minghelli et al., 2014	Computer/Gaming <10 vs. >10h/wk	LBP	No LBP 54.9% vs. LBP 41.5%		No association
Minghelli et al., 2014	TV <10h/wk vs. >10h/wk	LBP	No LBP 51.2% vs. LBP 48.8%		No association
Minghelli et al., 2016	Computer/Gaming <5 vs. >5h/wk	LBP	* OR 1.00 (0.68-1.47)	Age (Group), Gender	No association
Minghelli et al., 2016	TV <5h/wk vs. >5h/wk	LBP	* OR 1.13 (0.83-1.54)		No association
Mohseni et al., 2007	Computer	LBP	OR 0.86 (0.58-1.28)		No association
Mohseni et al., 2007	Homework	LBP	OR 0.76 (0.61-0.94)		Negative
Mohseni et al., 2007	TV	LBP	OR 0.66 (0.51-0.86)		Negative
Myrtveit et al., 2014	Computer(Chatting) <2vs. >2h/d	NSP	* F OR 1.06 (0.93-1.21)	Age, School, Family Economy, Depression	No association
Myrtveit et al., 2014	Computer(Chatting) <2vs. >2h/d	NSP	* M OR 1.02 (0.83-1.26)		No association
Myrtveit et al., 2014	Computer(Emailing)<2h vs. >2h/d	NSP	* F OR 1.24 (0.90-1.71)		No association
Myrtveit et al., 2014	ST(Other) <2h vs. >2h/d	NSP	* F OR 0.97 (0.84-1.11)		No association
Myrtveit et al., 2014	ST(Other) <2h vs. >2h/d	NSP	* M OR 1.19 (0.97-1.46)		No association
Myrtveit et al., 2014	TV(Gaming) <2h vs. >2h/d	NSP	* F OR 1.27 (0.83-1.94)		No association
Myrtveit et al., 2014	TV(Gaming) <2h vs. >2h/d	NSP	* M OR 0.96 (0.74-1.23)		No association
Myrtveit et al., 2014	Computer(Emailing)<2h vs. >2h/d	NSP	* M OR 1.95 (1.30-2.92)		Positive
Myrtveit et al., 2014	Computer(Gaming)<2h vs. >2h/d	NSP	* F OR 1.62 (1.22-2.13)		Positive
Myrtveit et al., 2014	Computer(Gaming)<2h vs. >2h/d	NSP	* M OR 1.31 (1.06-1.64)		Positive
Noll et al., 2016	Computer <6h/d vs. >6h/d	SP	OR 1.03 (0.97-1.09)		No association
Noll et al., 2016	TV <4h/d vs. >4h/d	SP	OR 1.05 (1.01-1.09)		Positive
Noll et al. (b.), 2016	Computer <2h/d vs. >2h/d	SP	* OR 1.09 (0.99-1.21)	Age, Sex	No association
Noll et al. (b.), 2016	TV <4h/d vs. >4h/d	SP	* OR 1.05 (0.86-1.28)		No association
Noll et al. (c.), 2017	Computer <2h/d vs. >2h/d	SP (High Intensity)	* PR 1.15 (1.01-1.33)	High intensity SP, High frequency SP, SES, Psychosocial, Hereditary Anthropometric, Behavioural, Postural, Level Of Exercise	Positive

