JYU DISSERTATIONS 233

Marleena Rossi

Back Pain in Youth

Occurrence and Risk Factors

UNIVERSITY OF JYVÄSKYLÄ
FACULTY OF SPORT AND
HEALTH SCIENCES

JYU DISSERTATIONS 233

Marleena Rossi

Back Pain in Youth

Occurrence and Risk Factors

Esitetään Jyväskylän yliopiston liikuntatieteellisen tiedekunnan suostumuksella
julkisesti tarkastettavaksi yliopiston vanhassa juhlasalissa S212
syyskuun 11. päivänä 2020 kello 12.

Academic dissertation to be publicly discussed, by permission of
the Faculty of Sport and Health Sciences of the University of Jyväskylä,
in building Seminarium, Old Festival Hall S212, on September 11, 2020 at 12 o'clock noon.

UNIVERSITY OF JYVÄSKYLÄ
FACULTY OF SPORT AND
HEALTH SCIENCES

JYVÄSKYLÄ 2020

Editors
Anne Viljanen
Faculty of Sport and Health Sciences, University of Jyväskylä
Timo Hautala
Open Science Centre, University of Jyväskylä

Copyright © 2020, by University of Jyväskylä
This is a printout of the original online publication.
Permanent link to this publication: http://urn.fi/URN:ISBN:978-951-39-8184-6

ISBN 978-951-39-8184-6 (PDF)
URN:ISBN:978-951-39-8184-6
ISSN 2489-9003
Jyväskylä University Printing House, Jyväskylä 2020

ABSTRACT

Rossi, Marleena Katariina
Back Pain in Youth – Occurrence and Risk Factors
Jyväskylä: University of Jyväskylä, 2020, 118 p.
(JYU Dissertations
ISSN 2489-9003; 233)
ISBN 978-951-39-8184-6

Research shows that a majority of people will experience back pain (BP) during their lifetime. Low back pain (LBP) in youth has a tendency of increasing the odds for LBP in adulthood, and it is commonly concurrent with other musculoskeletal (MSK) complaints, but also other factors such as sleep problems, reduction of physical activity and school absenteeism. Some studies have suggested that youth taking part in sports are at increased risk for LBP. Therefore, the main objective of this thesis was to investigate the prevalence of BP in youth and explore the association between LBP incidence and plausible risk factors in youth basketball and floorball players.

The prevalence of back pain (BP) was first investigated in youth based on their participation in organized sports club activities. Twenty-four percent of boys and 35% of girls reported BP. BP was associated with other musculoskeletal complaints. In boys, being a sports club member the odds for LBP were increased compared to non-members. On the other hand, frequent neck and shoulder pain (NSP) was less common among sports club members than it was among non-members.

In addition, BP prevalence, incidence and risk factors for LBP were investigated in youth basketball and floorball players using a prospective design. At the beginning of every study year, the players participated in baseline tests that measured muscle strength and flexibility, general joint hypermobility, ground reaction force (GRF) during vertical drop jump and movement control during movement tests. During the follow-up of one to three years, individual training and game hours and back pain resulting in at least 24-hour time-loss were recorded.

We found that, LBP was common among young team sport players: 45% and 64% of basketball and floorball players reported having experienced LBP, respectively. The onset of the symptoms seemed to be mostly gradual without any identifiable trauma and LBP was most prevalent during the playing season. The longitudinal analysis revealed that 13% of the players reported time-loss LBP during the follow-up with median time-loss of 14 days. The incidence of BP was 0.4 per 1,000 hours of training and games. In the risk factor analyses, we found an association between hip-pelvic control during single-leg vertical drop landing and LBP. We did not observe a similar association in standing knee lift test and hip-pelvic control. No associations were found between LBP and impact force of landing, lower extremity maximal strength nor flexibility or hypermobility.

LBP is a common complaint among youth and youth athletes and is concomitant with other MSK complaints. LBP hampers sports participation in youth athletes. Decreased hip-pelvic control in single-leg landing task was associated with increased risk for LBP incidence in youth floorball and basketball players. In the future, the association between movement and position control and LBP incidence in youth athletes should be investigated further using prospective and intervention designs.

Keywords: Back pain, Youth athlete, Sports injury, Epidemiology, Risk factors, Sports participation

TIIVISTELMÄ (ABSTRACT IN FINNISH)

Rossi, Marleena Katariina
Selkäkipujen yleisyys ja riskitekijät nuorilla suomalaisilla
Jyväskylä: University of Jyväskylä, 2020, 118 s.
(JYU Dissertations
ISSN 2489-9003; 233)
ISBN 978-951-39-8184-6

Tutkimusten mukaan suurin osa kokee elämänsä aikana selkäkipuja. Alaselkäkivut nuoruudessa altistavat alaselkäkivuille aikuisuudessa ja esiintyvät usein yhdessä muiden tuki- ja liikuntaelin (TULE) vaivojen kanssa. Alaselkäkivut on yhdistetty myös muun muassa uniongelmiin, fyysisen aktiivisuuden määrän vähentymiseen ja koulupoissaoloihin. Joidenkin tutkimusten mukaan urheiluun osallistuminen altistaa alaselkäkivuille. Tämän tutkimuksen tavoitteena oli tutkia selkäkipujen yleisyyttä suomalaisilla nuorilla ja selvittää mahdollisten riskitekijöiden yhteyttä alaselkäkipujen ilmaantuvuuteen nuorilla koripallon ja salibandyn pelaajilla.

Ensin selkäkipujen yleisyyttä selvitettiin urheiluseuratoimintaan osallistuvilla ja ei-osallistuvilla nuorilla. Kaksikymmentäneljä prosenttia pojista ja 35 % tytöistä raportoi selkäkipuja edellisen kolmen kuukauden aikana. Selkäkivut olivat yhteydessä muihin TULE-vaivoihin. Pojilla urheiluseurassa harrastaminen lisäsi selkäkipujen todennäköisyyttä, mutta toisaalta urheiluseurassa liikkuvilla nuorilla oli harvemmin toistuvia niska- ja hartiaseudunkipuja.

Tämän jälkeen selvitettiin seurantatutkimuksella selkäkipujen yleisyyttä, ilmaantuvuutta ja alaselkäkipujen riskitekijöitä nuorilla koripallon ja salibandyn pelaajilla. Jokaisen tutkimusvuoden alussa pelaajat osallistuivat laajoihin alkutesteihin, joissa mitattiin lihasvoimaa ja -venyvyyttä, nivelten yliliikkuvuutta, törmäysvoimaa kahden jalan pudotushypyn alastulossa sekä liikkeen hallintaa liiketesteissä. Seurannan aikana kerättiin yksilölliset tiedot harjoittelu- ja pelimääristä sekä vähintään vuorokauden poissaolon harjoituksista aiheuttaneista selkäkivuista.

Neljälläkymmenelläviidellä prosentilla koripallon pelaajista ja 64 % salibandynpelaajista oli joskus ollut selkäkipuja. Tyypillisesti selkäkivut olivat alkaneet hitaasti ilman edeltävää traumaa ja niitä koettiin eniten kilpapelikaudella. Seurannan aikana 13% pelaajista raportoi selkäkipuja, jotka estivät täysipainoisen osallistumisen harjoituksiin ja peleihin (mediaani poissaolo oli 14 päivää). Selkäkipujen ilmaantuvuus oli yhteensä 0.4 tuhatta harjoitus- ja pelituntia kohden. Riskitekijäanalyyseissä havaittiin yhteys selkäkipujen ja lonkan ja lantion hallinnan välillä yhden jalan alastulossa. Vastaavaa yhteyttä ei todettu seisten tehdyssä polvennostotestissä. Yhteyttä ei myöskään havaittu alaselkäkipujen ja alastulon aiheuttaman iskun suuruuden, alaraajojen maksimilihasvoiman, lihasvenyvyyden tai liikkuvuuden välillä.

Alaselkäkivut olivat yleisiä jo nuorilla ja ne esiintyivät usein yhdessä muiden TULE-vaivojen kanssa. Alaselkäkivut häiritsivät myös nuorten urheilijoiden harjoittelua. Heikompi lonkan ja lantion hallinta dynaamisessa liiketestissä lisäsi riskiä alaselkäkivuille nuorilla salibandyn ja koripallon pelaajilla. Tulevaisuudessa nuorten urheilijoiden asennon- ja liikkeenhallinnan yhteyttä selkäkipuihin kannattaa tutkia lisää seuranta- ja interventiotutkimusten avulla.

Asiasanat: Selkäkipu, nuori urheilija, urheiluvamma, epidemiologia, riskitekijät, urheiluun osallistuminen

Author Marleena Katariina Rossi, MSc, PT
Faculty of Sport and Health Sciences
University of Jyväskylä
Finland
marleena.k.rossi@jyu.fi
ORCID: orcid.org/0000-0002-5714-6436

Supervisors Professor Kati Pasanen, PhD, PT
Sport Injury Prevention Research Centre
Faculty of Kinesiology
University of Calgary
Canada
Tampere Research Center of Sports Medicine
UKK Institute
Finland

Professor Ari Heinonen, PhD, PT
Faculty of Sport and Health Sciences
University of Jyväskylä
Finland

Docent Jari Parkkari, PhD, MD
Tampere Research Center of Sports Medicine
UKK Institute
Finland

Reviewers Docent Peter Lüthje, PhD, MD
North Kymi Hospital
Finland

Professor Michael Skovdal Rathleff, PhD, PT
Department of Health Science and Technology
Aalborg University
Denmark

Opponent Professor Martin Hägglund, PhD, PT
Department of Health Medicine and Caring Sciences
Linköping University
Sweden

ACKNOWLEDGEMENTS

This dissertation is part of two bigger study projects carried out at the Tampere Research Center of Sports Medicine, the UKK Institute for Health Promotion Research, Tampere, Finland and the Faculty of Sports and Health Sciences, University of Jyväskylä, Finland. Firstly, I would like to express my sincerest gratitude to my supervisors – Professor Kati Pasanen, Professor Ari Heinonen and Docent Jari Parkkari. I am very thankful for your advice and guidance throughout the dissertation project. Being a bit detached from the rest of the study group was not ideal, but with your help, I was able to finish this project.

I want to thank statistician Kari Tokola, who was instrumental in the statistical analyses in my research. For this, I am extremely grateful. I have learnt a lot from all the co-authors I worked with during these years. So, I owe you all my sincerest gratitude. I also want to acknowledge Docent Peter Lüthje and Professor Michael Skovdal Rathleff, for their effort in reviewing this dissertation. Your observations and comments are greatly appreciated.

When getting closer to finishing this project, I received a few personal grants to help speed up the project towards the finish lines. Thank you to the Björkvist fund, the Ellen and Artturi Nyyssönen Foundation, to Suomen Fysioterapeutit and University of Jyväskylä. These grants were crucial in getting me here today.

This dissertation project was quite long as, for most of the time I was working on it, I was also in full time employment. Therefore, I also need to acknowledge my boss Mika Huotari for allowing me to work flexible hours and my Physiotools colleagues who have been very understanding.

Because I was so detached from the rest of the study group, I often felt quite alone during the project. Therefore, the support I got from my family means even more than I can express with words. I would not have been able to survive the PhD journey on my own. I want to thank my sister, for always looking after me - I love you to the moon and back. Thank you, mom and dad for your support over the years. And thank you Tommi, I don't even know what to say. This project has made me a bit mental from time to time (and by that, I mean very often) and you are still there. How lucky am I?

Finally, I want to dedicate this dissertation to the most amazing Oskari, Oliver and Sara. I hope you never lose your love and passion for sports and being active.

Tampere 9.3.2020
Marleena

FIGURES

TABLES

SUPPLEMENTS

LIST OF ORIGINAL PUBLICATIONS

I. Rossi M, Pasanen K, Kokko S, Alanko L, Heinonen OJ, Korpelainen R, Savonen K, Selänne H, Vasankari T, Kannas L, Kujala U, Villberg J, Parkkari J. 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 Musculoskeletal Disorders 2016 17:263 DOI 10.1186/ s12891-016-1114-8

II. Pasanen K, Rossi M, Parkkari J, Kannus P, Heinonen A, Tokola K, Myklebust G. Low back pain in young basketball and floorball players: a retrospective study. Clinical Journal of Sports Medicine 2016;26(5):376–380 DOI 10.1097/JSM.0000000000000263.

III. Rossi MK, Pasanen K, Heinonen A, Myklebust G, Kannus P, Kujala UM, Tokola K, Parkkari J. Incidence and risk factors for back pain in young floorball and basketball players: a prospective study. Scandinavian Journal of Medicine and Science in Sports 2018;28(11):2407-2415 DOI 10.1111/sms.13237.

IV. Rossi MK, Pasanen K, Heinonen A, Äyrämö S, Räisänen AM, Leppänen M, Myklebust G, Vasankari T, Kannus P, Parkkari J. Performance in dynamic movement tasks and occurrence of low back pain in youth floorball and basketball players. BMC Musculoskeletal Disorders 2020;21: 350 DOI 10.1186/s12891-020-03376-1

V. Rossi MK, Pasanen K, Heinonen A, Äyrämö S, Leppänen M, Myklebust G, Vasankari T, Kannus P, Parkkari J. Standing knee lift test is not a useful screening tool for time-loss LBP in youth basketball and floorball players. (Submitted)

In studies I, III, IV and V Marleena Rossi was the first author and was responsible for the statistical analyses, with assistance from a statistics expert when needed, interpretation of the results as well as writing process and the submission of the articles. In study II, Rossi was responsible for data collection, data preparation and literature review, and she provided substantive feedback on the manuscript and contributed to the final manuscript.

ABBREVIATIONS

ACL	Anterior cruciate ligament
AE	Athletic exposure
ASIS	Anterior superior iliac spine
BMI	Body mass index
BP	Back pain (spinal pain)
CI	Confidence interval
CL	Contralateral
FHPSC	Finnish Health Promoting Sport Club
FPA	Femur-pelvic angle
GEE	Generalized estimating equations
GRF	Ground reaction force
HR	Hazard ratio
ICC	Intra class correlation
Kg	Kilograms
LBP	Low back pain
LEI	Lower extremity injury
MRI	Magnetic resonance imaging
MSK	Musculoskeletal
N	Newton
NSP	Neck and shoulder pain
OR	Odds ratio
PA	Physical activity
PROFITS	Predictors of Lower Extremity Injuries in Team Sports
PSIS	Posterior superior iliac spine
ROM	Range of motion
SD	Standard deviation
SKL	Standing knee lift test
SLVDJ	Single-leg vertical drop jump
VAS	Visual analogue scale
VDJ	Vertical drop jump
vGRF	Vertical ground reaction force
2D	Two-dimensional
3D	Three-dimensional

CONTENTS

1 INTRODUCTION

Back pain (BP) is an expensive public health problem and results in serious economic burden. The majority of people will have BP at some point in their life (Lemeunier et al. 2012). A systematic review, including 150 studies from all over the world, reported a mean lifetime prevalence of low back pain (LBP) is 40%(Hoy et al. 2012), but the prevalence is higher in western high-income countries. In Finland, the Health 2011 -study reported that in 30- to 40-year-olds the prevalence of BP during the past 30 days is 35% among males and 37% among females (Viikari-Juntura et al. 2012). Among adults, the one-month prevalence of activity-limiting LBP lasting for at least one day has been estimated to be 23%(Hoy et al. 2012). Furthermore, in Finland back diseases, including BP, were responsible for sickness benefit expenditure of approximately 97 million euros and over 1.7 million days of covered illness in year 2017 (Statistical Yearbook of the Social Insurance Institution 2017). BP itself caused approximately 34 million euros of sickness benefit expenditure and 614,000 covered days of illness (Statistical Yearbook of the Social Insurance Institution 2017).

Even though BP is most common among middle aged and older populations, it is not uncommon among younger populations either (Hoy et al. 2012). A meta-analysis focusing on younger populations reported mean lifetime and one-month LBP prevalence of 39.9% (range 8.6% to 64.8%) and 18.3% (range 2.5% to 39.8%), respectively, based on cross-sectional studies in children and youth (Calvo-Muñoz et al. 2013).

BP in youth has been linked with activity reduction (Szpalski et al. 2002, Staes et al. 2003), sleep problems (Auvinen et al. 2010), school absenteeism (Wedderkopp et al. 2001, Szpalski et al. 2002, Hangai et al. 2010, Coenen et al. 2017), as well as increased risk for future BP (Kjaer et al. 2011, Smith et al. 2017, Coenen et al. 2017). For example, 12% of children and youth reported having stayed at home and over 20% had reduced their physical activity (PA) due to LBP in a Danish study by Wedderkopp et al. (2001). In addition, work or school absence due to BP in youth seems to increase the likelihood of work absence later in life (Coenen et al. 2018).

Therefore, it is essential to study BP and aim to decrease the incidence and recurrence of BP in youth. An appropriate context for this are sports clubs with one of their objectives being health promotion. In Finland, participation in sports club activities among youth has increased during the last decades (Husu et al. 2011, p. 22). Half of 9- to 15-year-olds are active participants in organized sports club activities and an additional 11% take part occasionally (Mononen et al. 2016). Even though participation decreases during youth, and is at its lowest in 15-year-olds, still almost half (48%) take part (Mononen et al. 2016).

Although PA is the recommended treatment for LBP in adult population (Foster et al. 2018), the burden of BP affects physically active youth as well. Sato et al. (2011) reported a higher lifetime prevalence of LBP and a higher perceived limitation due to LBP among youth taking part in sports activities. In children, LBP incidence is higher in organized sports compared to other physical activity when adjusted with hours of activity (Franz et al. 2016). Moreover, a Finnish study reported a higher incidence of LBP among youth athletes: 44% of the athletes reported activity-limiting LBP during a three-year follow-up compared to 18% of the non-athletes (Kujala et al. 1996). In addition, sport is the leading cause of injury overall among youth (Parkkari et al. 2016).

The purpose of this doctoral thesis is to further explore the association between sports participation and LBP and to investigate the burden and risk factors of LBP in youth athletes.

1.1 Sports-related injuries

In Finland, half of adolescents between 11- and 15 years of age have been injured at least once during the preceding year while participating in PA in organized sports, PA during school hours or leisure time activities (Parkkari et al. 2016). Most of the reported injuries occurred during organized sports: 49% of youth sports club participants had been injured (Parkkari et al. 2016). In Canada, 30% to 40% of youth (age range 11–18 years) seek medical consultation due to sports-related injury annually (Emery et al. 2006, Emery & Tyreman 2009). Thus, it is warranted to investigate predisposing factors for sports-related injuries and pain.

According to the van Mechelen model, there are four steps in sports injury research aiming at injury prevention (van Mechelen et al. 1992) (Figure 1). In the first step, when the occurrence and severity of an injury are of interest, prevalence and incidence are often reported. Prevalence describes the proportion of cases (N or %) in the population of interest at a particular time (Bonita et al. 2006, p. 18) (commonness). Incidence describes the rate of new cases occurring in the population of interest during a defined period (Bonita et al. 2006, p. 18) (occurrence). In the second step, factors and mechanisms that are associated with the new injuries are analysed. In the third step, measures that are based on previous steps are introduced with aim to decrease the incidence and/or severity of the injuries. In the final step the effect of the intervention is evaluated by going back to the first step (van Mechelen et al. 1992).

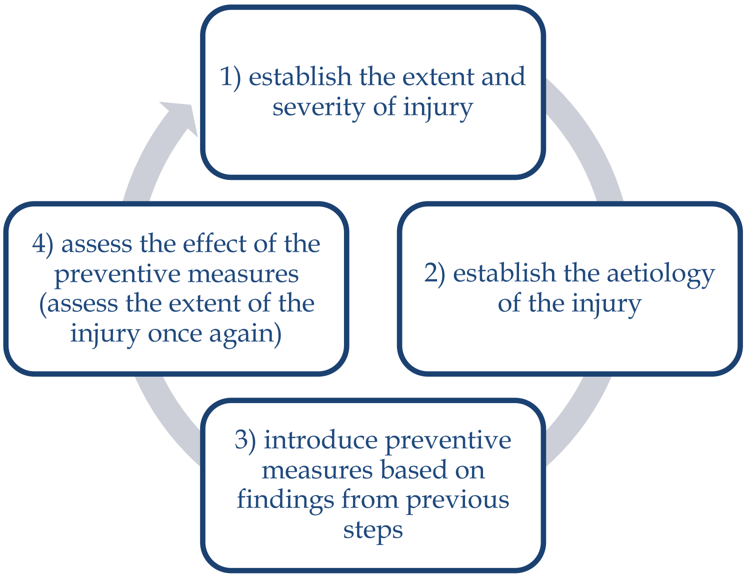

FIGURE 1 Traditional model of sports injury prevention research (Adapted from van Mechelen et al. 1992).

In sports injury studies, injury is often defined as any physical complaint sustained by an athlete that results from participation in a sport, irrespective of the need for medical attention or time-loss from participating in training or games/competitions (Fuller et al. 2006). It is also common to use 'time-loss' and 'medical injury' definitions as criteria for a recordable injury in order to notice injuries that result in disability and are considered 'substantial injuries'. Time-loss injuries are injuries that result in an athlete being unable to fully participate in normal training or games/competitions (Fuller et al. 2006), that is, they result in some level of disability. This means that the player might be able to participate in training but needs to modify the training due to their pain or injury. For example, perform upper body strength training instead of lower body strength training because of a leg injury. If the athlete consults medical personnel due to their injury, it is then called a medical injury (Fuller et al. 2006).

2 BACK PAIN

The International Association for the Study of Pain defines pain as 'an unpleasant sensory and emotional experience associated with actual or potential tissue damage or described in terms of such damage (Merskey & Bogduk 1994). Pain may be related to a tissue injury, but tissue injury can also occur without pain. For example, a change in mechanical, chemical or thermal state activates nerve terminals in muscles and joints (nociceptive pain). Nociception, that is, the encoding and processing of stimulus that is potentially harmful can also happen without pain, for example situations where an injury situation in not painful and the pain is felt later. Pain can also occur without nociception. Pain is modulated throughout the central nervous system and psychosocial factors, such as sleep quality, stress and anxiety, might affect the functioning of theses receptors, lowering, for example, the threshold for receptor activation. On the other hand, the functioning of these receptors may change due to some other unknown reason without tissue injury (Hainline et al. 2017).

BP is often classified into groups based on pain location: neck, upper back pain, lower back pain (for example Wedderkopp et al. 2003, Aartun et al. 2014). In research, BP and LBP are often defined in terms of duration of symptoms (for at least one day, one week, at least 30 days within the past six months, etc.), timeframe describing when the symptoms have occurred (past week, past three months, past six months, past 12 months or ever/in a lifetime) and sometimes additional refinements are used, such as the need for medical consultation, disability produced by pain and so on (see for example Hoy et al. 2012). All in all, the inconsistency between definitions can make comparisons and summarizing findings between studies difficult.

A consensus approach towards the definition of LBP was made in 2008 by 28 experts in BP research using the Delphi method (Dionne et al. 2008). They suggested standards to make future comparisons between BP studies possible. The standardized definitions produced in the study were 'minimal definition' and 'optimal definition'. The minimal definition included the area of pain (drawing with low back area shaded when possible) and disability, meaning whether the pain limited usual activities or changed daily routines. The optimal definition added to the minimal definition by assessing the presence of sciatica (pain that goes down the leg above or under the knee) and included a mention of exclusion of pain due to menstruation or feverish illness. The optimal LBP definition also included frequency, duration of symptoms and severity, which was described as intensity of pain using numerical scale. A time frame of four weeks was agreed on for both minimal and optimal definitions (Dionne et al. 2008). Despite the aim of the consensus approach, the BP definitions and timeframe used in studies are heterogeneous.

According to the definition of a sports injury by Fuller et al. (2006), BP resulting from sports participation is regarded as a sports injury located in the back area, that is, a back injury. However, BP is a symptom that has several possible contributing factors and for most BP, the origin of pain remains unknown because often it is not possible to identify a specific nociceptive cause (Hartvigsen et al. 2018). Therefore, throughout this thesis, the term 'back pain' is used instead of 'back injury' or 'spine injury'.

2.1 General overview of back pain in youth

The overall lifetime prevalence of BP, including thoracic spine and neck, has been reported to be 60% among girls and 78% among boys in youth (13 to 16 years) (Wirth et al. 2013) and even as high as 88% among 14- to 15-year-olds (Aartun et al. 2014). Thoracic spine pain seems to be common already in childhood and LBP becomes more common in early adolescence (Wedderkopp et al. 2001, Kjaer et al. 2011). A systematic review summarized previous cross-sectional studies investigating LBP prevalence in youth (Calvo-Muñoz et al. 2013). A mean lifetime and one-month LBP prevalence was reported to range from 8.6% to 64.8% and 2.5% to 39.8%, respectively (Calvo-Muñoz et al. 2013).

As can be seen from Table 1, the prevalence rates among youth and young adults under 21 years differ considerably depending on BP location (lumbar, thoracic, neck, all together), definition (disabling, activity limiting, any BP, time-loss) and time-period used as well as frequency and duration of symptoms.

When considering longitudinal studies without prospective data collection, there is also a case of recall bias, especially when using prevalence rates in the far history. For that reason, among younger population a maximum of 12-month recall prevalence has been recommended (Hestbaek et al. 2006, Milanese & Grimmer-Somers 2010).

It has been shown consistently within previous studies that prevalence (Table 1) of LBP increases with age (Poussa et al. 2005, Hestbaek et al. 2006, Kjaer et al. 2011, Sano et al. 2015, Coenen et al. 2017). For instance, a Danish study noticed an increase in one-month prevalence of LBP from 22% in 12- to 14-year-olds to 36% in 15- to 17-year-olds (Kjaer et al. 2011).

Increased occurrence with age has also been seen among athletic population (Finch et al. 2010, Shah et al. 2014, Rössler et al. 2016). Rössler et al. (2016) observed that 11- to 12-year-old soccer players had over three times (*OR* 3.22, 95% *CI* 0.34 to 30.97) higher odds for back complaints than 9- to 10-year-old players did. However, it should be noted that a significant increase in odds with increasing age is not often seen with a short time-interval (Feldman et al. 2001, Greene et al. 2001) and that the increases become subtler with age (Hestbaek et al. 2006, Grimmer et al. 2006, Coenen et al. 2017).

The majority of longitudinal studies recorded incidence retrospectively (Table 2). This type of data collection does not take into account incidents of LBP occurring between baseline and follow-up outside the defined period. For example, in a Finnish study the follow-up lasted from age 16 to age 19 and the LBP incident was recorded if LBP during the preceding six-months was reported every follow-up year (Mikkonen et al. 2013). Then all LBP incidents following baseline and before the last six-months before the follow-up questionnaire are not considered and therefore do not describe the true number of new incidents. We could identify only one longitudinal study, the Danish CHAMPS study (Franz et al. 2014, Franz et al. 2016), using prospective BP data collection in children (6 to 12 years), but none in youth.

The results regarding the sex difference in LBP prevalence are inconsistent. Some studies have found that girls report more LBP than boys do (van Gessel et al. 2011, Mikkonen et al. 2016, Coenen et al. 2017, Smith et al. 2017), some studies found similar prevalence in boys and girls (Kujala et al. 1996, Feldman et al. 2001, Greene et al. 2001, Poussa et al. 2005, Müller et al. 2016) and some studies state that men/boys have a higher risk of LBP (Clarsen et al. 2015).

Franz et al. (2014) noticed no difference between LBP prevalence between boys and girls between 6 and 12 years, but it seemed that sex difference might develop at older age. Grimmer et al. (2006) noticed in Australian youths, that the ‘trend line’ for recent LBP incidence (new cases) was different for boys and girls. They noticed that the incidence decreased in girls and increased in boys from age 13 and speculated it was due to differences in puberty timing between the sexes.

In young adult athletes a Norwegian study noticed that in a multivariate analysis adjusted for sporting group (but not for training volume), young women were at decreased risk for substantial LBP and a trend towards decreased risk for all LBP was also seen (Clarsen et al. 2015). On the other hand, a German study reported, in a similar age sample (age range 16.1 to 25.7, n = 1,424), that in both elite athletes and a physically active control group, young women reported significantly more LBP than men did, but again the analyses were not adjusted for training volume (Fett et al. 2017).

TABLE 1 Longitudinal studies reporting back pain prevalence at baseline and follow-up among young general population.

Study Author	Sample (n)	LBP definition	Age (group)	Period prevalence (%) Lifetime	One-year	Six months	One-month	One-week	Point
Sjolie et al. (2004)	*n* = 88	LBP as pain or ache in the low back during the preceding year (female/male)	14 to 16	66 (74/60)					
	n = 85		17 to 19	67 (78/57)					
Grimmer et al. (2006)	*n* = 434	LBP experienced in the previous week (female/male)	13					7.1 (8.2/7.2)	
	n = 315		14					12.7 (15.3/10.3)	
	n = 300		15					15.3 (22.8/11.9)	
	n = 244		16					17.3 (22.7/15.8)	
	n = 174		17					16.7 (26.1/10.5)	
Hestbaek et al. (2006)	*n* = 6,540	LBP for more than zero days during the previous year (Persistent LBP: LBP for more than 30 days during the previous year)	12 to 15		16 (2)				
			16 to 19		40 (7)				
			20 to 22		50 (10)				
			20 to 23		36 (10)				
			24 to 27		38 (9)				
			28 to 30		43 (11)				
Auvinen et al. (2009)	*n* = 970/770	Pain or aching during the last 6 months in low back area (female/male)	16			42.8/31.4			
	n = 960/760		18			56.4/41.3			
Kjaer et al. (2011)	*n* = 484	BP was defined overall and specifically in the three spinal regions as having reported pain within the past month.	12 to 14				28.0		
	n = 443		15 to 17				48.0		

	n = 484	LBP pain within the past month	12 to 14			22.0		
	n = 443		15 to 17			36.0		
Mikkonen et al. (2013)		LBP during past six-months (female/male)	16		48/36			
			18		63/47			
			19		61/49			
Aartun et al. (2014)	*n* = 1,291	Spinal pain was defined as pain in any of the three locations, i.e. lumbar, thoracic, neck	11 to 13	89.0			35.9	16.9
	n = 1,064		13 to 15	88.8			48.5	22.9
	n = 1,291	LBP (female/male)	11 to 13	48.5/40.8			13.2/9.9	59/42
	n = 1,064		13 to 15	58.5/45.7			21.7/18.4	81/59
Sano et al. (2015)	*n* = 4,597	Subjective LBP	9	10.1				2.8
	n = 5,449		10	14.8				3.7
	n = 5,408		11	17.2				5.2
	n = 5,754		12	20.5				7.2
	n = 5,588		13	24.2				9.2
	n = 5,800		14	24.7				9.0
Coenen et al. (2017)	*n* = 1,050	LBP during preceding one-month (Medical LBP)	17			32 (12)		
	n = 1,112		20			45 (15)		
	n = 1,033		22			45 (22)		

LBP, low back pain; BP, back pain

TABLE 2 Longitudinal studies reporting incidence of new back pain complaints among young general population (12-year-old or older).

Author	Follow-up period and status at baseline	Age[1]	Incidence (percentage of all exposed)
Brattberg et al. (1994)	Follow-up: Two-years Status: Symptom free	8, 11 and 13	Two-year cumulative incidence (95% *CI*) Age 8 to 10 16% (9 to 22) Age 11 to 13 22% (16 to 29) Age 13 to 15 22% (15 to 30)
Nissinen et al. (1994)	Follow-up: One-year Status: No history of LBP prior to baseline	12.8	One-year incidence Age 13.8: female 18.4%, male 16.9%
Feldman et al. (2001)	Follow-up: 12-months Status: No LBP at least once a week within past six-months at baseline	13.8	LBP at least once a week within six-months: (12-month cumulative incidence) 17.2%
Jones et al. (2003)	Follow-up: One-year Status: Free of LBP at baseline	11 to 14	New-onset one-month LBP prevalence Age 12: 12.5% Age 15: 24.1%
Poussa et al. (2005)	Follow-up: Eight-years Status: No BP that occurred on eight or more days during the past year at baseline	14	BP lifetime cumulative incidence Age 14: female 18.4%, male 16.9% Age 22: female 78.9%, male 78.4%
Grimmer et al. (2006)	Follow-up: Five-years Status: No LBP experienced in the previous week at baseline, LBP experienced in the previous week	13	LBP experienced in the previous week Age 14: female 13.2%, male 9.5% Age 15: female 9.4%, male 5.2% Age 16: female 8.3%, male 7.4% Age 17: female 8.7%, male 6.7%
El-Metwally et al. (2007)	Follow-up: One-year Status: No musculoskeletal pain at baseline	10.8	LBP three-month incidence Age 11.8: close to 2%
	Follow-up: Two-years Status: No LBP during past six-months at baseline	16	Six-month LBP prevalence Age 18: female: 46%, male: 32%

LBP, low back pain; BP, back pain. [1] Age at baseline.

2.1.1 Prevalence and incidence of back pain in youth athletes

BP prevalence has been reported to be higher among young adult elite athletes compared to active controls (Fett et al. 2017). LBP prevalence has also been shown to be higher in youth sport participants (Kujala et al. 1996, Auvinen et al. 2008, to be higher in youth sport participants (Kujala et al. 1996, Auvinen et al. 2008, Hangai et al. 2010, Hoskins et al. 2010, Jonasson et al. 2011, Sato et al. 2011) than it is in the general population. Yet not all studies have found similar results regarding the link between sports participation and higher LBP prevalence (Wedderkopp et al. 2003, Diepenmaat et al. 2006, Mogensen et al. 2007, Tunås et al. 2014). One factor affecting the conflicting results might be that self-reported PA levels in youth may not be that reliable (Wedderkopp et al. 2003).

There is evidence that some sports might be associated with a higher incidence of BP than other sports are. For instance, there seems to be a trend towards a higher incidence of LBP in contact sports than in non-contact sports (Greene et al. 2001, Junge et al. 2004). In addition, studies analysing youth sports suggest that the contribution of LBP to the total injury burden differs between sports. Among team sports, such as soccer, volleyball, basketball, field hockey, handball and netball, the percentage of new BP complaints out of all injuries range approximately from 1% to 15% (Hopper & Elliott 1993, Gomez et al. 1996, Hickey et al. 1997, Messina et al. 1999, Peterson et al. 2000, Junge et al. 2004, Le Gall et al. 2006, Timpka et al. 2008, Rishiraj et al. 2009, Aoki et al. 2010, Clausen et al. 2014, Shah et al. 2014, Bere et al. 2015, Rössler et al. 2016, von Rosen et al. 2018a). There seems to be a slightly higher relative burden in cricket (13% to 43%) (Finch et al. 2010, Martin et al. 2017), gymnastics (13% to 16%)(Caine et al. 2003, Cupisti et al. 2007), among power athletes (including jumpers, throwers, and athletes competing in combined athletic events) 25%, and endurance skiing (16%)(von Rosen et al. 2018a), for example. However, comparison is difficult with studies using different measures and definitions. A recent systematic review pooled data from studies using the same data collection and focusing on adult athletes. It reported that lifetime prevalence and one-year prevalence range between 46% to 65% and 35% to 63%, respectively, but again the differences between studies were difficult to analyse due to differences in methodologies (Trompeter et al. 2017).

Sports injuries located in the trunk and back area account for 6% to 16% of all game and practice injuries, respectively, in many team sports (Agel et al. 2007a, Agel et al. 2007b, Agel et al. 2007c, Dick et al. 2007a, Dick et al. 2007b, Dick et al. 2007d) In cross-sectional retrospective studies among youth team sport players, the 12-month prevalence of LBP has been reported to range from 47% to 64% (van Hilst et al. 2015, Grosdent et al. 2016) (Table 3). The difference between reported prevalence rates is likely to be due to different definitions of LBP (time-loss vs. any BP, traumatic vs. non-traumatic), different sports included (field hockey vs. soccer), difference in age and playing level of the athletes as well as differences in data recording.

Prospective studies investigating BP in youth sport are outlined in Table 4. To our knowledge there are no prospective studies reporting BP data in youth floorball players and only a few in youth basketball players (Gomez et al. 1996, Hickey et al. 1997, Messina et al. 1999, Meeuwisse et al. 2003). Therefore, BP reported in team sports with similarities to basketball and floorball, like running spurts with sudden turns and stops and frequent jumps and landings, are also reviewed to acquire a sense of the previous research and knowledge caps. These sports include player contact during the play, but do not emphasize it as in full contact sports like lacrosse, rugby, and American as well as Australian-rules football.

Within youth team sports, the overall incidence of time-loss back complaints per 1,000 training and game hours ranges from 0.1 to 0.7 (Table 4) and the proportion of injured out of all exposed players ranges from 8% to 13% (Table 4). Back complaints comprised 3% to 42% out of all injuries (Table 4). For younger players, the incidence (BP requiring medical attention) seems to be lower, 0.006[i] to 0.02[i] per 1,000 training and game hours in 7- to 12-year-olds compared to 0.25 per 1,000 training and game hours in 14- to 18-year-olds (Gomez et al. 1996, Rössler et al. 2016).

According to prospective investigations, BP comprises approximately 5% to 6% out of the total injury burden in youth basketball (Gomez et al. 1996, Messina et al. 1999, Meeuwisse et al. 2003). Hickey et al. (1997) performed a retrospective investigation using medical records and noticed that within sports injuries requiring physician consultation, the percentage of back complaints was slightly higher (11.7%). Moreover, repeated cross-sectional studies investigating collegiate basketball have reported that trunk and back complaints constituted approximately 7% to 11% of game injuries and 10% to 14% of practice injuries in college basketball (Agel et al. 2007b, Dick et al. 2007a). Meeuwisse et al. (2003) reported an incidence of 0.21 per 1,000 athlete exposure (AE) for low back and pelvis pain resulting in less than seven days lost from training and games, and 0.02 per 1,000 AE for low back and pelvis pain that resulted in longer time-loss among college-aged basketball players. Incidences of 0.18 (Messina et al. 1999) and 0.25 per 1,000 training and game hours[ii] (Gomez et al. 1996) have been reported for back complaints resulting in time-loss or medical consultation among 14- to 18-year-old boys and girls, respectively. The average time-loss from participation was 5 days (Meeuwisse et al. 2003) and no difference between boys and girls was found (Messina et al. 1999).

Hickey et al. (1997) reported that within medical sports injuries, the percentage of traumatic onset BP complaints were 54%. Cumps et al. (2007) studied older players (age range: 15.1 to 36.5 years) and noticed that there was no difference between the occurrence of non-traumatic and traumatic onset back complaints (non-traumatic 0.6/1,000 hours, 95% *CI* 0.3 to 0.9; traumatic 0.6/1,000 hours, 95% *CI* 0.3 to 0.9). They included traumatic injuries requiring medical treatment and resulted in one-day time-loss and non-traumatic injuries that were present during or after basketball participation and lasted three basketball-active days. No data on the relative prevalence of non-traumatic and traumatic back complaints that do not result in time-loss or medical consultation were found.

No studies investigating BP among youth floorball players were found. Pasanen et al. (2008) investigated floorball injuries in young adults using prospective data collection and concluded that half of the reported back complaints (n = 7) had non-traumatic gradual onset and half (n = 7) had acute traumatic onset. They also reported that the low back was the fourth most

---

[i] Calculated based on information provided in the research report (mean player-hours based on team exposure hours and number of injuries)

[ii] Calculated based on information provided in the research report (exposure and number of injuries)

commonly injured body part, with 8% of the total injury burden. Clarsen et al. (2015) investigated the weekly prevalence of LBP in a prospective study with floorball, volleyball and handball players with a mean age of approximately 21 years. They reported that non-traumatic LBP was more common among floorball players than among handball or volleyball players, with an average 7-day prevalence of LBP among floorball players was 29% (95% *CI* 25 to 33) and 3% (95% *CI* 1 to 4) for substantial LBP. Their generalized estimating equations (GEE) analysis (adjusted for age, sex, years of participation, height and weight) revealed a trend towards floorball players having nearly two-times (*OR* 1.90, 95% *CI*, 0.77 to 4.68; *OR* 1.98, 95% *CI* 0.83 to 4.63) higher odds for any LBP complaints compared to handball or volleyball players, respectively. However, when they investigated substantial complaints (i.e. complaints that resulted in moderate or severe reductions in training volume or performance, or not able to participate), there was a trend towards floorball players having lower odds than volleyball (*OR* 0.52, 95% *CI* 0.14 to 1.92) and handball (*OR* 0.94, 95% *CI* 0.26 to 3.39) players. Even though the average prevalence of substantial LBP among floorball players was low, the impact of LBP among floorball players is high (adjusted cumulative severity score 7.65) (Clarsen et al. 2013).

The majority of the studies did not state the onset of the symptoms (Hopper & Elliott 1993, Messina et al. 1999, Junge et al. 2004, Le Gall et al. 2006, Rishiraj et al. 2009), or reported only traumatic onset injuries (Soligard et al. 2012, Shah et al. 2014). However, it seems that at least in young soccer players BP complaints related to overuse and complaints without known tissue injury were more common compared to acute onset BP (Peterson et al. 2000, Aoki et al. 2010). By contrast, Clausen et al. (2014) observed more traumatic onset LBP complaints resulting in time-loss among 15- to 18-year-old female soccer players (U18 teams).

Possible reasons for the conflicting results are related to injury definition, sport, level of play, injury reporting and sex. For example, Aoki et al. (2010) reported only complaints that resulted in a one-week absence, compared to Shah et al. (2014) with a minimum of 48-hour absence. Peterson et al. (2000) and Aoki et al. (2010) failed to confirm whether players were boys or girls or both. In one study the injuries were self-reported (Clausen et al. 2014) and in two studies recorded by coaching staff or medical personnel (Peterson et al. 2000, Aoki et al. 2010). It has also been shown that lower-level youth players acquire more traumatic onset injuries than higher level youth players (Peterson et al. 2000). Therefore, one can speculate that players in the Clausen et al. (2014) study were possibly less skilled.

In young adult floorball players, an equal number of acute traumatic and non-traumatic onset BP complaints have been reported and 43% of the acute traumatic complaints resulted from non-contact situations (Pasanen et al. 2008). Yet in youth soccer players player contact was associated with a majority of the reported traumatic onset BP complaints (Shah et al. 2014).

TABLE 3 Cross-sectional/retrospective studies reporting prevalence of back complaints among youth team sport players.

Study	Design	Sample size, age and sport	Back complaint definition and area	Percentage (%) of all injuries	Percentage (%) of all exposed athletes
Hopper & Elliott (1993)	Retrospective	*n* = 78+75 Age: U21, U16 Sex: not reported Sport: netball	Pain and some degree of dysfunction in the back Recorded by team/medical personnel		U16 8.7% U21 12.8% (over 21 years 11.8%)
Agel et al. (2007b)	Repeated cross-sectional 16-year period	*n* = average 40 schools/year Age: college Sex: girls Sport: basketball	Medical injury + time-loss (Injury to trunk or back area, Low back muscle-tendon strain injuries)	Trunk/back injury Game injuries: 7.4% Practice injuries: 10.4% Low back muscle-tendon strain Game injuries: 1.3% Practice injuries: 2.9%	
Agel et al. (2007c)	Cross-sectional 15-year period	*n* = average 40 schools/year Age: college Sex: girls Sport: volleyball	Medical injury + time-loss (Injury to trunk or back area, Low back muscle-tendon strain injuries, Lower back ligament sprain)	Trunk/back injury Game injuries: 10.8% Practice injuries: 17.4% Low back muscle-tendon strain with over 10 d time-loss Game injuries: 4.8% Low back muscle-tendon strain injury Practice injuries: 7.9% Low back ligament sprain Practice injuries: 1.8%	

Dick et al. (2007a)	Repeated cross-sectional 16-year period	*n* = average 40 schools/year Age: college Sex: boys Sport: basketball	Medical injury + time-loss (Injury to trunk or back area, Low back muscle-tendon strain injuries)	Trunk/back injury Game injuries: 11.4% Practice injuries: 13.5% Low back muscle-tendon strain Game injuries: 2.2% Practice injuries: 3.6%
Dick et al. (2007b)	Repeated cross-sectional 15-year period	*n* = average 40 schools/year Age: college Sex: girls Sport: field hockey	Medical injury + time-loss (Injury to trunk or back area, Low back muscle-tendon strain injuries)	Trunk/back injury Game injuries: 16.2% Practice injuries: 7.1% Low back Muscle-tendon strain Game injuries: 2.1% Practice injuries: 5.2%
Dick et al. (2007c)	Repeated cross-sectional 15-year period	*n* = average 40 schools/year Age: college Sex: girls Sport: soccer	Medical injury + time-loss (Injury to trunk or back area, Low back muscle-tendon strain injuries)	Trunk/back injury Game injuries: 8.4% Practice injuries: 13.2% Low back muscle-tendon strain Game injuries: 1.3% Practice injuries: 1.6%
Dick et al. (2007d)	Repeated cross-sectional 16-year period	*n* = average 40 schools/year Age: college Sex: boys Sport: baseball	Medical injury + time-loss (Injury to trunk or back area, Low back muscle-tendon strain injuries)	Trunk/back injury Game injuries: 8.3% Practice injuries: 11.5% Low back muscle-tendon strain Game injuries: 1.8% Practice injuries: 4.2%

van Hilst et al. (2015)	Cross-sectional	*n* = 236 Age: 14 to 25 years Sex: both (soccer only male) Sport: field hockey, soccer	Any LBP, LBP that hampered performance, medical (during preceding 12-months)	Any LBP Field hockey: 67% in female 33% in male (Overall 56%) Soccer (male): 64% LBP (hampering) Field hockey: 22% in female 0% in male Soccer (male): 7% Medical LBP Field hockey: 63% in female 57% in male Soccer (male): 83%
Souza et al. (2015)	Cross-sectional	*n* = 188 Age: 11 to 17 years Sex: boys Sport: soccer	Medical injury + time-loss (recorded from clinical records) (LBP)	16.1%
Grosdent et al. (2016)	Cross-sectional	*n* = 43 Age: mean 18.2 ± 1.4 years Sex: boys Sport: soccer (elite)	Two-day time-loss (LBP during the previous 12-months)	47%
Noll et al. (2017)	Cross-sectional	*n* = 251 but only 104 included as only these reported BP Age: 14 to 20 years Sex: both Sport: handball, soccer, basketball, volleyball	BP during preceding three-months	41.3% 7.6% experienced BP 4 or more times per week.

LBP, low back pain; BP, back pain; AE, athlete exposure

TABLE 4 Longitudinal studies reporting incidence/prevalence of back complaints among youth team sport players.

Author	Study design and follow-up time	Age, sample size, sport, pain area and injury recording	Incidence per training and match hours	Percentage (%) out of all injuries	Injured players/all exposed players
Hopper & Elliot (1993)	Longitudinal (tournament)	*n* = 78+75 (+ open group over 21) Age: U21 and U16 Sex: not reported Sport: netball Back Disability with pain and some degree of dysfunction Recorded by team/medical personnel		13.5%	
Gomez et al. (1996)	Prospective cohort study, one season follow-up	Age: 14 to 18 years Sample size: *n* = 890 Sex: girls Sport: high school basketball Back Time-loss or medical consultation. Weekly recorded by team trainer (team exposure collected, and total hours calculated using average player number)	Approximately 0.25/1,000 hours[1]	6%	
Hickey et al. (1997)	Retrospective based on medical records, six-years	Age: mean age 16.8 years Sample size: *n* = 49 (72 athlete-years) Sex: girls Sport: basketball Lower back Medical records (physician consultation) (not just new injuries)		11.7% (10.1% out of traumatic injuries, 14.3% out of non-traumatic) (not just new injuries)	

Messina et al. (1999)	Prospective	Age: 14 to 18 years Sample size: n = 973 Sex: boys Sport: basketball Back Time-loss or medical injury Recorded by (team/medical personnel)	0.18/1,000 player hours[1] 0.03/athlete season (Girls: 0.22/1,000 player hours[1])	6% (Girls: 6%)	
Peterson et al. (2000)	Prospective study, one-year follow-up	Age: 16 to 18 years and 14 to 16 years (included also adult players) Sample size: n = 264 (-134 excluded due to missing data) Sex: not reported Sport: soccer Lower back Weekly physician examination and injury recording, injury defined as any tissue damage caused by football, complaints meant no tissue damage Complaint= no recognized injury	High level 16 to 18 years: 0.57/1,000 hours[1] 14 to 16 years: 0.47/1,000 hours[1] low level 16 to 18 years: 2.1/1,000 hours[1] 14 to 16 years: 2.4/1,000 hours[1] When calculated using avg. training and game hours the estimate incidences were higher in low level players and younger players.	In all age groups 5.7%	36.7% complaints 10.2% complaints and injury 26.5% complaints, but no injury Complaints, but no injury: 16 to 18 years: high level 18.8% low level 40.9% 14 to 16 years: high level 14.3% low level 34.8%

Meeuwisse et al. (2003)	Prospective cohort study, two-year follow-up	Age: College (age not specified) Sample size: *n* = 142 Sex: boys Sport: basketball Lower back Time-loss (one or partial session) Recorded daily by (team/medical personnel)	LBI resulting in less than 7 sessions missed (*n* = 9): 0.21 /1,000 AE LBI resulting in 7 sessions or more (*n* = 1): 0.02/1,000 AE.	
Junge et al. (2004)	Prospective cohort study, one season follow-up	Age: 14 to 18 years Sample size: *n* = 145 (soccer) *n* = 123 (rugby) Sex: boys Sport: rugby, soccer Thoracic and lower back Any injury Weekly recording by medical personnel Individual hours recorded	Soccer: 1.82/1,000 hours Rugby: 2.47/1,000 hours	Soccer: 6.5% Rugby: 5%
Le Gall et al. (2006)	Prospective observational cohort study, data collected during 10-seasons, player follow-up three-years	Age: U14 U15 U16 Sample size: *n* = 528 Sex: boys Sport: soccer Back Time-loss (at least 48 -hours) Recorded by (team/medical personnel)	0.05/1,000 AE[1] (108 back injuries/237,600 hours)	9.4% U14 *n* = 29, 6.9% U15 *n* = 35, 9.7% U16 *n* = 44, 11.9%

Timpka et al. (2008)	Prospective cohort study, 48-months follow-up	Age: 13 to 16 years Sample size: n = 1,800 Sex: boys Sport: Soccer (community-level) Lower back Time-loss (Any injury occurring during soccer games that resulted in one or more of the following: medical attention, the inability to complete the game, or missing a subsequent soccer session) Recorded by (team/medical personnel)		7%
Rishiraj et al. (2009)	Longitudinal (training camp), five years?	n = 75 Age: mean age 18 years Sex: girls Sport: field hockey Lower back Medical and time-loss injury AE recorded	Approximately 10.0/1,000 AE (exact value not reported)	14%
Aoki et al. (2010)	Case-controlled prospective study, one-year follow-up	Age: 12 to 17 years Sample size: n = 322 (301). Sex: not reported. Sport: soccer Natural turf: n = 212 Artificial turf: n = 89 Back/lower back Time-loss injuries (one-week) Daily recording	Non-traumatic: Back Artificial turf: 1.08/1,000 player hours (95% *CI* 0.78 to 1.47) Natural turf: 0.67/1,000 player hours (95% *CI* 0.49 to 0.89)	Traumatic: NT: Low back contusion/Sprain 14.1% AT: Back contusion/Sprain 15.4% Non-traumatic ('chronic') back: Natural turf: 33.3% Artificial turf: 42.3%

Moller et al. (2012)	Prospective cohort study, 31-wk follow-up	Age: U16 and U18 Sample size: u16 n = 194, U18 n = 152 Sex: both Sport: handball Lower back Time-loss Prospective registration of injuries and exposure hours by SMS messages+ structured interview	U18: Non-traumatic gradual 0.1/1,000 AE (0.03 to 0.4) Traumatic acute 0.1/1,000 AE (0.03 to 0.4) U16: Non-traumatic gradual 0.2/1,000 AE (0.04 to 0.4) Traumatic acute 0.2/1,000 AE (0.04 to 0.4)	
Soligard et al. (2012)	Prospective cohort study, Norway cup 2005 to 2008, one-week tournament	Age: 13 to 19 years Sample size: 7,848 matches; 5,491 (70%) played by boys and 2,357 (30%) by girls Sex: both Sport: soccer Back Any acute traumatic injury/pain sustained during tournament week Recorded by team/medical personnel	Artificial turf: 3.1/1,000 match hours (*SD* 0.7) Natural turf: 1.3/1,000 match hours (*SD* 0.2)	
Clausen et al. (2014)	Descriptive epidemiology study and cohort study	Age: 15 to 18 years Sample size: n = 498 Sex: girls Sport: soccer Lower back Any injury or pain (time-loss/no time loss) Self-report	Time-loss injuries: Acute traumatic 0.7/1,000 hours (0.4 to 1.2) Non-traumatic gradual onset 0.4/1,000 hours (0.2 to 0.9)	Acute traumatic 7% (95% *CI* 4 to 10) Non-traumatic gradual onset 4% (95% *CI* 2 to 6)

Shah et al. (2014)	Descriptive epidemiology study, prospective five seasons follow-up	Age: 9 to 16 years Sample size: *n* = 12,306 Sex: not reported Sport: soccer Lower back Time-loss (at least 48 -hours) Recorded daily by team/medical personnel		3.0%	
Bere et al. (2015)	Prospective four-year data (from FIVB tournaments)	Age: U18 U19 U20 U21 and U23 Sample size: not reported Sex: not reported Sport: volleyball Lower back Medical injury Recorded by team/medical personnel		Boys: 6.7% Girls: 4.5%	
Clarsen et al. (2015)	Longitudinal, 13-weeks follow-up	*n* = 65 Age: U19 Sex: both Sports: volleyball Lower back Self-report (Weekly recording verified after 13-weeks) All physical complaints + time-loss			Weekly prevalence average Any LBP 14% (95% *CI* 11 to 16) Time-loss LBP 1% (95% *CI* 1 to 2)
Rössler et al. (2016)	Descriptive epidemiology study, prospective two seasons follow-up	Age: 7 to 12 years Sample size: 6038 player seasons Sex: both Sport: soccer Lower back Time-loss (at least partial session)/medical injury Recorded daily by team/medical personnel)	9 to 10 years: 0.4/player-season[1] and 0.006/1,000 training and game hours[1] 11 to 12 years: 1.48/player-season[1] and 0.02/1,000 training and game hours[1] 7 to 8 years: 0	1%	

von Rosen et al. (2018a)	Prospective cohort study, one-year follow-up	Age: 15 to 19 years Sample size: n = 284 Sex: both Sport: elite athletes from sport high schools Lower back Time-loss injury Self-report by weekly questionnaire (OS-TRC)	11.7% (Thoracic spine: 2.8%)	Female: 13% Male: 10% Power athletes: 25% Endurance skiing: 16.2% Sprint: 12.9% Handball: 7.8% Endurance running: 2.9%

[1] Calculated based on LBP incidence and training and/or match hours reported in the original articles
AE, athletic exposure; LBP, low back pain; LB, low back; LBI, low back injury.

2.1.2 Consequences of back pain among youth

LBP has a fluctuating nature (Hestbaek et al. 2006, Kjaer et al. 2017), with variations in pain status over time. In young adult athletes, non-traumatic sports injuries were investigated by plotting weekly prevalence data over time for a period of 13 weeks (Clarsen et al. 2015). The study showed how the prevalence of LBP complaints increased and decreased during the study period among the athletes.

A need for consultation with medical personnel seems to be low among youth, but it increases with age. Mikkonen et al. (2016) reported the prevalence of LBP during the preceding six months to be 44% and 31% among 16-year-old girls and boys, respectively, and only 5% of both had consulted medical personnel due to LBP. In an Australian study the percentage of youth seeking professional advice or treatment due to their LBP increased significantly with age (12% at age 17, 15% at age 20 and 22% at age 22)(Coenen et al. 2017).

In addition, disability due to LBP seems to increase with age. Coenen et al. (2017) found that absence from work or school, interference with normal daily activities and recreational PA due to LBP increased significantly with age. At age 17, LBP had resulted in absence from school or work in 17%, interfered with normal activities in 12% and hampered with recreational physical activities in 14%. They also noticed that by age 22, 10% reported LBP causing absence from school or work, one in four felt that LBP interfered with normal activities and hampered recreational physical activities (Figure 2).

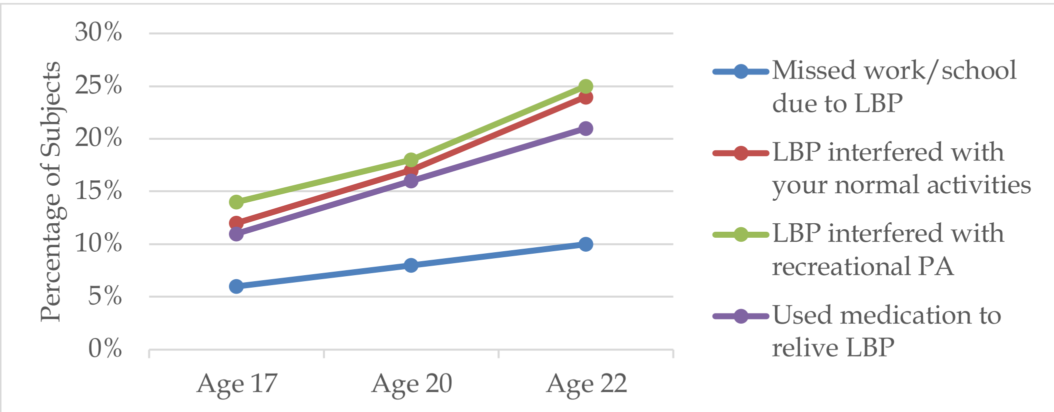

FIGURE 2 Consequences of low back pain increase with age (Data adapted from Coenen et al. 2017. Age 17 (n = 1,050), age 20 (n = 1,112) and age 22 (n = 1,033)).

In a Danish study, including 481 children and 325 youth, 39% reported BP within preceding month and 38% of the youth reported at least one consequence. In other words, the LBP they experienced, resulted in medical consultation, reduced physical activities or missing school (Wedderkopp et al. 2001).

Pain severity score and LBP-related daily activity limitations have been shown to be associated with seeking professional advice due to LBP (Staes et al.

2003, Tiira et al. 2012). A Belgian study showed that youth who report pain they would like to seek help for report higher mean pain score than youth who feel no need for medical consultation (VAS 6.7 vs 4.2) (Staes et al. 2003). They also noticed that almost one fifth (18%) of youth with LBP reported to have reduced or stopped sport activities due to their LBP. The perception of pain severity and negative effect, which reflects a predominance of negative feelings, was associated with the decision to reduce sports and leisure-time activities (Staes et al. 2003).

Among youth athletes, pain that interferes with training may have a negative effect on mood, sleep and identity (von Rosen et al. 2018b). LBP affects performance (Taimela & Kujala 1992, Nadler et al. 2002b) and deficits in lumbo-pelvic neuromuscular function may linger even after symptoms have resolved (Cholewicki et al. 2002).

In a Dutch study, 22% of female field hockey players felt that BP hampered their performance (van Hilst et al. 2015). The study also reported that in youth field hockey, soccer and speed skating athletes, 40% to 83% of the athletes consulted medical professional due to their BP (van Hilst et al. 2015), which is more than double compared to what was reported by an Australian study among same age general population (Coenen et al. 2017). The Dutch study also found that in field hockey players the satisfaction of the players with their own performance and satisfaction with the coaching staff was associated with LBP (van Hilst et al. 2015).

2.1.3 Spinal pathologies and association with low back pain

A cross-sectional study by Kjaer et al. (2005) investigated the one-month prevalence of LBP and magnetic resonance imaging (MRI) findings and plausible associations between structural findings and LBP in 12- to 14-year-old (n = 439) Danes. They observed that LBP that had resulted in seeking care was associated with abnormal MRI findings. However, radiological changes are also common in asymptomatic youth, so structural changes cannot always be shown to be the cause for the pain symptoms (Kjaer et al. 2005).

Kjaer et al. (2005) noticed that a majority of the youth had 'abnormal' findings and the most prevalent findings were disc related. Other findings included nerve root compromise (13%), Modic changes (< 1%), spondylolisthesis (anterolisthesis) (3%) and endplate changes in relation to disc (6%).

Radiological changes have been reported to be more common among the athletic population (Hangai et al. 2009). However, it is not clear which activities are detrimental. Schroeder et al. (2016) investigated the prevalence of structural abnormalities in youth who had visited sports medicine or orthopaedic clinic and had MRI scan taken. According to Schroeder et al. (2016) 55% of the youth investigated, had abnormal findings and athletes had significantly more than non-athletes, 67% vs 40%, respectively. They noticed that the prevalence of spondylolysis was higher in athletes, compared to non-athletes, but no difference in disc related abnormalities. Furthermore, they were unable to find differences between athletes taking part in hyperextension sports and non-athletes nor between non-athletes and rotation-related sports participants (Schroeder et al.

2016). In contrast, Takatalo et al. (2017) reported that swimming and running at least twice a week is associated with lumbar disk degeneration among youth and young adults. On the other hand, running has also been regarded as beneficial to disk health (Belavý et al. 2016).

There is some evidence that disc-related changes (Kjaer et al. 2005, Takatalo et al. 2012) and, in girls, spondylolisthesis/spondylolysis (Kjaer et al. 2005) are somewhat related to LBP. However, disc-related changes and other structural abnormalities are also seen among asymptomatic subjects (Takatalo et al. 2012) and, for instance, abnormal findings among youth does not necessarily increase the risk for LBP in adulthood more than in youth without abnormal findings (Harreby et al. 1995). Furthermore, Videman et al. (1995) reported no difference in BP prevalence in adulthood, between former athletes and controls in general, even though radiological changes in former athletes were common. They observed, for instance, that ball game athletes seemed to have significantly lower odds for LBP than did the controls (*OR* 0.6, 95% *CI* 0.440 to 0.82).

Shah et al. (2014) analysed traumatic onset time-loss injuries among 41 English youth soccer professional academies and prospectively collected sport-related injury data. Players were between 8 and 19 years of age. During the data collection, 310 LBP complaints were recorded. The most common injury diagnoses in the low back area were LBP (49.4%), low back strain (15.2%), spondylolysis/spondylolisthesis (5.8%), muscular contusion (3.5%), and tissue bruising (3.9%). So-called ‘other diagnosis' was recorded for 4.5% of the recorded complaints and for 6.8% no diagnosis was recorded at all. According to Shah et al. (Shah et al. 2014) fractures were not common among this population. However, systematic radiological investigations were not used and therefore there is a possibility of underreporting pathologies such as spondylolysis and spondylolisthesis because they are sometimes asymptomatic.

2.2 The potential risk factors for low back pain in youth

In addition to the prevalence of LBP increasing with age, there are several other factors suggested to be associated with LBP in the general population. These factors include, but are not limited to, the lifestyle, psychosocial and physical factors listed in Table 5, which presents risk factors investigated in a prospective manner. In general, in youth MSK pain has been associated with smoking, overweight, poor mental health and sleep problems (Kamper et al. 2006).

2.2.1 Intrinsic risk factors

There is evidence that some health and wellbeing factors such as psychosocial factors and distress (Feldman et al. 2001, Szpalski et al. 2002, Jones et al. 2003, Mustard et al. 2005, Hestbaek et al. 2008, Mikkonen et al. 2016, Smith et al. 2017), other pain and somatic complaints (Jones et al. 2003, Hestbaek et al. 2006, Coenen et al. 2017, Smith et al. 2017), and lifestyle factors such as smoking (Feldman et al. 1999, Feldman et al. 2001, Mustard et al. 2005, Mikkonen et al. 2008) are likely to be associated with LBP in youth. Psychosomatic symptoms, such as headache and tiredness, have been associated also with future MSK pain in children and youth (El-Metwally et al. 2007).

Family history of BP is also likely to be associated with LBP (Balagué et al. 1999, Ferreira et al. 2013). Yet it is still unclear whether height, weight, BMI, posture, sitting and screen time are associated with BP or not (Kamper et al. 2017). Ferreira et al. (2013) suggested that there might be genetic and family history–related moderators affecting the association between LBP, obesity and smoking.

The participation in competitive or high-level sport and its relationship with LBP incidence has been discussed and the results are inconsistent (Kamper et al. 2017). The association between PA and LBP will be discussed in more detail in section 2.2.2.

Supplementary Table 1 lists longitudinal cohort studies investigating risk factors for BP and LBP in youth athletes. Nearly consistently longitudinal studies state that previous injury to the low back or a history of BP is a significant risk factor for future LBP in youth athletes (Greene et al. 2001, Meeuwisse et al. 2003, Cholewicki et al. 2005, Hjelm et al. 2012). This relationship between a history of LBP and future LBP has also been seen in the youth general population (Kamper et al. 2017). For instance, in youth basketball players the risk for LBP during follow-up was over three times higher if the player had a history of previous LBP complaints (*RR* 3.65, 95% *CI* 1.06 to 12.52) (Meeuwisse et al. 2003).

In the youth general population, it has been shown, quite consistently, that reduced muscle endurance of trunk extensors is weakly associated LBP, but the studies are cross-sectional and limited in number (n = 3)(Potthoff et al. 2018). Furthermore, it seems that the predictive value of isometric endurance of the back extensors, measured with the Sorensen test, is low (Aartun et al. 2016b). Preliminary results among rowers showed that back muscle endurance is associated with LBP also in youth athletes (significantly lower in rowers with LBP than without LBP) (Perich et al. 2006). The relationship between trunk flexor strength and endurance are conflicting in youth general population (Potthoff et al. 2018), but in youth tennis players performance in trunk flexor strength test (sit ups) did not predispose for future LBP (Hjelm et al. 2012). Thus, there is no strong evidence that trunk flexor or extensor strength is associated with future LBP, but that people with LBP may show reduced muscle strength compared to people without LBP.

There is also inconsistency in the association between trunk mobility and LBP in the youth general population (Potthoff et al. 2018). In addition, a prospective study by Aartun et al. (2016b) reported no significant risk factors in trunk flexibility measures such as Schober's test, intersegmental spine joint mobility or fingertip-to-floor distance test nor with decreased cervical ROM. However, among youth athletes – specifically ice hockey and soccer players, figure skaters and gymnasts – decreased lumbar ROM to either flexion or extension seems to be a plausible risk factor for LBP (Kujala et al. 1994). Kujala et al. (1994) investigated flexibility and joint range of motion among sports participants in a prospective setting and it could be speculated that in sports that include flexion or extension of the lumbar spine or both, decreased range of mobility increases the susceptibility to strain and overloading in the back and over time might lead to pain. Hjelm et al. (2012) studied tennis players and noticed that larger cervical spine lateral flexion ROM to the dominant side decreased the odds for LBP during the follow-up, suggesting that impairment upper in the kinetic chain might increase the odds for future impairment lower in the kinetic chain.

Among adults with prolonged LBP, impairments in gluteal muscle function, for example hip abductor strength, have been reported (Kankaanpää et al. 1998, Leinonen et al. 2000, Kendall et al. 2010). Potthoff et al. (2018) also concluded that there is an association between lower extremity muscle function (reduced muscle strength and endurance) and LBP in the youth general population. In a small cohort of adult runners (n = 18), decreased quadriceps strength was observed with LBP, but interestingly no difference in hip extensor or abductor strength (Cai et al. 2017). In youth athletes girls reporting LBP, or a lower extremity injury had larger hip extensor strength asymmetry, but no difference in hip abductor asymmetry (Nadler et al. 2000). Interestingly, Ng et al. (2015) found in youth rowers that pain and disability decreased, and lower extremity muscle endurance increased after cognitive functioning therapy. These results might suggest some kind of an association between lower extremity and LBP. However, prospective studies investigating lower extremity strength and LBP are lacking.

Furthermore, there are also several other studies suggesting that there is an association between lower extremity function and LBP. Studies have shown an association between lower extremity injuries or pain complaints and LBP in active individuals (Nadler et al. 1998, Seay et al. 2018, Yabe et al. 2019) and in children (Fuglkjær et al. 2018). According to a systematic review, there is also some evidence of an association between lower extremity injuries and neuromuscular function of the trunk (De Blaiser et al. 2018). Neuromuscular impairments of the trunk and hip complex have also been associated with LBP, but the changes observed are inconsistent and causality cannot be determined (van Dieën et al. 2019).

Cholewicki et al. (2005) and Silfies at al. (2007) examined the association between LBP and the function of the neuromuscular system prospectively in youth athletes. Silfies et al. (2007) was unable to find a significant difference in trunk repositioning error in the transverse plane between university varsity athletes who did or did not report LBP during the follow-up period. Cholewicki et al. (2005) examined whether there was a difference in trunk muscle reflex responses in varsity athletes sustaining LBP or staying pain-free. They found that every millisecond delay in muscle response latency to unexpected quick force release isometric trunk exertions increased the odds for LBI by 2% to 3%, meaning that if it took longer to relax from the isometric contraction when the load was suddenly released the risk for LBP was increased. These results suggest that changes in neuromuscular control might also predispose for LBP in athletes.

Potthoff et al. (2018) concluded that there is limited importance of hamstrings flexibility in relation to LBP in youth general population. In longitudinal studies, not included in the systematic review, knee extensors flexibility was associated with higher prevalence of LBP among youth (Feldman et al. 2001, Kanchanomai et al. 2015). Feldman et al. (2001) also reported association between decreased Hamstring flexibility and LBP. In contrast, two studies on youth athletes (Kujala et al. 1994, Hjelm et al. 2012) and one study in youth general population (Kanchanomai et al. 2015) did not find an association between hamstring flexibility and LBP incidence.

Furthermore, regarding the link between lower extremity and LBP, Rosenhagen et al. (2018) analysed whether lower extremity alignment (varus/valgus), measured during neutral standing position, is associated with persistent LBP in team sport players (*n* = 54). They noticed that 42% of players with knee misalignment and 17% of players without knee misalignment developed persistent LBP during the follow up.

2.2.2 Extrinsic risk factors

Foster et al. (2018) concluded that in adults there is moderate to low evidence that exercise is effective in LBP prevention, but no studies among youth and children so far. In a prospective population-based cohort study among 19- to 21-year-old men (military conscripts), moderate PA and a good level of fitness were found to protect the subjects from LBP (Taanila et al. 2012). However, the reports on the association between LBP and PA are not consistent (Heneweer et al. 2011). In prospective studies, PA has been shown on to either increase (Jones et al. 2003, Smith et al. 2017) or decrease (Wedderkopp et al. 2009) the risk for LBP or not to have a significant association at all (Aartun et al. 2016a, Smith et al. 2017). According to a very recent systematic review the relationship between PA and LBP leans towards PA being associated with increased risk for LBP in youth when the level of PA is high (Calvo-Muñoz et al. 2018). However, the association between LBP and PA might also differ in different samples. For example, in young marine trainees, a history of less physical training increased the risk for LBP during the marine training course (Monnier et al. 2019). This suggests that the amount of optimal PA might depend on the other loads placed on the individual.

It has been also previously suggested that the relationship between LBP and PA is U-shaped (Jones & Macfarlane 2005). Wedderkopp et al. (2009) compared objectively measured PA in 9-year-old children and noticed that children with the lowest levels of PA were four times more likely to have LBP three years later than the children with the highest levels of PA. Furthermore, Franz et al. (2017) observed a tendency towards a protective relationship between the amount of moderate intensity PA and BP as well as an increased risk for LBP with light or vigorous intensity PA (Franz et al. 2017). The same study groups also observed in their earlier study that the incidence of LBP per 1,000 hours of activity was highest in organized sports compared to physical education lessons and leisure time PA, even though the number of BP complaints was highest during leisure time PA (Franz et al. 2016). Furthermore, a recent systematic review stated that there is a lack of good quality studies investigating treatment and prevention in youth, but exercise is likely to be effective (Kamper et al. 2017).

In addition to PA intensity and frequency, the association of PA and LBP might be related to type of PA. There is evidence that there is an association between organized sports and LBP (Kujala et al. 1996, Auvinen et al. 2008, Hangai et al. 2010, Jonasson et al. 2011) and in younger children the risk for LBP is increased in organized sports (Franz et al. 2016). The risk for LBP seems to be higher also in contact sports compared to sports without any particular aim for contact during play (Greene et al. 2001, Junge et al. 2004). Junge et al. (2004), for example, reported a BP injury incidence ratio of 0.7 in youth soccer and rugby players, indicating that soccer players had fewer BP complaints compared to rugby (Incidence: rugby 2.47/1,000 hours and soccer 1.82/1,000 hours.

Seasonal and within game variations in LBP risk have been shown, with prevalence increasing after training pauses and during the second half of games (Shah et al. 2014). The increase in LBP after training pauses might be associated with spikes in training load (training volume + subjective exertion). In general, higher training volume has been associated with increased prevalence of sports injuries (Emery & Tyreman 2009). In a cross-sectional Dutch study, self-reported higher training hours were associated with LBP in field hockey but not in speed skating or soccer (van Hilst et al. 2015). Hjelm et al. (2012) found significant association between LBP and playing tennis for more than six hours per week. In prospective studies among athletic populations, no association between training volume and LBP was found (Kujala et al. 1996, Alricsson & Werner 2006, Müller et al. 2016). Aoki et al. (2010) also failed to find an association when looking at players training on artificial turf and natural turf together, but when looking at only players training mostly on artificial turf, they noticed that an increase in weekly and yearly training hours slightly increased the odds for LBP. It should be noted that performance factors affect the tolerance of training load (Malone et al. 2019), which very likely affects the relationship between LBP incidence and training volume.

There is also evidence from soccer that turf type is associated with LBP incidence. Turf type was investigated in two studies and both concluded that the incidence of BP was likely to be higher on artificial turf compared to natural turf (Aoki et al. 2010, Soligard et al. 2012). To our knowledge, the association between BP and playing surface has not been studied in team sports played indoors.

TABLE 5 Longitudinal studies investigating risk factors for low back pain in youth general population.

	Association	
	Studies where an association was found (yes)	Studies where no association was found (no)
Physical activity	Jones et al. 2003, Wedderkopp et al. 2009, Franz et al. 2016, Franz et al. 2017, Smith et al. 2017	Aartun et al. 2016a
Puberty	Janssens et al. 2011	Smith et al. 2017
Growth spurt	Feldman et al. 2001, Poussa et al. 2005	Jones et al. 2003, Alricsson & Werner 2006
Height	Jones & Macfarlane 2009	Jones et al. 2003, Poussa et al. 2005
BMI	Balagué et al. 2010, Kountouris et al. 2012, Mikkonen et al. 2013, Sano et al. 2015	Nissinen et al. 1994, Feldman et al. 2001, Jones et al. 2003, Alricsson & Werner 2006, Jones & Macfarlane 2009
Weight	Szpalski et al. 2002, Cholewicki et al. 2005, Aoki et al. 2010	Jones et al. 2003, Poussa et al. 2005, Jones & Macfarlane 2009, Aoki et al. 2010, Kountouris et al. 2012, Müller et al. 2016
Posture	Nissinen et al. 1994, Smith et al. 2017, Rosenhagen et al. 2018	Poussa et al. 2005, Aartun et al. 2016b
Screen time		Jones et al. 2003, Smith et al. 2017
Previous LBP	Kjaer et al. 2011, Coenen et al. 2017, Smith et al. 2017	
Other MSK pain and somatic complaints	Vikat et al. 2000, Jones et al. 2003, Hestbaek et al. 2006, Coenen et al. 2017, Smith et al. 2017	Smith et al. 2017
Smoking	Feldman et al. 1999, Feldman et al. 2001, Mustard et al. 2005, Mikkonen et al. 2008	
Sleep	Auvinen et al. 2010	
Psychosocial factors and socioeconomic background	Feldman et al. 2001, Szpalski et al. 2002, Jones et al. 2003, Mustard et al. 2005, Hestbaek et al. 2008, Mikkonen et al. 2016, Smith et al. 2017	
Family history of BP	Balagué et al. 2010	
Flexibility/ROM	Kujala et al. 1994, Feldman et al. 2001, Hjelm et al. 2012, Kanchanomai et al. 2015	Kujala et al. 1994, Feldman et al. 2001, Jones & Macfarlane 2009, Hjelm et al. 2012, Kanchanomai et al. 2015, Aartun et al. 2016b
Muscle strength/endurance	Smith et al. 2017	Feldman et al. 2001, Hjelm et al.2012, Aartun et al. 2016b, Smith et al. 2017

BP, back pain; BMI, body mass index; MSK; musculoskeletal, ROM; range of motion

2.3 Rationale for this thesis

LBP is not uncommon in youth whether they are physically active or not. LBP is negatively associated with other factors in life, such as sleep and school (Szpalski et al. 2002, Auvinen et al. 2010) and may have longstanding consequences (Hestbaek et al. 2006, Coenen et al. 2018). The prevalence of LBP increases with age and therefore focus on prevention and management at a young age is supported. There is some evidence that participation in organized sports might be associated with higher prevalence in LBP among youth. Sato et al. (2011), for instance, reported higher perceived limitation due to LBP among youth taking part in organized sports activities. As Hill et al. (2010) stated already in the title of their review, risk factors for LBP among youth are rarely validated across samples and conditions. Identifying risk factors is however important in order to be able to propose and study effective methods for prevention.

According to the van Mechelen model, we first need to identify the size of the problem. After reviewing the literature, the size of the problem that LBP introduces seems to somewhat differ between sports disciplines. There is an imbalance between the different types of sports, the lack of studies within in some sports such as floorball and basketball, and the existence of more studies conducted in, for example, soccer.

To be able to prescribe effective measures, one needs to identify factors that predispose to injuries and complaints. Several factors have been associated with LBP, such as movement control, trunk and lower extremity strength, flexibility and joint ROM, but the results are inconsistent, often assessed using cross-sectional design and rarely validated across samples. A lack of prospective risk factor studies, especially studies among physically active youth taking account of the time spent on doing the activity, was identified.

There is some evidence that lower extremity alignment (Rosenhagen et al. 2018), muscle performance (Potthoff et al. 2018) and lower extremity pain and injuries (Nadler et al. 1999, Fuglkjær et al. 2018, Seay et al. 2018, Yabe et al. 2019) are associated with LBP. This implies that impairments lower in the kinetic chain might be associated with BP complaints at some level and should be investigated further, especially in athletes spending time in weight-bearing activities such as running and jumping. Association between flexibility and lower extremity strength also requires further investigation, especially within youth athletic populations.

3 PURPOSE OF THE THESIS

The focal point of this thesis is positioned within the first two initiatives of the van Mechelen model (van Mechelen et al. 1992): determine the size of the problem and identify the risk factors. Therefore, the main purpose of the thesis was to investigate the occurrence of BP in the youth athlete population and identify what factors predispose for LBP in youth basketball and floorball players.

The following aims were addressed in the five studies:

I. To determine the prevalence, frequency and severity of LBP and NSP and to explore the associations between LBP and NSP with the health and health behaviours in youth, paying special attention to participation in organized sports.

II. To assess the prevalence and associated factors of LBP in youth female and male basketball and floorball players.

III. To investigate the incidence of BP and examine flexibility and strength as risk factors for LBP in youth female and male basketball and floorball players.

IV. To investigate kinetic and kinematic factors as risk factors for LBP in youth female and male basketball and floorball players in dynamic movement tasks.

V. To determine the association between pelvic kinematics during standing knee lift in youth female and male basketball and floorball players.

4 RESEARCH METHODS

This thesis consists of five original articles (studies) and is part of two larger projects: the multi-institutional Finnish Health Promoting Sports Club study (FHPSC) and Predictors of Lower Extremity Injuries in Team Sports study (PROFITS) carried out at the UKK Institute, Tampere, Finland. The methodologies used in the five studies included in the thesis are summarized in Table 6.

TABLE 6 Methodologies of original studies included in the thesis.

	Study I	Study II	Study III	Study IV	Study V
Design	Retrospective, cross-sectional		Prospective		
Data collection	Web-based questionnaire	Questionnaire	Questionnaire, baseline tests (i.e. physical/performance tests), structured injury questionnaire, game and training hour recording		
Outcome measures	NSP and LBP within preceding three-months, LBP prevalence (lifetime, one week)	LBP	BP and LBP incidence per 1,000 player years and game and training hours. Potential risk factors: Hamstrings flexibility, Thomas test (quadriceps and iliopsoas flexibility), generalised joint hypermobility, 1-RM leg press, isometric hip abduction strength.	LBP and potential risk factors: dynamic balance, knee frontal plane projection angle, hip-pelvic frontal plane movement, landing kinematics and kinetics.	LBP and potential risk factors: sagittal and frontal plane pelvic kinematics during standing knee lift test.
Sample size	*n* = 962 sports club members *n* = 675 non-members	*n* = 401	*n* = 396/383	*n* = 383	*n* = 258
Data origin	FHPSC		PROFITS		

NSP; Neck- and shoulder pain, LBP; low back pain; BP, back pain; FHPSC, Finnish Health Promoting Sports club study; PROFITS, Predictors of Lower Extremity Injuries in Team Sports study; RM, repetition maximum.
Sports club members= sport club participants
Non-members=not actively participating in organized sport club activities

4.1 Study design and subjects

A retrospective design was used to investigate the prevalence of BP and neck and shoulder pain (NSP) in Finnish youth (14- to 16-years-old), and compare youth based on their participation in organized sports in Study I. As shown in Figure 3, 2,074 pupils from the school-based sample and 1,889 athletes from the sports club sample were invited to participate in the study. A total of 1,637 youth were included in the analyses; 675 participants were analysed as 'non-members' and 962 as (sports club) 'members'. Membership in organized sports club was based on the question 'Are you a current member of a sports club?' ('no / yes / yes, but I don't participate in training provided by the club'). Subjects that provided inconsistent or inconclusive information concerning gender and/or age or sports club membership were excluded.

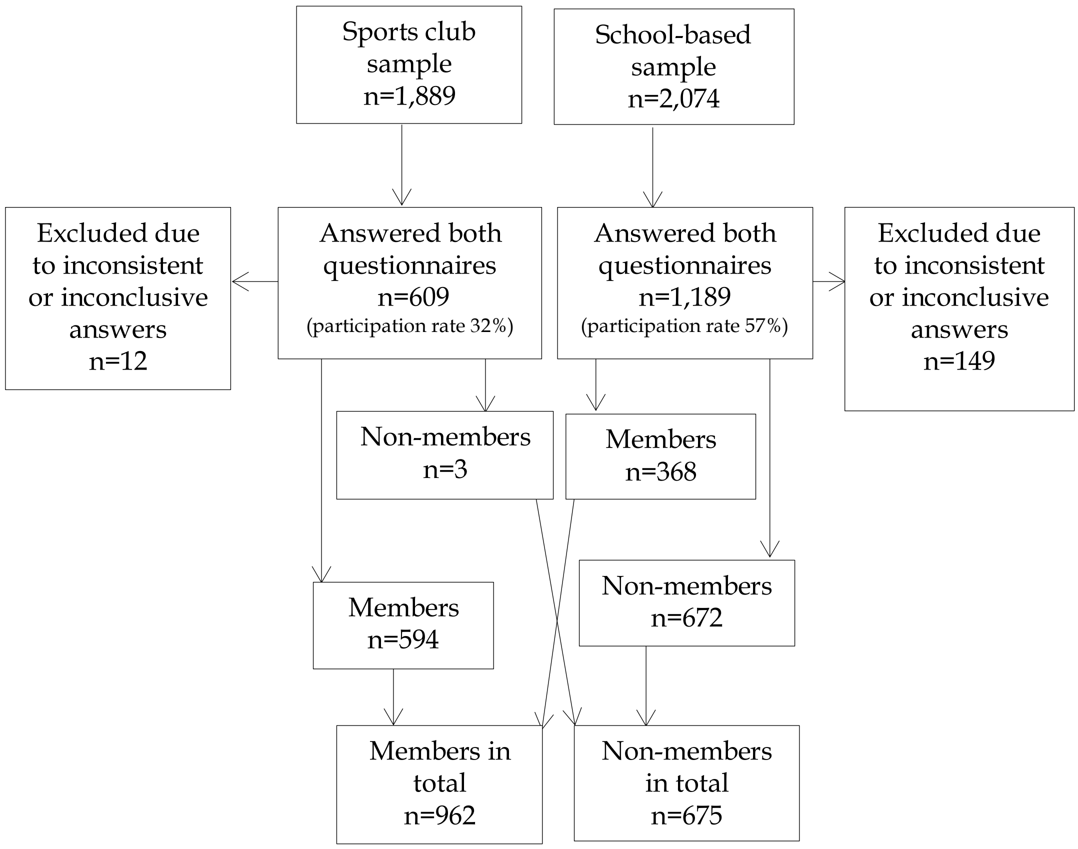

FIGURE 3 Participant flow of sports club members (active organized sports club participants) and non-members (youth who are not participating in organized sport club activities) (study I).