Continued

Study	Exposure	Outcome	Estimate	Confounders	Finding
Cross-sectional studies					
O'Sullivan et al., 2011	Computer (Weekly Total)	SP	* OR 0.98 (0.82-1.19)	Slump Sitting, Other Physical, Lifestyle & Psychosocial Factors	No association
O'Sullivan et al., 2011	TV (Weekly)	SP	* OR 0.98 (0.80 -1.21)		No association
Palm et al., 2007	Computer <56h vs. >56h/wk	NSP	F PR 1.33 (1.08-1.64)		Positive
Palm et al., 2007	Computer <56h vs. >56h/wk	NSP	M PR 1.59 (1.03-2.47)		Positive
Picavet et al., 2016	TST <2h/d vs. >2h/d	SP	* OR 1.22 (0.91-1.64)	Age, Sex	No association
Picavet et al., 2016	TST <2h/d vs. >2h/d	UQMP	* OR 1.00 (0.73-1.36)		No association
Prista et al., 2004	TV <1h/d vs. >1h/d	LBP	11% vs. 14%		No association
Rossi et al., 2016	TST	NSP	* F OR 1.03 (0.98-1.07)	Age, BMI, Chronic Disease, Smoking, School Attainment Level	No association
Rossi et al., 2016	TST	LBP	* F OR 1.06 (1.01-1.10)		Positive
Rossi et al., 2016	TST	LBP	* M OR 1.07 (1.01-1.12)		Positive
Rossi et al., 2016	TST	NSP	* M OR 1.05 (1.00-1.10)		Positive
Shan et al., 2013	Computer < 1.5h vs. >1.5h/d	NSP	* OR 1.243 (1.063-1.454)	Gender, Grade (School Year)	Positive
Shan et al., 2013	Sit (After School) <3h vs. >3h/d	LBP	* OR 1.246 (1.042-1.490)		Positive
Shan et al., 2013	Sit (After School) <3h vs. >3h/d	NSP	* OR 1.854 (1.561-2.202)		Positive
Shan et al., 2014	Computer <1.5h vs. >1.5h/d	NSP	* OR 1.24 (1.05-1.46)	Sex, Family History NSP	Positive
Shan et al., 2014	Sit (After School) <3h vs. >3h/d	NSP	* OR 1.89 (1.57-2.26)		Positive
Silva et al., 2016	TST <4h vs. >4h/d	TLP	* OR 1.33 (1.00-1.75)	Gender, Total Screen Time, Paid Job, Nutritional Status	Positive
Silva et al., 2016	TST <4h vs. >4h/d	NP	* OR 1.61 (1.13-2.28)		Positive
Silva et al., 2017	Computer <4h/d vs. >4h/d	LBP	* OR 2.14 (0.86-5.58)	Age, Gender, Social Class, Family Structure, Physical Activity, Total Screen Time recommendations	No association
Silva et al., 2017	Mobile <5h/d vs. >5h/d	LBP	* OR 1.45 (0.64-3.25)		No association
Silva et al., 2017	Mobile <5h/d vs. >5h/d	TP	* OR 1.38 (0.58-3.26)		No association
Sjolie, 2004	TV/Computer	LBP	* OR 1.7 (1.2-2.5)	Age, Gender, Distance Walked/ Bicycled To School/Activities, Physical activity	Positive
Skemiene et al., 2012	Computer <4h/d vs. >4h/d	NSP	13-15yrs F OR 1.88 (0.91-3.90)		No association
Skemiene et al., 2012	Computer <4h/d vs. >4h/d	NSP	13-15yrsM OR1.31 (0.67-2.53)		No association
Skemiene et al., 2012	Computer <4h/d vs. >4h/d	NSP	16-18yrs F OR 1.47 (0.89-2.43)		No association
Skemiene et al., 2012	Computer <4h/d vs. >4h/d	NSP	16-18yrsM OR0.99 (0.61-1.60)		No association
Skemiene et al., 2012	Computer <4h/d vs. >4h/d	SP	16-18yrsM OR1.11 (0.68-1.80)		No association
Skemiene et al., 2012	Computer <4h/d vs. >4h/d	SP	16-18yrs F OR 1.80 (1.20-2.71)		No association
Skemiene et al., 2012	Computer <4h/d vs. >4h/d	SP	13-15yrs F OR 2.50 (1.22-5.13)		Positive