An open cohort design was applied to study BP prevalence, incidence and risk factors for LBP in youth basketball and floorball players (studies II to V). For the retrospective analyses (*s*tudy II) 401 players were included; 118 players in 2011, 82 players in 2012, and 201 players in 2013. From the players participating in the baseline questionnaire (*n* = 401), 98.6% (*n* = 396) also participated in the prospective follow-up: 261 for one study year, 80 for two study years and 55 for three study years (*s*tudy III). In study V, the follow-up was 12 months (2013 to 2014) (Figure 4).

Players who had an ongoing acute injury affecting the baseline test participation or no complete baseline test data were excluded from risk factor analyses. Data from all players entering the follow-up was included in the analyses for the time they participated.

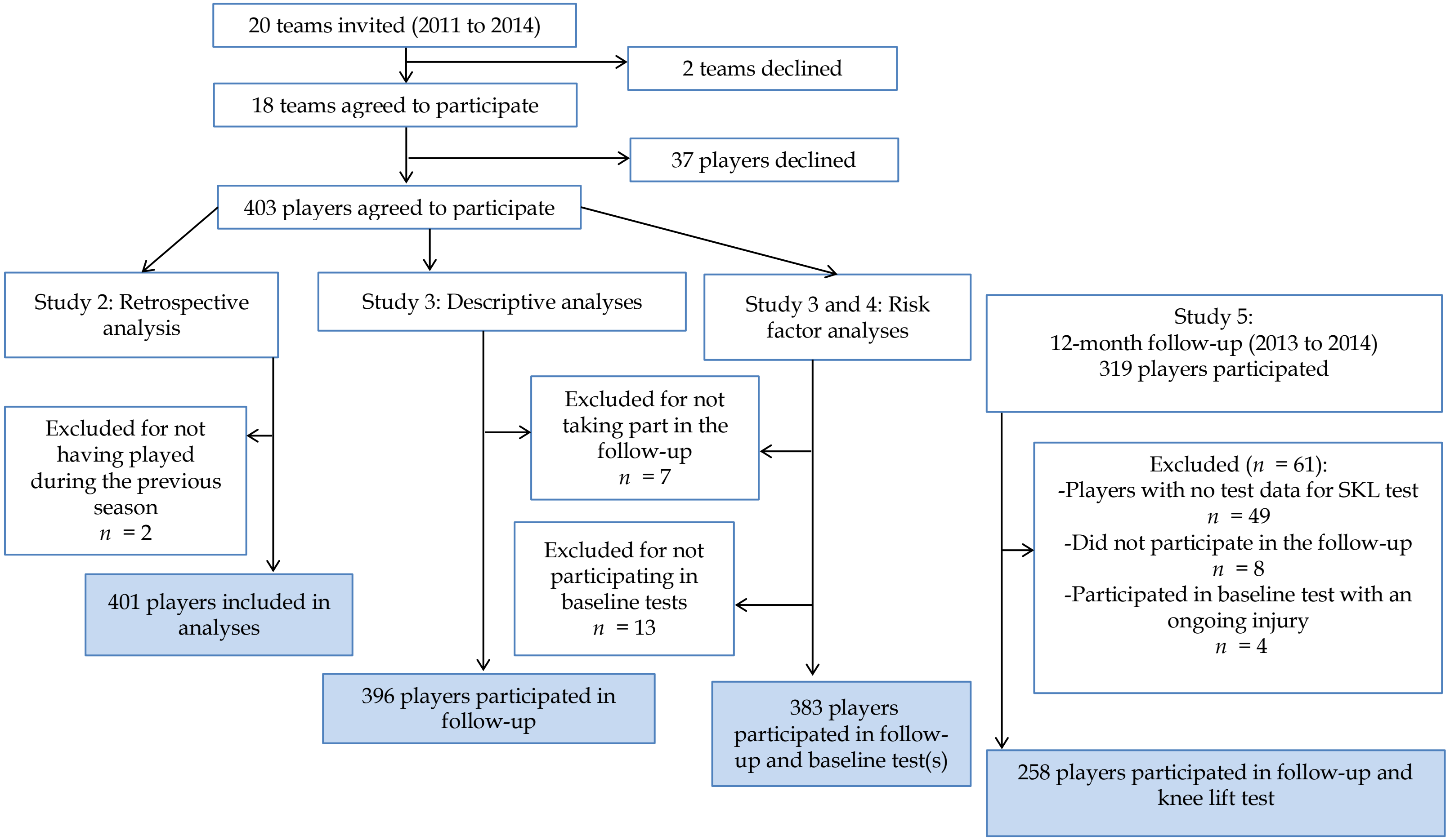

FIGURE 4 Participant flow (studies II to V).

4.2 Outcomes and data collection

The primary outcomes investigated were BP (study III), LBP (studies I to V) and NSP (study I). The outcome definitions are summarized in Table 7. BP and LBP definition in studies III and V was based on time-loss sports injury definition by Fuller et al. (2006). In the consensus statement, a time-loss sports injury is defined as 'an injury that results in a player being unable to take a full part in future training or match play'. The severity of LBP was expressed as time lost in days from training and playing.

TABLE 7 Summary of operational definitions of outcomes.

Outcomes	Pain definition
LBP (three-months) (study I)	Ache or pain in lower back more than once a month
Frequent LBP (three-months) (study I)	Ache or pain in low back at least once a week
NSP (three-months) (study I)	Ache or pain in neck and shoulders more than once a month
Frequent NSP (three-months) (study I)	Ache or pain in neck and shoulders at least once a week
LBP (seven days, 12-months) (study I, II)	Ache, pain or discomfort of lumbar region with or without radiation to one or both legs (sciatica)(Kuorinka et al. 1987)
BP (incidence) (study III, IV) LBP (incidence) (study III, IV, V) Thoracic spine pain (incidence) (study III)	Pain in the upper and/or lower back area that resulted in at least 24-hour time-loss from full participation in the team training and playing

LBP, low back pain; NSP, neck- and shoulder pain; BP, back pain

4.2.1 Questionnaires

4.2.1.1 Health behaviour and musculoskeletal health surveys for sports club members and non-members (study I)

The sports club members and non-members filled in two online surveys (presented in an online supplement in the original article) (study I). The first survey focused on self-reported health behaviours such as screen time and overall PA. The sports club members also answered additional questions regarding their training. The second questionnaire focused on injuries and the musculoskeletal health and included more specific questions regarding LBP. The questions used were compiled from previously validated questions in other studies like the Health Behaviour in School-aged Children (HBSC) study

(Pasanen et al. 2008, Kokko 2010, Kokko et al. 2011, Currie & Alemán-Díaz 2015) and the standardized Nordic questionnaire of musculoskeletal symptoms (Kuorinka et al. 1987) (Table 8).

4.2.1.2 Background questionnaire for youth floorball and basketball players (studies II to V)

The youth basketball and floorball players filled in a background questionnaire during the same days as baseline tests were performed (tests described in chapter 4.2.2) at the UKK Institute over one day at the beginning of every follow-up year (May–April 2011, May–April 2012 and May–April 2013)(studies II to V). The questionnaire covered the following demographics: age, sex, dominant leg, diet, alcohol and nicotine use (snus and smoking), menstrual history, chronic illnesses, medication use, family history of musculoskeletal disorders, playing years, playing position and level, previous injuries, BP history, and training and playing history during the previous year. Questions about LBP were based on Standardized Nordic questionnaire of musculoskeletal symptoms and its modified version for athletes (Kuorinka et al. 1987, Bahr et al. 2004) (Table 8).

TABLE 8 The low back pain questions based on the standardized Nordic questionnaire of musculoskeletal symptoms (study I) and its modified version for athletes (studies II to V).

THE LBP QUESTIONS BASED ON THE STANDARDIZED NORDIC QUESTIONNAIRE OF MUSCULOSKELETAL SYMPTOMS
Have you ever experienced problems in your low back? (area illustrated by a picture) (no/yes)
Have you ever had surgery because of LBP? (no/yes)
Have you ever had radiating LBP?" (no/yes)
Have you ever had sleeping difficulties because of LBP? (no/yes how often?)
Have you had LBP during the previous seven days? (no/yes)
Have you experienced low back pain that has required consultation or treatments by a physician physiotherapist or chiropractor in the previous 12 months? (no/yes)
How did your LBP symptoms occur? suddenly (after an injury)/ gradually (without a sudden injury)/ or both
Have you used pain killers (NSAID) for your low back? (no/yes)
QUESTIONS IN THE MODIFIED VERSION FOR ATHLETES
Have you ever experienced LBP?
Have you ever had surgery because of LBP?
Have you ever had radiating LBP?
Have you ever had sleeping difficulties because of LBP?
How many days have you had LBP during the past 12 months: none, 1 to 7 days, 8 to 30 days, >30 days but not daily, daily?
Have you had LBP during the previous 7 days?
Have you been examined or treated for LBP by medical personnel in the previous 12 months?
How did your LBP symptoms occur: sudden, gradual, both?
How many days of practicing have you missed because of LBP during the past 12 months: none, 1 to 7 days, 8 to 30 days, >30 days?
How many matches have you missed because of LBP during the past 12 months: none, 1 to 3 matches, 4 to 10 matches, >10 matches?
Have you had LBP during the following parts of the previous season: basic training period, competitive season, off-season?
Have you had LBP as result of body contacts in training or playing?
Have you experienced LBP during the following training: sport-specific training, strength training, plyometric training, other training?

LBP, low back pain; NSAID, Nonsteroidal anti-inflammatory drug.

4.2.2 Baseline tests (studies III to V)

The floorball and basketball players took part in baseline tests and anthropometric measurements, performed over one day, at the beginning of every study year they participated. The tests are briefly described below and in more detail in the original articles.

4.2.2.1 Strength tests (study III)

Supine isometric hip abduction strength test was used to measure maximal hip abductor strength. During maximal isometric hip abduction test the player was lying on their back with their pelvis and other leg stabilized with a belt. The measurement was taken approximately two centimetres proximal to lateral malleolus using a hand-held dynamometer (Hydraulic Push-Pull Dynamometer, Baseline® Evaluation Instruments, White Plains, NY, USA). With the hip straight and in neutral rotation, the athlete abducted the leg against the fixed resistance for two seconds as hard as they could. The test performance included two trials per leg with 10 seconds rest between trials. The best result was used from both legs to calculate the side-to-side difference: *Hip abduction strength asymmetry= MAX (left, right) - MIN (left, right)*. The test has shown to have good reliability in athletic population with ICC 0.84 (0.65–0.92). However, there is a possibility of intertester bias related to sex(Thorborg et al. 2013).

One repetitions maximum (1RM) of leg press was performed to measure lower extremity extension strength (Nilstad et al. 2014). The players performed a standardized warm up (5 min bike ergometer and warm up sets in leg press machine) prior to test. The test was performed with the player in a seated leg press machine (Technogym®, Gambettola, Italy) with straight legs and performed a squat to 80° knee flexion and back to starting position. The test started from 80 to 100 kg. After each successful trial the weights were increased by 10 to 30 kg (Olympic Iron Weight Plates, Leiko Oy, Tampere, Finland) for the next attempt and until 1RM level was reached. The recovery period between the attempts was two minutes. In a valid trial, the knees were bent to 80° before the athlete pressed the weight platform back up.

4.2.2.2 Flexibility tests (study III)

A standardized passive knee extension test was used to measure hamstring flexibility. In the hamstring flexibility test the players were lying on their back with their pelvis and the non-tested leg was stabilized using belts. The hip of the testing leg was fixed at 120° flexion with a belt and the athlete prevented further hip flexion by pressing distally against the femur with both hands. The knee was passively extended with standardised 8 kg of force (a fish scale, Salter Super Samson, Taylor Precision Products Inc., Illinois, USA) and the knee angle achieved was measured with a goniometer (HiRes, Baseline® Evaluation Instruments, White Plains, NY, USA). A side-to-side difference was calculated as follows: *Hamstring asymmetry=MAX (left, right) - MIN (left, right)*. The inter-rater and test-retest reliabilities have been reported to be high (both ICC scores ranging between 0.88 to 0.97) when the point of measurement is standardised (Gnat et al. 2010).

A modified Thomas test was used to measure the flexibility of hip flexors and knee extensors. The player lay on their back on an examination table with buttocks on the edge of the table and held one leg close to their chest with hip in maximal flexion. The opposite leg was relaxed and the angle of hip relative to horizontal (Bubble Inclinometer, Baseline® Evaluation Instruments, White Plains, NY, USA) and flexion of the knee (starting point with knee straight at 0°) (HiRes goniometer, Baseline® Evaluation Instruments, White Plains, NY, USA). The inter-rater reliability of Thomas test has been shown to be good to excellent (hip flexor ICC 0.92, 95% *CI* 0.79 to 0.92; Quadriceps ICC 0.90, 95% *CI* 0.72 to 0.96)(Gabbe et al. 2004). Test-retest has been shown to vary from moderate to good (ICC from 0.69 to 0.75, 95% *CI* ranging from 0.29 to 0.95) to excellent (ICC 0.91 to 0.94)(Harvey 1998).

Generalised joint laxity (Beighton-Horan index (Boyle et al. 2003)) was used to measure general joint hypermobility. The measurement was performed in a standing position and excessive joint laxity was measured from the trunk, the fifth fingers, thumbs, elbows and knees using a goniometer. This measurement has been shown to have excellent intra- and inter-rater reliability with rho values of 0.86 and 0.87, respectively (Boyle et al. 2003).

4.2.2.3 Dynamic movement tests (kinetics/kinematics) (studies IV and V)

4.2.2.3.1 Two-dimensional movement test

An SLVDJ test was performed to test frontal plane hip-pelvic alignment using two-dimensional (2D) movement analysis. The players performed a standardized warm-up that included 2 x 8 repetitions of two-legged squats, and 2 x 5 repetitions of two-legged jumps, with 30 seconds of recovery between sets. The warm-up was performed just before the test prior to SLVDJ test and an SLVDJ test followed immediately after no separate warm-up was needed.

During a valid SLVDJ test performance, the player stood in front of the video camera (Sony® Digital HD Video Camera Recorder HXR-NX70E, Sony Corporation, Tokyo, Japan), on a 10-cm box. Using one leg, the player dropped off the box and landed on one leg. Immediately after landing, the player performed a maximal jump straight up with the same leg. An overhead goal was used for maximum effort (Ford et al. 2005). The test was performed three times and trials with jumping from the box instead of dropping, leg touching the ground or falling/clear loss of balance, were considered invalid. The test started with the right leg.

During data preparation, the frontal plane knee and pelvic angles were estimated by a physiotherapist by marking the ankle, knee and hip joint centres, and ASIS in the still video image (Java-based software ImageJ, National Institutes of Health) at the point of maximum knee flexion during drop landing.

The *femur-pelvic angle (FPA)* was calculated as the angle between femur and pelvis, a smaller angle indicating increased femur adduction and/or pelvic drop. FPA was calculated from the intersection of a line created by the left and right anterior superior iliac spines (ASIS) and knee joint centre. The measured angles are described in Figure 5. Two-dimensional femur-pelvic angle has demonstrated good intertester as well as within- and between-day reliability in single-leg landing tasks (ICC ranging between 0.72 to 0.89)(Herrington et al. 2017). The femur-pelvic angle measured in 2D (also known as hip adduction) has shown good correlation with 3D measurements in a single-leg landing task ($r = 0.62$, $p = 0.013$)(Herrington et al. 2017).

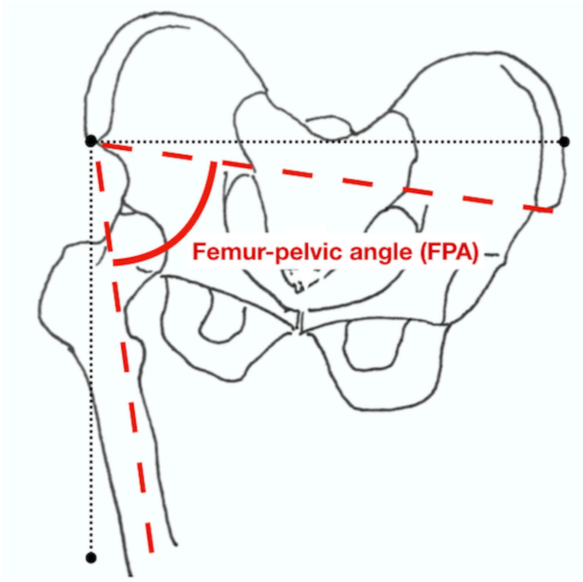

FIGURE 5 Angles measured in single-leg vertical drop jump (SLVDJ) test using a still video image.

4.2.2.3.2 Three-dimensional movement tests

Three-dimensional (3D) motion analysis and two force plates were used to test the kinetics and kinematics during double-leg vertical drop jump (VDJ) and standing knee lift test (SKL). The 3D motion analysis comprised of eight cameras (Vicon T40, Oxford, UK), 16 lower body markers (Plug-In Gait, Vicon, Oxford, UK) and two force plates (AMTI, Watertown, Massachusetts) where data were recorded synchronously at 300 frames per second (fps) and 1,500 Hz, respectively.

Sixteen reflective markers were placed by two physiotherapists on anatomical landmarks on the lower extremities on both sides (ASIS, PSIS, lateral thigh, lateral knee, lateral tibia, lateral malleolus, and over shoe on second metatarsal and calcaneus) according to Vicon Nexus Plug-in Gait lower body model. One physiotherapist was in charge of placing the markers during each year. After the markers were placed the player performed a standardised warm-up with a bike ergometer for five minutes. A static calibration trial was performed before actual testing.

VDJ was used to test landing kinematics and impact of landing (vGRF). During the VDJ test performance, the player stood on a 30-cm box, dropped off the box and landed symmetrically on both feet on the force plates. Immediately after landing the player jumped as high as possible. An overhead goal was used for maximum effort (Ford et al. 2005) and the player was instructed to try to touch the goal with his/her head. Three valid trials were collected. The trials were accepted if the entire foot landed on the force plate and the markers stayed tightly on the athlete's skin throughout the task.

A standing knee lift (SKL) test was used to assess hip and pelvic stability. The SKL test is a modified Trendelenburg test and is often used as a clinical screening test for LBP patients. During the test the players stood with their feet 20 cm apart (standardized using a 20-cm-wide wooden block), one foot on each force plate and arms by theirs sides. The players were instructed to lift one knee twice by flexing their hip and knee and holding the position for a few seconds. The player was instructed to lift the front thigh to horizontal and the height was estimated by the tester. The test started with the player lifting the dominant leg followed by the non-dominant leg. The leg dominance was determined by asking which leg their preferred kicking leg was (left/right/both or do not know). During an invalid trial the hip angle was below 45° or the standing foot was moved. All the kinetic measurements were performed from foot lift to foot contact, that is, the period when the vertical ground reaction force on the force plate was lower than a threshold of 25 N. Two trials with both legs were performed and the mean of the two trials was calculated for the right and left leg.

Vicon Nexus Plug-in Gait model was used for the analyses. More precise description of the 3D data preparation and analysis can be reviewed in the original articles IV and V. From VDJ the following variables were calculated: peak vGRF (absolute and normalized by bodyweight) and vGRF asymmetry (side-to-side difference).

The primary kinematic factor investigated in the SKL test was sagittal plane pelvic tilt and the following predefined variables were calculated: peak pelvic anterior tilt and peak pelvic posterior tilt. For the sub-analysis, a secondary independent factor investigated was frontal plane *pelvic obliquity*, which was calculated as an angle relative to the horizontal with negative values indicating a CL pelvic drop and positive values a CL pelvic hike (i.e. pelvic rise). For all investigated risk factors, a mean of two trials was calculated for the right and left legs. The variables from the 3D analysis are described in Table 9.

TABLE 9 Description of kinetic and kinematic variables from vertical drop jump (VDJ) and standing knee lift (SKL) tests (studies IV and V).

VARIABLES	DESCRIPTION	INTERPRETATION OF VALUES
VDJ		
vGRF	Three trials from both legs were averaged and the side with the larger value was chosen for analyses as peak vGRF. Normalized by body weight.	Higher value denotes higher relative impact during first landing in VDJ.
vGRF asymmetry	Calculated as MAX (left, right)-MIN (left, right) from the vGRF measure	Higher value denotes higher difference between left and right leg.
SKL Primary independent variables		
Peak pelvic anterior tilt	Maximal point of anterior tilt in relation to global vertical line during the knee lift (mean of two trials).	Positive value = Pelvic tilts anteriorly. Negative value = Pelvis tilts posteriorly (ASIS superior to PSIS).
Peak pelvic posterior tilt	Maximal point of posterior tilt in relation to global vertical line during the knee lift (mean of two trials).	
Secondary independent variables		
Pelvic obliquity: peak contralateral drop angle	Angle between the horizontal and the line between the left and right ASIS, when the contralateral pelvic ASIS is at its lowest point during the knee lift (mean of two trials).	Negative value = contralateral pelvic drop (ASIS drops below horizontal line). Positive value = contralateral pelvic hike (ASIS stays above horizontal line).
Pelvic obliquity: peak contralateral hike angle	Angle between the horizontal and the line between left and right ASIS, when the contralateral pelvic ASIS is at its highest point during the knee lift (mean of two trials).	

VDJ: vertical drop jump; SKL: standing knee lift; vGRF: vertical ground reaction force; CL: contralateral; ASIS: anterior spina iliaca superior; PSIS: posterior spina iliaca superior

4.2.3 Injury and exposure recording (studies III to V)

Sports injury registration was in line with the consensus statement by Fuller et al. (2006). LBP was registered if a physical complaint resulted in time lost from normal training or games for at least 24 hours and the symptoms occurred during or after a scheduled team practice or game. During the follow-up, injuries registered weekly by team personnel and verified by one of the five study physicians. A study physician contacted the teams once a week to acquire information about new injuries and to interview the players using a structured injury questionnaire (Table 10).

BP resulting from a specific and identifiable event such as falling was referred to as acute traumatic BP. BP without single identifiable event was referred as non-traumatic gradual onset BP often described also as an overuse injury. Situations where acute traumatic BP occurred were categorized as 'contact', 'indirect contact', and 'non-contact' injuries (Olsen et al. 2004). A contact injury was defined as an injury sustained by the injured body region because of direct contact with another player or object, such as a stick. An indirect contact injury was defined as an injury occurring without direct contact to the injured body region, for example, a body check to an area other than the back. A non-contact injury was defined as an injury occurring without any contact with another player or object. All BP resulting from direct contact during the three-year follow-up (n = 8) were excluded from this study. These included coccyx fracture (n = 2), sacrum contusion (n = 1), upper back contusion (n = 1), and lower back contusion (n = 4).

During the follow-up, all individual athlete training and game hours were collected by the coach and handed over to the investigators monthly.

TABLE 10 The structured injury questionnaire used by the study physicians to collect injury data (study III to V).

1. Date of injury
2. Where did the injury occur? (in official game / friendly game / sports specific training / conditioning training / other)
    Questions for game injury:
    - Playing position
    - Game period
    - Time of game period
3. Surface (wooden / artificial / other specify)
4. Injured body part
5. Injured body side (right / left / both / not applicable)
6. Type of injury
7. Onset of injury (acute / overuse)
8. New / recurrent injury
    Question for recurrent injury: Specify date of return to full participation from the previous injury.
9. Use of protective or supportive equipment (no/yes specify)
10. Was the injury caused by contact or collision? (no / yes contact with another player / yes contact with the ball stick or other object)
    Question for contact injury: Direct contact to the injured body part / indirect contact.
11. Describe the injury situation
12. Existing video material of the injury situation (no / yes)
13. Where the injury was treated
14. Medical investigations (MRI / ultrasound / other specify)
15. Diagnosis
16. Orthopaedic operations due to the injury (no / yes specify)
17. Time-loss from training (number of days)
18. Time-loss from games (number of games)
19. Time-loss from school/work (number of days)
20. Previous menstruation (date)
21. Direct costs of the injury

4.3 Statistical methods

Descriptive and inferential statistics used in the five original studies are summarized in Table 11. Only the first BP per location (upper back or lower back) during the follow-up was included in the incidence calculations.

4.3.1 Associations (studies I and II)

The multilevel modelling failed to give additional information and therefore binary logistic regression analyses were applied (study I). The analyses were adjusted by age, sex, BMI, chronic diseases, smoking and school attainment level (i.e. school grade average) and analysis was made separately for health, health behaviour and training variables. In the analyses of health and health behaviour, the variables were entered in the model simultaneously. In the analyses for training variables, separate analyses were conducted for all variables.

Multivariate associations with LBP and risk factors in floorball and basketball players were assessed using a generalized linear mixed model (GLMM) with binomial family and log-link function. To control the random effects associated with the team, the analyses were adjusted by team (study II). Odds ratios (*OR*) were reported with 95% confidence intervals (95% *CI*s).

4.3.1.1 Risk factor analyses (studies III to V)

Cox's proportional hazard models with mixed effects were used to investigate the associations between baseline characteristics and time-loss LBP incidence. Analyses were performed separately for gradual onset non-traumatic LBP and any LBP (studies III and IV), the latter also including acute traumatic onset LBP. The incidence of acute traumatic LBP was low and therefore no separate analyses were performed. In addition, risk factors analyses were not stratified by sport or sex. For players reporting more than one LBP period following baseline testing, only the first was included in the risk factor analysis.

Measurements for quadriceps and iliopsoas flexibility started during the second study year so players who had LBP in the first study (2011–2012) year or participated only during the first study year, were excluded from the analyses for these two variables (n = 41). Time-varying variables were used in the Cox analyses (study III), when data from several years was available. If a player participated in the injury follow-up for several years but had only valid results from part of the participation years, the last valid result was imputed to where the test result was missing, assuming non-temporal nature of the variable.

A few different methods for covariate selection were used. The first method was that age, sex, BMI, nicotine use, family history of LBP, starting age in the sport, participation in other sports, and LBP during the previous 12-months, as reported in the baseline, were initially entered into the model but only variables with a p value close to .20 or less were entered in the final model (study III). In studies IV and V, the number of confounders in the model was based on the number of events in the analysis (Peduzzi et al. 1995, Peduzzi et al. 1996) and only the most significant variables were included as confounding factors, and these were LBP during the previous 12 months and leg dominance with two categories; 'dominant leg right or left' and 'don't know or both'.

The sports club was used in all models as a random effect. Monthly training and game hours, from the start of the follow-up until the first LBP or the end of follow-up were included in the models. The results were presented as hazard ratios (*HR*) and reported with 95% *CI*s.

TABLE 11 Summary of statistics used (studies I to IV).

	Descriptive statistics	Inferential statistics	Software
Study I	Frequency (*n*), percentage (%), mean, standard deviation (*SD*)	Generalized linear mixed model with binomial family and log-link function, t-test, Pearson's chi-square	SPSS for Windows version 21.0
Study II		Binary logistic regression, t-test, Pearson's chi-square	IBM SPSS Statistics (v. 22.0)
Study III	Mean, median, standard deviation (*SD*) and 95% confidence intervals (*CI*). Incidence: number of injured players per 1,000 athlete-years and per 1,000 game and training hours	Pearson's chi-square, t-test/Mann-Whitney test, Cox's proportional hazard models with mixed effects.	IBM SPSS Statistics (v. 23-24.0), R (v 3.1.2; R Foundation for Statistical Computing) package coxme (Therneau 2015, R Core Team 2016)
Study IV	Mean, median, standard deviation (*SD*) and 95% confidence intervals (*CI*)	Pearson's chi-square, t-test/Mann-Whitney test, Cox's proportional hazard models with mixed effects and time-varying variables.	
Study V	Mean, median, standard deviation (*SD*) and 95% confidence intervals (*CI*) Incidence: number of injured players per 1,000 athlete-years and per 1,000 game and training hours	Pearson's chi-square, t-test/Mann-Whitney test, Cox's proportional hazard models with mixed effects.	

4.4 Ethical considerations

This thesis, and the five original studies it includes, are part of two larger study projects. Both projects have obtained ethics approval before the start of the studies. The FHSPC study from Ethics Committee of Health Care District of Central Finland, Jyväskylä (record number 23U/2012) and the PROFITS study from the Ethics Committee of the Pirkanmaa Hospital District, Tampere (ETL-code R10169).

Both studies were carried out in conformance with the Declaration of Helsinki. All subjects signed a written informed consent form (also from a parent or guardian if the subject was under the age of 18 years) and participated of their free will. All participants were notified that they had a right to refuse to participate and withdraw from the study at any time.

5 RESULTS

5.1 Demographics of the sports club members and non-members (study I)

A total of 1,637 youth sports club members and non-members were included in the analyses and the subject demographics are outlined in Table 12. Among sports club members, the mean training hours per week during training season was 8.1 (*SD* 4.5) hours in girls and 9.2 (*SD* 5.1) hours in boys. During competition season, the training hours per week in girls and boys were 8.3 (*SD* 4.7) hours and 9.0 (*SD* 5.0) hours, respectively.

TABLE 12 Subject characteristics by sports club participation and sex (n = 1,637) (study I).

Variable	Male (n = 772) Member	Non-member	p value[1]	Female (n = 865) Member	Non-member	p value[1]
Age, (mean (*SD*))	15.5 (1)	15.5 (0)	0.643	15.5 (1)	15.5 (0)	0.880
Weight, kg, (mean (*SD*))	64.0 (9.9)	65.5 (11.2)	0.991	57.1 (7.9)	57.2 (11.6)	0.793
Height, cm, (mean (*SD*))	174.7 (7.5)	174.7 (8.8)	0.051	166.3 (6.0)	164.5 (6.0)	< 0.001
BMI, (mean (*SD*))	20.9 (2)	21.5 (4)	< 0.05	20.6 (2)	21.1 (4)	< 0.05
Menarche, % (n = 819)	-	-		92.8	97.5	< 0.001
Chronic disease[2], %	30.4	26.4	0.242	30.1	29.4	0.818
Regular medication[3], %	23.5	18.6	0.113	29.0	33.2	0.189
NSAID use previous month, %	59.6	46.1	< 0.001	75.0	73.7	0.655
Special diet[4], %	8.0	5.7	0.245	17.2	18.0	0.754
Dietary supplements use[5], %	67.3	36.8	< 0.001	70.1	57.2	< 0.001
No Smoking, %	94.5	81.4	< 0.001	92.6	73.9	< 0.001
Screen time[6], (mean (*SD*))	4.6 (4)	6.4 (5)	< 0.001	3.6 (2)	5.6 (5)	< 0.001
Leisure time PA[7, 8], %			< 0.001			< 0.001
Approx. < 30 min/wk	0.8	15.4		0.9	18.5	
Approx. 1–3 hours/wk	16.3	53.9		14.9	56.9	
Approx. 4-6 hours/wk or more	82.9	30.7		84.2	24.6	

'Member', sport club member; 'Non-member', not active participant in sport club activities; NSAID, nonsteroidal anti-inflammatory drug.
[1] p value for difference between members and non-members of sports clubs.
[2] Allergy, asthma, diabetes, epilepsy, heart condition etc.
[3] Contraceptives or other hormonal medication, allergy, asthma, insulin, epilepsy, or heart or blood pressure medication.
[4] Vegetarian, low carb, lactose free, dairy free, gluten free or other special diet.
[5] For example, vitamins, protein supplements, amino acid supplements, creatine.
[6] TV, computer, computer/console games, phone and tablet use.
[7] Male n = 770, female n = 863, total n = 1,633.
[8] Intensity: breathlessness and sweating.

5.2 Demographics of basketball and floorball players (studies II to V)

The baseline demographics of the basketball and floorball players are outlined in Table 13. A total of 586 athlete-years and 134,849 practice and game hours were recorded during the three-year follow-up. The age range of the players was 12 to 21 years on the day they entered the study.

TABLE 13 Baseline subject characteristics by sport and sex (studies II to IV).

	STUDY II: Retrospective			STUDY III: Incidence					STUDY III and IV: Risk factor analyses					STUDY V: Risk factor analysis with 12-month follow-up		
	Basketball (*n* = 207)	Floorball (*n* = 194)		Basketball (*n* = 203)	Floorball (*n* = 193)		All (*n* = 396)		Basketball (*n* = 199)	Floorball (*n* = 184)		All (*n* = 838)		Basketball (*n* = 128)	Floorball (*n* = 130)	
	Mean (*SD*)	Mean (*SD*)	*p* value	Mean (*SD*)	Mean (*SD*)	*p* value	Median	Mean (*SD*)	Mean (*SD*)	Mean (*SD*)	*p* value	Median	Mean (*SD*)	Mean (*SD*)	Mean (*SD*)	*p* value
Age (years)																
All	14.9 (1.6)	16.8 (1.6)	≤ 0.001	14.9 (1.6)	16.8 (1.6)	≤0.001	16.0	15.8 (1.9)	14.9 (1.6)	16.7 (1.6)	≤ 0.001	16.0	15.7 (1.8)			≤0.001
Female	14.6 (1.6)	16.6 (2.0)		14.6 (1.6)	16.5 (1.9)				14.6 (1.6)	16.5 (1.9)				14.4 (1.3)	17.3 (1.8)	
Male	15.2 (1.6)	16.9 (1.3)		15.2 (1.6)	16.9 (1.3)				15.2 (1.6)	16.8 (1.2)				15.1 (1.8)	16.9 (1.3)	
Height (cm)																
All	173.8 (9.9)	173.5 (8.6)	0.777	173.8 (9.8)	173.5 (8.6)	0.774	173.5	173.7 (9.2)	173.7 (9.7)	173.2 (8.5)	0.576	173.5	173.5 (9.1)			0.633
Female	168.9 (6.7)	166.5(5.7)		168.4 (6.5)	166.6 (5.7)				168.4 (6.6)	166.6 (5.7)				168.5 (6.5)	167.0 (6.0)	
Male	179.3 (9.4)	178.6 (6.5)		179.3 (9.5)	178.6 (6.5)				179.1 (9.4)	178.3 (6.5)				179.2 (10.3)	177.3 (6.0)	
Weight (kg)																
All	64.9 (12.2)	66.5 (9.5)	0.148	64.8 (12.1)	66.4 (9.3)	0.078	64.7	65.6 (10.8)	64.8 (12.0)	65.9 (9.0)	0.187	64.5	65.4 (10.7)			0.087
Female	61.1 (9.9)	61.2 (7.5)		60.9 (9.4)	61.2 (7.5)				61.1 (9.4)	61.1 (7.4)				60.9 (8.6)	62.3 (7.6)	
Male	68.9 (13.2)	70.4 (8.9)		68.9 (13.2)	70.1 (8.7)				68.7 (13.1)	69.6 (8.4)				68.2 (13.8)	69.2 (8.6)	
BMI																
All	21.4 (3.0)	22.0 (2.5)	0.016	21.4 (3.0)	22.0 (2.4)	≤0.001	21.4	21.7 (2.7)	21.4 (3.0)	21.9 (2.4)	0.021	21.4	21.7 (2.7)			0.003
Female	21.5 (2.9)	22.1 (2.6)		21.4 (2.9)	22.1 (2.6)				21.5 (2.8)	22.0 (2.5)				21.4 (2.7)	22.3 (2.5)	

	STUDY II: Retrospective			STUDY III: Incidence					STUDY III and IV: Risk factor analyses					STUDY V: Risk factor analysis with 12-month follow-up		
	Basketball (*n* = 207)	Floorball (*n* = 194)		Basketball (*n* = 203)	Floorball (*n* = 193)		All (*n* = 396)		Basketball (*n* = 199)	Floorball (*n* = 184)		All (*n* = 838)		Basketball (*n* = 128)	Floorball (*n* = 130)	
	Mean (*SD*)	Mean (*SD*)	*p* value	Mean (*SD*)	Mean (*SD*)	*p* value	Median	Mean (*SD*)	Mean (*SD*)	Mean (*SD*)	*p* value	Median	Mean (*SD*)	Mean (*SD*)	Mean (*SD*)	*p* value
Male	21.3 (3.1)	22.0 (2.4)		21.3 (3.1)	22.0 (2.3)				21.3 (3.1)	21.9 (2.3)				21.0 (3.0)	21.9 (2.2)	
Playing years																
All	6.9 (2.9)	7.7 (3.1)	0.007	6.9 (2.9)	7.7 (3.0)	0.013	7.0	7.3 (3.0)	6.9 (2.9)	7.6 (3.0)	0.012	7.0	7.2 (3.0)			≤0.001
Female	6.5 (2.6)	6.1 (2.6)		6.5 (2.6)	6.2 (2.6)				6.5 (2.6)	6.2 (2.6)				6.6 (2.5)	7.2 (2.5)	
Male	7.3 (3.2)	8.9 (3.0)		7.3 (3.2)	8.7 (2.8)				7.3 (3.2)	8.7 (2.8)				6.8 (3.0)	8.8 (3.0)	
Training hours per week (mean SD)				Team practice hours per season (mean SD)					Team practice hours per season (mean SD)							
All	9.3 (3.1)	9.9 (4.0)	0.085	215.1 (102.9)	236.0 (114.1)	0.093	229.6	225.3 (108.9)	215.8 (103.0)	240.8 (113.9)	0.038	232.4	227.8 (109.0)			0.010
Female	8.9 (3.0)	9.1 (3.1)		179.4 (77.7)	221.5 (88.7)				182.1 (77.0)	220.8 (90.6)				170.9 (73.4)	231.7 (106.4)	
Male	9.8 (3.2)	10.6 (4.4)		252.0 (112.7)	246.6 (128.9)				249.9 (114.4)	256.1 (127.3)				246.8 (134.6)	257.7 (133.5)	
Games per season (mean SD)				Game hours per season[1] (mean SD)					Game hours per season[1] (mean SD)							
All	35.5 (16.4)	36.7 (15.2)	0.450	6.7 (4.6)	9.7 (6.7)	≤0.001	7.5	8.2 (5.9)	6.8 (4.6)	9.8 (6.7)	≤ 0.001	7.5	8.2 (5.9)			≤0.001
Female	38.1 (17.5)	35.7 (15.0)		7.2 (4.9)	9.1 (6.5)				7.2 (4.9)	9.0 (6.6)				7.6 (4.7)	10.7 (7.4)	
Male	32.7 (14.8)	37.4 (15.4)		6.3 (4.2)	10.1 (6.8)				6.3 (4.3)	10.4 (6.7)				7.5 (3.9)	10.0 (6.9)	

p values shown refer to the t-test/Mann-Whitney test between sports groups
[1]Active playing time in games during the season.

5.3 Prevalence of low back pain (studies I to II)

The prevalence of self-reported LBP during the preceding three-months ranged from 24.5% to 35.0% and the prevalence of self-reported NSP ranged from 27.3% to 52.9% in boys and girls, respectively (study I). The prevalence of LBP and NSP in non-members compared to sports club members can be seen in Table 14.

When looking more closely at youth basketball and floorball players (study II), over half (54.6%) of the youth floorball and basketball players reported to have had LBP at some point in their lifetime. Floorball players reported significantly more LBP compared to basketball players, as can be seen in Table 14.

The majority of players with a history of LBP reported that the onset was gradual (Figure 6). Several players reported that the LBP symptoms occurred during sports-specific training or playing (16% of basketball players and 26% of floorball players). Many players also perceived that LBP symptoms appeared during strength training (12% of basketball players and 17% of floorball players).

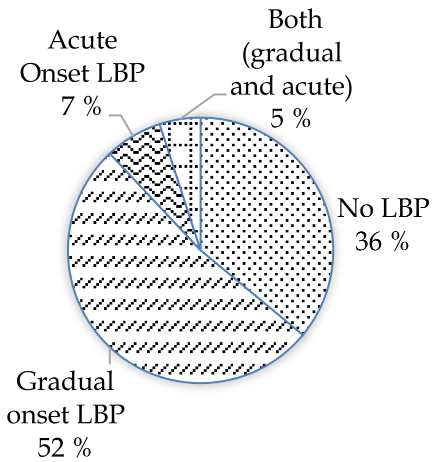

FIGURE 6 Onset of reported low back pain (LBP) (study II).

TABLE 14 Responses to the low back pain and neck- and shoulder pain questions (studies I to II).

Variable	Study I										Study II				
	Male (*n* = 772)					Female (*n* = 865)					Team sport players (*n* = 401)				
	Member		Non-member		*p* value[1]	Member		Non-member		*p* value[1]	Basketball (*n* = 207)		Floorball (*n* = 194)		*p* value[2]
	n	%	*n*	%		*n*	%	*n*	%		*n*	%	*n*	%	
Lifetime prevalence	259	52.7	122	43.4	< 0.02	284	60.3	246	62.4	0.520	94	45.4	125	64.4	< 0.001
LBP previous 12 months											92	44.4	120	61.9	0.001
LBP[3]	138	28.1	51	18.1	0.020	160	34.0	143	36.3	0.475	-	-	-	-	-
Frequent LBP[4]	30	6.1	12	4.3	0.278	51	10.8	44	11.2	0.874	-	-	-	-	-
LBP during the last seven days[5]	100	38.6	39	32.0	0.209	123	43.3	110	44.7	0.745	41	19.8	54	27.8	0.059
NSP[6]	130	26.5	81	28.8	0.481	222	47.1	236	59.9	< 0.001	-	-	-	-	-
Frequent NSP[7]	19	3.9	23	8.2	< 0.02	67	14.2	104	26.4	< 0.001	-	-	-	-	-

[1] *p* value for difference between members and non-members of sports clubs
[2] *p* value for difference between sports
[3] Low back pain more than once a month
[4] Low back pain at least once a week
[5] Study I: Male *n* = 381 Female *n* = 530
[6] Neck and shoulder pain more than once a month
[7] Neck and shoulder pain at least once a week

5.4 Incidence and onset of back pain resulting in time-loss (study III)

During the follow-up (586 player-years) we recorded BP in 13% of all players (*n* = 396) (study III). The incidence of BP in floorball and basketball players was 87 per 1,000 athlete-years and 0.4 per 1,000 hours of training and games (Figure 7). The incidence of non-traumatic gradual onset BP was higher than acute traumatic onset BP (Figure 7). The incidence was higher in girls compared to boys and in younger players compared to older players (Figure 7). Of the non-traumatic BP that was reported, 61% (*n* = 27) was reported to be recurrent. Nearly all pain complaints (90%, *n* = 43) were located in the lower back and posterior pelvis area.

Most of the acute traumatic BP occurred in non-contact situations (*n* = 14, 82%). The most reported situation leading to acute traumatic BP was landing from a jump or a sudden/unexpected movement (59%, *n* = 10). The majority (76%, *n* = 12) of acute traumatic BP occurred during practice mostly during conditioning training.

When looking at the follow-up period of 2013 to 2014 (study V), 36 LBP episodes were recorded in 35 players (*n* = 3 excluded direct contact injuries). The incidence of first-time LBP during the 12-month follow-up was 0.5 per 1,000 hours of training and games.

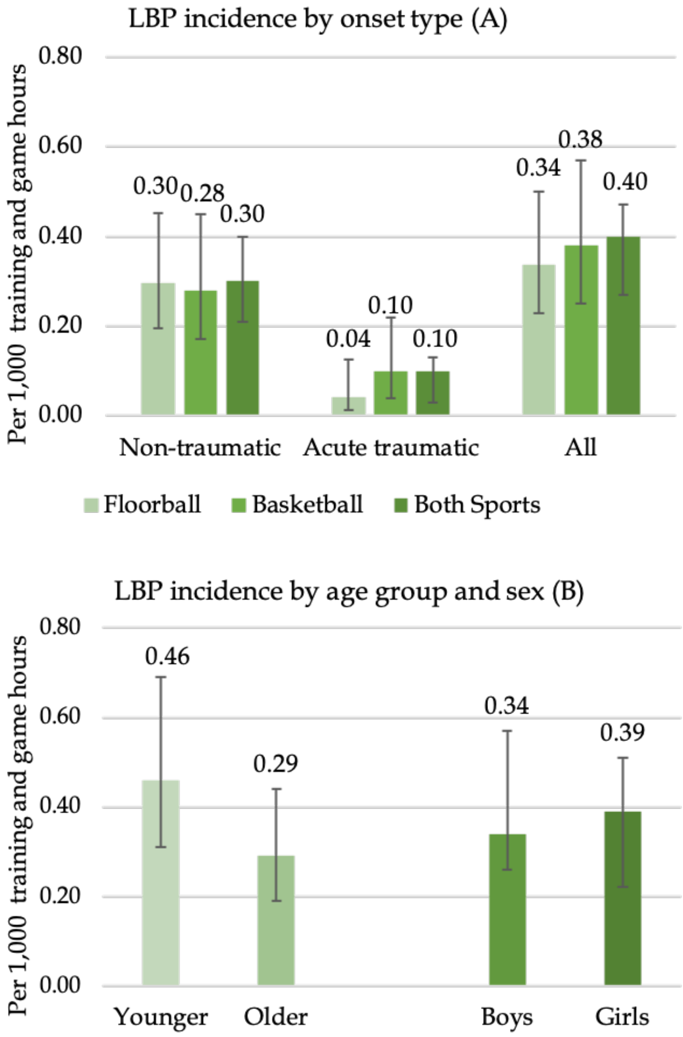

FIGURE 7 Incidence of low back pain (LBP) by onset type (A) and by sex and age group (B). Presented as incidence per 1,000 training and game hours (study III) 'Younger' are youth aged 12 to 15 and 'older' are youth aged 16 to 21.

5.4.1 Consequences of low back pain (studies I to III)

The results showed that among boys, sports club members sought medical assistance due to their LBP significantly more often than non-members (25.9% vs. 5.7%, $p < 0.001$) and used significantly more NSAIDs due to LBP (38.2% vs. 20.5%, $p < 0.002$) (study I). In team sport players (study II), the prevalence of medical injuries was quite low (12% of all reported LBP). Youth reporting for sleeping problems due to LBP ranged between 6 and 18% (studies I and II).

Nearly one fifth of basketball and floorball players had missed training due to LBP during the preceding 12-months (15.5% in basketball and 21.1% in floorball) (study II). Furthermore, when looking at the days lost due to LBP based on results from prospective follow-up study (study III), we noticed that nearly half of the non-traumatic LBP complaints resulting in time-loss lead to over 29 days off normal training, when close to 50% of traumatic onset LBP resulted in seven days or less time-loss (Figure 8).

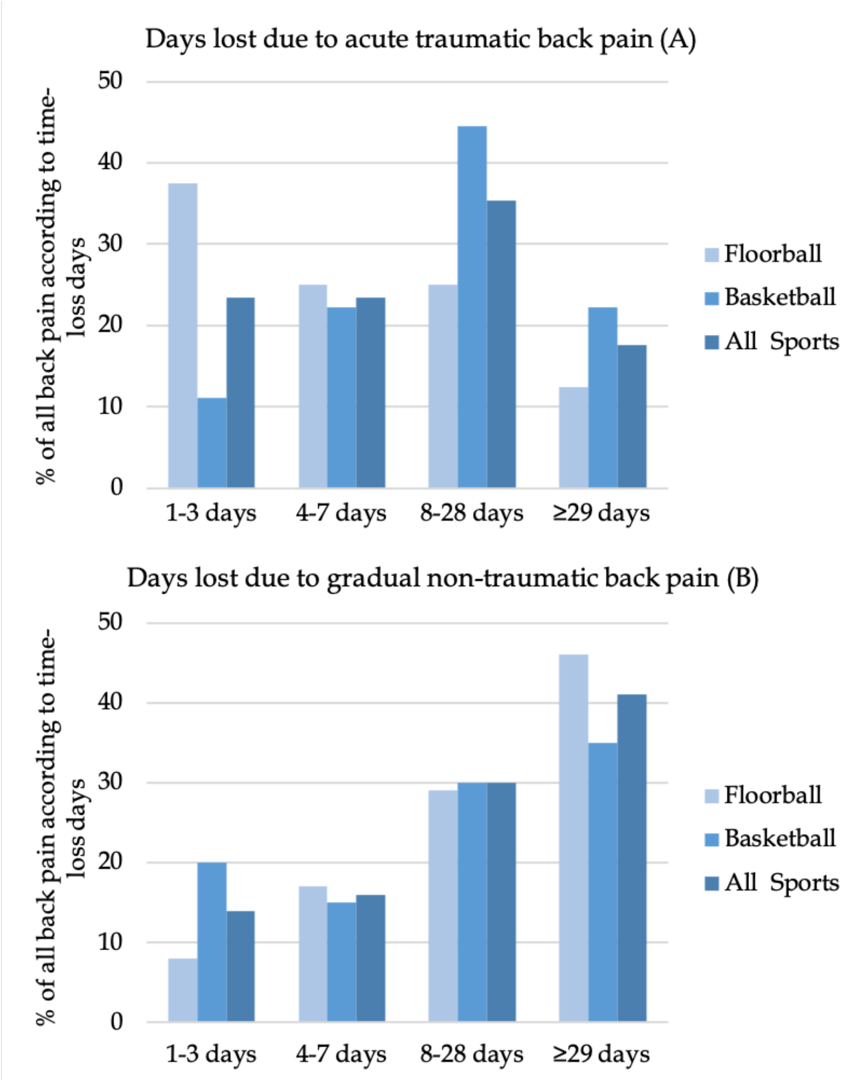

FIGURE 8 Days lost due to acute traumatic onset back pain (A) and gradual non-traumatic onset back (B) (study III).

5.5 Risk factors for low back pain

In youth sports club members and non-members, we observed significant associations between LBP and self-reported health and health-related behaviours presented in Table 15, but interestingly not with self-reported leisure time PA (study I). Odds ratios with 95% *CI*s are presented in the original article (study I).

Among youth floorball and basketball players (study II), we found that the odds for LBP in players with a family history of musculoskeletal disorders was double (*OR* 2.02, 95% *CI* 1.22 to 3.34) compared to players with no family history of LBP (study II).

TABLE 15 Summary of associations between low back pain and self-reported health and health behaviour in youth (study I and II).

FACTORS ASSOCIATED WITH LBP	FACTORS NOT ASSOCIATED WITH LBP
HEALTH	
MSK pain in other locations[1] (+)	Chronic diseases[5]
Family history of MSK disorders (+)	BMI
HEALTH BEHAVIOUR	
Smoking (+)	Self-reported leisure time PA[6]
Alcohol use[2] (+)	Active playing/practicing years
Screen time[4] (+)	
Organized sports participation (+)	
Training hours[3] (+)	
Number of competitions or games[3] (+)	
Number of rest days (-)	

LBP, low back pain; MSK, musculoskeletal; PA, physical activity; BMI, body mass index.
(-) Decreased odds
(+) Increased odds
[1] Neck, upper back, upper limb, lower limb
[2] At least or more often than 2–3 x month
[3] Only in male (during previous 12 months)
[4] Calculated per additional hour of screen time (i.e.TV, computer, computer/console games, phone, tablet use.
[5] Allergy, asthma, diabetes, epilepsy, heart condition etc.
[6] Intensity: breathlessness and sweating reference category 'Approx. < 30 min/wk'

5.5.1 Prospective risk factor analyses (studies III to V)

In the prospective risk factor analyses, the follow-up time was one year for 66% (*n* = 254) of the players, two years for 20% (*n* = 75) and three years for 14% (*n* = 54), except for study V, where the follow-up period 2013 to 2014 was examined. Of the 383 players, 54% (*n* = 205) reported no history of LBP at baseline, 11% (*n* = 48) sustained LBP during the follow up and 35% of them (*n* = 17) had not had BP prior to the study.

5.5.1.1 Muscle strength and flexibility (study III)

We found no association between LBP and investigated lower extremity muscle strength variables nor were there flexibility factors in the Cox analyses (Figure 9; for the unadjusted analyses, see Supplementary Table 2). Note, however, that the results between the original article and this dissertation differ slightly. This is because players with ongoing acute injury were not excluded from the first analysis if they participated despite their injury. The new analyses were performed and players with acute ongoing injury were excluded (leg press *n* = 25, hip abduction *n* = 17).

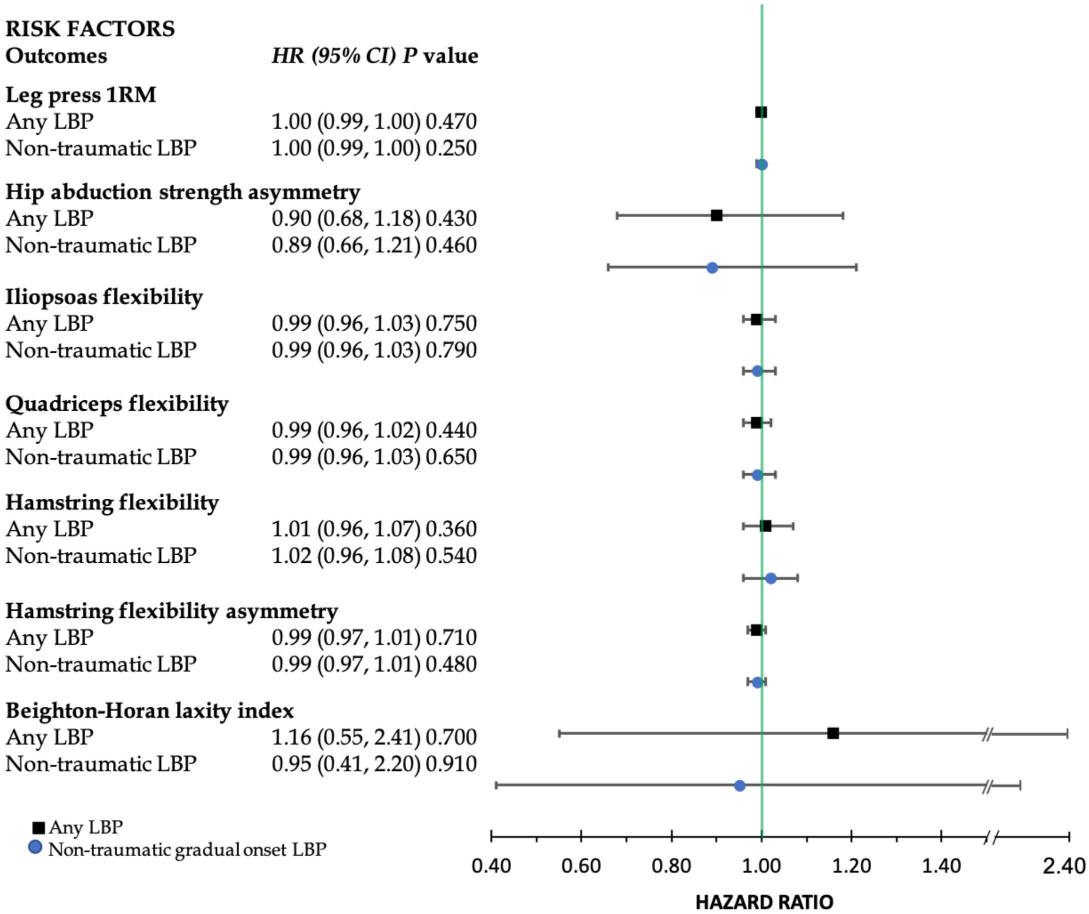

FIGURE 9 The adjusted hazard ratios from adjusted Cox analyses on strength and flexibility variables (study III). Any low back pain (LBP) includes traumatic acute onset and non-traumatic gradual onset low back pain.

5.5.1.2 Kinetics and kinematics in dynamic movement tasks (studies IV and V)

Kinetics and kinematics were investigated in the SLVDJ, VDJ and SKL tests. Table 16 shows the unadjusted and adjusted results from Cox regression analyses for the VDJ test separately for all LBP and non-traumatic onset LBP. According to our results, neither peak vGRF nor side-to-side asymmetry in vGRF during VDJ landing were associated with LBP.

Figure 10 reports the results from the SLVDJ test (unadjusted analyses and analyses with categorical variables can be found in the original article). We found increased risk for LBP in the players with decreased FPA during SLVDJ when landing on their right leg, a one-degree decrease in FPA increased the risk for LBP 1.9-fold. The analysis using categorical variables showed that players with 80 degrees of FPA or less during right leg landing had 2.2 times higher risk for LBP during the follow-up than did players with more than 80 degrees of FPA. There was no statistically significant association between risk for LBP and FPA during left leg landing from a drop jump.

Table 17 shows the adjusted and unadjusted hazard ratios between LBP and pelvic kinematic variables from the SKL test. We observed no statistically significant associations between LBP and hip-pelvic kinematics during the SKL test. Interestingly, the sample presented only a small number of players (n = 40) with actual pelvic drop and the maximum pelvic drop was -3.5 degrees. Therefore, the variable was analysed also as a categorical variable (No pelvic drop = CL pelvic drop values at zero or higher, Small pelvic drop = CL pelvic drop values smaller than zero). The results showed no significant difference in risk between players with or without pelvic drop (small pelvic drop vs. no pelvic drop: left leg *HR* 0.86, 95% *CI* 0.41 to 3.31, right leg *HR* 1.61, 95% *CI* 0.70 to 3.74, adjusted with history of LBP).

TABLE 16 The unadjusted and adjusted hazard ratios for any low back pain (including traumatic acute onset and non-traumatic gradual onset low back pain) and separately for non-traumatic gradual onset low back pain based on Cox regression analyses (study IV).

	Univariate		Adjusted	
	HR 95% *CI*	*p* value	*HR* 95% *CI*	*p* value
Continuous risk factor variables[1]				
All LBP				
Peak vGRF, N/Kg	1.03 (0.97 to 1.11)	0.340	1.03 (0.96 to 1.11)	0.380
Absolute Peak vGRF, N	1.00 (1.00 to 1.00)	0.760	1.00 (1.00 to 1.00)	0.870
Peak vGRF asymmetry, N/Kg	1.00 (0.85 to 1.18)	0.990	1.00 (0.85 to 1.18)	0.990
Absolute Peak vGRF asymmetry, N	1.00 (1.00 to 1.00)	0.970	1.00 (1.00 to 1.00)	0.940
Gradual onset non-traumatic LBP				
Peak vGRF, N/Kg	1.00 (1.00 to 1.00)	0.610	1.00 (1.00 to 1.00)	0.690
Absolute Peak vGRF, N	1.04 (0.96 to 1.12)	0.370	1.03 (0.96 to 1.12)	0.420
Peak vGRF asymmetry, N/Kg	1.03 (0.87 to 1.23)	0.720	1.02 (0.86 to 1.22)	0.810
Absolute Peak vGRF asymmetry, N	1.00 (1.00 to 1.00)	0.710	1.00 (1.00 to 1.00)	0.790
Dichotomous risk factor variables[2] (high vs. low)				
All LBP				
Peak vGRF[3], N/Kg	1.92 (1.00 to 3.68)	0.051	1.83 (0.95 to 3.51)	0.070
Absolute Peak vGRF[4], N	0.99 (0.53 to 1.83)	0.960	0.94 (0.51 to 1.76)	0.860
Peak vGRF asymmetry[5], N/Kg	1.23 (0.66 to 2.30)	0.510	1.22 (0.65 to 2.27)	0.530
Absolute Peak vGRF asymmetry[6], N	1.21 (0.65 to 2.25)	0.550	1.20 (0.64 to 2.23)	0.580
Gradual onset non-traumatic LBP				
Peak vGRF[3], N/Kg	1.47 (0.73 to 2.98)	0.610	1.41 (0.69 to 2.86)	0.340
Absolute Peak vGRF[4], N	0.98 (0.49 to 1.97)	0.370	0.94 (0.47 to 1.88)	0.850
Peak vGRF asymmetry[5], N/Kg	1.31 (0.65 to 2.64)	0.720	1.30 (0.64 to 2.61)	0.470
Absolute Peak vGRF asymmetry[6], N	1.28 (0.64 to 2.58)	0.710	1.26 (0.63 to 2.54)	0.510

HR, Hazard ratio; *CI*, confidence interval; LBP, low back pain; vGRF, vertical ground reaction force; N, Newton.

[1] Adjusted with history of LBP, leg dominance and nicotine use

[2] All LBP: Adjusted with history of LBP and leg dominance. Gradual onset LBP: Adjusted with history of LBP.

[3] Peak vGRF high >= 18.5, low < 18.5

[4] Absolute Peak vGRF high >= 1191.0, low < 1191.0

[5] Peak vGRF asymmetry high >= 1.6, low < 1.6

[6] Absolute Peak vGRF asymmetry high >= 103.3, low < 103.3

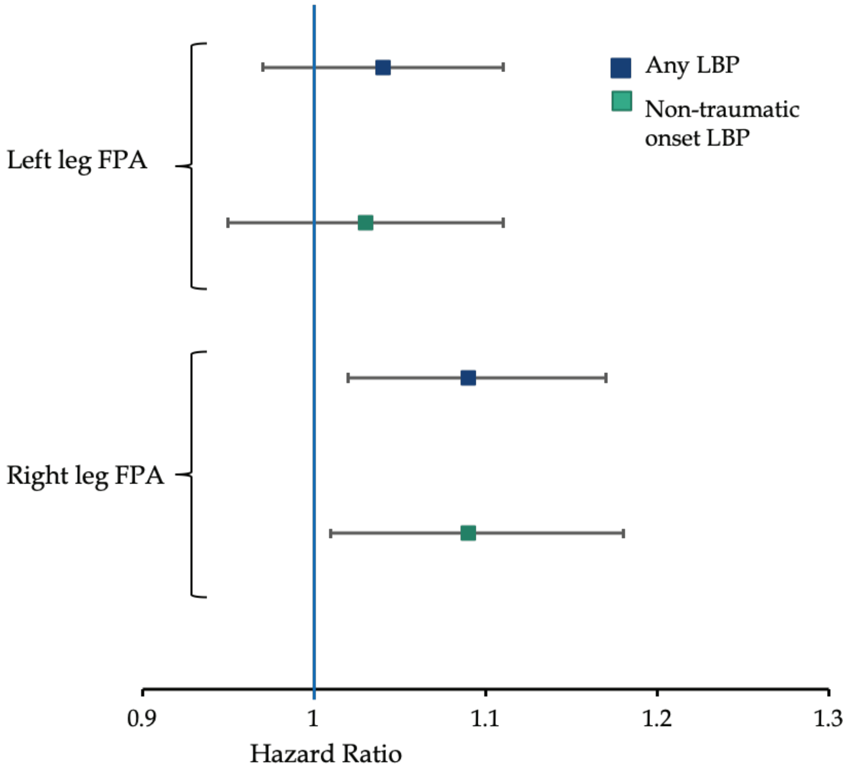

FIGURE 10 The adjusted hazard ratios (*HR*) and confidence intervals (*CI*s) from Cox mixed-effect analyses with incidence of low back pain (LBP) as outcome and femur-pelvic angle (FPA) as independent factors. Adjusted with history of LBP and leg dominance. *HR* calculated per one-degree decrease.

TABLE 17 The unadjusted and adjusted hazard ratios (*HR*) and confidence intervals (*CI*s) from Cox analyses with incidence of low back pain as outcome and pelvic tilt and obliquity as independent factors (study V).

	Unadjusted		Adjusted[1]	
Primary variables	*HR*	95% *CI*	*HR*	95% *CI*
Left leg				
Peak pelvic anterior tilt	1.00	(0.92, 1.09)	0.99	(0.91, 1.07)
Peak pelvic posterior tilt	0.98	(0.93, 1.05)	0.99	(0.93, 1.06)
Right leg				
Peak pelvic anterior tilt	0.98	(0.90, 1.07)	0.97	(0.89, 1.05)
Peak pelvic posterior tilt	0.99	(0.94, 1.06)	1.01	(0.95, 1.07)
Secondary variables				
Left leg				
Peak contralateral hike angle[2]	0.98	(0.89, 1.09)	0.98	(0.88, 1.09)
Peak contralateral drop angle	1.01	(0.85, 1.18)	0.98	(0.83, 1.16)
Right leg				
Peak contralateral hike angle[2]	0.94	(0.85, 1.04)	0.93	(0.84, 1.04)
Peak contralateral drop angle	1.08	(0.90, 1.28)	1.08	(0.90, 1.29)

HR, hazard ratio; *CI*, confidence interval.
[1] Adjusted with history of low back pain (LBP) and leg dominance (unilateral leg dominance/bilateral leg dominance).
[2] *HR* converted so that one-unit increase is interpreted as more pelvic hike

6 DISCUSSION

This thesis consisted of five original articles and used two datasets. Retrospective as well as prospective methods were applied. The main objective of this thesis was to assess the prevalence and incidence as well as the factors associated with LBP in youth basketball and floorball players.

6.1 The prevalence and incidence of LBP in youth

In general, girls reported recent LBP more often than boys did, which is consistent with several previous studies (Kamper et al. 2017). There was no significant difference in LBP prevalence in girls when comparing sports club members and non-members. Among boys, however, sports club members reported more LBP within the preceding three months and sought medical assistance due to LBP more often than non-members did. Interestingly, sports club members reported less frequent NSP compared to non-members. This result is supported by findings from the Norwegian Young-HUNT study, where they found that moderate PA was associated with decreased odds for NSP, compared to high or low level of PA in adolescents (Guddal et al. 2017).

We noticed that girls reported having more problems with sleeping due to LBP compared to boys. Yet girls participating in sports clubs seemed to have fewer problems with sleeping due to LBP compared to non-members did. However, a higher prevalence of sleep problems perceived to be due to LBP in non-members may be related to also other factors than sports participation status. According to Lund et al. (2010), perceived stress had stronger association between poor sleep in college age students (17- to 24-year-olds) compared to exercise frequency. In addition, not participating in sports has been associated with more mental health problems and stress (Eime et al. 2013, Jewett et al. 2014). However, disturbed sleep has also been associated with LBP in longitudinal settings (Auvinen et al. 2010), suggesting it might play some part in LBP development. Daytime tiredness and difficulties in falling asleep has been shown to be associated with non-traumatic onset MSK pain in children in general (El-Metwally et al. 2007).

Previous studies have found BP to be associated with somatic complaints or pain symptoms elsewhere in the musculoskeletal system (Jones et al. 2003, Hestbaek et al. 2006, Jonasson et al. 2011, Coenen et al. 2017, Smith et al. 2017). Jonasson et al. (2011) reported a strong correlation between hip pain and BP among athletes (age range 10 to 41 years). Holden et al. (2018) noted that youth with a median of two pain sites had a higher risk for reporting LBP. Pain in one part of the back is also associated with pain in other parts of the back (Jonasson et al. 2011). Our results are in line with previous research as we saw increased odds for LBP, when pain was reported elsewhere in the body (extremities and/or other parts of the back). These results may reflect spreading of pain or association between LBP and decline in health in general (Ferreira et al. 2013).

We observed an association between reporting LBP and higher screen time in youth. Yet, according to longitudinal studies, screen time is not a significant risk factor for LBP in youth (Jones et al. 2003, Smith et al. 2017). Baiden et al. (2019) found that excessive screen time is associated with insufficient sleep, which may explain, at least in part, our finding of an association between screen time and LBP. We did not find an association between LBP and self-reported time spent in leisure-time PA. However, the result might be affected by PA reduction due to LBP as the study was cross-sectional. In addition, it has been stated that self-reported PA level is not a reliable method when investigating association of PA and LBP in youth population (Wedderkopp et al. 2003). Self-reported PA may result in overestimation in time spent in high intensity PA and underestimation of time spent in moderate intensity PA (Wedderkopp et al. 2003).

When assessing the prevalence of LBP in youth floorball and basketball players specifically, using retrospective data from the baseline questionnaire, we found that LBP was common in youth basketball and floorball players. Of basketball and floorball players, 44% and 62%, respectively, reported having had LBP during the previous year. Nearly a fifth of the floorball and basketball players reported having missed training during the last 12 months due to LBP, meaning the LBP resulted in some level of disability. Among the general youth population, a fourth felt that LBP interfered with normal activities and hampered recreational physical activities (Coenen et al. 2017).

In summary, the prevalence of LBP varies across samples. Aartun et al. (2014) reported that 22% in 13- to 15-year-old girls and 18% in boys reported LBP during the previous week. According to our results, one-week prevalence in non-members and sports club members ranged from 32% to 45%, respectively. In contrast, in youth floorball and basketball players it ranged from 20% to 28%. There is no obvious explanation for this difference as the LBP question was the same in both queries. The most likely reason is the timing of the questionnaires: the middle of the competition season for sports club members and after the competition season in basketball and floorball players. We could also speculate that prevalence in youth floorball and basketball players was lower because most of the players play at a high level in the two sports. Playing level has been shown to be associated with LBP (Peterson et al. 2000). Furthermore, among non-members and sports club members, there are several sports that are believed to place a higher demand on the back, the level of participation is likely to be more varied and more different sports clubs were included.

The most common self-reported situation leading to LBP in floorball and basketball players was sport-specific training and playing, with strength training coming second. The perceived predisposing factors are close to what youth field hockey and soccer players, speed skaters (van Hilst et al. 2015) and varsity athletes (Greene et al. 2001) have reported: bended playing posture, dribbling, sprinting, twisting and turning, strength training, artificial turf and, in skating, endurance training. However, it should be noted that the reported situations leading to LBP are the perceptions of the players. It could be that BP beliefs influence the perceptions of LBP origin. For example, there is no strong evidence that strength training is a risk factor for LBP (Trompeter et al. 2017). Strength training has been shown to decrease the risk for sports injuries in general, yet mostly lower extremity injuries have been studied so far (Lauersen et al. 2018). Furthermore, in adults with LBP, high load lifting exercises (deadlift) resulted in similar decrease in pain or disability as low load movement control exercises (Michaelson et al. 2016), suggesting that high-load strength training might not constitute a risk factor for LBP per se.

In our cross-sectional study among floorball and basketball players, LBP was reported to have occurred most often during competitive playing season. We also found that in boys participating in organized sports the number of rest days slightly decreased the odds for LBP, while an increase in training hours slightly increased the odds. Shah et al. (2014) noticed that in youth soccer players' prevalence of LBP was higher after brakes. In rowers, LBP prevalence has also been reported to vary throughout the season and be strongly associated with the volume of training (Shah et al. 2014, Newlands et al. 2015). Increased prevalence in youth soccer players has been noticed also during games after the second half. These results would suggest that finding optimal training and progression should be of interest when trying to decrease the burden of LBP among youth athletes.

Our cross-sectional analyses suggested that LBP is not an uncommon complaint among youth floorball and basketball players. The results also suggested that floorball players might be predisposed to higher odds for LBP. We investigated this further using prospective data and discovered that 13% of the floorball and basketball players missed training or games due to BP during the follow-up. The incidence per training and game hours was slightly higher in basketball players compared to floorball with a risk ratio of 1.12 (95% *CI* 0.64 to 1.97), which is surprising because floorball players were older (16.8 vs. 15.9, $p <$ 0.001). This can be explained with the fact that incidence was higher in younger players (15 or younger vs. 16 or older; *IRR* 1.75, 95% *CI* 0.99 to 3.08). This seems to go hand in hand with previous studies where the prevalence shown to be higher among older, but first-time incidence is higher among younger populations. Our results are also in line with Peterson et al. (2000), who noticed that in soccer players, lower playing level and younger age increased the risk of BP. At the baseline, 51.4% of the players reported having had LBP during the previous year. Therefore, the incidence reported in this study is not a true incidence as it does not truly represent the first LBP occurrence in many of the players.

LBP incidence of 0.25 per 1,000 training and game hours[i] has been reported in youth female basketball players (Gomez et al. 1996) compared to 0.39 per 1,000 training and game hours reported in our study. On the other hand, LBP incidence of 0.18 per 1,000 hours of training and games[i]) has been reported in youth male basketball players (Messina et al. 1999), but the incidence was higher in our study (0.34 per 1,000 training and game hours in boys). The difference between studies might be related to differences in recording the exposure. Gomez et al. (1996) and Messina et al. (1999) did not take account of variable exposure hours in every player. We, on the other hand, recorded training and game hours individually for every player. The previous studies are also older, and it is likely that the sport of basketball has evolved during the past 15 years. Our results indicate that the incidence per 1,000 training and game hours was higher in girls compared to boys and higher than what previous studies have reported within basketball. Still, the results from previous studies show the same trend as our results: more LBP incidents reported in girls than in boys (0.25 vs 0.18 per 1,000 training and game hours[i]) (Messina et al. 1999). Regarding floorball, to our knowledge there are no studies reporting LBP incident to compare our findings to.

Our finding that LBP may be more prevalent in youth participating in organized sports is in line with previous findings that show increased risk of LBP in children participating in sports compared to other PA (i.e. leisure time PA and school PA classes), when adjusted with hours of activity (Franz et al. 2017). Organized sports participation has been reported to increase odds for LBP also in youth (Kujala et al. 1997, Sato et al. 2011). The reason why sports participation was associated with increased odds of LBP in boys, but not in girls might be related to boys participating more frequently in contact sports.

The possible reasons why athletes report LBP as often or sometimes even more often than non-athletes are numerous. For example, training in the athletes may be more homogeneous than PA in youth not taking part in organized sports. Repetitive twisting and bending to end-range during sports specific training might predispose for LBP pain in some sports, when performed over the threshold of the tissue. This again underlines the importance of optimal loading and progression to build up the resilience of the back and the player to adapt to the demands of the sport. Being a competitive athlete and possibly part of a team might also affect the psychosocial factors (e.g. stress and anxiety) that have been associated with LBP risk. Youth athletes may also be inactive during their leisure time. We noticed that 16% of the sports club participants did not reach the weekly PA recommendations. According to another study, three-quarters of Finnish children and youth aged 11 to 15 (Aira et al. 2013, p.15, Liukkonen et al. 2014) and even one third of sports club members in the Nordic countries do not meet the recommended level of PA (Eiosdottir et al. 2008). Therefore, it could be speculated that youth athletes are not ready for the intense bouts of training when they have been so inactive during their leisure time.

---

[i] Calculated based on exposure hours and LBP incidents reported in the study (incidents/hours)

6.2 Risk factors for low back pain in youth floorball and basketball players

In summary, our risk factor analyses suggest that lower extremity muscle flexibility, general hypermobility, lower extremity strength, and strength asymmetry, nor forces produced by landing were not statistically associated with the incidence of LBP in youth basketball and floorball players as measured in this study. We did find that decreased hip-pelvic control during single-leg landing increases the risk for LBP, but increased hip-pelvic movement during standing knee lift does not. This does not, however, mean that these factors are irrelevant in LBP development in youth in general.

6.2.1 Hip-pelvic kinematics and forces produced during landing

Lumbo-pelvic function is an essential part of successful athletic performance (Kibler et al. 2006). Low back and pelvis are part of a kinetic chain, where movement (or the lack of movement) of one segment affects the kinetic chain up and down. However, investigation into movement patterns and LBP in youth sport is essential and currently lacking (O'Sullivan et al. 2017).

Previous research has suggested that there might be an association between lower extremity injuries (LEI) and BP (Zazulak et al. 2007, Seay et al. 2018). Furthermore, decreased lower extremity control in a single leg decline squat task has been reported as a risk factor for LBP in youth cricket players (Bayne et al. 2016) and a cross-sectional study with adults described a relationship between frontal plane knee movement during a functional step-down task and LBP (Hernandez et al. 2017). Higher risk of BP has also been observed in children with history of lower extremity pain (Fuglkjær et al. 2018). Thus, it has been speculated that lower extremity kinematics or shared risk factors might explain the association between LEI and LBP (Seay et al. 2018). On the other hand, impaired lumbo-pelvic control has been shown to be associated with LBP (Dankaerts et al. 2006, Dankaerts et al. 2009, Astfalck et al. 2010b) and different lumbo-pelvic movement patterns have been identified in youth athletes with LBP compared to those without (Roussel et al. 2009, Campbell et al. 2014, Ng et al. 2015, Grosdent et al. 2016). For example, increased risk for LEI and LBP in dancers with impaired movement control of the lumbo-pelvic area in two movement control tests has been reported (Roussel et al. 2009). In addition, Chaudhari et al. (2014) observed increased odds for time-loss sports injury in baseball pitchers with larger sagittal plane lumbo-pelvic movement during a single leg raise test in standing. Therefore, we hypothesized that hip-pelvic kinematics might be associated with future LBP in youth floorball and basketball players.

We did not find an association between LBP incidence and sagittal plane pelvic tilt or frontal plane pelvic obliquity in youth basketball and floorball players during the 12-month follow-up. However, our results showed a small increase in risk (8%) for LBP with one-degree decrease in right-leg FPA during SLVDJ landing. There was a two-fold increase in risk among players with less than 80 degrees of FPA during right-leg landing than among players with more than 80 degrees of FPA. This association was not seen when the test was performed with the left side. This might be associated with the fact that the starting leg was not randomized, and the test was started with the right leg. Therefore, by the time they performed the test with their left leg, the players were more accustomed to the test.

Our hypothesis was that decreased hip-pelvic control might increase the risk for LBP by increasing the load and strain in the low back. The association between hip-pelvic control and LBP might be associated with compensatory movements produced by hip-pelvic control impairment during the landing to maintain balance, such as hip hike or trunk lateral flexion. Repeated trunk lateral flexion has been associated with increased LBP incidents in youth cricket players (Bayne et al. 2016). The performance in SLVDJ, which is more dynamic and ballistic than SKL, might be more relevant in basketball as well as floorball players performing a lot of running and dribbling, turning and twisting, passing and shooting and, specifically in basketball players, jumping and landing. We also observed that actual pelvic drop during the SKL test was not common among the young floorball and basketball players.

Association between postural and movement control factors have been observed when LBP has been divided into groups based on pain provocation patterns, but not when LBP has been considered as a homogenous symptom (Dankaerts et al. 2006, Dankaerts et al. 2009, Astfalck et al. 2010a, Astfalck et al. 2010b). Therefore, it would be interesting to continue the research and assess whether increased anterior pelvic tilt is associated with future extension-related LBP, for example.

When looking from a wider perspective, for example the risk factors studies investigating the association between lower extremity movement control and anterior cruciate ligament (ACL) injuries have also reported inconsistent results (Hewett et al. 2005, Krosshaug et al. 2016, Sharir et al. 2016, Leppänen et al. 2017). This is even though the lower extremity movement control, specifically dynamic knee valgus, has been shown to be the most common injury mechanism for ACL injury (Olsen et al. 2004, Krosshaug et al. 2007, Koga et al. 2010). Presumably, this and previous studies investigating risk factors for sports injuries may have found only few or no associations between movement control and injury risk, is due to the assumption of stable risk factors, as suggested by Meeuwisse et al. (2007). In fact, a large part of protective factors and risk factors can change over time. Every time when the player steps on the field, the set of his/her protecting and predisposing factors are different (see e.g. A dynamic, recursive model of etiology in sport injury by Meeuwisse et al. 2007).

In elite basketball teams, players have been reported to perform an average of 70 jumps and 3.4 kilometres of running per game, with jump landings producing higher forces, especially in the vertical direction (McClay et al. 1994). Landing produces GRFs that also affect the lumbar spine (Seay et al. 2008) and potentially could predispose for BP. Müller et al. (2017) did not notice any difference in vGRF in youth basketball and floorball players with or without recent LBP. However, to our knowledge association between vGRF produced by drop jump landing and LBP have not been previously studied in a prospective setting. Our results revealed that in youth basketball and floorball players, peak vertical GRFs measured in VDJ landing did not increase the risk of LBP.

6.2.2 Muscle strength

Cross-sectional studies have reported decreased lower extremity strength (knee extensor weakness (Bernard et al. 2008), decreased squat endurance (Astfalck et al. 2010a) and reduced lower extremity power (jump test) (Perry et al. 2009) in youth with LBP. In addition, gluteal muscles, which also function as pelvis stabilisers (Grimaldi 2011), have shown to have impaired function in people with LBP (Kankaanpää et al. 1998, Leinonen et al. 2000).

We investigated the association between LBP and lower extremity maximal strength and side-to-side asymmetry of hip abductors in youth basketball and floorball players. Our results showed no significant association between lower extremity extension strength during leg press and LBP incidence. In addition, there was no difference in hip abductor strength asymmetry in youth basketball and floorball players with and without future LBP, when measured with isometric maximal hip abduction in supine. Nadler et al. (2000) was also unable to find a relationship between hip abductor strength asymmetry and LBP in youth athletes. Therefore, it seems unlikely that in youth basketball and floorball players, the lower extremity strength itself would predispose for future LBP. It has been shown that level of strength does not always correlate with movement impairment associated with the function of the muscle. For example, hip abductors function as pelvic stabilizers, but pelvic drop during walking or during the Trendelenburg test does not always correlate with hip abductor strength (Kendall et al. 2010).

6.2.3 Flexibility

General joint hypermobility has been shown to be associated with impaired proprioception and muscle performance in children (Fatoye et al. 2009) and increases the risk for recurrent MSK pain in preadolescents (El-Metwally et al. 2004). Aartun et al. (2016b) found an association between Beighton scores greater than or equal to six and frequent LBP in youth (*OR* 3.38; 95% *CI* 1.14 to 10.1), but also observed that predictive validity was poor. In contrast, our prospective investigation in youth basketball and floorball players did not find joint hypermobility measured with the Beighton-Horan index to be associated with LBP. Our results are though in line with a cross-sectional study by Tobias et al. (2013) who did not find an association between BP and general hypermobility in youth general population. The inconsistency between the results may be explained by difference in LBP definitions (we investigated time-loss LBP and Aartun et al. (2016b) frequent LBP), different study settings, sports clubs vs. school, or more likely by the different cut-offs used. Aartun et al. (2016b) used the stricter cut-off recommended by Morris et al. (2016).

We were unable to identify any significant risk factors for LBP among the investigated muscle flexibility tests. Our results contradict previous findings to some extent as, for example, hamstring flexibility has been associated with LBP in youth (Feldman et al. 2001). On the other hand, our results are supported by previous research in youth athletes (Kujala et al. 1994, Hjelm et al. 2012) and in youth general population (Kanchanomai et al. 2015). Aartun et al. (2016b) also reported no association between posterior chain flexibility and frequent LBP. Thus, we would conclude that there is likely no strong association between hamstring flexibility and LBP incidence in youth floorball and basketball players.

Kujala et al. (1994) reported that hip flexor tightness might predispose athletes to LBP. This is not what we found in our results, nor did Hjelm et al. (2012) find this among youth tennis players. Increased risk for LBP was observed in the youth general population with decreased quadriceps flexibility (Feldman et al. 2001, Kanchanomai et al. 2015). We, however, did not find such association in youth basketball and floorball players. The results may differ due to different definitions of LBP, but also different tests, sports and settings.

6.3 Methodological considerations

6.3.1 Internal validity

There are some strengths and limitations to this thesis and the original studies included. One of the strengths is the relatively large sample sizes. To our knowledge, we conducted one of the largest prospective studies assessing risk factors for BP in youth team sport players. Among floorball and basketball players high participation and response rate in the baseline questionnaire (84% of all invited players participated in the study and all of them completed the questionnaire) is also a clear strength. The questionnaires were completed during the same day the basketball and floorball players participated in the baseline tests and study personnel could check the answers and ask the players to return to the questionnaire if answers were missing or incomplete.

One limitation in studies with retrospective design is the recall bias. For example, we used self-reported PA levels and training volumes in a few analyses that were reported retrospectively. Self-reported PA levels have been shown to be unreliable in the youth population (Wedderkopp et al. 2003).

Another clear strength was that individual training and game hours were recorded in the prospective parts of this study and included in the risk factor analyses. In addition, due to individual training and game hour recording, we were able to report incidence of BP in relation to exposure hours, which has not been reported previously in floorball players and only by few studies among youth basketball players (Gomez et al. 1996, Messina et al. 1999, Meeuwisse et al. 2003). Even though we adjusted for prospectively recorded individual training and game hours in the risk factor analyses, we assumed the loading during training and games was similar from hour to hour and game to game in every player and both sports. Yet, for instance, external loading from an hour of strength training might be different from an hour of sport-specific training. In addition, a subjective feeling of loading was not recorded or adjusted for.

Specific questions about LBP were based on widely used Standardized Nordic questionnaire of musculoskeletal symptoms (Kuorinka et al. 1987) and its modified version for athletes (Bahr et al. 2004). The standardized Nordic questionnaire has been shown to be a valid tool for identifying individuals with LBP in occupational settings (Takekawa et al. 2015). In addition, the reliability of most of the baseline tests has been shown to be from moderate to excellent as described in the methods section.