Continued

Study	Exposure	Outcome	Estimate	Confounders	Finding
Cross-sectional studies					
Skemiene et al., 2012	Computer <4h/d vs. >4h/d	SP	13-15yrs M OR 2.36 (1.21-4.62)		Positive
Smith et al., 2009	Computer <8.5h/wk vs. >8.5h/wk	NP	OR 1.7 (1.2-2.3)		Positive
Straker et al., 2018	Computer <21h vs. >21h/wk	NSP	OR 1.79 (1.12-2.85)		Positive
Torsheim et al., 2010	Computer	SP	* M OR 1.06 (1.03-1.09)	Age, Country, SES, Depressed Mood, School-Related Stress & PA	Positive
Torsheim et al., 2010	Computer	SP	* F OR 1.05 (1.02 -1.08)		Positive
Torsheim et al., 2010	Gaming	SP	* F OR 1.05 (1.01-1.10)		Positive
Torsheim et al., 2010	Gaming	SP	* M OR 1.04 (1.01-1.07)		Positive
Torsheim et al., 2010	TV	SP	* F OR 1.08 (1.05-1.12)		Positive
Torsheim et al., 2010	TV	SP	* M OR 1.05 (1.02-1.09)		Positive
Turk et al., 2011	TV h/d	LBP	No LBP 1.9±1.2 vs. LBP 1.5±0.9		Negative
Turk et al., 2011	Computer h/d	LBP	No LBP 1.4±1.1 vs. LBP 1.3±1.0		No association
Wedderkopp et al., 2003	Physical Inactivity	LBP	Most Inactive 9% vs. Least Inactive 5%	Age, Gender, Stage Of Puberty	No association
Wedderkopp et al., 2003	Physical Inactivity	TP	Most Inactive 16% vs. Least Inactive 19%		No association
Wedderkopp et al., 2003	Physical Inactivity	SP	Most Inactive 37% vs. Least Inactive 31%		No association
Wirth et al., 2015	TV/Computer	SP (Frequent)	* OR 1.03 (0.99-1.07)	Age, Gender, BMI, Headache, Finger Floor Distance, Adams Sign, Single Leg Stance Closed Eyes, Parental SP, Parental Smoking, Sleep Disorders, Abdominal Pain	No association
Wirth et al., 2015	TV/Computer	SP (Mild Pain)	*OR 1.03 (0.98-1.09)		No association
Wirth et al., 2015	TV/Computer	SP (>1region)	* OR 1.07 (1.01-1.14)		Positive
Yang et al., 2017	Mobile(Photo, Gaming) <3h vs. >3h/d	NP	OR 0.92 (0.50-1.68)		No association
Yang et al., 2017	Mobile(Talking) <3h vs. >3h/d	NP	OR 2.20 (0.82-5.90)		No association
Yang et al., 2017	Mobile(Texting) <3h vs. >3h/d	NP	OR 0.92 (0.48-1.78)		No association
Yang et al., 2017	Mobile(Weekend use) <3h vs. >3h/d	NP	OR 0.69 (0.39-1.24)		No association
Yang et al., 2017	Mobile(Photo, Gaming) <3h vs. >3h/d	LBP	OR 0.79 (0.43-1.47)		No association

Continued

Study	Exposure	Outcome	Estimate	Confounders	Finding
Cross-sectional studies					
Yang et al., 2017	Mobile(Talking) <3h vs. >3h/d	LBP	OR 2.31 (0.79-6.72)		No association
Yang et al., 2017	Mobile(Texting) <3h vs. >3h/d	LBP	OR 1.13 (0.57-2.22)		No association
Yang et al., 2017	Mobile(Weekend use) <3h vs. >3h/d	LBP	OR 0.89 (0.49-1.64)		No association
Yang et al., 2017	Mobile(Weekend use)<3h vs. >3h/d	TP	OR 0.51 (0.24-1.07)		No association
Yang et al., 2017	Mobile(Texting) <3h vs. >3h/d	TP	OR 0.54 (0.26-1.15)		No association
Yang et al., 2017	Mobile(Photo, Gaming) <3h vs. >3h/d	TP	OR 0.82 (0.41-1.66)		No association
Yang et al., 2017	Mobile(Talking) <3h vs. >3h/d	TP	OR 4.34 (1.10-17.11)		Positive
Zapata et al., 2006	Computer (Mean Saturdays)	SP	* OR 1.002 (1.000-1.004)	Age, Sex	Positive
Zapata et al., 2006	Computer (Mean Weekdays)	SP	* OR 1.003 (1.000-1.005)		Positive

h/d, hours per day; h/wk, hours per week; m/d, minutes per day; TV, television watching including video or DVD; ST, screen time; TSB, total sedentary behaviour; mth, months; yrs, years; M, male; F, female; OR(95%CI), odds ratio with 95% confidence interval in parenthesis; *, adjusted estimated of association; SP, spinal pain, including back pain and backache; LBP, low back pain; TLP, thoracolumbar pain; TP, thoracic pain, including mid back pain and upper back pain; NP, neck pain, including cervical pain; NOP, neck and occipital pain; NSP, neck and shoulder pain; UQMP, upper quarter musculoskeletal pain; SES, socio-economic status; BMI, body mass index; PA, physical activity