However, in cohort studies with a follow-up, the investigated factors may change over time. Especially in cohorts with active youth who are still growing as well as exposed to various stimuli due to their training (Meeuwisse et al. 2007). According to dynamic sports injury prevention model (Meeuwisse et al. 2007), exposure to repeated movement may produce an increased risk of injury through tissue changes (Byrne et al. 2004) that result in, for example, decreased proprioception. It may also decrease injury risk through adaptation, such as an increase in strength and range of motion. In other words, during the follow-up, before the possible event, they have matured, which in turn might affect their muscle flexibility; they might have gotten stronger as a training adaptation or they might have suffered a lower extremity injury that impaired their performance in single-leg tasks, for example. In addition, BP has been shown to produce changes in the lumbo-pelvic muscle function even after the pain has resolved. Therefore, the risk for further injuries may have increased after a BP episode.

In the risk factor analyses, we first used the first baseline test performance, even if the player had performed the test in the beginning of every study year. As this does not account for the temporal nature of physical abilities, we introduced time-varying risk factors into the following risk factor analyses. Because not all players participated as many times, we had to assume a non-temporal nature of test performance for some players. Even when using time-varying variables, the tests were performed only once a year.

Individual training and game hours recorded is a strength of this study, but the lack of psychosocial factors such as mood and internal training load, that is, self-perceived exertion due to training, is a limitation. Internal training load has been shown to be associated with sports injury risk in general among youth female soccer players (Watson et al. 2017). Longitudinal studies among youth people have shown psychosocial and socioeconomic factors are associated with LBP incidents (see e.g. Feldman et al. 2001, Szpalski et al. 2002, Jones et al. 2003, Hestbaek et al. 2008, Mikkonen et al. 2016, Smith et al. 2017). Pain is a subjective phenomenon and stressful life-events, anxiety and quality of sleep may affect the function of pain receptors and lower the activation threshold. On the other hand, the functioning of the receptors may change for some unknown reason without any specific tissue-related or neuropathic reason. Furthermore, even if sports participation has been associated with fewer mental health problems, that does not make athletes immune to these difficulties.

6.3.2 External validity

Sports club members and non-members are very likely to describe the situation in Finland among the same age range population as the data collection was nation-wide. It is also possible to extent the results to school and sport settings. The sports covered the ten most played sports among youth and therefore this part of the study represents the sports participants of the same age, however it should be remembered that some sports are very likely to be more predisposed for BP complaints than another for sport specific reasons as well as differences in training cultures. The percentage of youth participation in both questionnaires was low among sports club members (32%) and moderate (58%) among school setting and therefore caution in interpreting and generalizing the results should be used.

The results based on the youth floorball and basketball players are likely to describe floorball players and basketball players of the same age and playing level, at least in Finland. However, it is possible that participating sports clubs and teams may be more interested in sports injury prevention in general and may therefore differ from clubs and teams that refused to participate in terms of training programming and contents of training, for example. Actions were taken to enhance adequate reporting of background information and injuries, resulting in a high response rate and low drop-out rate.

Players with an existing injury at the baseline were excluded from risk factor analyses, even though some players participated in baseline tests despite their injury. Some injuries and pain complaints, however, were considered as the normal state for a youth athlete, such as Osgood-Schlatter knee pain (Fouasson-Chailloux et al. 2019), as the players continued to train and play despite the pain. A limitation of this study is that we did not systematically record which acute injury at the time of baseline testing was affecting the participation of the athlete and during data preparation we had to use our clinical expertise and notes from the test records to decide if the injury affected the test performance or not. The successful participation rate in baseline tests ranged from 74% to 100%. Therefore, when interpreting and extending the results from tests with a lower participation rate, it should be noted that players with an injury or the inability to perform the test correctly might be at increased risk for LBP and their absence from the analyses could very likely affect the results.

Approximately one fifth of players participating in baseline tests reported having had recent LBP (ache or pain or discomfort in the lumbar area, during the past seven days): first study year 26%, second year 17%, and third year 20%. These players reported LBP also within the past 12 months and we chose to use 'LBP within the past 12 months' as an adjusting factor in the risk factor analyses. If we had excluded all players with recent LBP, it would have affected the generalizability of the results as minor BP complaints are common in athletic population of young adults and youth and do not often lead to absence from sport, as shown by, for example, Clarsen et al. (2015).

6.3.3 General statistical considerations

Power calculation was performed for the PROFITS study, where the main outcome was lower extremity injuries. Even though the sample size was impressive in this prospective cohort study, the number of events per covariate was low in some analyses, which can lead to reduced statistical power. Bahr & Holme (2003) stated that one would need 30 to 40 events to detect moderate to strong associations and more than 200 events for small to moderate associations. Based on this it is possible that we could have missed some small to moderate risk factors and even moderate to strong associations if using only first-time LBP.

In some cases, the association between a risk factor and an event is not linear. However, categorizing continuous variables leads to loss of information as well as deficient adjustments of the confounding factors, which may reduce statistical power even further (Naggara et al. 2011). Therefore, we chose to use mostly continuous variables in our analyses.

Regarding missing data in risk factor analyses, we chose not to impute data, but those without a test result were not included in the risk factor analyses. In the Cox analyses with time-varying variables, we used the most recent test result prior to injury. The data in our sample were not missing purely by random. Instead, data were often missing from injured players, players were not able to perform a valid number of trials due to poor movement skills, or they performed in a way that markers were not shown in the 2D analyses. Therefore, multiple imputation was not used. According to Sterne et al. (2009), bias in analyses based on multiple imputation may be as big as or bigger than the bias in analyses of complete cases.

7 CONCLUSIONS

- Back complaints are common already in youth, whether they participate in organized sports activities or not. However, sports club participation seems to increase the odds for low back pain (LBP) and decrease the odds for neck and shoulder pain.
- LBP in youth is also associated with other musculoskeletal complaints.
- Approximately half of the youth basketball and floorball players had experienced LBP during the preceding year. During the 12-month follow-up, approximately 13% of the players reported LBP that prevented the player from fully participating in normal training and games for at least one day, with a median of 14 days of time loss. The majority of these LBP complaints are reoccurring and likely result in more time loss.
- LBP in youth is often associated with other musculoskeletal complaints. Prevention of LBP in youth is therefore warranted for promotion of health in general.
- The majority of the back pain in youth seems to have a gradual non-traumatic onset.
- The majority of acute traumatic onset back pain was associated with a sudden or unexpected movement or landing. The impact of landing was not associated with the risk for LBP, but we found a small association between LBP and hip-pelvic control during single-leg landing.
- Lower extremity extension strength and hip abductor asymmetry nor general joint hypermobility, lower extremity muscle flexibility or hip-pelvic control during knee lift were not predictors of LBP in youth floorball and basketball players.
- There are several modifiers that we were not able to adjust for that might have an effect on the association between the risk factor and LBP. In addition, the risk factors were tested only once a year and may have changed during the follow-up prior to LBP development. Future studies investigating predisposing factors for LBP in youth are needed

8 FUTURE PERSPECTIVES

Based on this study, one cannot state that, for example, improving hip-pelvic control will lead to a reduction of BP incidents among youth basketball and floorball players. Nor can one state that lower extremity strength, strength symmetry or muscle flexibility or general joint mobility are irrelevant factors in LBP prevention among youth floorball and basketball players. One can conclude that BP and LBP are common even though the complaints do not always result in time lost from organized sport activities. The majority of time-loss LBP episodes reoccur, thus resulting in more time-loss. Being injured has been shown to have an effect on the performance (Taimela & Kujala 1992) and mood of players (von Rosen et al. 2018b), suggesting that time-loss from the sport is not the only thing resulting from sports injuries.

To draw from this study and the previous literature reviewed at the beginning of the thesis, it is difficult to find risk factors that can be validated among different samples and back pain conditions. In the future, when investigating LBP in athletes, injury recording as suggested by Clarsen et al. (2013) should be adapted. In addition, measurements of risk factors should be performed more frequently to get a clearer picture of changes throughout the follow-up. In addition, it would also be beneficial to collect individual PA exposure hours in team sports in addition to team-based training exposure hours, as suggested by Hägglund et al. (2010). In the future, it would be essential to learn how to identify youth athletes with a risk for prolonged and disabling LBP.

It is likely that prevention of LBP in youth floorball and basketball players should include versatile training that prepares the player for the specific demands of the sport and takes account of the player as an individual. For example, BP has been strongly associated with psychosocial factors in previous studies. Stress, among other things, is a risk factor for LBP becoming a long-term complaint among athletes (Heidari et al. 2016). Therefore, in future studies and health promotion efforts among youth athletes researchers might also consider monitoring subjective ratings of wellbeing and perceived training load, such as RPE, as suggested previously by Watson et al. (2017). It is not realistic to assume that physical and mental loading outside of sport does not affect the risk of pain complaints perceived to be related to sports. The most common LBP onset reported was non-traumatic gradual onset LBP. Yet, based on this study, we cannot conclude that these non-traumatic onset LBP episodes were solely due to overuse or whether the symptoms are related to other factors associated with pain.

Roussel et al. (2009) observed that dancers with impaired lumbo-pelvic control were at increased risk for future LBP and lower extremity injuries. In this current study, we observed a small association between hip-pelvic control during landing task and LBP in youth basketball and floorball players. We also observed that many of the acute traumatic onset LBP complaints were associated with sudden and unexpected movement or jumping and landing. Therefore, it might be beneficial to pay some attention to these situations as part of the training. Intervention focusing in lower extremity alignment during jumping and landing has been shown promise in reducing lower extremity injuries (Aerts et al. 2013) and interventions including proper technical correction and feedback to produce changes to landing kinetics and kinematics (Monajati et al. 2016). Neuromuscular training interventions performed as warm-ups have also been shown to reduce the number of sports injuries in general, but also decreased incidence rate ratio of LBP within the intervention group (*RR* 0.11, 95% *CI* 0.01 to 0.91, *p* value 0.040) among youth soccer players (Soligard et al. 2008). Therefore, even though the effectiveness of these interventions in reducing BP specifically is still largely unknown and requires further investigation, implementation of these types of interventions might be beneficial.

REFERENCES

Aartun, E., Boyle, E., Hartvigsen, J., Ferreira, P. H., Maher, C. G., et al. 2016a. The most physically active Danish adolescents are at increased risk for developing spinal pain: a two-year prospective cohort study. BMJ Open Sport & Exercise Medicine 2 (1), e000097. doi:10.1136/bmjsem-2015-000097.

Aartun, E., Hartvigsen, J. & Hestbaek, L. 2016b. Validity of commonly used clinical tests to diagnose and screen for spinal pain in adolescents: a school-based cohort study in 1300 Danes aged 11–15 years. Journal of Manipulative and Physiological Therapeutics 39 (2), 76-87. doi:10.1016/j.jmpt.2016.01.007.

Aartun, E., Hartvigsen, J., Wedderkopp, N. & Hestbaek, L. 2014. Spinal pain in adolescents: prevalence, incidence, and course: a school-based two-year prospective cohort study in 1,300 Danes aged 11–13. BMC musculoskeletal disorders 15 (1), 187. doi:10.1186/1471-2474-15-187.

Aerts, I., Cumps, E., Verhagen, E., Wuyts, B., Gucht, S., et al. 2015. The effect of a 3-month prevention program on the jump-landing technique in basketball: a randomized controlled trial. Journal of Sport Rehabilitation 24 (1), 21-30. doi:10.1123/jsr.2013-0099.

Agel, J., Evans, T. A., Dick, R., Putukian, M. & Marshall, S. W. 2007a. Descriptive epidemiology of collegiate men's soccer injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2002-2003. Journal of Athletic Training 42 (2), 270-277.

Agel, J., Olson, D. E., Dick, R., Arendt, E. A., Marshall, S. W., et al. 2007b. Descriptive epidemiology of collegiate women's basketball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003-2004. Journal of Athletic Training 42 (2), 202-210.

Agel, J., Palmieri-Smith, R. M., Dick, R., Wojtys, E. M. & Marshall, S. W. 2007c. Descriptive epidemiology of collegiate women's volleyball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003-2004. Journal of Athletic Training 42 (2), 295.

Aira, T., Kannas, L., Tynjälä, J., Villberg, J. & Kokko, S. 2013. Miksi murrosikäinen luopuu liikunnasta? Liikunta-aktiivisuuden väheneminen murrosiässä. Valtion liikuntaneuvoston julkaisuja 2013:3.

Alricsson, M. & Werner, S. 2006. Young elite cross-country skiers and low back pain—A 5-year study. Physical Therapy in Sport 7 (4), 181-184. doi:10.1016/j.ptsp.2006.06.003.

Aoki, H., Kohno, T., Fujiya, H., Kato, H., Yatabe, K., et al. 2010. Incidence of injury among adolescent soccer players: a comparative study of artificial and natural grass turfs. Clinical Journal of Sport Medicine 20 (1), 1-7. doi:10.1097/JSM.0b013e3181c967cd.

Astfalck, R. G., O'Sullivan, P. B., Straker, L. M. & Smith, A. J. 2010a. A detailed characterisation of pain, disability, physical and psychological features of a small group of adolescents with non-specific chronic low back pain. Manual Therapy 15 (3), 240-247. doi:10.1016/j.math.2009.12.007.

Astfalck, R. G., O'Sullivan, P. B., Straker, L. M., Smith, A. J., Burnett, A., et al. 2010b. Sitting postures and trunk muscle activity in adolescents with and without nonspecific chronic low back pain: an analysis based on subclassification. Spine 35 (14), 1387-1395. doi:10.1097/BRS.0b013e3181bd3ea6.

Auvinen, J. P., Paananen, M. V. J., Tammelin, T. H., Taimela, S. P., Mutanen, P. O. A., et al. 2009. Musculoskeletal pain combinations in adolescents. Spine 34 (11), 1192-1197. doi:10.1097/BRS.0b013e3181a401df.

Auvinen, J. P., Tammelin, T., Taimela, S., Zitting, P. & Karppinen, J. 2008. Associations of physical activity and inactivity with low back pain in adolescents. Scandinavian Journal of Medicine & Science in Sports 18 (2), 188-194. doi:10.1111/j.1600-0838.2007.00672.x.

Auvinen, J., Tammelin, T., Taimela, S., Zitting, P., Järvelin, M., et al. 2010. Is insufficient quantity and quality of sleep a risk factor for neck, shoulder and low back pain? A longitudinal study among adolescents. European Spine Journal 19 (4), 641-649. doi:10.1007/s00586-009-1215-2.

Bahr, R. & Holme, I. 2003. Risk factors for sports injuries -- a methodological approach. British Journal of Sports Medicine 37 (5), 384-392. doi:10.1136/bjsm.37.5.384.

Bahr, R., Andersen, S. O., Løken, S., Fossan, B., Hansen, T., et al. 2004. Low back pain among endurance athletes with and without specific back loading—a cross-sectional survey of cross-country skiers, rowers, orienteerers, and nonathletic controls. Spine 29 (4), 449-454. doi:10.1097/01.BRS.0000096176.92881.37.

Baiden, P., Tadeo, S. K. & Peters, K. E. 2019. The association between excessive screen-time behaviors and insufficient sleep among adolescents: Findings from the 2017 youth risk behavior surveillance system. Psychiatry Research 281, 112586. doi:10.1016/j.psychres.2019.112586.

Balagué, F., Bibbo, E., Mélot, C., Szpalski, M., Gunzburg, R., et al. 2010. The association between isoinertial trunk muscle performance and low back pain in male adolescents. European Spine Journal 19 (4), 624-632. doi:10.1007/s00586-009-1168-5.

Balagué, F., Troussier, B. & Salminen, J. J. 1999. Non-specific low back pain in children and adolescents: risk factors. European Spine Journal 8 (6), 429-438. doi:10.1007/s005860050201.

Bayne, H., Elliott, B., Campbell, A. & Alderson, J. 2016. Lumbar load in adolescent fast bowlers: A prospective injury study. Journal of Science and Medicine in Sport 19 (2), 117-122. doi:10.1016/j.jsams.2015.02.011.

Belavý, D., Albracht, K., Bruggemann, G., Vergroesen, P. & van Dieën, J. 2016. Can exercise positively influence the intervertebral disc? Sports Medicine 46 (4), 473-485. doi:10.1007/s40279-015-0444-2.

Bere, T., Kruczynski, J., Veintimilla, N., Hamu, Y. & Bahr, R. 2015. Injury risk is low among world-class volleyball players: 4-year data from the FIVB Injury Surveillance System. British Journal of Sports Medicine 49 (17), 1132-1137. doi:10.1136/bjsports-2015-094959.

Bernard, J., Bard, R., Pujol, A., Combey, A., Boussard, D., et al. 2008. Muscle assessment in healthy teenagers, comparison with teenagers with low back pain. Annales de readaptation et de medecine physique : revue scientifique de la Societe francaise de reeducation fonctionnelle de readaptation et de medecine physique 51 (4), 263. doi:10.1016/j.annrmp.2008.03.010.

Bonita, R., Beaglehole, R. & Kjellström, T. 2006. Basic epidemiology. (2nd edition) Geneva: World Health Organization.

Boyle, K. L., Witt, P. & Riegger-Krugh, C. 2003. Intrarater and interrater reliability of the beighton and horan joint mobility index. Journal of Athletic Training 38 (4), 281.

Brattberg, C. 1994. The incidence of back pain and headache among Swedish school children. Quality of Life Research 3 (Suppl 1), S27-S31. doi:10.1007/bf00433372.

Byrne, C., Twist, C. & Eston, R. 2004. Neuromuscular Function After Exercise-Induced Muscle Damage: Theoretical and Applied Implications. Sports Medicine 34 (1), 49-69. doi:10.2165/00007256-200434010-00005.

Cai, C., Yang, Y. & Kong, P. 2017. Comparison of lower limb and back exercises for runners with chronic low back pain. Medicine & Science in Sports & Exercise 49 (12), 2374-2384. doi:10.1249/MSS.0000000000001396.

Caine, D., Knutzen, K., Howe, W., Keeler, L., Sheppard, L., et al. 2003. A three-year epidemiological study of injuries affecting young female gymnasts. Physical Therapy in Sport 4 (1), 10-23. doi:10.1016/S1466-853X(02)00070-6.

Calvo-Muñoz, I., Gómez-Conesa, A. & Sánchez-Meca, J. 2013. Prevalence of low back pain in children and adolescents: a meta-analysis. BMC Pediatrics 13 (1), 14. doi:10.1186/1471-2431-13-14.

Calvo-Muñoz, I., Kovacs, F., Roqué, M., Gago Fernández, I. & Seco Calvo, J. 2018. Risk factors for low back pain in childhood and adolescence: a systematic review. The Clinical Journal of Pain 34 (5), 468-484. doi:10.1097/AJP.0000000000000558.

Campbell, A., O'Sullivan, P., Straker, L., Elliott, B. & Reid, M. 2014. Back pain in tennis players: a link with lumbar serve kinematics and range of motion. Medicine & Science in Sports & Exercise 46 (2), 351. doi:10.1249/MSS.0b013e3182a45cca.

Chaudhari, A. M. W., McKenzie, C. S., Pan, X. & Oñate, J. A. 2014. Lumbopelvic control and days missed because of injury in professional baseball pitchers. The American Journal of Sports Medicine 42 (11), 2734-2740. doi:10.1177/0363546514545861.

Cholewicki, J., Greene, H. S., Polzhofer, G. K., Galloway, M. T., Shah, R. A., et al. 2002. Neuromuscular function in athletes following recovery from a recent acute low back injury. The Journal of Orthopaedic and Sports Physical Therapy 32 (11), 568-575. doi:10.2519/jospt.2002.32.11.568.

Cholewicki, J., Silfies, S. P., Shah, R. A., Greene, H. S., Reeves, N. P., et al. 2005. Delayed trunk muscle reflex responses increase the risk of low back injuries. Spine 30 (23), 2614-2620. doi:10.1097/01.brs.0000188273.27463.bc.

Clarsen, B., Bahr, R., Heymans, M., Engedahl, M., Midtsundstad, G., et al. 2015. The prevalence and impact of overuse injuries in five Norwegian sports: Application of a new surveillance method. Scandinavian Journal of Medicine and Science in Sports 25 (3), 323-330. doi:10.1111/sms.12223.

Clarsen, B., Myklebust, G. & Bahr, R. 2013. Development and validation of a new method for the registration of overuse injuries in sports injury epidemiology: the Oslo Sports Trauma Research Centre (OSTRC) Overuse Injury Questionnaire. British Journal of Sports Medicine 47 (8), 495-502. doi:10.1136/bjsports-2012-091524.

Clausen, M. B., Zebis, M. K., Møller, M., Krustrup, P., Hölmich, P., et al. 2014. High injury incidence in adolescent female soccer. The American Journal of Sports Medicine 42 (10), 2487-2494. doi:10.1177/0363546514541224.

Coenen, P., Smith, A., Kent, P., Harris, M., Linton, S. J., et al. 2018. The association of adolescent spinal-pain-related absenteeism with early adulthood work absenteeism: A six-year follow-up data from a population-based cohort. Scandinavian Journal of Work, Environment & Health 44 (5), 521-529. doi:10.5271/sjweh.3744.

Coenen, P., Smith, A., Paananen, M., O'Sullivan, P., Beales, D., et al. 2017. Trajectories of low back pain from adolescence to young adulthood. Arthritis Care & Research 69 (3), 403-412. doi:10.1002/acr.22949.

Cumps, E., Verhagen, E. & Meeusen, R. 2007. Prospective epidemiological study of basketball injuries during one competitive season: ankle sprains and overuse knee injuries. Journal of Sports Science & Medicine 6 (2), 204-211.

Cupisti, A., D'Alessandro, C., Evangelisti, I., Umbri, C., Rossi, M., et al. 2007. Injury survey in competitive sub-elite rhythmic gymnasts: results from a prospective controlled study. The Journal of Sports Medicine and Physical Fitness 47 (2), 203.

Currie, C. & Alemán-Díaz, A. Y. 2015. Building knowledge on adolescent health: reflections on the contribution of the Health Behaviour in School-aged Children (HBSC) study. European Journal of Public Health 25 (suppl 2), 4-6. doi:10.1093/eurpub/ckv017.

Dankaerts, W., O'Sullivan, P., Burnett, A. & Straker, L. 2006. Differences in sitting postures are associated with nonspecific chronic low back pain disorders when patients are subclassified. Spine 31 (6), 698-704. doi:10.1097/01.brs.0000202532.76925.d2.

Dankaerts, W., O'Sullivan, P., Burnett, A., Straker, L., Davey, P., et al. 2009. Discriminating healthy controls and two clinical subgroups of nonspecific chronic low back pain patients using trunk muscle activation and lumbosacral kinematics of postures and movements: a statistical classification model. Spine 34 (15), 1610-1618. doi:10.1097/BRS.0b013e3181aa6175.

De Blaiser, C., Roosen, P., Willems, T., Danneels, L., Bossche, L. V., et al. 2018. Is core stability a risk factor for lower extremity injuries in an athletic population? A systematic review. Physical Therapy in Sport 30, 48-56. doi:10.1016/j.ptsp.2017.08.076.

Dick, R., Hertel, J., Agel, J. & Grossman, J. 2007a. Descriptive epidemiology of collegiate men's basketball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003-2004. Journal of Athletic Training 42 (2), 194.

Dick, R., Hootman, J. M., Agel, J., Vela, L., Marshall, S. W., et al. 2007b. Descriptive epidemiology of collegiate women's field hockey injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2002-2003. Journal of Athletic Training 42 (2), 211.

Dick, R., Putukian, M., Agel, J., Evans, T. A. & Marshall, S. W. 2007c. Descriptive epidemiology of collegiate women's soccer injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2002-2003. Journal of Athletic Training 42 (2), 278.

Dick, R., Sauers, E. L., Agel, J., Keuter, G., Marshall, S. W., et al. 2007d. Descriptive epidemiology of collegiate men's baseball injuries: National Collegiate Athletic Association Injury Surveillance System, 1988-1989 through 2003-2004. Journal of Athletic Training 42 (2), 183-193.

Diepenmaat, A. C. M., van der Wal, M. F., de Vet, H. C. W. & Hirasing, R. A. 2006. Neck/shoulder, low back, and arm pain in relation to computer use, physical activity, stress, and depression among dutch adolescents. Pediatrics 117 (2), 412-416. doi:10.1542/peds.2004-2766.

Dionne, C. E., Dunn, K. M., Croft, P. R., Nachemson, A. L., Buchbinder, R., et al. 2008. A consensus approach toward the standardization of back pain definitions for use in prevalence studies. Spine 33 (1), 95-103. doi:10.1097/BRS.0b013e31815e7f94.

Eime, R. M., Young, J. A., Harvey, J. T., Charity, M. J. & Payne, W. R. 2013. A systematic review of the psychological and social benefits of participation in sport for children and adolescents: informing development of a conceptual model of health through sport. The International Journal of Behavioral Nutrition and Physical Activity 10 (1), 98. doi:10.1186/1479-5868-10-98.

Eiosdottir, S. P., Kristjansson, A. L., Sigfusdottir, I. D. & Allegrante, J. P. 2008. Trends in physical activity and participation in sports clubs among Icelandic adolescents. European Journal of Public Health 18 (3), 289-293. doi:10.1093/eurpub/ckn004.

El-Metwally, A., Salminen, J. J., Auvinen, A., Kautiainen, H. & Mikkelsson, M. 2004. Prognosis of non-specific musculoskeletal pain in preadolescents: A prospective 4-year follow-up study till adolescence. Pain 110 (3), 550-559. doi:10.1016/j.pain.2004.03.021.

El-Metwally, A., Salminen, J. J., Auvinen, A., Macfarlane, G. & Mikkelsson, M. 2007. Risk factors for development of non-specific musculoskeletal pain in preteens and early adolescents: a prospective 1-year follow-up study. BMC Musculoskeletal Disorders 8 (1), 46. doi:10.1186/1471-2474-8-46.

Emery, C. A., Meeuwisse, W. H. & McAllister, J. R. 2006. Survey of Sport Participation and Sport Injury in Calgary and Area High Schools. Clinical Journal of Sport Medicine 16 (1), 20-26. doi:10.1097/01.jsm.0000184638.72075.b7.

Emery, C. A. & Tyreman, H. 2009. Sport participation, sport injury, risk factors and sport safety practices in Calgary and area junior high schools. Paediatrics & Child Health 14 (7), 439-444. doi:10.1093/pch/14.7.439.

Fatoye, F., Palmer, S., Macmillan, F., Rowe, P. & van der Linden, M. 2009. Proprioception and muscle torque deficits in children with hypermobility syndrome. Rheumatology 48 (2), 152-157. doi:10.1093/rheumatology/ken435.

Feldman, D. E., Rossignol, M., Shrier, I. & Abenhaim, L. 1999. Smoking. A risk factor for development of low back pain in adolescents. Spine 24 (23), 2492. doi:10.1097/00007632-199912010-00011.

Feldman, D. E., Shrier, I., Rossignol, M. & Abenhaim, L. 2001. Risk factors for the development of low back pain in adolescence. American Journal of Epidemiology 154 (1), 30-36. doi:10.1093/aje/154.1.30.

Ferreira, P. H., Beckenkamp, P., Maher, C. G., Hopper, J. L. & Ferreira, M. L. 2013. Nature or nurture in low back pain? Results of a systematic review of studies based on twin samples. European Journal of Pain 17 (7), 957-971. doi:10.1002/j.1532-2149.2012.00277.x.

Fett, D., Trompeter, K. & Platen, P. 2017. Back pain in elite sports: A cross-sectional study on 1114 athletes. PLoS One 12 (6), e0180130. doi:10.1371/journal.pone.0180130.

Finch, C. F., White, P., Dennis, R., Twomey, D. & Hayen, A. 2010. Fielders and batters are injured too: A prospective cohort study of injuries in junior club cricket. Journal of Science and Medicine in Sport 13 (5), 489-495. doi:10.1016/j.jsams.2009.10.489.

Ford, K., Myer, G., Smith, R., Byrnes, R., Dopirak, S., et al. 2005. Use of an overhead goal alters vertical jump performance and biomechanics. Journal of Strength and Conditioning Research 19 (2), 394-399. doi:10.1519/15834.1.

Foster, N. E., Anema, J. R., Cherkin, D., Chou, R., Cohen, S. P., et al. 2018. Prevention and treatment of low back pain: evidence, challenges, and promising directions. The Lancet 391 (10137), 2368-2383. doi:10.1016/S0140-6736(18)30489-6.

Fouasson-Chailloux, A., Mesland, O., Menu, P. & Dauty, M. 2019. Soccer injuries documented by F-MARC guidelines in 13- and 14-year old national elite players: A 5-year cohort study. Science et Sports doi:10.1016/j.scispo.2019.10.005.

Franz, C., Jespersen, E., Rexen, C. T., Leboeuf-Yde, C. & Wedderkopp, N. 2016. Back injuries in a cohort of schoolchildren aged 6-12. Scandinavian Journal of Medicine & Science in Sports 26 (8), 918. doi:10.1111/sms.12519.

Franz, C., Møller, N. C., Korsholm, L., Jespersen, E., Hebert, J. J., et al. 2017. Physical activity is prospectively associated with spinal pain in children (CHAMPS Study-DK). Scientific Reports 7 (1), 11598-8. doi:10.1038/s41598-017-11762-4.

Franz, C., Wedderkopp, N., Jespersen, E., Rexen, C. T. & Leboeuf-Yde, C. 2014. Back pain in children surveyed with weekly text messages - a 2.5 year prospective school cohort study. Chiropractic & Manual Therapies 22 (1), 35. doi:10.1186/PREACCEPT-1465471670128835.

Fuglkjær, S., Vach, W., Hartvigsen, J., Wedderkopp, N., Junge, T., et al. 2018. Does lower extremity pain precede spinal pain? A longitudinal study. European Journal of Pediatrics 177 (12), 1803-1810. doi:10.1007/s00431-018-3235-6.

Fuller, C. W., Ekstrand, J., Junge, A., Andersen, T. E., Bahr, R., et al. 2006. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. British Journal of Sports Medicine 40 (3), 193-201. doi:10.1136/bjsm.2005.025270.

Gabbe, B. J., Bennell, K. L., Wajswelner, H. & Finch, C. F. 2004. Reliability of common lower extremity musculoskeletal screening tests. Physical Therapy in Sport 5 (2), 90-97. doi:10.1016/j.ptsp.2004.01.003.

Gnat, R., Kuszewski, M., Koczar, R. & Dziewonska, A. 2010. Reliability of the passive knee flexion and extension tests in healthy subjects. Journal of Manipulative and Physiological Therapeutics 33 (9), 659-665. doi:10.1016/j.jmpt.2010.09.001.

Gomez, E., DeLee, J. & Farney, W. 1996. Incidence of injury in texas girls' high school basketball. The American Journal of Sports Medicine 24 (5), 684-687. doi:10.1177/036354659602400521.

Graham, R. B., Costigan, P. A., Sadler, E. M. & Stevenson, J. M. 2011. Local dynamic stability of the lifting kinematic chain. Gait & Posture 34 (4), 561-563. doi:10.1016/j.gaitpost.2011.06.022.

Greene, H. S., Cholewicki, J., Galloway, M. T., Nguyen, C. V. & Radebold, A. 2001. A History of low back injury is a risk factor for recurrent back injuries in varsity athletes. The American Journal of Sports Medicine 29 (6), 795-800. doi:10.1177/03635465010290062001.

Grimaldi, A. 2011. Assessing lateral stability of the hip and pelvis. Manual Therapy 16 (1), 26-32. doi:10.1016/j.math.2010.08.005.

Grimmer, K., Nyland, L. & Milanese, S. 2006. Longitudinal investigation of low back pain in Australian adolescents: a five - year study. Physiotherapy Research International 11 (3), 161-172. doi:10.1002/pri.340.

Grosdent, S., Demoulin, C., Rodriguez de La Cruz, Carlos, Giop, R., Tomasella, M., et al. 2016. Lumbopelvic motor control and low back pain in elite soccer players: a cross-sectional study. Journal of Sports Sciences 34 (11), 1021-1029. doi:10.1080/02640414.2015.1085077.

Guddal, M. H., Stensland, S. Ø, Småstuen, M. C., Johnsen, M. B., Zwart, J., et al. 2017. Physical activity level and sport participation in relation to musculoskeletal pain in a population-based study of adolescents. Orthopaedic Journal of Sports Medicine 5 (1), 2325967116685543. doi:10.1177/2325967116685543.

Hainline, B., Turner, J. A., Caneiro, J. P., Stewart, M. & Moseley, L. G. 2017. Pain in elite athletes—neurophysiological, biomechanical and psychosocial considerations: a narrative review. British Journal of Sports Medicine 51 (17), 1259-1264. doi:10.1136/bjsports-2017-097890.

Hangai, M., Kaneoka, K., Hinotsu, S., Shimizu, K., Okubo, Y., et al. 2009. Lumbar intervertebral disk degeneration in athletes. The American Journal of Sports Medicine 37 (1), 149-155. doi:10.1177/0363546508323252.

Hangai, M., Kaneoka, K., Okubo, Y., Miyakawa, S., Hinotsu, S., et al. 2010. Relationship between low back pain and competitive sports activities during youth. The American Journal of Sports Medicine 38 (4), 791-796. doi:10.1177/0363546509350297.

Harreby, M., Neergaard, K., Hesselsøe, G. & Kjer, J. 1995. Are radiologic changes in the thoracic and lumbar spine of adolescents risk factors for low back pain in adults? A 25-year prospective cohort study of 640 school children. Spine 20 (21), 2298-2302. doi:10.1097/00007632-199511000-00007.

Hartvigsen, J., Hancock, M. J., Kongsted, A., Louw, Q., Ferreira, P. H., et al. 2018. What low back pain is and why we need to pay attention. The Lancet 391 (10137), 2356-2367. doi:10.1016/S0140-6736(18)30480-X.

Harvey, D. 1998. Assessment of the flexibility of elite athletes using the modified Thomas test. British Journal of Sports Medicine 32 (1), 68-70. doi:10.1136/bjsm.32.1.68.

Heidari, J., Mierswa, T., Kleinert, J., Ott, I., Levenig, C., et al. 2016. Parameters of low back pain chronicity among athletes: Associations with physical and mental stress. Physical Therapy in Sport 21, 31-37. doi:10.1016/j.ptsp.2016.03.003.

Hewett, T. E., Myer, G. D., Ford, K. R., Heidt, R. S., Jr, Colosimo, A. J., et al. 2005. Biomechanical measures of neuromuscular control and valgus loading of the knee predict anterior cruciate ligament injury risk in female athletes: a prospective study. The American Journal of Sports Medicine, 33(4), 492–501. doi:10.1177/0363546504269591.

Heneweer, H., Staes, F., Aufdemkampe, G., van Rijn, M. & Vanhees, L. 2011. Physical activity and low back pain: a systematic review of recent literature. European Spine Journal 20 (6), 826-845. doi:10.1007/s00586-010-1680-7.

Herrington, L., Alenezi, F., Alzhrani, M., Alrayani, H. & Jones, R. 2017. The reliability and criterion validity of 2D video assessment of single leg squat and hop landing. Journal of Electromyography & Kinesiology 34, 80-85. doi:10.1016/j.jelekin.2017.04.004.

Hestbaek, L., Korsholm, L., Leboeuf-Yde, C. & Kyvik, K. 2008. Does socioeconomic status in adolescence predict low back pain in adulthood? A repeated cross-sectional study of 4,771 Danish adolescents. European Spine Journal 17 (12), 1727-1734. doi:10.1007/s00586-008-0796-5.

Hestbaek, L., Leboeuf-Yde, C., Kyvik, K. O. & Manniche, C. 2006. The course of low back pain from adolescence to adulthood: eight-year follow-up of 9600 twins. Spine 31 (4), 468-472. doi:10.1097/01.brs.0000199958.04073.d9.

Hernandez, A., Gross, K. & Gombatto, S. 2017. Differences in lumbar spine and lower extremity kinematics during a step down functional task in people with and people without low back pain. Clinical Biomechanics 47, 46-52. doi:10.1016/j.clinbiomech.2017.05.012.

Hickey, G., Fricker, P. & McDonald, W. 1997. Injuries to young elite female basketball players over a six-year period. Clinical Journal of Sport Medicine 7 (4), 252-256. doi:10.1097/00042752-199710000-00002.

Hill, J. J. & Keating, J. L. 2010. Risk factors for the first episode of low back pain in children are infrequently validated across samples and conditions: a systematic review. Journal of Physiotherapy 56 (4), 237-244. doi:10.1016/S1836-9553(10)70006-0.

Hjelm, N., Werner, S. & Renstrom, P. 2012. Injury risk factors in junior tennis players: a prospective 2 - year study. Scandinavian Journal of Medicine & Science in Sports 22 (1), 40-48. doi:10.1111/j.1600-0838.2010.01129.x.

Holden, S., Rathleff, M. S., Roos, E. M., Jensen, M. B., Pourbordbari, N., et al. 2018. Pain patterns during adolescence can be grouped into four pain classes with distinct profiles: A study on a population based cohort of 2953 adolescents. European Journal of Pain 22 (4), 793-799. doi:10.1002/ejp.1165.

Hopper, D. & Elliott, B. 1993. Lower limb and back injury patterns of elite netball players. Sports Medicine 16 (2), 148-162. doi:10.2165/00007256-199316020-00006.

Hoskins, W., Pollard, H., Daff, C., Odell, A., Garbutt, P., et al. 2010. Low back pain in junior Australian Rules football: a cross-sectional survey of elite juniors, non-elite juniors and non-football playing controls. BMC Musculoskeletal Disorders 11 (1), 241. doi:10.1186/1471-2474-11-241.

Husu, P., Paronen, O., Suni, J. & Vasankari, T. 2011. Suomalaisten fyysinen aktiivisuus ja kunto 2010 - Terveyttä edistävän liikunnan nykytila ja muutokset. Opetus- ja kulttuuriministeriön julkaisuja 2011:15.

Hoy, D., Bain, C., Williams, G., March, L., Brooks, P., et al. 2012. A systematic review of the global prevalence of low back pain. Arthritis and Rheumatism 64 (6), 2028-2037. doi:10.1002/art.34347.

Hägglund, M., Waldén, M., Til Pérez, L. & Pruna Grivé, R. 2010. The importance of epidemiological research in sports medicine. Apunts: Medicina de l'esport 45 (166), 57-59.

Jewett, R., Sabiston, C. M., Brunet, J., O'Loughlin, E. K., Scarapicchia, T., et al. 2014. School sport participation during adolescence and mental health in early adulthood. Journal of Adolescent Health 55 (5), 640-644. doi:10.1016/j.jadohealth.2014.04.018.

Jonasson, P., Halldin, K., Karlsson, J., Thoreson, O., Hvannberg, J., et al. 2011. Prevalence of joint-related pain in the extremities and spine in five groups of top athletes. Knee Surgery, Sports Traumatology, Arthroscopy 19 (9), 1540-1546. doi:10.1007/s00167-011-1539-4.

Jones, G. T. & Macfarlane, G. J. 2005. Epidemiology of low back pain in children and adolescents. Archives of Disease in Childhood 90 (3), 312-316. doi:10.1136/adc.2004.056812.

Jones, G. T. & Macfarlane, G. J. 2009. Predicting persistent low back pain in schoolchildren: A prospective cohort study. Arthritis Care & Research 61 (10), 1359-1366. doi:10.1002/art.24696.

Jones, G. T., Watson, K. D., Silman, A. J., Symmons, D. P. M. & Macfarlane, G. J. 2003. Predictors of low back pain in british schoolchildren: a population-based prospective cohort study. Pediatrics 111 (4), 822-828. doi:10.1542/peds.111.4.822.

Janssens, K. A. M., Rosmalen, J. G. M., Ormel, J., Verhulst, F. C., Hunfeld, J. A. M., et al. 2011. Pubertal status predicts back pain, overtiredness, and dizziness in american and dutch adolescents. Pediatrics 128 (3), 553-559. doi:10.1542/peds.2010-2364.

Junge, A., Cheung, K., Edwards, T. & Dvorak, J. 2004. Injuries in youth amateur soccer and rugby players—comparison of incidence and characteristics. British Journal of Sports Medicine 38 (2), 168-172. doi:10.1136/bjsm.2002.003020.

Kamper, S. J., Henschke, N., Hestbaek, L., Dunn, K. M., & Williams, C. M. 2016. Musculoskeletal pain in children and adolescents. Brazilian Journal of Physical Therapy, 20(3), 275-284. doi:10.1590/bjpt-rbf.2014.0149

Kamper, S. J., Yamato, T. P. & Williams, C. M. 2017. The prevalence, risk factors, prognosis and treatment for back pain in children and adolescents: An overview of systematic reviews. Best Practice & Research: Clinical Rheumatology 30 (6), 1021-1036. doi:10.1016/j.berh.2017.04.003.

Kanchanomai, S., Janwantanakul, P., Pensri, P. & Jiamjarasrangsi, W. 2015. A prospective study of incidence and risk factors for the onset and persistence of low back pain in thai university students. Asia-Pacific Journal of Public Health 27 (2), NP106-NP115. doi:10.1177/1010539511427579.

Kankaanpää, M., Taimela, S., Laaksonen, D., Hänninen, O. & Airaksinen, O. 1998. Back and hip extensor fatigability in chronic low back pain patients and controls. Archives of Physical Medicine and Rehabilitation 79 (4), 412-417. doi:10.1016/S0003-9993(98)90142-3.

Kendall, K. D., Schmidt, C. & Ferber, R. 2010. The relationship between hip-abductor strength and the magnitude of pelvic drop in patients with low back pain. Journal of Sport Rehabilitation 19 (4), 422-435. doi:10.1123/jsr.19.4.422.

Kibler, W. B., Press, J. & Sciascia, A. 2006. The role of core stability in athletic function. Sports Medicine 36 (3), 189-198. doi:10.2165/00007256-200636030-00001.

Kjaer, P., Korsholm, L., Leboeuf-Yde, C., Hestbaek, L. & Bendix, T. 2017. Individual courses of low back pain in adult Danes: a cohort study with 4-year and 8-year follow-up. BMC Musculoskeletal Disorders 18 (1), 28. doi:10.1186/s12891-016-1377-0.

Kjaer, P., Leboeuf-Yde, C., Sorensen, J. S. & Bendix, T. 2005. An epidemiologic study of MRI and low back pain in 13-year-old children. Spine 30 (7), 798-806. doi:10.1097/01.brs.0000157424.72598.ec.

Kjaer, P., Wedderkopp, N., Korsholm, L. & Leboeuf-Yde, C. 2011. Prevalence and tracking of back pain from childhood to adolescence. BMC Musculoskeletal Disorders 12 (1), 98. doi:10.1186/1471-2474-12-98.

Koga, H., Nakamae, A., Shima, Y., Iwasa, J., Myklebust, G., et al. 2010. Mechanisms for noncontact anterior cruciate ligament injuries: knee joint kinematics in 10 injury situations from female team handball and basketball. The American Journal of Sports Medicine, 38(11), 2218–2225. doi:10.1177/0363546510373570

Kokko, S. 2010. Health promoting sports club: youth sports clubs' health promotion profiles, guidance, and associated coaching practice, in Finland. University of Jyväskylä. Studies in Sport, physical education and health 144.

Kokko, S., Kannas, L., Villberg, J. & Ormshaw, M. 2011. Health promotion guidance activity of youth sports clubs. Health Education 111 (6), 452-463. doi:10.1108/09654281111180454.

Kountouris, A., Portus, M. & Cook, J. 2012. Quadratus lumborum asymmetry and lumbar spine injury in cricket fast bowlers. Journal of Science and Medicine in Sport 15 (5), 393-397. doi:10.1016/j.jsams.2012.03.012.

Krosshaug, T., Nakamae, A., Boden, B. P., Engebretsen, L., Smith, G., et al. 2007. Mechanisms of anterior cruciate ligament injury in basketball. Video analysi of 39 cases. American Journal of Sports Medicine, 35(3), 359–367. doi:10.1177/0363546506293899.

Krosshaug, T., Steffen, K., Kristianslund, E., Nilstad, A., Mok, K. M., et al. 2016. The vertical drop jump is a poor screening test for acl injuries in female elite soccer and handball players: a prospective cohort study of 710 athletes. The American journal of sports medicine, 44(4), 874–883. doi:10.1177/0363546515625048.

Kujala, U. M., Taimela, S., Erkintalo, M., Salminen, J. J. & Kaprio, J. 1996. Low-back pain in adolescent athletes. Medicine & Science in Sports & Exercise 28 (2), 165-170. doi:10.1097/00005768-199602000-00002.

Kujala, U. M., Taimela, S., Oksanen, A. & Salminen, J. J. 1997. Lumbar mobility and low back pain during adolescence. A longitudinal three-year follow-up study in athletes and controls. American Journal of Sports Medicine 25 (3), 363-368. doi:10.1177/036354659702500316.

Kujala, U. M., Taimela, S., Salminen, J. J. & Oksanen, A. 1994. Baseline anthropometry, flexibility and strength characteristics and future low-back pain in adolescent athletes and nonathletes. Scandinavian Journal of Medicine and Science in Sport 4 (3), 200-205. doi:10.1111/j.1600-0838.1994.tb00426.x.

Kuorinka, I., Jonsson, B., Kilbom, A., Vinterberg, H., Biering-Sørensen, F., et al. 1987. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Applied Ergonomics 18 (3), 233-237. doi:10.1016/0003-6870(87)90010-X.

Lauersen, J. B., Andersen, T. E. & Andersen, L. B. 2018. Strength training as superior, dose-dependent and safe prevention of acute and overuse sports injuries: a systematic review, qualitative analysis and meta-analysis. British Journal of Sports Medicine 52 (24), 1557-1563. doi:10.1136/bjsports-2018-099078.

Le Gall, F., Carling, C., Reilly, T., Vandewalle, H., Church, J., et al. 2006. Incidence of injuries in elite french youth soccer players. The American Journal of Sports Medicine 34 (6), 928-938. doi:10.1177/0363546505283271.

Leinonen, V., Kankaanpää, M., Airaksinen, O. & Hänninen, O. 2000. Back and hip extensor activities during trunk flexion/extension: Effects of low back pain and rehabilitation. Archives of Physical Medicine and Rehabilitation 81 (1), 32-37. doi:10.1016/S0003-9993(00)90218-1.

Lemeunier, N., Leboeuf-Yde, C. & Gagey, O. 2012. The natural course of low back pain: a systematic critical literature review. Chiropractic & Manual Therapies 20 (1), 33. doi:10.1186/2045-709X-20-33.

Leppänen, M., Pasanen, K., Kujala, U. M., Vasankari, T., Kannus, P., et al. 2017. Stiff landings are associated with increased acl injury risk in young female basketball and floorball players. The American Journal of Sports Medicine, 45(2), 386–393. doi:10.1177/0363546516665810.

Liukkonen, J., Jaakkola, T., Kokko, S., Gråstén, A., Yli-Piipari, S., et al. 2014. Results from Finland's 2014 report card on physical activity for children and youth. Journal of Physical Activity & Health 11 Suppl 1, S51. doi:10.1123/jpah.2014-0168.

Lund, H. G., Reider, B. D., Whiting, A. B. & Prichard, J. R. 2010. Sleep patterns and predictors of disturbed sleep in a large population of college students. Journal of Adolescent Health 46 (2), 124-132. doi:10.1016/j.jadohealth.2009.06.016.

Malone, S., Hughes, B., Doran, D. A., Collins, K. & Gabbett, T. J. 2019. Can the workload–injury relationship be moderated by improved strength, speed and repeated-sprint qualities? Journal of Science and Medicine in Sport 22 (1), 29-34. doi:10.1016/j.jsams.2018.01.010.

Martin, C., Olivier, B. & Benjamin, N. 2017. Asymmetrical abdominal muscle morphometry is present in injury free adolescent cricket pace bowlers: A prospective observational study. Physical Therapy in Sport 28, 34-42. doi:10.1016/j.ptsp.2017.08.078.

McClay, I. S., Robinson, J. R., Andriacchi, T. P., Frederick, E. C., Gross, T., et al. 1994. A profile of ground reaction forces in professional basketball. Journal of Applied Biomechanics 10 (3), 222-236. doi:10.1123/jab.10.3.222.

Meeuwisse, W., Sellmer, R. & Hagel, B. E. 2003. Rates and risks of injury during intercollegiate basketball. The American Journal of Sports Medicine 31 (3), 379-385. doi:10.1177/03635465030310030901.

Meeuwisse, W., Tyreman, H., Hagel, B. & Emery, C. 2007. A dynamic model of etiology in sport injury: the recursive nature of risk and causation. Clinical Journal of Sport Medicine 17 (3), 215-219. doi:10.1097/JSM.0b013e3180592a48.

Merskey, H. & Bogduk, N. 1994. Classification of Chronic Pain, Part III: Pain Terms, A Current List with Definitions and Notes on Usage. In H. Merskey, N. Boduk (eds.) International Association for the Study of Pain. (2nd edition) Seattle: IASP Press, 209-214.

Messina, D. F., Farney, W. C. & DeLee, J. C. 1999. The incidence of injury in texas high school basketball: a prospective study among male and female athletes. The American Journal of Sports Medicine 27 (3), 294-299.

Michaelson, P., Holmberg, D., Aasa, B. & Aasa, U. 2016. High load lifting exercise and low load motor control exercises as interventions for patients with mechanical low back pain: A randomized controlled trial with 24-month follow-up. Journal of Rehabilitation Medicine 48 (5), 456-463. doi:10.2340/16501977-2091.

Mikkonen, P., Heikkala, E., Paananen, M., Remes, J., Taimela, S., et al. 2016. Accumulation of psychosocial and lifestyle factors and risk of low back pain in adolescence: a cohort study. European Spine Journal 25 (2), 635-642. doi:10.1007/s00586-015-4065-0.

Mikkonen, P., Laitinen, J., Remes, J., Tammelin, T., Taimela, S., et al. 2013. Association between overweight and low back pain: a population-based prospective cohort study of adolescents. Spine 38 (12), 1026-1033. doi:10.1097/BRS.0b013e3182843ac8.

Mikkonen, P., Leino-Arjas, P., Remes, J., Zitting, P., Taimela, S., et al. 2008. Is smoking a risk factor for low back pain in adolescents?: a prospective cohort study. Spine 33 (5), 527-532. doi:10.1097/BRS.0b013e3181657d3c.

Milanese, S. & Grimmer-Somers, K. 2010. What is adolescent low back pain? Current definitions used to define the adolescent with low back pain. Journal of Pain Research 3, 57-66. doi:10.2147/jpr.s10025.

Mogensen, A. M., Gausel, A. M., Wedderkopp, N., Kjaer, P. & Leboeuf - Yde, C. 2007. Is active participation in specific sport activities linked with back pain? Scandinavian Journal of Medicine & Science in Sports 17 (6), 680-686. doi:10.1111/j.1600-0838.2006.00608.x.

Monajati, A., Larumbe-Zabala, E., Goss-Sampson, M. & Naclerio, F. 2016. The effectiveness of injury prevention programs to modify risk factors for non-contact anterior cruciate ligament and hamstring injuries in uninjured team sports athletes: a systematic review. PloS one 11 (5), e0155272. doi:10.1371/journal.pone.0155272.

Monnier, A., Larsson, H., Nero, H., Djupsjöbacka, M. & Äng, B. O. 2019. A longitudinal observational study of back pain incidence, risk factors and occupational physical activity in Swedish marine trainees. BMJ Open 9 (5), e025150. doi:10.1136/bmjopen-2018-025150.

Mononen, K., Blomqvist, M., Koski, P. & Kokko, S. 2016. Urheilu ja seuraharrastaminen. In S. Kokko & A. Mehtälä (eds.) Lasten ja nuorten liikuntakäyttäytyminen Suomessa. LIITU-tutkimuksen tuloksia 2016. Valtion liikuntaneuvoston julkaisuja 2016:4, 27-35.

Morris, S. L., O'Sullivan, P. B., Murray, K. J., Bear, N., Hands, B., et al. 2016. Hypermobility and musculoskeletal pain in adolescents. Journal of Pediatrics 181, 213-221.e1. doi:10.1016/j.jpeds.2016.09.060.

Moller, M., Attermann, J., Myklebust, G. & Wedderkopp, N. 2012. Injury risk in Danish youth and senior elite handball using a new SMS text messages approach. British Journal of Sports Medicine 46 (7), 531-537. doi:10.1136/bjsports-2012-091022.

Müller, S., Müller, J., Stoll, J., Prieske, O., Cassel, M., et al. 2016. Incidence of back pain in adolescent athletes: a prospective study. BMC Sports Science, Medicine & Rehabilitation 8 (1), 38. doi:10.1186/s13102-016-0064-7.

Müller, S., Stoll, J., Müller, J., Cassel, M. & Mayer, F. 2017. Trunk muscle activity during drop jump performance in adolescent athletes with back pain. Frontiers in Physiology 8, 274. doi:10.3389/fphys.2017.00274.

Mustard, C. A., Kalcevich, C., Frank, J. W. & Boyle, M. 2005. Childhood and early adult predictors of risk of incident back pain: Ontario child health study 2001 follow-up. American Journal of Epidemiology 162 (8), 779-786. doi:10.1093/aje/kwi271.

Nadler, S. F., Malanga, G. A., Bartoli, L. A., Feinberg, J. H., Prybicien, M., et al. 2002a. Hip muscle imbalance and low back pain in athletes: influence of core strengthening. Medicine & Science in Sports & Exercise 34 (1), 9-16.

Nadler, S. F., Malanga, G. A., DePrince, M., Stitik, T. P. & Feinberg, J. H. 2000. The Relationship Between Lower Extremity Injury, Low Back Pain, and Hip Muscle Strength in Male and Female Collegiate Athletes. Clinical Journal of Sports Medicine 10 (2), 89-97. doi:10.1097/00042752-200004000-00002.

Nadler, S. F., Malanga, G. F., Price, E., DePrince, M., Nadler, R., et al. 1999. Low back pain in college athletes: the relationship between hip extensor muscle balance and reported history. Medicine & Science in Sports & Exercise 31 (5), S357.

Nadler, S. F., Moley, P., Malanga, G. A., Rubbani, M., Prybicien, M., et al. 2002b. Functional deficits in athletes with a history of low back pain: A pilot study. Archives of Physical Medicine and Rehabilitation 83 (12), 1753-1758. doi:10.1053/apmr.2002.35659.

Nadler, S. F., Wu, K. D., Galski, T. & Feinberg, J. H. 1998. Low back pain in college athletes. A prospective study correlating lower extremity overuse or acquired ligamentous laxity with low back pain. Spine 23 (7), 828-833. doi:10.1097/00007632-199804010-00018

Naggara, O., Raymond, J., Guilbert, F., Roy, D., Weill, A., et al. 2011. Analysis by categorizing or dichotomizing continuous variables is inadvisable: an example from the natural history of unruptured aneurysms. American Journal of Neuroradiology 32 (3), 437-440. doi:10.3174/ajnr.A2425.

Newlands, C., Reid, D. & Parmar, P. 2015. The prevalence, incidence and severity of low back pain among international-level rowers. British Journal of Sports Medicine 49 (14), 951-956. doi:10.1136/bjsports-2014-093889.

Ng, L., Caneiro, J. P., Campbell, A., Smith, A., Burnett, A., et al. 2015. Cognitive functional approach to manage low back pain in male adolescent rowers: a randomised controlled trial. British Journal of Sports Medicine 49 (17), 1125-1131. doi:10.1136/bjsports-2014-093984.

Noll, M., Silveira, E. A. & Silveira de Avelar, I. 2017. Evaluation of factors associated with severe and frequent back pain in high school athletes. PLoS One 12 (2), e0171978. doi:10.1371/journal.pone.0171978.

Nilstad, A., Andersen, T. E., Bahr, R., Holme, I. & Steffen, K. 2014. Risk factors for lower extremity injuries in elite female soccer players. The American Journal of Sports Medicine 42 (4), 940-948. doi:10.1177/0363546513518741.

Nissinen, M., Heliövaara, M., Seitsamo, J., Alaranta, H. & Poussa, M. 1994. Anthropometric measurements and the incidence of low back pain in a cohort of pubertal children. Spine 19 (12), 1367-1370. doi:10.1097/00007632-199406000-00010.

Olsen, O., Myklebust, G., Engebretsen, L. & Bahr, R. 2004. Injury mechanisms for anterior cruciate ligament injuries in team handball. The American Journal of Sports Medicine 32 (4), 1002-1012. doi:10.1177/0363546503261724.

O'Sullivan, P., Smith, A., Beales, D. & Straker, L. 2017. Understanding adolescent low back pain from a multidimensional perspective: implications for management. The Journal of Orthopaedic and Sports Physical Therapy 47 (10), 741-751. doi:10.2519/jospt.2017.7376.

Parkkari, J., Räisänen, A., Pasanen, K. & Rimpelä, A. 2016. Liikuntavammat koulussa, vapaa-ajalla ja urheiluseuroissa. In S. Kokko & A. Mehtälä (eds.). Lasten ja nuorten liikuntakäyttäytyminen Suomessa. LIITU-tutkimuksen tuloksia 2016. Valtion liikuntaneuvoston julkaisuja 2016:4, 62-66.

Pasanen, K., Parkkari, J., Pasanen, M., Hiilloskorpi, H., Mäkinen, T., et al. 2008. Neuromuscular training and the risk of leg injuries in female floorball players: cluster randomised controlled study. British Journal of Sports Medicine 42 (10), 802-99. doi:10.1136/bmj.a295.

Peduzzi, P., Concato, J., Feinstein, A. R. & Holford, T. R. 1995. Importance of events per independent variable in proportional hazards regression analysis II. Accuracy and precision of regression estimates. Journal of Clinical Epidemiology 48 (12), 1503-1510. doi:10.1016/0895-4356(95)00048-8.

Peduzzi, P., Concato, J., Kemper, E., Holford, T. R. & Feinstein, A. R. 1996. A simulation study of the number of events per variable in logistic regression analysis. Journal of Clinical Epidemiology 49 (12), 1373-1379. doi:10.1016/S0895-4356(96)00236-3.

Perich, D., Burnett, A. & O'Sullivan, P. 2006. Low back pain in adolescent female rowers and the associated factors. In H. Schwameder, E. Müller, S. Lindinger, V. Fastenbauer & G. Strutzenberger (eds.) 24 International Symposium on Biomechanics in Sports. Salzburg – Austria: International society of biomechanics in sports, 1-4.

Perry, M., Straker, L., O'Sullivan, P., Smith, A. & Hands, B. 2009. fitness, motor competence, and body composition are weakly associated with adolescent back pain. The Journal of Orthopaedic and Sports Physical Therapy 39 (6), 439-449. doi:10.2519/jospt.2009.3011.

Peterson, L., Junge, A., Chomiak, J., Graf-Baumann, T. & Dvorak, J. 2000. Incidence of football injuries and complaints in different age groups and skill-level groups. The American Journal of Sports Medicine 28 (5_suppl), 51-57. doi:10.1177/28.suppl_5.s-51.

Potthoff, T., de Bruin, E. D., Rosser, S., Humphreys, B. K. & Wirth, B. 2018. A systematic review on quantifiable physical risk factors for non-specific adolescent low back pain. Journal of Pediatric Rehabilitation Medicine 11 (2), 79-94. doi:10.3233/PRM-170526.

Poussa, M., Heliövaara, M., Seitsamo, J., Könönen, M., Hurmerinta, K., et al. 2005. Anthropometric measurements and growth as predictors of low-back pain: a cohort study of children followed up from the age of 11 to 22 years. European Spine Journal 14 (6), 595-598. doi:10.1007/s00586-004-0872-4.

R Core Team 2016. R: A language and environment for statistical computing. Vienna, Austria. R Foundation for Statistical Computing.

Reeves, N. P., Cholewicki, J. & Silfies, S. P. 2006. Muscle activation imbalance and low-back injury in varsity athletes. Journal of Electromyography and Kinesiology 16 (3), 264-272. doi:10.1016/j.jelekin.2005.07.008.

Rishiraj, N., Taunton, J. E. & Niven, B. 2009. Injury profile of elite under-21 age female field hockey players. The Journal of Sports Medicine and Physical Fitness 49 (1), 71.

Rosenhagen, A., Niederer, D., Vogt, L. & Banzer, W. 2018. Knee misalignment and exercise amount: Predictive value for chronic low back pain in young competitive athletes. Human Movement Science 57, 178-183. doi:10.1016/j.humov.2017.12.004.

Rössler, R., Junge, A., Chomiak, J., Dvorak, J. & Faude, O. 2016. Soccer injuries in players aged 7 to 12 years. The American Journal of Sports Medicine 44 (2), 309-317. doi:10.1177/0363546515614816.

Roussel, N. A., Nijs, J., Mottram, S., Van Moorsel, A., Truijen, S., et al. 2009. Altered lumbopelvic movement control but not generalized joint hypermobility is associated with increased injury in dancers. A prospective study. Manual Therapy 14 (6), 630-635. doi:10.1016/j.math.2008.12.004.

Sano, A., Hirano, T., Watanabe, K., Endo, N., Ito, T., et al. 2015. Body mass index is associated with low back pain in childhood and adolescence: a birth cohort study with a 6-year follow-up in Niigata City, Japan. European Spine Journal 24 (3), 474-481. doi:10.1007/s00586-014-3685-0.

Sato, T., Ito, T., Hirano, T., Morita, O., Kikuchi, R., et al. 2011. Low back pain in childhood and adolescence: assessment of sports activities. European Spine Journal 20 (1), 94-99. doi:10.1007/s00586-010-1485-8.

Schroeder, G. D., LaBella, C. R., Mendoza, M., Daley, E. L., Savage, J. W., et al. 2016. The role of intense athletic activity on structural lumbar abnormalities in adolescent patients with symptomatic low back pain. European Spine Journal 25 (9), 2842-2848. doi:10.1007/s00586-016-4647-5.

Seay, J., Selbie, W. S. & Hamill, J. 2008. In vivo lumbo-sacral forces and moments during constant speed running at different stride lengths. Journal of Sports Sciences 26 (14), 1519. doi:10.1080/02640410802298235.

Seay, J., Shing, T., Wilburn, K., Westrick, R. & Kardouni, J. 2018. Lower-extremity injury increases risk of first-time low back pain in the us army. Medicine & Science in Sports & Exercise 50 (5), 987-994. doi:10.1249/MSS.0000000000001523.

Shah, T., Cloke, D. J., Rushton, S., Shirley, M. D. F. & Deehan, D. J. 2014. Lower back symptoms in adolescent soccer players. Orthopaedic Journal of Sports Medicine 2 (4), 2325967114529703. doi:10.1177/2325967114529703.

Sharir, R., Rafeeuddin, R., Staes, F., Dingenen, B., George, K., et al. 2016. Mapping current research trends on anterior cruciate ligament injury risk against the existing evidence: In vivo biomechanical risk factors. Clinical biomechanics, 37, 34–43. doi:10.1016/j.clinbiomech.2016.05.017

Silfies, S. P., Cholewicki, J., Reeves, N. P. & Greene, H. S. 2007. Lumbar position sense and the risk of low back injuries in college athletes: a prospective cohort study. BMC Musculoskeletal Disorders 8 (1), 129. doi:10.1186/1471-2474-8-129.

Sjolie, A. N. 2004. Low ‐ back pain in adolescents is associated with poor hip mobility and high body mass index. Scandinavian Journal of Medicine & Science in Sports 14 (3), 168-175. doi:10.1111/j.1600-0838.2003.00334.x.

Smith, A., Beales, D., O'Sullivan, P., Bear, N. & Straker, L. 2017. Low back pain with impact at 17 years of age is predicted by early adolescent risk factors from multiple domains: analysis of the western australian pregnancy cohort (Raine) study. The Journal of Orthopaedic and Sports Physical Therapy 47 (10), 752-762. doi:10.2519/jospt.2017.7464.

Soligard, T., Bahr, R. & Andersen, T. E. 2012. Injury risk on artificial turf and grass in youth tournament football. Scandinavian Journal of Medicine & Science in Sports 22 (3), 356-361. doi:10.1111/j.1600-0838.2010.01174.x.

Soligard, T., Myklebust, G., Steffen, K., Holme, I., Silvers, H., et al. 2008. Comprehensive warm-up programme to prevent injuries in young female footballers: cluster randomised controlled trial. BMJ 337 (7686), 95-99. doi:10.1136/bmj.a2469.

Souza, L., Morimoto, T., von Mühlen, P., Gonçalves, T. C., Felippe, P. d. S., et al. 2015. Relation between performance in side bridge and injuries in amateur soccer. Fisioterapia em Movimento 28 (3), 447-457. doi:10.1590/0103-5150.028.003.AO03.

Staes, F., Stappaerts, K., Lesaffre, E. & Vertommen, H. 2003. Low back pain in Flemish adolescents and the role of perceived social support and effect on

the perception of back pain. Acta Pædiatrica 92 (4), 444-451. doi:10.1111/j.1651-2227.2003.tb00576.x.
Sterne, J. A. C., White, I. R., Carlin, J. B., Spratt, M., Royston, P., et al. 2009. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. British Medical Journal 338 (7713), 157-160. doi:10.1136/bmj.b2393.
Szpalski, M., Gunzburg, R., Balagué, F., Nordin, M. & Mélot, C. 2002. A 2-year prospective longitudinal study on low back pain in primary school children. European Spine Journal 11 (5), 459-464. doi:10.1007/s00586-002-0385-y.
Taanila, H. P., Suni, J. H., Pihlajamäki, H. K., Mattila, V. M., Ohrankämmen, O., et al. 2012. Predictors of low back pain in physically active conscripts with special emphasis on muscular fitness. The Spine Journal 12 (9), 737-48. doi:10.1016/j.spinee.2012.01.006.
Taimela, S. & Kujala, U. M. 1992. Reaction times with reference to musculoskeletal complaints in adolescence. Perceptual and Motor Skills 75 (3_suppl), 1075-1082. doi:10.2466/pms.1992.75.3f.1075.
Takatalo, J., Karppinen, J., Näyhä, S., Taimela, S., Niinimäki, J., et al. 2017. Association between adolescent sport activities and lumbar disk degeneration among young adults. Scandinavian Journal of Medicine & Science in Sports 27 (12), 1993-2001. doi:10.1111/sms.12840.
Takatalo, J., Karppinen, J., Niinimäki, J., Taimela, S., Mutanen, P., et al. 2012. Association of modic changes, schmorl's nodes, spondylolytic defects, high-intensity zone lesions, disc herniations, and radial tears with low back symptom severity among young finnish adults. Spine 37 (14), 1231-1239. doi:10.1097/BRS.0b013e3182443855.
Takekawa, K. S., Gonçalves, J. S., Moriguchi, C. S., Coury, H. & de Oliveira Sato, T. 2015. Can a self-administered questionnaire identify workers with chronic or recurring low back pain? Industrial Health 53 (4), 340-345. doi:10.2486/indhealth.2014-0241.
Statistical Yearbook of the Social Insurance Institution 2017. Official statistics of Finland. Social protection 2018. The Social Insurance Institution.
Therneau, T. M. 2015. coxme: Mixed Effects Cox Models. R package. (2.2-5 edition).
Thorborg, K., Bandholm, T., Schick, M., Jensen, J. & Hölmich, P. 2013. Hip strength assessment using handheld dynamometry is subject to intertester bias when testers are of different sex and strength. Scandinavian Journal of Medicine & Science in Sports 23 (4), 487-493. doi:10.1111/j.1600-0838.2011.01405.x.
Tiira, A. H., Paananen, M. V., Taimela, S. P., Zitting, P. J., Järvelin, M., et al. 2012. Determinants of adolescent health care use for low back pain. European Journal of Pain 16 (10), 1467. doi:10.1002/j.1532-2149.2012.00178.x.
Timpka, T., Risto, O. & Björmsjö, M. 2008. Boys soccer league injuries: a community-based study of time-loss from sports participation and long-term sequelae. European Journal of Public Health 18 (1), 19-24. doi:10.1093/eurpub/ckm050.

Tobias, J. H., Deere, K., Palmer, S., Clark, E. M. & Clinch, J. 2013. Joint hypermobility is a risk factor for musculoskeletal pain during adolescence: findings of a prospective cohort study. Arthritis & Rheumatism 65 (4), 1107-1115. doi:10.1002/art.37836.

Trompeter, K., Fett, D. & Platen, P. 2017. Prevalence of back pain in sports: a systematic review of the literature. Sports Medicine 47 (6), 1183-1207. doi:10.1007/s40279-016-0645-3.

Tunås, P., Nilstad, A. & Myklebust, G. 2014. Low back pain in female elite football and handball players compared with an active control group. Knee Surgery, Sports Traumatology, Arthroscopy 23 (9), 2540-2547. doi:10.1007/s00167-014-3069-3.

van Dieën, J. H., Reeves, N. P., Kawchuk, G., van Dillen, L. R. & Hodges, P. W. 2019. Motor control changes in low-back pain: divergence in presentations and mechanisms. The Journal of Orthopaedic and Sports Physical Therapy 49 (6), 370-379. doi:10.2519/jospt.2019.7917.

van Gessel, H., Gaßmann, J. & Kröner-Herwig, B. 2011. Children in pain: recurrent back pain, abdominal pain, and headache in children and adolescents in a four-year-period. The Journal of Pediatrics 158 (6), 977-983.e2. doi:10.1016/j.jpeds.2010.11.051.

van Hilst, J., Hilgersom, N. F. J., Kuilman, M. C., F M Kuijer, P. Paul et al. 2015. Low back pain in young elite field hockey players, football players and speed skaters: Prevalence and risk factors. Journal of Back and Musculoskeletal Rehabilitation 28 (1), 67-73. doi:10.3233/BMR-140491.

van Mechelen, W., Hlobil, H. & Kemper, H. C. 1992. Incidence, severity, aetiology and prevention of sports injuries. A review of concepts. Sports Medicine 14 (2), 82-99. doi:10.2165/00007256-199214020-00002.

Videman, T., Sarna, S., Battié, M. C., Koskinen, S., Gill, K., et al. 1995. The long-term effects of physical loading and exercise lifestyles on back-related symptoms, disability, and spinal pathology among men. Spine 20 (6), 699-709. doi:10.1097/00007632-199503150-00011.

Viikari-Juntura, E., Häliövaara, M., Solovieva, S. & Shiri, R. 2012. Tuki- ja liikuntaelinsairaudet. In S. Koskinen, A. Lundqvist & N. Ristiluoma (eds.) Terveys, toimintakyky ja hyvinvointi Suomessa 2011. Terveyden ja hyvinvoinnin laitos. Raportti 68/2012, 92-95.

Vikat, A., Rimpela, M., Salminen, J. J., Rimpela, A., Savolainen, A., et al. 2000. Neck or shoulder pain and low back pain in Finnish adolescents. Scandinavian Journal of Public Health 28 (3), 164-173. doi:10.1080/140349400444850.

von Rosen, P., Heijne, A., Frohm, A., Fridén, C. & Kottorp, A. 2018a. High injury burden in elite adolescent athletes: a 52-week prospective study. Journal of Athletic Training 53 (3), 262-270. doi:10.4085/1062-6050-251-16.

von Rosen, P., Kottorp, A., Fridén, C., Frohm, A. & Heijne, A. 2018b. Young, talented and injured: Injury perceptions, experiences and consequences in adolescent elite athletes. European Journal of Sport Science 18 (5), 731-740. doi:10.1080/17461391.2018.1440009.

Watson, A., Brickson, S., Brooks, A. & Dunn, W. 2017. Subjective well-being and training load predict in-season injury and illness risk in female youth soccer players. British Journal of Sports Medicine 51 (3), 194-199. doi:10.1136/bjsports-2016-096584.

Wedderkopp, N., Kjaer, P., Hestbaek, L., Korsholm, L. & Leboeuf-Yde, C. 2009. High-level physical activity in childhood seems to protect against low back pain in early adolescence. The Spine Journal 9 (2), 134-141. doi:10.1016/j.spinee.2008.02.003.

Wedderkopp, N., Leboeuf-Yde, C., Andersen, L. B., Froberg, K. & Hansen, H. S. 2001. Back pain reporting pattern in a danish population-based sample of children and adolescents. Spine 26 (17), 1879-1883. doi:10.1097/00007632-200109010-00012.

Wedderkopp, N., Leboeuf-Yde, C., Bo Andersen, L., Froberg, K. & Steen Hansen, H. 2003. Back pain in children: no association with objectively measured level of physical activity. Spine 28 (17), 2019-2024. doi:10.1097/01.BRS.0000083238.78155.31.

Wirth, B., Knecht, C. & Humphreys, K. 2013. Spine day 2012: spinal pain in Swiss school children– epidemiology and risk factors. BMC Pediatrics 13 (1), 159. doi:10.1186/1471-2431-13-159.

Yabe, Y., Hagiwara, Y., Sekiguchi, T., Momma, H., Tsuchiya, M., et al. 2019. Knee pain is associated with lower back pain in young baseball players: a cross-sectional study. Knee Surgery, Sports Traumatology, Arthroscopy 27 (3), 985-990. doi:10.1007/s00167-018-5129-6.

Zazulak, B. T., Hewett, T. E., Reeves, N. P., Goldberg, B. & Cholewicki, J. 2007. Deficits in neuromuscular control of the trunk predict knee injury risk. American Journal of Sports Medicine 35 (7), 1123-1130. doi:10.1177/0363546507301585.

SUPPLEMENTS

SUPPLEMENT TABLE 1 Longitudinal studies investigating associations between potential risk factors and back complaints in youth athletes

STUDY	STUDY DESIGN	AGE, SAMPLE SIZE, SEX AND SPORT	BACK PAIN DEFINITION AND REGISTRATION DURING FOLLOW-UP	ASSOCIATIONS (*OR; RR; T-TEST, HR*)
Kujala et al. (1996)	Prospective, case-control, 2- to 3-year follow-up	Age: 10.3 to 13.3 Sample size: *n* = 65 athletes, *n* = 33 non-athletes Sex: both Sport: ice hockey, soccer, gymnastic, figure skating	Injury definition: LBP interfering with schoolwork or leisure activities for at least a one-week period Injury recording: Questionnaire + all the subjects with prolonged LBP problems were examined by a physician	LBP: Sports participation + Sex – New MRI abnormalities: Acute back injury + (higher prevalence in girls with LB injury without acute back injury) Training –

STUDY	STUDY DESIGN	AGE, SAMPLE SIZE, SEX AND SPORT	BACK PAIN DEFINITION AND REGISTRATION DURING FOLLOW-UP	ASSOCIATIONS (*OR; RR; T-TEST, HR*)
Kujala et al. (1997)	Prospective study, three-years follow-up No previous severe LBP	Age: 10.3 to 13.3 Sample size: *n* = 65 athletes, *n* = 33 non-athletes Sex: both Sport: ice hockey, soccer, gymnastic, figure skating	Injury definition: LBP interfering with school or leisure activities for at least one-week period Injury and AE recording: Injuries and exposure recorded with questionnaires at baseline 2nd and 3th yr.	Boys: Maximal lumbar flexion mobility + Sports participation - Lower segment lumbar mobility - Maximal lumbar extension mobility - Weight - Girls: Lower segment lumbar mobility + Maximal lumbar extension mobility + Weight + Maximal lumbar flexion mobility - Sports participation -
Nadler et al. (1998)	Prospective study, one-year follow-up	Age: college (age not specified) Sample size: *n* = 275 Sex: both Sport: varsity athletes	Injury definition: LBP that required treatment. Injury registration: Athletic trainer recorded if any athlete required treatment for LBP during the follow-up.	Sex + (girls vs boys 15 vs 6%, p=0.048) LE impairment (majority of participants with LBP had also LE impairment, 58 vs 42%, p=0.001) Leg length asymmetry – Hip flexor flexibility – History of LBP –

STUDY	STUDY DESIGN	AGE, SAMPLE SIZE, SEX AND SPORT	BACK PAIN DEFINITION AND REGISTRATION DURING FOLLOW-UP	ASSOCIATIONS (*OR; RR; T-TEST, HR*)
Greene et al. (2001)	Prospective study, one-year follow-up	Age: mean 19 (*SD* 1) Sample size: *n* = 679 Sex: both Sport: university varsity athletes from 30 sport disciplines	Injury definition: LBP that caused an athlete to miss or not participate fully in at least three practice sessions or competitions and that resulted in a visit to a sports physician (at the university sports clinic) Injury recording: by the sports physician during the visit.	LBP at baseline + (*RR* 6.5). History of LBI/LBP (*RR* 3.1). Satisfaction with coach - Satisfaction with teammates – Age – Sex – Sport -
Nadler et al. (2002a)	Prospective, intervention	Age: college (age not specified) Sample size: 1st year: *n* = 164, 2nd year: *n* = 236, 3th year: *n* = 225 Sex: not reported Sport: various sports	Injury definition: LBP that required treatment. Injury registration: Athletic trainer recorded if any athlete required treatment for LBP during the follow-up.	Hip abduction strength + (in girls)
Meeuwisse et al. (2003)	Prospective cohort study, two-years follow-up	Age: college (age not specified) Sample size: *n* = 142 Sex: boys Sport: basketball	Injury definition: Any injury resulting in one or more complete or partial sessions of time loss. Injury and AE registration: individual participation, exposure, and any injury data recorded daily on standardized form by team/student therapists	History of LBP/LBI + (*RR* 3.65 95% *CI* 1.06 to 12.52)
Cholewicki et al. (2005)	Prospective observational study, 2—3-year follow-up	Age: mean 19.4 Sample size: *n* = 292 Sex: both Sport: college varsity athletes	Injury definition: LBP resulting in 3 days' time lost from practice or competitions, and a visit to a sports physician or athletic trainer. Injury recording: Athletes were asked to contact the PI in case of LBI occurred during the follow-up (regularly scheduled electronic mailings to study participants inquiring if they had had LBI)	Longer mean latencies + (Every millisecond delay in muscle response latency increased the odds for LBI by 2 to 3% (95% *CI* 1.02 to 1.03) History of LBI + (*OR* 2.8) Weight + (*OR* 1.03)

STUDY	STUDY DESIGN	AGE, SAMPLE SIZE, SEX AND SPORT	BACK PAIN DEFINITION AND REGISTRATION DURING FOLLOW-UP	ASSOCIATIONS (*OR; RR; T-TEST, HR*)
Alricsson & Werner (2006)	Prospective, 5-year follow-up	Age: mean 13.6 (0.9) Sample size: *n* = 15 Sex: both Sport: elite cross-country skiing	Injury definition: Based on questions about LBP related to X-country skiing Injury recording: no	Difference between thoracic kyphosis and lumbar lordosis + (18 deg. vs. 10 deg.) Participation in other sports + (sig. more in LBP developers) Growth – Kyphosis – Lordosis – Training hours – BMI –
Reeves et al. (2006)	Experimental, prospective, two- to three-year follow-up	Age: boys 19.9 (3.1) girls 19.4 (1.0) Sample size: *n* = 242 Sex: both Sport: varsity athletes	Injury definition: LBI was defined as any LBP significant enough to cause an athlete to miss three days of training and/or competition. Injury registration: Not described	Thoracic-lumbar muscle activation imbalance –
Silfies et al. (2007)	Prospective cohort study, 2- to 3-year follow-up.	Age: college age (approx. 19) Sample size: *n* = 292 Sex: not reported Sport: university varsity athletes	Injury definition: LBP that caused the athlete to seek medical attention (physician, athletic trainer, or physical therapist) and to miss at least 3 days of participating in their sport or training routine Injury registration: Self-reported through regular electronic mailings. Verified with training room and team physician records.	Lumbar spine proprioception -

STUDY	STUDY DESIGN	AGE, SAMPLE SIZE, SEX AND SPORT	BACK PAIN DEFINITION AND REGISTRATION DURING FOLLOW-UP	ASSOCIATIONS (*OR; RR; T-TEST, HR*)
Aoki et al. (2010)	Case-controlled prospective study, one-year follow-up	Age: 12 to 17 Sample size: *n* = 322 Sex: not reported Sport: soccer LBP Groups (playing on artificial turf (AT) or natural turf (NT) 80% of the time): Artificial turf Natural turf	Injury registration: Medically diagnosed acute injuries and non-traumatic overuse pain were recorded daily by team health care staff. Injury definition: Acute injury or overuse pain complaint that resulted in absence from training/matches for at least 1 week	Both groups together: Age – Height – Weight – Playing experience – Training hours - AT group: Training hours + (*OR* 1.02, 95% *CI* 1.01 to 1.02). Age + (*OR* 0.50, 95% *CI* 0.439 to 0.721) Height + (*OR* 0.59, 95% *CI* 0.442 to 0.779) Training hours per year+ (*OR* 1.21, 95% CI 1.019 to 1.444) Incidence rate ratios (*IRR*s): AT versus the NT group 1.62 (95% *CI*, 1.06-2.48)

STUDY	STUDY DESIGN	AGE, SAMPLE SIZE, SEX AND SPORT	BACK PAIN DEFINITION AND REGISTRATION DURING FOLLOW-UP	ASSOCIATIONS (*OR; RR; T-TEST, HR*)
Hjelm et al. (2012)	Prospective cohort study, two-years follow-up model (univariate/multivariate)	Age: 12 to 18 Sample size: *n* = 55 (10 dropouts) Sex: both Sport: tennis (sport club setting)	Injury definition: An injury resulting in inability to participate in regular tennis training or playing matches during at least one occasion (a time loss injury). Injury recording: Player informed the PI about injuries AE recording: Player informed PI if changes in normal training amounts PI contacted the players every 3 months to secure correct info on exposure and injuries. When injured the PI did the clinical examination, when possible.	Increase in training hours (>6 hours/wk) + (*OR* 1.3, 95% *CI* 1.3 to 99.6). History of LBI + (*OR* 4.7, 95% *CI* 1.1 -20.5) Decreased neck ROM + (lateral flexion) (*OR* 0.8, 95% *CI* 0.7-1.0) Joint laxity – Balance/postural stability – Flexibility – Strength – Agility – ROM (other than neck) –
Kountouris et al. (2012)	Prospective cohort study	Age: 12 to 17 Sample size: *n* = 38 Sex: boys Sport: cricket fast bowlers LBI (soft tissue or bone stress injury)	Injury definition: Musculoskeletal lumbar spine injuries based on MRI Injury recording: At baseline reported no LBP or spine injury. If player reported LBP physician performed clinical examination and radiological investigation.	Age – Height – Weight – BMI + (back bone stress injury) QL asymmetry –

STUDY	STUDY DESIGN	AGE, SAMPLE SIZE, SEX AND SPORT	BACK PAIN DEFINITION AND REGISTRATION DURING FOLLOW-UP	ASSOCIATIONS (*OR; RR; T-TEST, HR*)
Soligard et al. (2012)	Prospective cohort study, Norway cup 2005 to 2008, one-week tournament	Age: 13 to 19 Sample size: 7,848 matches; 70% played by boys and 30% by girls Sex: both Sport: soccer	Injury definition: Any injury, painful condition, or physical complaint sustained by a player in a Norway Cup match, irrespective of the need for medical attention or time loss from football activities Injury registration: Coaches recorded injuries that occurred during matches.	Turf type + (AT vs. NT *RR* 2.23 (1.33-3.72) (AT: *OR* 1.92, 95% *CI* 1.10 to 3.36))
Shah et al. (2014)	Descriptive epidemiology study, prospective, five seasons	Age: 9 to 16 Sample size: n = 12,306 Sex: not reported Sport: soccer	Injury definition: complaint resulting in absence from participating in full training and matches for 48 hours or longer. Moderate injuries were defined as an 8- to 28-day absence, and severe injuries as an absence 28 days, as classified by the UEFA model for defining injury severity. Injury registration: Medical personnel recorded injuries.	Season phase + (more prevalent after brakes) Game phase + (more prevalent in second half) Age + (higher in older) Player contact + (majority of injuries through contact) Player position – Competitive vs. non-competitive play –
Müller et al. (2016)	Prospective,1- to 2-year follow up	Age: mean 13.2 (1.4) Sample size: n = 321 Sex: both Sport: elite athletes from sports schools	Injury definition: acute pain present at the time of answering the questionnaire and/or during the 7 days prior to the examination. Pain was assessed with a 5-step face scale (face 1–2 = no pain; face 3–5 = pain). Faces 3 to 5 were considered as LBP. Injury registration: no prospective registration, point/7-day prevalence of back pain at follow-up	Sport type – Sex – Age – Weight – Height – Training hours per week – Training year –

STUDY	STUDY DESIGN	AGE, SAMPLE SIZE, SEX AND SPORT	BACK PAIN DEFINITION AND REGISTRATION DURING FOLLOW-UP	ASSOCIATIONS (*OR; RR; T-TEST, HR*)
Rössler et al. (2016)	Descriptive epidemiology study, prospective two seasons follow-up	Age: 7 to 12 Sample size: 6,038 player seasons (season 1, *n* = 51 and *n* = 845; season 2, *n* = 61 and n = 846) Sex: boys & girls Sport: soccer	Injury definition: Any physical complaint sustained during a scheduled training session or match play resulting in at least 1 of the following: (1) inability to complete the current match or training session, (2) absence from subsequent training sessions or matches, and (3) injury requiring medical attention Injury and AE registration: Injury and exposure data recorded by coaches through an internet-based platform.	Age +
Rosenhagen et al. (2018)	Prospective observational (case-control) study, seven-year follow-up	Age: 12 to 18 Sample size: n = 789, Subjects with knee misalignment, irrespective of genu valgum or varum, were 2:1-matched with controls, using age, gender and sport as criteria therefore only 64 were analysed. No previous back impairments. Sex: not reported Sport: various youth team sports	Injury definition: CLBP if persistent pain for >13 weeks including (at least one) painful episode(s) in the past two weeks and for at least half of the time of the previous 12 months, in single or multiple episodes Injury registration: After 7 years AE registration: Actual sport and exercise engagement was recorded according to the FITT-principle (frequency, intensity, time, type)	Knee misalignment + (*OR* 3.4, 95% *CI*: 1.1–10.8)

RR, risk ratio; *HR*, Hazards ratio; *OR*, odds ratio; LBP, low back pain; LBI, low back injury; PI, principal investigator; QL, quadratus lumborum; BMI, body mass index; AT, artificial turf; NT, natural turf; ROM, range of motion.

SUPPLEMENT TABLE 2 Unadjusted and adjusted Cox analyses on strength and flexibility variables. Analysis corrected after original article was published, therefore values slightly differ from original article (study III)

		Unadjusted			Adjusted		
Any LBP	*n* (incidents)	*HR*	95% *CI*	*p* value	*HR*	95% *CI*	*p* value
Leg press 1RM	358 (44)	0.99	(0.99, 1.00)	0.640	0.99	(0.99, 1.00)	0.470
Hip Abduction strength asymmetry	366 (47)	0.87	(0.67, 1.14)	0.330	0.89	(0.68, 1.18)	0.430
Iliopsoas flexibility	342 (42)	1.00	(0.97, 1.04)	0.850	0.99	(0.96, 1.03)	0.750
Quadriceps flexibility	342 (42)	1.01	(0.98, 1.04)	0.460	1.01	(0.98, 1.04)	0.440
Hamstring flexibility	382 (48)	0.99	(0.97, 1.01)	0.400	0.99	(0.97, 1.01)	0.360
Hamstring flexibility asymmetry	382 (48)	1.01	(0.96, 1.07)	0.600	1.01	(0.96, 1.07)	0.710
Laxity index [a] (Hyperflexibility as reference)	383 (48)	1.14	(0.55, 2.35)	0.720	1.15	(0.55, 2.41)	0.700
Non-traumatic LBP							
Leg press 1RM	358 (36)	0.99	(0.99, 1.00)	0.430	0.99	(0.99, 1.00)	0.250
Hip Abduction strength asymmetry	366 (39)	0.87	(0.65, 1.17)	0.380	0.89	(0.66, 1.21)	0.460
Iliopsoas flexibility	342 (35)	1.00	(0.97, 1.04)	0.940	0.99	(0.96, 1.03)	0.790
Quadriceps flexibility	342 (35)	1.01	(0.97, 1.04)	0.800	1.01	(0.97, 1.04)	0.650
Hamstring flexibility	382 (39)	0.99	(0.97, 1.01)	0.530	0.99	(0.97, 1.01)	0.540
Hamstring flexibility asymmetry	382 (39)	1.02	(0.97, 1.09)	0.400	1.02	(0.96, 1.09)	0.480
Laxity index [1] (Hyperflexibility as reference)	383 (39)	1.06	(0.47, 2.42)	0.880	0.95	(0.41, 2.20)	0.910

HR; Hazards Ratio, *CI*; Confidence interval, LBP; low back pain, 1RM; one-repetition maximum

[1] Beighton-Horan Laxity index: Normal range 0-3, hyperflexibility 4-9

ORIGINAL PAPERS

I

LOW BACK AND NECK AND SHOULDER PAIN IN MEMBERS AND NON-MEMBERS OF ADOLESCENTS' SPORTS CLUBS: THE FINNISH HEALTH PROMOTING SPORTS CLUB (FHPSC) STUDY

by

Rossi Marleena, Pasanen Kati, Kokko Sami, Alanko Lauri, Heinonen Olli J, Korpelainen Raija, Savonen Kai, Selänne Harri, Vasankari Tommi, Kannas Lasse, Kujala Urho M, Villberg Jari, Parkkari Jari 2016

BMC Musculoskeletal Disorders vol 17:263

https://doi.org/10.1186/s12891-016-1114-8

Reproduced in accordance with the CC BY-NC 4.0 license.

.

Rossi *et al. BMC Musculoskeletal Disorders* (2016) 17:263
DOI 10.1186/s12891-016-1114-8

BMC Musculoskeletal Disorders

RESEARCH ARTICLE Open Access

Low back and neck and shoulder pain in members and non-members of adolescents' sports clubs: the Finnish Health Promoting Sports Club (FHPSC) study

M. Rossi[1*], K. Pasanen[1,8], S. Kokko[5], L. Alanko[2], O. J. Heinonen[3], R. Korpelainen[4,9,10], K. Savonen[6], H. Selänne[7], T. Vasankari[8], L. Kannas[5], U. Kujala[5], J. Villberg[5] and J. Parkkari[1,8]

Abstract

Background: The objective of this study was to investigate the prevalence of self-reported low back pain (LBP) and neck and shoulder pain (NSP), and the related factors in members and non-members of adolescents' sports clubs.

Methods: This cross-sectional study was based on surveys of 14–16-year-olds as a part of the Finnish Health Promoting Sports Club (FHPSC) Study. The surveys on self-reported health behaviours, injuries, and musculoskeletal health were conducted among sports club members ($n = 962$) and non-members ($n = 675$). Binary logistic regression analysis was applied to study the associations between dependent variables of LBP and NSP, and the independent factors.

Results: The prevalence of LBP during the preceding 3 months was 35.0 % in girls and 24.5 % in boys ($p < 0.05$ for sex difference). The prevalence of NSP was 55.9 % in girls and 27.3 % in boys ($p < 0.001$ for sex difference). Being a sports club member increased the odds for LBP in boys (odds ratio [OR] 2.35, 95 % CI 1.48–3.72). On the other hand, sports club participation was associated with lower odds of frequent NSP in girls (OR 0.52, 95 % CI 0.33–0.82). No associations were found between other leisure-time physical activity and LBP or NSP. Higher screen time (computer games, TV/DVD, phone, Internet) during leisure-time increased the odds of NSP in boys and LBP in boys and girls.

Conclusions: In this study, self-reported LBP and NSP were already relatively common among adolescents. Girls have a higher risk for reporting LBP and NSP. Measures that are more effective in the prevention of LBP in male sports club members are needed. Excessive screen time is weakly associated with LBP and NSP, which should be taken into account in health promotion among adolescents.

Keywords: Neck and shoulder pain, Low back pain, Adolescence, Sports club participation, Prevalence

Background

Back problems are a major public health problem. In Finland in 2013, back diseases were responsible for a sickness benefit expenditure of approximately 118 million euros, and they caused over two million days of covered illness [1]. Backache itself caused approximately 787,000 covered days of illness [1]. Low back pain (LBP) is relatively common already among adolescents [2]. Neck and shoulder pain (NSP) has been studied less, especially among adolescent athletes [2–4], but the prevalence of NSP seems to have increased during the 21st century [3]. The prevalence of LBP increases with age [5, 6]. Among 15–16-years-olds, LBP prevalence has been reported to be 32 % in boys and 45 % in girls [7]. Five per cent of those aged 15–16 years ($n = 7344$) sought medical assistance due to their LBP symptoms [7]. LBP in adolescence has a tendency of increasing the probability of LBP also in adulthood [8], and it is commonly concurrent with other

* Correspondence: marleena.k.rossi@student.jyu.fi
[1]Tampere Research Center of Sports Medicine, P.O. Box 30FI-33501 Tampere, Finland
Full list of author information is available at the end of the article

BioMed Central

© 2016 The Author(s). **Open Access** This article is distributed under the terms of the Creative Commons Attribution 4.0 International License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated.

musculoskeletal pain [9]. Therefore, it is important to identify risk populations and to effect the early prevention of LBP and NSP. Some studies have already investigated the differences in LBP between adolescent athletes and non-athletes [10, 11]. Physical activity as a risk factor has been studied previously [10, 12–14]. However, the results remain inconclusive.

This study is a part of a multidisciplinary and multi-institutional study (the Finnish Health Promoting Sports Club (FHPSC)) [15] where the overall aim is to investigate the effects of sports club participation and the activity of health promotion within sports clubs on adolescent health. Therefore, the specific objectives of this study were to determine the prevalence, frequency, and severity of LBP and NSP in the 14–16-year-old population. We also explored the associations between LBP and NSP with the health and health behaviour of adolescents, paying special attention to participation in organized sports (sports club membership).

Methods

This study is part of the Finnish Health Promoting Sports Club (FHPSC) study conducted in Finland by the University of Jyväskylä in conjunction with six sports medicine centres and the UKK institute [15]. This cross-sectional study was based on surveys among 14–16-year-olds, and it was carried out in accordance with the Declaration of Helsinki. The adolescents were notified that they have a right to refuse to participate and withdraw their consent later without giving a reason. A written consent from both a guardian and the adolescent him/herself for the pre-participation screening were obtained for participants under the age of 16. Ethical approval was received from the Ethics Committee of Health Care District of Central Finland (record number 23U/2012). All permission papers included detailed information of the study.

Data collection

In order to obtain a nationally representative sample of the most popular sports for youths, a total of two hundred and forty youth sports clubs from the ten most popular sports disciplines in Finland (basketball, cross-country skiing, floorball, football, gymnastics, ice-hockey, orienteering, skating, swimming, and track and field) were targeted. Twenty-four clubs were selected from each sport for the sample and 154 youth sports clubs out of 240 participated (64 %) in the FHPSC study. Data was collected in the middle of the main competition season from January to May 2013 for winter sports, and from August to December 2013 for summer sports. In total, 1889 sports club participants were invited to participate in two separate internet questionnaires (Fig. 1.). From the sports clubs 609 adolescents completed both questionnaires.

In order to compare the health behaviours and health status of youths participating in organized sports clubs (club members) to non-participating youths (non-members), the second sample included in this study was a group of secondary school children aged 14–16. The schools were collated from each district where the sports medicine centres were located, including nearby rural areas. School-based data was collected in two portions following the sports clubs' data collection timeframe (100 schools participated).

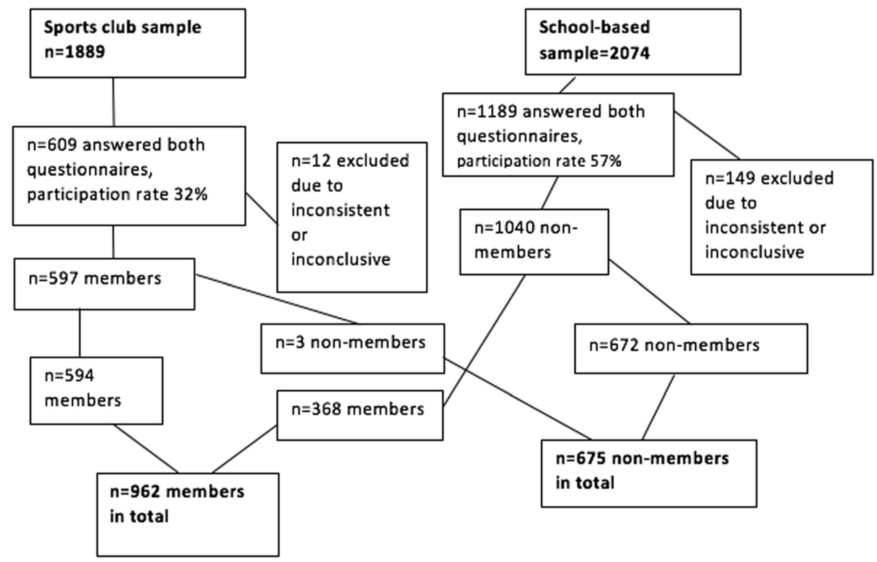

Fig. 1 Study sample

In total, 2074 pupils were asked to participate in the study during the normal school day and 1189 completed both questionnaires.

Members of the school-based sample were asked about their sports club participation ("At the moment are you a member of a sports club?" "no/yes/yes, but I don't participate to training provided by the club") and those who reported being members of a sports club were treated as sports club members ($n = 368$) in the following analyses. Three subjects from the sports club sample were analysed as non-members as they reported not participating in sports club activities (answered no to the question "Are you participating in sports club activities?" "yes/no"). Subjects that provided inconsistent or inconclusive concerning gender and/or age or sports club membership were excluded ($n = 12$ from sports club sample and $n = 149$ from school-based sample). In total, 962 sports club members (368 from school-based sample and 594 from sports club sample) and 675 non-members were included ($n = 1637$) (Fig. 1.).

Surveys

Two surveys were conducted (see Additional files 1 and 2). The first focused on the health behaviours of the adolescents, including self-evaluated overall physical activity. The questions included for example: "How many hours on a regular school day you spend your time sitting with one of the following devices? (TV, video/DVD, computer, console games, tablet/phone)" and "Outside school hours: How many hours do you usually do physical activity so that you sweat and get out of breath?". Unlike the questionnaire for non-members, the questionnaire for sports club members included some extra questions on training characteristics, such as active playing/practicing years (at least 2 times a week), training frequency, duration and number of rest days during training and competition seasons, as well as number of competitions. The second questionnaire focused on injuries and the musculoskeletal health of the adolescents. The questions used in these questionnaires were compiled from previously validated questions in other studies, like the Health Behaviour in School-aged Children (HBSC) study [16–20].

Outcomes

The main dependent outcomes were NSP and LBP within the preceding 3 months. The questions in the questionnaire were "How often have you had the following symptoms in the preceding 3 months?" Answer options included "aches or pain in the neck and shoulders" and "aches or pain in the low back" daily, more than once a week, approximately once a week, 2–3 times a month, approximately once a month, and less than once a month or not at all. Two dependent variables were formed for both LBP and NSP. These were LBP (low back pain more than once a month) and frequent LBP (low back pain at least once a week), and NSP (neck and shoulder pain more than once a month) and frequent NSP (neck and shoulder pain at least once a week). Questions that were more specifically about LBP were based on the standardized Nordic questionnaire of musculoskeletal symptoms [21]. LBP was defined as "an ache, pain, or discomfort of the lumbar region with or without radiation to one or both legs (sciatica)." The questions in the questionnaire included:

- "Have you ever experienced problems in your low back?" (area illustrated by a picture) (no/yes)
- "Have you ever had surgery because of LBP?" (no/yes)
- "Have you ever had radiating LBP?" (no/yes)
- "Have you ever had sleeping difficulties because of LBP?"(no/yes, how often?)
- "Have you had LBP during the previous 7 days?" (no/yes)
- "Have you experienced low back pain that has required consultation or treatments by a physician, physiotherapist, or chiropractor in the previous 12 months?" (no/yes)
- "How did your LBP symptoms occur?" suddenly (after an injury)/gradually (without a sudden injury)/or both
- "Have you used pain killers (NSAID) for your low back?" (no/yes)

Statistical methods

IBM SPSS Statistics (v. 22.0) was used to carry out all analyses. Sample size was power calculated by Stata 11.0 using data of Kokko et al. [18]. Differences between the groups were assessed using crosstabs and the chi-square test (and *t*-test when appropriate). The subject characteristics are presented for girls and boys, and sports club members and non-members separately as means ± SDs and percentages. Low back pain and neck and shoulder pain prevalence are expressed as a number and percentage of members and non-members separately for girls and boys. As multilevel modelling failed to give additional information, binary logistic regression analysis was applied to study the associations between the dependent variables of LBP (low back pain) and NSP (neck and shoulder pain) and the independent factors. Binary logistic regression analyses were adjusted by age, sex, BMI, chronic diseases, smoking, and school attainment level (i.e. school grade average). The binary logistic regression analyses were conducted separately for health, health behaviour and training variables. In the analyses for the health and health behaviour the variables were entered into the model simultaneously. In the analyses for training variables separate analyses were conducted for all variables. Odds ratios are reported with 95 % confidence intervals. *P*-value, 0.05 was regarded significant.

Results

The significant differences in background characteristics between sports club members and non-members are highlighted in Table 1. There were more girls who had already had menarche among non-members than members (97.5 % vs 92.7 %, $p < 0.001$). The use of dietary supplements and pain killers (NSAIDs) was more frequent among sports club members. They were physically more active in their leisure time than non-members and had shorter daily screen time ((mean) 4.1 vs 5.9 h/day, $p < 0.001$).

Low back pain

The prevalence of self-reported LBP during the preceding 3 months was 35.0 % in all girls ($n = 865$) and 24.5 % in all boys ($n = 772$) ($p < 0.001$ for sex difference) girls being more likely to have frequent LBP than boys (OR 2.33 95 % CI 1.58–3.45). No differences between sports club members and non-members were found in girls for LBP (Table 2). However, the prevalence of LBP during the preceding 3 months was significantly higher in male sports club members than in non-members (28.1 % vs 18.1 %, $p < 0.02$) (Table 2).

Among boys, sports club members sought medical assistance due to their LBP significantly more often than non-members did (25.9 % vs 5.7 % respectively, $p < 0.001$). They also used significantly more NSAIDs due to LBP (Table 3). Among girls, non-members had more sleeping difficulties due to LBP compared to members (11.6 % vs 17.9 %, $p < 0.05$) (Table 3). However, LBP that radiated to the lower extremities was more common in female sports club members than in non-members (23.2 % vs 15.0 %, $p < 0.05$).

Neck and shoulder pain

The prevalence of self-reported NSP was higher in girls (52.9 %) than in boys (27.3 %) ($p < 0.001$ for sex difference). In addition, the prevalence of frequent NSP was higher in girls than in boys (19.8 % vs 5.4 %, $p < 0.001$ for sex difference). Girls were more likely to have frequent NSP than boys (OR 4.44 95 % CI 3.08–6.40). As shown in Table 4, among girls, non-members had a higher prevalence of NSP than sports club members (59.9 % vs 47.1 %, $p < 0.001$). The prevalence of frequent NSP during the preceding 3 months was higher in non-members for both girls and boys (Table 4).

Risk factors for low back pain

Adjusted odds ratios regarding health (Table 5), health behaviour (Table 6), and training characteristics (Table 7) are shown in the tables. LBP was associated with reporting neck, thoracic spine, and lower limb pain in boys and girls, and it was also associated with upper limb pain in boys. Higher screen time, as calculated per additional hour of screen time (computer games, TV/DVD, phone, Internet) during leisure time, increased the odds slightly for LBP in boys (OR 1.07, 95 % CI 1.01–1.12) and girls (OR 1.06, 95 % CI 1.01–1.10, Table 6). For girls,

Table 1 Subject characteristics by sports club participation and gender

	Boys ($n = 772$)			Girls ($n = 865$)			Total ($n = 1637$)		
Variable	Member	Non-member	*P*-value[*]	Member	Non-member	*P*-value[*]	Member	Non-member	*P*-value[*]
Age, mean (SD)	15.5(1)	15.5(0)	0.643	15.5(1)	15.5(0)	0.880	15.5(1)	15.5(1)	0.839
BMI, mean (SD)	**20.9(2)**	**21.5(4)**	**<0.05**	**20.6(2)**	**21.1(4)**	**<0.05**	**20.7(2)**	**21.3(4)**	**<0.002**
Menarche,% ($n = 882$)	-	-		**92.8 %**	**97.5 %**	**<0.001**	-	-	-
Chronic disease,[a]%	30.4 %	26.4 %	0.242	30.1 %	29.4 %	0.818	30.2 %	28.1 %	0.358
Regular medication,[b]%	23.5 %	18.6 %	0.113	29.0 %	33.2 %	0.189	26.2 %	27.1 %	0.680
NSAID use, previous month,%	**59.6 %**	**46.1 %**	**<0.001**	75.0 %	73.7 %	0.655	**67.2** %	**62.2** %	**<0.05**
Special diet,[c]%	8.0 %	5.7 %	0.245	17.2 %	18.0 %	0.754	12.5 %	12.9 %	0.804
Dietary supplements use,[d]%	**67.3** %	**36.8** %	**<0.001**	**70.1** %	**57.2** %	**<0.001**	**68.7** %	**48.7** %	**<0.001**
No Smoking, %	**94.5** %	**81.4** %	**<0.001**	**92.6** %	**73.9** %	**<0.001**	**93.6** %	**77.0** %	**<0.001**
Screen time,[e] mean (SD)	**4.6(4)**	**6.4(5)**	**<0.001**	**3.6(2)**	**5.6(5)**	**<0.001**	**4.1(3)**	**5.9(5)**	**<0.001**
Leisure time PA, [f, g] %			**<0.001**			**<0.001**			**<0.001**
Approx. <30 min/week	**0.8 %**	**15.4 %**		**0.9 %**	**18.5 %**		**0.8 %**	**17.2 %**	
Approx. 1–3 h/week	**16.3 %**	**53.9 %**		**14.9 %**	**56.9 %**		**15.6 %**	**55.6 %**	
Approx. 4–6 h/week or more	**82.9 %**	**30.7 %**		**84.2 %**	**24.6 %**		**83.5 %**	**27.2 %**	

Statistically significant findings are indicated in bold
[*] *p*-value for difference between members and non-members of sports clubs
[a] Allergy, asthma, diabetes, epilepsy, heart condition, etc.
[b] Contraceptives or other hormonal medication, allergy, asthma, insulin, epilepsy, or heart or blood pressure medication
[c] Vegetarian, low carb, lactose free, dairy free, gluten free, or other special diet
[d] For example, vitamins, protein supplements, amino acid supplements, creatine
[e] TV, computer, computer/console games, phone, tablet use
[f] Boys $n = 770$, girls $n = 863$, total $n = 1633$
[g] Intensity: breathlessness and sweating

Table 2 Prevalence of LBP in members and non-members of sports clubs

Variable	Category	Boys (*n* = 772)					Girls (*n* = 865)				
		Member		Non-member		*P*-value[*]	Member		Non-member		*P*-value[*]
		n	%	*n*	%		*n*	%	*n*	%	
Lifetime prevalence	Yes	**259**	**52.7**	**122**	**43.4**	**<0.02**	284	60.3	246	62.4	0.520
	No	**232**	**47.3**	**159**	**56.6**		187	39.7	148	37.6	
LBP[a]	Yes	**138**	**28.1**	**51**	**18.1**	**0.02**	160	34.0	143	36.3	0.475
	No	**353**	**71.9**	**230**	**81.9**		311	66.0	251	63.7	
Frequent LBP[b]	Yes	30	6.1	12	4.3	0.278	51	10.8	44	11.2	0.874
	No	461	93.9	269	95.7		420	89.2	350	88.8	
LBP during the last seven days[c]	Yes	100	38.6	39	32.0	0.209	123	43.3	110	44.7	0.745
	No	159	61.4	83	68.0		161	56.7	136	55.3	

Statistically significant results are indicated in bold
[*]*p*-value for difference between members and non-members of sports clubs
[a]LBP more than once a month
[b] LBP at least once a week
[c]Boys *n* = 381, girls *n* = 530

screen time exceeding 4 h/day increased the odds for LBP by 1.46 (95 % CI 1.08–1.95). Associations were not found between leisure-time physical activity and LBP or frequent LBP (Table 6). However, in boys, sports club membership was associated with LBP (OR 2.35, 95 % CI 1.48–3.72). Furthermore, the odds for frequent LBP was higher in male sports club members than in non-members (OR 2.73 95 % CI 1.17–6.34) (Table 6). LBP was associated with smoking in both boys and girls, and with alcohol use in boys (Table 6).

Among boys, the training hours during the training season, the number of competitions/games during the preceding 12 months increased the odds of having LBP as calculated per additional hour of training (Table 7). More rest days during the competition season decreased the odds of having LBP in boys and girls, and more rest

Table 3 Characteristics of LBP in members and non-members of sports clubs

Variables	Category	Boys (*n* = 381)					Girls (*n* = 530)				
		Member		Non-member		*P*-value[*]	Member		Non-member		*P*-value[*]
		n	%	*n*	%		*n*	%	*n*	%	
LBP that has demanded medical assistance in the previous 12 months[a]	Yes	**67**	**25.9**	**7**	**5.7**	**<0.001**	47	16.5	31	12.6	0.201
	No	**192**	**74.1**	**115**	**94.3**		237	83.5	215	87.4	
NSAID use due to LBP symptoms	Yes	**99**	**38.2**	**25**	**20.5**	**<0.002**	111	39.1	112	45.5	0.134
	No	**160**	**61.8**	**97**	**79.5**		173	60.9	134	54.5	
Sleeping difficulties due to LBP	Yes	13	5.0	7	5.7	0.769	**33**	**11.6**	**44**	**17.9**	**<0.05**
	No	246	95.0	115	94.3		**251**	**88.4**	**202**	**82.1**	
Radiating LBP[b]	Yes	57	22.0	19	15.6	0.143	**66**	**23.2**	**37**	**15.0**	**<0.02**
	No	202	78.0	103	84.4		**218**	**76.8**	**209**	**85.0**	
Operation due to your LBP	Yes	2	0.8	0	0.0	0.330	1	0.4	1	0.4	0.919
	No	257	99.2	122	100.0		283	99.6	245	99.6	
LBP origin						0.413					0.653
	Acute[c]	46	17.8	17	13.9		23	8.1	22	8.9	
	Overuse[d]	185	71.4	95	77.9		239	84.2	200	81.3	
	Both	28	10.8	10	8.2		22	7.7	24	9.8	

Statistically significant results are indicated in bold
[*]*p*-value for difference between members and non-members of sports clubs
[a] From a physician, physiotherapist, or chiropractor
[b]LBP that radiates to the lower extremities (buttocks, thigh, knee, lower leg, or foot)
[c] After injury to low back
[d] Slowly without injury

Table 4 Prevalence of NSP in members and non-members of sports clubs

Variables	Category	Boys ($n = 772$)					Girls ($n = 865$)				
		Member		Non-member		*P*-value*	Member		Non-member		*P*-value*
		n	%	*n*	%		*n*	%	*n*	%	
NSP[a]	Yes	130	26.5	81	28.8	0.481	**222**	**47.1**	**236**	**59.9**	**<0.001**
	No	361	73.5	200	71.2		**249**	**52.9**	**158**	**40.1**	
Frequent NSP[b]	Yes	**19**	**3.9**	**23**	**8.2**	**<0.02**	**67**	**14.2**	**104**	**26.4**	**<0.001**
	No	**472**	**96.1**	**258**	**91.8**		**404**	**85.8**	**290**	**73.6**	

Statistically significant results are indicated in bold
*p-value for difference between members and non-members of sports clubs
[a]NSP more than once a month
[b]NSP at least once a week

days during the training season decreased the odds of having LBP in boys.

Risk factors for neck and shoulder pain

Adjusted odds ratios of health (Table 8), health behaviour (Table 9), and training characteristics (Table 10) are shown in the tables. The odds for self-reported NSP were increased by having chronic disease(s) (OR 1.85, 95 % CI 1.23–2.80 for boys and OR 1.49, 95 % CI 1.05–2.10 for girls), and also with reporting low back, thoracic spine, and upper limb pain (Table 8).

Higher screen time, as calculated per additional hour of screen time (computer games, TV/DVD, phone, Internet) during leisure time, slightly increased the odds of NSP in boys, as presented in Table 9 (OR 1.05, 95 % CI 1.00–1.10). For girls, the increased odds were not statistically significant (also shown in Table 9). However, analysis also detected a significant increase in the odds for NSP among girls when screen time exceeded 4 h/day (OR 1.39, 95 % CI 1.05–1.85). Smoking increased the odds of NSP (OR 1.65, 95 % CI 1.04–2.59, Table 9) in girls. Sports club membership was associated with a lower risk for frequent NSP in girls (OR 0.52, 95 % CI 0.33–0.82). Associations were not found between NSP and training characteristics (Table 10) other than an additional year of active playing/practicing slightly increased the odds of NSP in girls (OR 1.07, 95 % CI 1.00–1.14).

Discussion

In this multidisciplinary multicenter study, we investigated the prevalence of self-reported low back pain and neck and shoulder pain, and the related factors in members and non-members of adolescents' sports clubs. Our findings show that self-reported low back pain (LBP) and neck and shoulder pain (NSP) are already common among adolescents. Girls seem to be at a higher risk for

Table 5 Associations between LBP and health variables in 14 to 16 year old Finnish adolescents

Variables	Category	LBP[a]				Frequent LBP[b]			
		Boys ($n = 768$)		Girls ($n = 856$)		Boys ($n = 768$)		Girls ($n = 856$)	
		OR[c]	95 % CI	OR[c]	95 % CI	OR[c]	95 % CI	OR[c]	95 % CI
Chronic diseases[d]	No	1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	Yes	0.71	(0.44–1.13)	1.36	(0.95–1.96)	0.72	(0.34–1.55)	1.38	(0.84–2.25)
BMI		1.04	(0.97–1.11)	0.96	(0.91–1.02)	1.14	(0.44–2.99)	1.01	(0.94–1.09)
Neck pain	No	1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	Yes[e]	**1.83**	(**1.13–2.96**)	**2.13**	(**1.47–3.09**)	1.65	(0.72–3.77)	1.74	(0.91–3.33)
Thoracic spine pain	No	1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	Yes[e]	**9.39**	(**5.39–16.34**)	**6.31**	(**4.15–9.59**)	**2.88**	**(1.22–6.82)**	**4.49**	(**2.61–7.74**)
Upper limb pain	No	1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	Yes[e]	**1.87**	**(1.02–3.44)**	1.41	(0.90–2.12)	0.77	(0.26–2.27)	**1.95**	(**1.12–3.40**)
Lower limb pain	No	1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	Yes[e]	**1.74**	(**1.02–2.96**)	**1.53**	(**1.03–2.27**)	1.52	(0.61–3.76)	1.42	(0.82–2.46)

Statistically significant results are indicated in bold
[a]LBP more than once a month during the last 3 months
[b]LBP at least once a week during the last 3 months
[c]Binary logistic regression was used and all variables were included in the same model. Analyses were adjusted by age, BMI, chronic diseases, smoking, school attainment level
[d]Allergy, asthma, diabetes, epilepsy, heart condition, etc.
[e]At least once a month

Table 6 Associations between LBP and health behaviour variables in 14 to 16 year old Finnish adolescents

Variables	Category	LBP[a]				Frequent LBP[b]			
		Boys ($n = 768$)		Girls ($n = 856$)		Boys ($n = 768$)		Girls ($n = 856$)	
		OR[c]	95 % CI	OR[c]	95 % CI	OR[c]	95 % CI	OR[c]	95 % CI
Screen time[d]		**1.07**	**(1.01–1.12)**	**1.06**	(**1.01–1.10**)	1.04	(0.99–1.10)	1.03	(0.99–1.09)
Leisure time PA[e]	Approx. <30 min/week	1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	Approx. 1–3 h/week	1.38	(0.58–3.29)	1.31	(0.74–2.31)	2.04	(0.40–10.27)	0.79	(0.35–1.79)
	Approx.4-6 h/week or more	1.56	(0.63–3.82)	1.75	(0.95–3.23)	1.11	(0.20–6.10)	1.20	(0.50–2.85)
Sports club membership	No	1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	Yes	**2.35**	(**1.48–3.72)**	0.97	(0.67–1.42)	**2.73**	**(1.17–6.34)**	0.99	(0.56–1.76)
Use of alcohol	<1x month	1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	1 x month	1.15	(0.59–2.22)	1.40	(0.77–2.55)	1.39	(0.45–4.29)	1.63	(0.76–3.50)
	≥2–3 x month	**2.25**	**(1.04–4.90)**	1.17	(0.61–2.25)	2.73	(0.87–8.60)	0.57	(0.19–1.75)
Smoking	No	1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	Yes	**2.32**	(**1.29–4.19)**	**1.96**	(**1.26–3.04**)	1.42	(0.53–3.78)	1.46	(0.78–2.76)

Statistically significant results are indicated in bold
[a]LBP more than once a month during the last 3 months
[b]LBP at least once a week during the last 3 months
[c]Binary logistic regression was used and all variables were included in the same model. Analyses were adjusted by age, BMI, chronic diseases, smoking, school attainment level
[d]TV, computer, computer/console games, phone, tablet use, OR calculated per additional hour of screen time
[e] Intensity: breathlessness and sweating

reporting LBP and NSP. Our results also suggest that the prevalence of LBP is higher in boys who participate in organized sports club activities. On the other hand, sports club members seem to suffer NSP less frequently than non-members do in general.

The strength of this study was the representative sample of adolescents, who were aged 14–16 years and from different regions and sizes of municipality. The sports club sample comprised the ten most popular sports in Finland. Organized sports clubs are the main setting for leisure-time physical activity in adolescents, especially in the Nordic countries. In Finland, nearly half (46 %) of children and adolescents aged 10–16 years take part in organized sports club activities [22]. Due to their wide reach and the informal educational nature, sports clubs offer a potential setting for health promotion [23]. However, even though sports clubs are positively oriented towards the idea of health promotion, the clubs' practices have been shown to be limited and directed mainly towards sports performance and less towards other areas of health [24].

It is a common belief that those who participate in sports club activities automatically have a more physically active and healthy lifestyle than non-members. Research findings on these issues are, however, inconsistent. Three quarters of the general population of Finnish children and adolescents aged 11–15 [22, 25] and one third of sports club members in the Nordic countries do not meet the recommended level of physical activity [26–28]. In the present study, sports club members were significantly more active than non-members; nevertheless, 16 % of the members reported only approximately 1–3 h of leisure time activity per week.

We found a 49.5 % lifetime prevalence of self-reported LBP in boys, and the same prevalence for girls was 61.3 %,

Table 7 Associations between LBP and training characteristics in 14 to 16 year old sports club members

Training Characteristics	Boys		Girls	
	OR[a]	95 % CI	OR[a]	95 % CI
Active playing/practicing years (boys $n = 488$, girls $n = 465$)	1.05	(0.97–1.13)	1.07	(1.00–1.14)
Training hours per week during training season (boys $n = 486$, girls $n = 463$)	**1.05**	**(1.01–1.09)**	1.01	(0.96–1.05)
Training hours per week during competition season (boys $n = 482$, girls $n = 448$)	1.03	(0.99–1.08)	1.03	(0.99–1.08)
Number of competitions/games during previous 12 months (boys $n = 485$, girls $n = 462$)	**1.01**	**(1.00–1.02)**	1.00	(0.98–1.01)
Number of rest days during training season (boys $n = 483$, girls $n = 461$)	**0.78**	**(0.65–0.94)**	0.96	(0.83–1.11)
Number of rest days during competition season (boys $n = 480$, girls $n = 459$)	**0.79**	**(0.66–0.94)**	**0.84**	**(0.72–1.00)**

Statistically significant results are indicated in bold
[a]All training variables analysed in separate models. Adjusted by age, BMI, chronic diseases, smoking, school attainment level

Table 8 Associations between NSP and health variables in 14 to 16 year old Finnish adolescents

Variables	Category	NSP[a]				Frequent NSP[b]			
		Boys ($n = 768$)		Girls ($n = 856$)		Boys ($n = 768$)		Girls ($n = 856$)	
		OR[c]	95 % CI	OR[c]	95 % CI	OR[c]	95 % CI	OR[c]	95 % CI
Chronic diseases[d]	No	1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	Yes	**1.85**	**(1.23–2.80)**	**1.49**	**(1.05–2.10)**	1.00	(0.46–2.18)	1.21	(0.81–1.79)
BMI		1.03	(0.97–1.10)	1.03	(0.97–1.08)	1.02	(0.91–1.15)	**1.07**	**(1.01–1.13)**
Low back pain	No	1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	Yes[e]	**1.88**	**(1.16–3.03)**	**2.15**	**(1.48–3.11)**	1.84	(0.73–4.66)	**1.88**	**(1.22–2.91)**
Thoracic spine pain	No	1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	Yes[e]	**3.53**	**(1.97–6.33)**	**4.87**	**(2.92–8.11)**	**4.91**	**(1.94–12.42)**	**3.87**	**(2.48–6.06)**
Upper limb pain	No	1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	Yes[e]	**6.47**	**(3.73–11.23)**	**4.00**	**(2.39–6.61)**	1.00	(0.35–2.88)	**1.94**	**(1.21–3.10)**
Lower limb pain	No	1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	Yes[e]	1.39	(0.83–2.33)	1.44	(0.98–2.12)	0.65	(0.23–1.88)	1.07	(0.68–1.68)

Statistically significant results are indicated in bold
[a]NSP more than once a month during the last 3 months
[b]NSP at least once a week during the last 3 months
[c]Binary logistic regression was used and all variables were included in the same model. Analyses were adjusted by age, BMI, chronic diseases, smoking, school attainment level
[d]Allergy, asthma, diabetes, epilepsy, heart condition, etc.
[e]At least once a month

which is in line with the findings of Harreby at al. [29], who investigated the risk factors of LBP in a cohort of 1389 Danish children aged 12–16 years (49.8 % in boys and 67.4 % in girls) and had similar definition of LBP as our study. Van Gent et al. [30] reported 3-month prevalence of LBP in adolescents aged 12–14 years ($n = 745$) as 53.8 % for girls and 39.4 % for boys. In the present study, the prevalence of frequent LBP was in line with the results of severe LBP in the study Van Gent et al. [30] (11.0 % vs 9.5 % in girls and 5.4 % vs 4.5 % in boys, respectively). Van Gent et al. [30] defined LBP complaints severe if they bothered the children daily, demanded medication use or affected normal functioning, which is somewhat different than in our study. In our study LBP was defined as"ache or pain in the low back" and frequent LBP was reported to occur at least once a week.

Table 9 Associations between NSP and health behaviour variables in 14 to 16 year old Finnish adolescents

Variables	Category	NSP[a]				Frequent NSP[b]			
		Boys ($n = 768$)		Girls ($n = 856$)		Boys ($n = 768$)		Girls ($n = 856$)	
		OR[c]	95 % CI	OR[c]	95 % CI	OR[c]	95 % CI	OR[c]	95 % CI
Screen time[d]		**1.05**	**(1.00–1.10)**	1.03	(0.98–1.07)	1.03	(0.98–1.09)	1.02	(0.98–1.06)
Leisure time PA[e]	Approx. <30 min/week	1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	Approx. 1–3 h/week	0.81	(0.40–1.65)	1.37	(0.80–2.33)	1.94	(0.53–7.11)	1.29	(0.69–2.39)
	Approx. 4–6 h/week or more	0.79	(0.37–1.66)	1.07	(0.60–1.90)	1.27	(0.31–5.15)	1.23	(0.62–2.41)
Sports club membership	No	1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	Yes	1.09	(0.72–1.65)	0.76	(0.53–1.10)	0.64	(0.30–1.37)	**0.52**	**(0.33–0.82)**
Use of alcohol	<1 x month	1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	1 x month	1.70	(0.91–3.17)	1.84	(0.97–3.49)	1.46	(0.47–4.54)	1.34	(0.68–2.62)
	≥2–3 x month	**2.75**	**(1.29–5.83)**	1.52	(0.77–2.99)	2.73	(0.92–8.09)	0.96	(0.45–2.06)
Smoking	No	1 (referent)		1 (referent)		1 (referent)		1 (referent)	
	Yes	1.36	(0.76–2.43)	**1.65**	**(1.04–2.59)**	1.56	(0.61–3.98)	1.42	(0.87–2.32)

Statistically significant results are indicated in bold
[a]NSP more than once a month during the last 3 months
[b]NSP at least once a week during the last 3 months
[c]Binary logistic regression was used and all variables were included in the same model. Analyses were adjusted by age, BMI, chronic diseases, smoking, school attainment level
[d]TV, computer, computer/console games, phone, tablet use, OR calculated per additional hour of screen time
[e]Intensity: breathlessness and sweating

Table 10 Associations between NSP and training characteristics in 14 to 16 year old sports club members

Training Characteristics	Boys		Girls	
	OR[a]	95 % CI	OR[a]	95 % CI
Active playing/practicing years (boys *n* = 488, girls *n* = 465)	0.94	(0.87–1.01)	**1.07**	**(1.00–1.14)**
Training hours per week during training season (boys *n* = 486, girls *n* = 463)	1.00	(0.96–1.04)	0.98	(0.94–1.02)
Training hours per week during competition season (boys *n* = 482, girls *n* = 448)	0.98	(0.93–1.02)	1.00	(0.96–1.04)
Number of competitions/games during previous 12 months (boys *n* = 485, girls *n* = 462)	1.00	(0.99–1.00)	1.00	(0.99–1.01)
Number of rest days during training season (boys *n* = 483, girls *n* = 461)	1.10	(0.92–1.30)	1.05	(0.91–1.21)
Number of rest days during competition season (boys *n* = 480, girls *n* = 459)	1.15	(0.96–1.37)	0.96	(0.83–1.10)

Statistically significant results are indicated in bold
[a]All training variables analysed in separate models. Adjusted by age, BMI, chronic diseases, smoking, school attainment level

Van Gent et al. [30] reported that among 12–14-years-old, the prevalence of severe NSP is 6.5 % for girls and 5.0 % for boys. Diepenmaat et al. [13] reported that among 12–16-year-olds, the prevalence of frequent NSP (more than 4 days a month) is 14.2 % for girls and 8.7 % for boys. Myrtveit et al. [31] reported that among 18-year-olds, weekly NSP was suffered by 28 % of girls and 11 % of boys. Similarly, Ståhl et al. [4] found a 19 % prevalence of weekly neck pain among of 13–16-year-old boys and girls. Our findings on the prevalence of frequent NSP are in line with these previous findings. However, the prevalence of NSP in girls was higher in our sample compared to previous studies [13, 30].

It has been suggested that the relationship between LBP and physical activity is U-shaped [32]. Some studies have found that as the intensity or amount of physical activity increases, so does the risk of LBP in the adolescents [7, 10, 12, 33]. Some studies have not been able to find an association between physical activity and LBP [13, 14, 30, 34] or the development of neck and upper limb/shoulder pain [13, 35–38]. In a recent prospective population-based cohort study among 19–21-year-old men, moderate physical activity and a good fitness level were found to protect the subjects from LBP [39]. Physical activity has been reported to be associated with a reduced risk for NSP [31]. Wedderkopp and et al. [36] did not notice significant increases in the odds of neck pain when they compared physical activity (low, mid, high) measured objectively with an accelerometer in 9-year-old children. However, they noticed that 9-year-old children with the lowest levels of physical activity were four times more likely to have low back pain 3 years later than the children with the highest levels of physical activity [36].

Mogensen et al. [34] investigated the difference of the 1-month prevalence of low back pain and neck pain in adolescents (12–13-years-old) participating in sports and those who did not take part in any sport. They found no difference between the groups for LBP (40 % vs 39 %) or neck pain (13 % vs 11 %). Even though we did not find statistically significant associations between self-reported leisure-time physical activity and LBP or NSP in the present study, we did find a significantly higher prevalence of LBP in male sports club members and a higher prevalence of NSP in non-members in general. According to a prospective study, athletes participating in sports club activities at least twice a week reported significantly more LBP than non-athletes (*n* = 116, age range 10.3–13.3) [40]. The higher prevalence of LBP in boys who are sports club members might be due to the higher volume and intensity of exercise. The increased prevalence of LBP in male sports club members might be due to insufficient recovery, as suggested by our finding on the association between LBP and the number of rest days.

In the present study, the majority of the subjects – both members and non-members – reported the origin of LBP to be overuse, and the results are in line with previous reports within athletic and general populations [11, 40–43]. In addition, previous results [4, 44] on concomitant pain being more common than single LBP or single NSP are supported by our findings.

With regard to gender, our results are in line with previous results. In general, girls are at a higher risk for developing LBP [2, 3, 9, 29] and NSP [2–4, 9, 30, 31]. However, the recent meta-analysis of LBP in children and adolescents by Calvo-Muñoz et al. [5] and the study by Schmidt et al. [45] – who studied the prevalence of LBP in adolescent athletes – found no association between gender and LBP. We found that the girls' odds of having frequent LBP and frequent NSP were 2.33- (95 % CI 1.58–3.45) and 4.45-times (95 % CI 3.08–6.40) higher than the boys' odds.

Interestingly our results showed a trend towards self-reported LBP being more common in non-members in girls, contrary what was seen among the boys. This might simply be a consequence of boys participating more frequently in sports with higher spinal loads (flexion and rotation), such as ice hockey and football. We found higher prevalence of frequent NSP in non-members. In relation to previous studies that have found frequent computer-related activities to increase the risk of NSP and LBP in adolescents [2] it could be speculated that the increased prevalence in the present study may be at least partly associated with the higher screen time reported by the non-members. On the other hand, NSP has also been associated with depressive symptoms and stress in a study where computer use was not found to be significantly associated with NSP or LBP [13].

It could be expected that when the amount of rest and recovery time decreases, the incidence in overuse injuries in particular increases. High frequency of training and lack of rest days are possible risk factors that sports clubs can control and thus modify the predisposing factors for injuries. In this study, no significant associations between training exposure hours per week and LBP were found in girls, which is in accordance with findings of the study by Tunas et al. [11]. However, we found a negative association between LBP and rest days and a positive association between LBP and number of competitions, and training hours in males. The number of rest days was also associated with LBP in girls, the association being negative. Schmidt et al. [45] found a statistically significant trend towards an increased prevalence of LBP in those athletes who were training the most. Ristolainen et al. [46] found that elite athletes (aged 15–35) with less than two rest days per week during the training season were more than five times more likely to report an overuse injury (95 % CI 1.89–14.06, $P = 0.001$). It is therefore important at the sports club-level to tackle the challenge of how to minimize the possibility of overload and to decrease the incidence of overuse injuries.

There are some limitations in the present study that must be acknowledged. Due to the cross-sectional design of the study, one must be cautious in drawing conclusions, especially concerning causality –that is, to differentiate the associated factors as predisposing factors or simply consequences. For example, pain may have affected training frequency or duration and influenced the physical activity or inactivity of the study subjects. In addition, there is a possible recall bias as with retrospective designs, the ability of the subject to remember and report the information correctly is a potential issue. The validity of the surveys was not studied; however, the questionnaires used in these surveys were compiled from previously validated questions in other similar studies of school-aged adolescents [16–20].

Also psychosocial factors have been shown to be associated with LBP and NSP in adolescents [44, 47]. The lacking of these variables as potential confounders could have influenced the results of this study as screen time has been shown to be associated with symptoms of depression and anxiety in adolescent [48].

Conclusions

Self-reported low back pain and neck and shoulder pain are common among 14–16-year-olds. The prevalence of LBP was higher in male sports club members and the prevalence of NSP was higher among non-members in general. It also seems that higher screen time is weakly associated with musculoskeletal symptoms of the back, neck, and shoulder regions among adolescents.

Additional file

Additional file 1: HPSC Health behaviour survey. (PDF 197 kb)

Additional file 2: HPSC MSK survey. (PDF 254 kb)

Abbreviations
LBP, low back pain; NSP, neck and shoulder pain

Acknowledgements
Not applicable.

Funding
This study was financially supported by the Finnish Ministry of Education and Culture. (grant number: 6/091/2011).

Availability of data and materials
The data can not be shared because permission was not asked from the participants or their parents.

Authors' contributions
All authors contributed to study conception and design. SK and JP coordinated and managed all parts of the study. MR carried out the literature search. SK and JV conducted data collection and performed preliminary data preparations. MR and JV conducted data analyses and all the authors contributed to the interpretation of data. MR and JP wrote the first draft of the paper and all authors provided substantive feedback on the paper and contributed to the final manuscript. All authors have approved the submitted version of the manuscript. JP is the guarantor.

Authors' information
Not applicable.

Competing interests
All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare that all authors had: (1) no financial support for the submitted work from anyone other than their employer; (2) no financial relationships with commercial entities that might have an interest in the submitted work; (3) no spouses, partners, or children with relationships with commercial entities that might have an interest in the submitted work; and (4) no non-financial interests that may be relevant to the submitted work.

Consent for publication
Not applicable.

Ethics approval and consent to participate
Ethical approval was received from the Ethics Committee of Health Care District of Central Finland (record number 23U/2012). All sports clubs participated in the study by free will and were notified that they had a right to refuse to participate and withdraw from the study at any time. A written consent was obtained as required by the ethical statement.

Author details
[1]Tampere Research Center of Sports Medicine, P.O. Box 30FI-33501 Tampere, Finland. [2]Clinic for Sports and Exercise Medicine, Alppikatu 2, FI-00530 Helsinki, Finland. [3]Paavo Nurmi Centre & Department of Health and Physical Activity, University of Turku, Kiinamyllynkatu 10, FI-20520 Turku, Finland. [4]Department of Sports and Exercise Clinic, Oulu Deaconess Institute, Albertinkatu 18, FI-90100 Oulu, Finland. [5]Department of Health Sciences, University of Jyväskylä, P.O. Box 35FI-40014 Jyväskylä, Finland. [6]Kuopio Research Institute of Exercise Medicine, Haapaniementie 16, FI-70100 Kuopio, Finland. [7]LIKES Foundation for Sports and Health Sciences and Mehiläinen

Physical Activity Clinic, P.O. Box 35FI-40720 Jyväskylä, Finland. [8]UKK Institute for Health Promotion Research, P.O. Box 30FI-33501 Tampere, Finland. [9]University of Oulu, Center for Life Course Health Research, Oulu, Finland. [10]Medical Research Center, University of Oulu and University Hospital of Oulu, Oulu, Finland.

Received: 7 January 2016 Accepted: 2 June 2016
Published online: 01 July 2016

References

1. Statistical yearbook of the social insurance institution 2013. Kansaneläkelaitos - The Social Insurance Institution of Finland. 2015. http://www.kela.fi/documents/10180/1630875/Statistical_Yearbook_of_the_Social_Insurance_Institution_2013.pdf/0578574a-2b93-4ca5-ac0f-650f12d15141. Accessed 2 Aug 2015.
2. Hakala P, Rimpelä A, Salminen JJ, Virtanen SM, Rimpelä M. Back, neck, and shoulder pain in Finnish adolescents: national cross sectional surveys. Brit Med J. 2002;325:743–5.
3. Hakala PT, Rimpelä AH, Saarni LA, Salminen JJ. 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.
4. Ståhl M, MIkkelson M, Kautianen H, Häkkinen A, Ylinen J, Salminen JJ. Neck pain in adolescence. A 4-year follow-up of pain-free preadolescents. Pain. 2004;110:427–31.
5. Calvo-Muñoz I, Gomez-Conesa A, Sanchez-Meca J. Prevalence of low back pain in children and adolescents: A meta-analysis. BMC Pediatr. 2013;13:14.
6. Taimela S, Kujala UM, Salminen JJ, Viljanen T. The prevalence of low back pain among children and adolescents. A nationwide, cohort-based questionnaire survey in Finland. Spine. 1997;22:1132–6.
7. Auvinen J, Tammelin T, Taimela S, Zitting P, Karppinen J. Associations of physical activity and inactivity with low back pain in adolescents. Scand J Med Sci Sports. 2008;18(2):188–94.
8. Hestbaek LDC, Leboeuf-Yde CDC, Kyvik KO, Manniche CDMS. The course of low back pain from adolescence to adulthood: Eight-year follow-up of 9600 twins. Spine. 2006;31(4):468–72.
9. Ståhl M, El-Metwally A, Rimpelä A. Time trends in single versus concomitant neck and back pain in finnish adolescents: results from national cross-sectional surveys from 1991 to 2011. BMC Musculoskelet Disord. 2014;15:296.
10. Hoskins W, Pollard H, Daff C, et al. Low back pain in junior Australian rules football: A cross-sectional survey of elite juniors, non- elite juniors and non-football playing controls. BMC Musculoskelet Disord. 2010;11:241.
11. Tunas P, Nilstad A, Myklebust G. Low back pain in female elite football and handball players compared with an active control group. Knee Surg Sports Traumatol Arthrosc. 2014 May 18. [Epub ahead of print]
12. Sato T, Ito T, Hirano T, et al. Low back pain in childhood and adolescence: Assessment of sports activities. Eur Spine J. 2011;20(1):94–9.
13. Diepenmaat ACM, van der Wal MF, de Vet HCW, Hirasing RA. Neck/shoulder, low back, and arm pain in relation to computer use, physical activity, stress, and depression among Dutch adolescents. Pediatrics. 2006;117:412–6.
14. Wedderkopp N, Leboeuf-Yde C, Bo Andersen L, Froberg C, Steen HH. Back Pain in Children, No Association with Objectively Measured Level of Physical Activity. Spine. 2003;28(17):2019–24.
15. Kokko S, Selänne H, Alanko L, Heinonen O, Korpelainen R, Savonen K, et al. Health promotion activities of sports clubs and coaches, and health and health behaviours in youth participating in sports clubs: the Health Promoting Sports Club study. BMJ Open Sport Exerc Med. 2015;1:e000034.
16. Currie C, Aleman-Diaz A. Building knowledge on adolescent health: reflections on the contribution of the Health Behaviour in School-aged Children (HBSC) study. Eur J Pub Health. 2015;25(Supp 2):4–6.
17. Alaranta A. Medication use in Elite Athletes. University of Helsinki. Yliopistopaino: Helsinki. 2006.
18. Kokko S. Health Promoting Sports Club – Youth Sports Clubs' Health Promotion Profiles, Guidance, and Associated Coaching Practice, in Finland. University of Jyväskylä, Studies in Sport, Physical Activity and Health 144. 2010.
19. Kokko S, Kannas L, Villberg J, Ormshaw M. Health promotion guidance activity of youth sports clubs. Health Education. 2011a; 111:452-63.
20. Pasanen K, Parkkari J, Pasanen M, Hiilloskorpi H, Mäkinen T, Järvinen M, Kannus P. Neuromuscular training and the risk of leg injuries in female floorball players: cluster randomised controlled study. BMJ. 2008;337:96–102.
21. Kuorinka I, Jonsson B, Kilbom A, Vinterberg H, Biering-Sørensen F, Andersson G, et al. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. App Ergonomics. 1987;18:233–7.
22. Aira, T, Kannas, L, Tynjälä, J, Villberg, J, Kokko, S. Liikunta-aktiivisuuden väheneminen murrosiässä. Drop off-ilmiön aikatrendejä ja kansainvälistä vertailua WHO-Koululaistutkimuksen (HBSC-Study) aineistoilla 1986-2010. Miksi murrosikäinen luopuu liikunnasta? Valtion liikuntaneuvoston julkaisuja 3. [Diminishing Physical Activity in Adolescence. The Time Trends and International Comparisons of the Drop-off Phenomena in the 1986-2010 Data of Health Behavior in School-aged Children Study. In the publication Why adolescents give up on physical activity? Publications of State Council of Sport 3.] 2013. 2013, 12-29.
23. Kokko S. Sports clubs as settings for health promotion: Fundamentals and an overview to research. Scand J Public Healt. 2014; 42 Suppl 15: 60-65.
24. Kokko S, Kannas L, Villberg J. Health promotion profile of youth sports clubs in Finland: club officials' and coaches' perceptions. Health Promot. Int. 2009; 24:26-35.
25. Liukkonen J, Jaakkola T, Kokko S, Gråstén A, Yli-Piipari S, Koski P, et al. Results from Finland's 2014 Report Card on Physical Activity for Children and Youth. J Phys Act Health. 2014;11(Supp. 1):51–7.
26. Hakkarainen H, Härkönen A, Niemi-Nikkola K, Mäenpää P, Potinkara P, Kujala A et al. (eds.) Selvitysraportti – Urheilevien lasten ja nuorten fyysis-motorinen harjoittelu. Nuori Suomi ry, Suomen Olympiakomitea ry, Suomen Valmentajat ry. [Report – The physio-motor training of children and adolescents. The Young Finland assoc., The Finnish Olympic Committee, The Coaching assoc. Finland]. Helsinki: SLU-paino. 2008.
27. Eiosdottir SP, Kristjansson AL, Sigfusdottir ID, Allegrante JP. Trends in physical activity and participation in sports clubs among Icelandic adolescents. Eur J Public Health. 2008;18:289–93.
28. Kokko S, Villberg J, Kannas L. Nuori urheilijan polulla – 13 - 15 -vuotiaiden urheilijoiden arvioita harjoitus-määristään, harjoittelun monipuolisuudesta sekä elämäntavoista. Nuoren Suomen julkaisuja. [Youth on the athlete track – the evaluation of 13 to 15 years old athletes on their training volume, versatility and lifestyle. Publication of the Young Finland Association.] 2011c.
29. Harreby M, Nygaard B, Jessen T, et al. Risk factors for low back pain in a cohort of 1389 Danish school children: An epidemiologic study. Eur Spine J. 1999;8(6):444–50.
30. Van Gent C, Dols JJ, de Rover CM, Hira Sing RA, de Vet HC. The weight of schoolbags and the occurrence of neck, shoulder, and back pain in young adolescents. Spine (Phila Pa 1976). 2003;28(9):916–21.
31. Myrtveit SM, Sivertsen B, Skogen JC, Frostholm L, Stormark KM, Hysing M. Adolescent Neck and Shoulder Pain The Association With Depression, Physical Activity, Screen-Based Activities, and Use of Health Care Services. J Adolesc Health. 2014;55:366–72.
32. Jones MA, Stratton G, Reilly T, Unnithan VB. A school-based survey of recurrent non-specific low-back pain prevalence and consequences in children. Health Educ Res. 2004;19(3):284–9.
33. Hangai M, Kaneoka K, Okubo YPT, et al. Relationship between low back pain and competitive sports activities during youth. Am J Sports Med. 2010;38(4):791–6.
34. Mogensen AM, Gausel AM, Wedderkopp N, Kjaer P, Leboeuf-Yde C. Is active participation in specific sport activities linked with back pain? Scand J Med Sci Sports. 2007;17(6):680–6.
35. Ehrmann Feldman D, Shrier I, Rossignol M, Abenhaim L. Risk Factors for the Development of Neck and Upper Limb Pain in Adolescents. Spine. 2002;27:523–8.
36. Wedderkopp N, Kjaer P, Hestbaek L, Korsholm L, Leboeuf-Yde C. High-level physical activity in childhood seems to protect against low back pain in early adolescence. Spine J. 2009;9:134–41.
37. Østerås N, Ljunggren AE, Gould KS, Wærsted M, Veiersted KB. Muscle pain, physical activity, self-efficacy and relaxation ability in adolescents. Adv Physiother. 2006;8:33–40.
38. Mikkelsson LO, Nupponen H, Kaprio J, Kautiainen H, Mikkelsson M, Kujala UM. Adolescent flexibility, endurance strength, and physical activity as predictors of adult tension neck, low back pain, and knee injury: a 25 year follow up study. Br J Sports Med. 2006;40:107–13.
39. Taanila HP, Suni JH, Pihlajamaki HK, et al. Predictors of low back pain in physically active conscripts with special emphasis on muscular fitness. Spine J. 2012;12(9):737–48.
40. Kujala UM, Taimela S, Erkintalo M, Salminen JJ, Kaprio J. Low-back pain in adolescent athletes. Med Sci Sports Exerc. 1996;28:165–70.
41. Haydt R, Pheasant S, Lawrence K. The incidence of low back pain in NCAA division iii female field hockey players. Int J Sports Phys Ther. 2012;7(3):296–305.

42. Verhagen EALM, Van der Beek AJ, Bouter LM, Bahr RM, Mechelen WV. A one season prospective cohort study of volleyball injuries. Br J Sports Med. 2004;38(4):477–81.
43. Pasanen K, Rossi M, Parkkari J, Kannus P, Heinonen A, Tokola K, Myklebust G. Low back pain in young basketball and floorball players: a retrospective study. Clin J Sports Med. 2015;0:1–5.
44. Vikat A, Rimpelä M, Salminen JJ, Rimpelä A, Savolainen A, Virtanen SM. Neck or shoulder pain and low back pain in Finnish adolescents. Scand J Public Health. 2000;28(3):164–73.
45. Schmidt CP, Zwingenberger S, Walther A, Reuter U, Kasten P, Seifert J, Günther KP, Stiehler M. Prevalence of Low Back Pain in Adolescent Athletes – an Epidemiological Investigation. Int J Sports Med. 2014;35(8):684–9.
46. Ristolainen L, Kettunen JA, Waller B, Heinonen A, Kujala UM. Training-related risk factors in the etiology of overuse injuries in endurance sports. J Sports Med Phys Fitness. 2014;54(1):78–87.
47. Watson KD, Papageorgiou AC, Jones GT, Taylor S, Symmons DP, Silman AJ, Macfarlane GJ. Low back pain in schoolchildren: the role of mechanical and psychosocial factors. Arch Dis Child. 2003;88(1):12–7.
48. Maras D, Flament M, Murray M, Buchholz A, Henderson K, Obeid N, Goldfield G. Screen time is associated with depression and anxiety in Canadian youth. Prev Med. 2015;73:133–8.

Submit your next manuscript to BioMed Central and we will help you at every step:

- We accept pre-submission inquiries
- Our selector tool helps you to find the most relevant journal
- We provide round the clock customer support
- Convenient online submission
- Thorough peer review
- Inclusion in PubMed and all major indexing services
- Maximum visibility for your research

Submit your manuscript at
www.biomedcentral.com/submit

BioMed Central

II

LOW BACK PAIN IN YOUNG BASKETBALL AND FLOORBALL PLAYERS: A RETROSPECTIVE STUDY

by

Pasanen Kati, Rossi Marleena, Parkkari Jari, Kannus Pekka, Heinonen Ari, Tokola Kari, Myklebust Grethe 2015

Clinical Journal of Sports Medicine vol 26:376–80

https://doi.org/10.1097/JSM.0000000000000263

Reproduced with kind permission by Wolters Kluwer.

III

INCIDENCE AND RISK FACTORS FOR BACK PAIN IN YOUNG FLOORBALL AND BASKETBALL PLAYERS: A PROSPECTIVE STUDY

by

Rossi Marleena K, Pasanen Kati, Heinonen Ari, Myklebust Grethe,
Kannus Pekka, Kujala Urho M, Tokola Kari, Parkkari Jari 2018

Scandinavian Journal of Medicine & Science in Sports vol 28:2407–2415

https://doi.org/10.1111/sms.13237

Reproduced with kind permission by Wiley.

Accepted: 4 June 2018
DOI: 10.1111/sms.13237

ORIGINAL ARTICLE

WILEY

Incidence and risk factors for back pain in young floorball and basketball players: A Prospective study

M. K. Rossi[1,2] | K. Pasanen[1,3,4] | A. Heinonen[2] | G. Myklebust[5] | P. Kannus[6] | U. M. Kujala[2] | K. Tokola[1] | J. Parkkari[1,3]

[1]Tampere Research Center of Sports Medicine, Tampere, Finland
[2]Faculty of Sport and Health Sciences, University of Jyväskylä, Jyväskylä, Finland
[3]UKK Institute for Health Promotion Research, Tampere, Finland
[4]Faculty of Kinesiology, Sport Injury Prevention Research Centre, University of Calgary, Calgary, Canada
[5]Department of Sports Sciences, Oslo Sports Trauma Research Center, Norwegian School of Sport Sciences, Oslo, Norway
[6]Injury and Osteoporosis Research Center, UKK Institute, Tampere, Finland

Correspondence
Marleena Rossi, Tampere Research Center of Sports Medicine, Tampere, Finland.
Email: marleena.rossi@gmail.com

Funding information
The Finnish Ministry of Education and Culture; Competitive State Research Financing of the Expert Responsibility Area of Tampere University Hospital, Grant/Award Number: 9N053, 9S047, 9T046, 9U044

The aim of this study was to investigate the incidence of back pain in young basketball and floorball players under 21 years of age. The secondary aim was to examine risk factors especially for low back pain (LBP). Nine basketball and nine floorball teams (n = 396) participated in this prospective follow-up study (2011-2014). Young athletes (mean age 15.8 ± 1.9) performed physical tests and completed a questionnaire at baseline. The follow-up lasted 1-3 years per player. During the follow-up, back pain reported by the players was registered on a weekly basis and verified by a study physician. The exposure time (AE) on team practices and games was recorded by the coach. Altogether back pain was reported 61 times by 51 players. The incidence of back pain was 87 per 1000 athlete-years and 0.4 per 1000 hours of AE. Hamstrings, quadriceps and iliopsoas extensibility and general joint hypermobility were not associated with LBP. Furthermore, no association between LBP and leg extension strength or isometric hip abduction strength asymmetry was found in these young basketball and floorball players. In conclusion, back pain can lead to a considerable time-loss from training and competition among young basketball and floorball players and the pain tends to reoccur. Lower extremity muscle extensibility, general joint hypermobility or investigated lower extremity strength measures were not associated with the risk of LBP.

KEYWORDS
back injury, spinal pain, sports injury, team sports, Youth athlete

1 | INTRODUCTION

Lifetime occurrence of back pain has been reported to range between 47% and 90% in the adult athlete population and most frequently pain occurs in the low back.[1] Back pain, especially in the low back (LBP), is also common in the young athlete population.[2-4] For example, Van Hilst et al[3] reported 33%-64% annual prevalence in field hockey, 64% in football and Schmidt et al.[4] A total of 57% in athletes participating in various sports.

In Finland, half of all children and adolescents take part in organized sports club activities, floorball and basketball being among the most popular sports.[5] Basketball has approximately 450 million players around the world.[6] Floorball, also called innebandy, indoor bandy, and unihockey, is a popular sport in Scandinavia and some European countries such as the Czech Republic and Switzerland. Floorball, has nearly 310 000 licenced players and the number is still growing.[7] Both sports include sprinting; sudden turns, stops, and landings; and dual tasking in terms of handling a ball while moving. In addition, both sports include rotational movements and asymmetrical manoeuvers. Furthermore, the stance is similar, with the knees and hips being bent. In floorball, the playing position also often includes trunk flexion and rotation and asymmetrical positions due to the use of a stick. According to our previous report,

 © 2018 John Wiley & Sons A/S. Published by John Wiley & Sons Ltd

annual prevalence of LBP in young basketball and floorball players ranges from 44% up to 62%.[8]

Back pain, especially LBP, has long-term consequences.[9] It is also known to be associated with other musculo-skeletal complaints[10] and neuromuscular impairments in the low back and pelvic area.[11] It is not entirely clear whether these impairments are the cause or the effect of LBP. Nevertheless, these impairments have been reported to predispose athletes to lower extremity injuries.[12] A history of back pain has also been reported to decrease performance[13] and a previous back injury is reported to be associated with new changes seen in imagining studies in the lower back in young athletes.[14]

To our knowledge, prospective studies investigating the incidence and risk factors for back pain in young athletes under 21 years of age are limited. To develop effective preventive methods, the magnitude and causes behind the problem need to be established.[15] Therefore, the primary aim of this study was to investigate the incidence of back pain among young floorball and basketball players in Finland. The secondary aim was to explore possible risk factors for low back pain (LBP) and especially for non-traumatic LBP.

2 | MATERIALS AND METHODS

2.1 | Design and participants

This study is part of the large PROFITS-study (Predictors of Lower Extremity Injuries in Team Sports) carried out in Finland between 2011 and 2015. More detailed information on the PROFITS- study is described elsewhere.[16] Briefly, from the Tampere City district in Finland, 10 basketball and 10 floorball teams were invited from six sports clubs. Nine basketball teams and nine floorball teams agreed to participate. The flow diagram of teams and players can be seen in Figure 1. Altogether, 396 young basketball and floorball players took part (mean age 15.8 ± 1.9 years.). The baseline characteristics of the subjects are presented in Table 1 and S1. The players entered the study in the April-May of 2011, 2012 or 2013 (Figure S1). A total of 261 players were observed prospectively for one study year, 80 for two study years and 55 for three study years. A total of 586 athlete-years and 134 849 training and game hours (athlete exposure; AE) were recorded during the follow-up (2011-2014).

2.2 | Baseline questionnaire and tests

At baseline, the players performed physical tests and completed a baseline questionnaire at the UKK Institute, Tampere, Finland. The baseline questionnaire covered the following demographics: age, sex, dominant leg, diet, alcohol and nicotine use, menstrual history, chronic illnesses, medication use, family history of musculo-skeletal

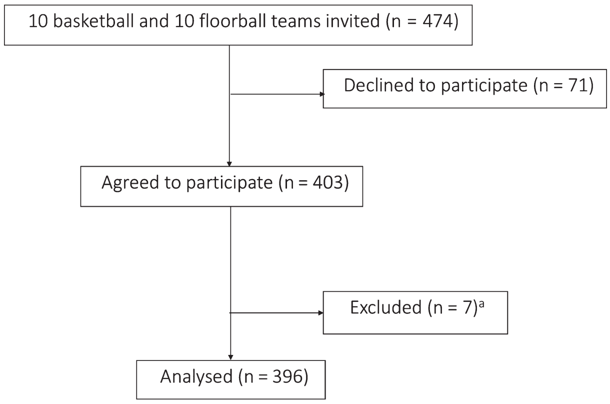

FIGURE 1 Flow of players in the study ([a]Excluded due to not being official members of the team)

disorders, playing years, playing position and level, previous injuries, back pain history (Standardized Nordic questionnaire of musculo-skeletal symptoms/modified version for athletes)[17,18] and training and playing history during the previous 12 months. The Physical tests were performed at the UKK Institute over 1 day. The tests included anthropometric measurements; hamstring, quadriceps, and iliopsoas extensibility; generalized joint laxity (Beighton-Horan index); isometric hip abduction strength; and a one repetition maximum (1RM) of the leg press. The tests are described in detail in Data S1 and in the study protocol.[16] All AE (games and training) was collected for each player by the coaches.

2.3 | Back pain definitions and data collection

Fuller et al's consensus statement for sports injury definitions and data collection is widely used in sports injury research[19] and in this study, the definition of back pain was based on it. Thus, back pain was defined as pain in the upper and/or lower back area, that prevented the player from fully participating in the team training and playing during the following 24 hours. Severity was expressed as time lost from training and playing. Back pain was registered if it occurred during or after scheduled team practice or game. During the follow-up, back pain was registered weekly and verified by one of the five study physicians. A study physician contacted the teams once a week to gain information about new back complaints and to interview the players.

A structured injury questionnaire (Data S2) was used to register back pain including the location, cause, type, time of onset and suspected mechanism (acute traumatic vs non-traumatic), as recommended by Fuller et al.[19] Back pain resulting from a specific and identifiable event, such as falling, was referred as acute traumatic back pain. Back pain without single identifiable event was referred as non-traumatic back

TABLE 1 Baseline characteristics (n = 396)

				Total	
Variables	**Basketball**	**Floorball**	***P*-value**	**Median**	**Mean**
Age, y (mean, (SD))					
All	14.9 (1.6)	16.8 (1.6)	≤.001	16.0	15.8 (1.9)
Female	14.6 (1.6)	16.5 (1.9)			
Male	15.2 (1.6)	16.9 (1.3)			
Height, cm (mean, SD)					
All	173.8 (9.8)	173.5 (8.6)	.774	173.5	173.7 (9.2)
Female	168.4 (6.5)	166.6 (5.7)			
Male	179.3 (9.5)	178.6 (6.5)			
Weight, kg (mean, SD)					
All	64.8 (12.1)	66.4 (9.3)	.078	64.7	65.6 (10.8)
Female	60.9 (9.4)	61.2 (7.5)			
Male	68.9 (13.2)	70.1 (8.7)			
BMI (mean, SD)					
All	21.4 (3.0)	22.0 (2.4)	≤.001	21.4	21.7 (2.7)
Female	21.4 (2.9)	22.1 (2.6)			
Male	21.3 (3.1)	22.0 (2.3)			
Playing years (mean, SD)					
All	6.9 (2.9)	7.7 (3.0)	.013	7.0	7.3 (3.0)
Female	6.5 (2.6)	6.2 (2.6)			
Male	7.3 (3.2)	8.7 (2.8)			
Training hours[a] (mean, SD)					
All	215.1 (102.9)	236.0 (114.1)	.093	229.6	225.3 (108.9)
Female	179.4 (77.7)	221.5 (88.7)			
Male	252.0 (112.7)	246.6 (128.9)			
Game hours[b] (mean, SD)					
All	6.7 (4.6)	9.7 (6.7)	≤.001	7.5	8.2 (5.9)
Female	7.2 (4.9)	9.1 (6.5)			
Male	6.3 (4.2)	10.1 (6.8)			

Boys: basketball n = 100, floorball n = 111; Girls: basketball n = 103, floorball n = 82.

[*] *P*-values shown refer to the *t* test/Mann-Whitney test between sports groups.

[a] Team practice hours/season.

[b] Active playing time in games during the season.

pain. Situations where acute traumatic back pain occurred were categorized as "contact", "indirect contact", and "non-contact" injuries.[20] A contact injury was defined as an injury sustained by the injured body region because of direct contact with another player or object. An indirect contact and non-contact injury was defined as occurring without direct contact to the injured body region. All back pain resulting from direct contact (n = 8) were excluded from this study. These included coccyx fracture (n = 2), sacrum contusion (n = 1), upper back contusion (n = 1), and lower back contusion (n = 4). The reason for the exclusion was that it was considered unlikely that the risk factors investigated in this study are associated with direct contact injury, such as a blow to the back with a stick.

2.4 | Ethics approval

Informed consent was collected from each player (and parent or guardian if the player was under 18 years of age) in writing. The study was approved by the Ethics Committee of Pirkanmaa Hospital District (ETL-code R10169) before the start of the study, and it was carried out in accordance with the Declaration of Helsinki and the guidelines for good scientific practice.

TABLE 2 Incidence of back pain[#] per 1000 AE (95% CI)

	Floorball[a]			Basketball[b]			Total[c]		
	Total number (%)	Incidence[a]	95%CI	Total number (%)	Incidence[b]	95%CI	Total number (%)	Incidence[c]	95%CI
Low back/pelvis									
Non-traumatic	22 (81.5)	71.7	(47.9, 107.2)	17 (70.8)	60.9	(38.4, 96.6)	39 (76.5)	66.6	(49.1, 90.1)
Acute traumatic	3 (11.1)	9.8	(3.2, 30.1)	6 (25.0)	21.5	(9.8, 47.5)	9 (17.6)	15.4	(8.0, 29.4)
Total	25 (92.6)	81.4	(55.9, 118.6)	23 (95.8)	82.4	(55.7, 121.9)	48 (94.1)	81.9	(62.5, 107.4)
Upper Back									
Non-traumatic	1 (3.7)	3.3	(0.5, 23.1)	0 (0.0)	0.0	(0.0, 0.0)	1 (2.0)	1.7	(0.2, 12.1)
Acute traumatic	1 (3.7)	3.3	(0.5, 23.1)	1 (4.2)	3.6	(0.5, 25.4)	2 (3.9)	3.4	(0.9, 13.6)
Total	2 (7.4)	6.5	(1.6, 25.9)	1 (4.2)	3.6	(0.5, 25.4)	3 (5.9)	5.1	(1.7, 15.8)
All									
Non-traumatic	23 (85.2)	74.9	(50.6, 111.0)	17 (70.8)	60.9	(38.4, 96.6)	40 (78.4)	68.3	(50.6, 92.1)
Acute traumatic	4 (14.8)	13.0	(4.9, 34.5)	7 (29.2)	25.1	(12.1, 52.1)	11 (21.6)	18.8	(10.5, 33.7)
Total	27 (100.0)	88.0	(61.3, 126.1)	24 (100.0)	86.0	(58.7, 126.1)	51 (100.0)	87.0	(67.0, 113.1)

[#]Ten players reported more than one back pain episode, but only the first is included in the incidence calculations.
[a]Incidence per 1000 athlete-years (athlete-years n = 307).
[b]Incidence per 1000 athlete-years (athlete-years n = 279).
[c]Incidence per 1000 athlete-years (athlete-years n = 586).

2.5 | Statistical methods

IBM SPSS Statistics (v. 23-24.0) was used to carry out descriptive statistical analyses. Differences between the baseline characteristics of the groups were assessed using crosstabs and the Chi-square test (and the *t* test/Mann-Whitney test when appropriate), and the results are reported as the mean, standard deviation (SD), and 95% confidence intervals (95% CI). The baseline was the first year the player took part in the study, leading to the follow-up being 1-3 years, depending on the player. The primary outcome was back pain, including both acute traumatic and non-traumatic onset back pain that resulted in time lost from training and/or games. The incidence of back pain was expressed as the number of injured players per 1000 athlete-years and per 1000 hours of AE.

Cox's proportional hazard models with mixed effects were used to investigate the associations between baseline characteristics and low back pain, except for iliopsoas and quadriceps extensibility. Measurements for quadriceps and iliopsoas extensibility started during the second study year, so players who had low back pain in the first study year were excluded from the analyses for these two variables. Analyses were performed separately for non-traumatic low back pain (ntLBP) and all low back pain (aLBP) the latter also including acute traumatic low back pain. For players reporting more than one LBP period following baseline testing, only the first was included in the risk factor analysis. The sports club was used in all models as a random effect. Monthly exposure time, including all training and games, from the start of the follow-up until the first LBP or the end of follow-up was included in the models. Age, sex, BMI, nicotine use, family history of LBP, starting age in the sport, participation in other sports, and LBP during the previous 12 months, as reported in the baseline were initially entered to the model, but only variables with a *P*-value close to .20 or less were entered into the final model. R (v 3.1.2; R Foundation for Statistical Computing)[21] package coxme[22] was used for the risk factor analyses. The results are presented as hazard ratios (HR) and reported with 95% CIs.

3 | RESULTS

3.1 | Back pain incidence and onset mechanisms

During the follow-up, back pain was reported 61 times by 51 players (13%). The incidence of back pain in floorball and basketball players was 87 per 1000 athlete-years and 0.4 per 1000 hours of AE. The incidence of back pain by sport is shown in Table 2. Acute traumatic back pain was reported 17 (27%) times and non-traumatic back pain 44 (73%) times.

The incidence of non-traumatic back pain was 75 per 1000 athlete-years (0.3 per 1000 hours of AE) in floorball players and 61 per 1000 (0.3 per 1000 hours of AE) in basketball players. Of the non-traumatic back pain, 61% (n = 27) was reported to be recurrent. Most of the non-traumatic back pain (77%) was classified as non-specific, and 98% (n = 43) located in the lumbar-pelvic area. Of the non-traumatic back pain, nearly half (46%) in floorball and 35% in basketball resulted in more than 29 days of absence from normal training (Figure 2).

Most of the acute traumatic back pain occurred in non-contact situations (n = 14, 82%), with only three (17%) resulting from indirect contact. Of the acute traumatic back pain, 24% (n = 4) was classified as muscle-tendon injuries, such as a spasm or strain. The most reported situations (59%, n = 10) leading to acute traumatic back pain were landing from a jump or sudden/unexpected movement. The majority (76%, n = 12) of acute traumatic back pain occurred during practice, mostly during conditioning training.

3.2 | Risk factors for low back pain

Thirty-nine non-traumatic LBP and nine acute traumatic LBP were included in the risk factor analysis. The hazard ratios for the Cox's Regression models are shown in Table 3. Hamstring extensibility ($P = .540$ for ntLBP, $P = .360$ for aLBP), extensibility asymmetry ($P = .430$ for ntLBP, $P = .650$ for aLBP), quadriceps ($P = .640$ for ntLBP, $P = .430$ for aLBP) and iliopsoas extensibility ($P = .790$ for ntLBP, $P = .760$ for LBP), and general joint hypermobility ($P = .890$ for ntLBP, $P = .720$ for aLBP) were not statistically significantly associated with LBP. Furthermore, no association between LBP and lower extremity strength measures were found in these young basketball and floorball players (Leg press 1RM $P = .240$ for ntLBP, $P = .450$ for aLBP; isometric hip abduction strength asymmetry $P = .310$ for ntLBP, $P = .340$ for aLBP).

4 | DISCUSSION

This study showed that the incidence of time-loss back pain in floorball and basketball players was 87 per 1000 athlete-years (0.4 per 1000 hours of AE). The incidence of non-traumatic back pain was 75 per 1000 athlete-years (0.3 per 1000 hours of AE) in floorball players and 61 per 1000 (0.4 per 1000 hours of AE) in basketball players. Nearly, half of the non-traumatic back pain resulted in more than 29 days missed from normal training and more than half were reported to be recurrent. No significant associations were observed between LBP and generalized joint mobility, lower extremity muscle extensibility, leg extension strength (leg press 1 RM) or hip abduction strength asymmetry.

The definition of back pain used in this study excluded minor back complaints that did not prevent participation in normal training during the following 24 hours. Therefore, it is likely that the prevalence and incidence of any back complaints in this population are even higher. In fact, in the baseline questionnaire, the players were asked about any low back complaints and 53% of the players reported low back pain during the preceding 12 months. In addition, in our previous cross-sectional study, we found an annual prevalence of any back pain as high as 44% in basketball players and 62% in floorball players,[8] which is in line with previous studies.[3,18] Van Hilst et al[3] found the prevalence of LBP to be 54%-66% in young speed skaters, 33%-64% in field hockey players and 64% in football players. Bahr et al[18] reported prevalence rates of 63% among skiers, 55% among rowers, and 50% among orienteers. The recurrence rate in this study was similar to that previously reported in young athletes.[3] Van Hilst et al reported the recurrence of LBP being 50%-60%.[3] Non-traumatic back pain was also more severe in terms of time lost from normal training. Nearly, half of the injured players were not able to participate in normal training for 29 days or longer.

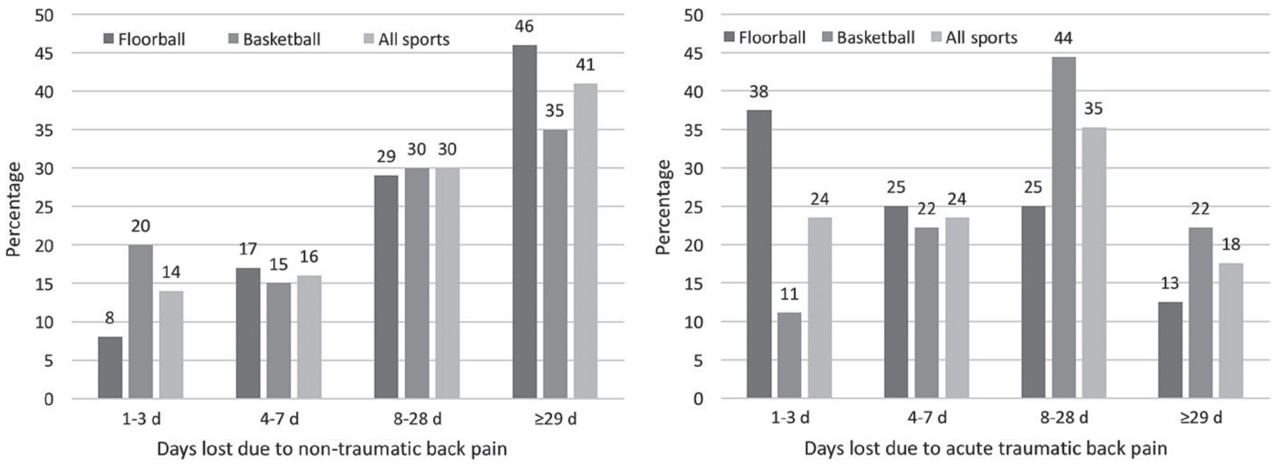

FIGURE 2 Severity of the non-traumatic (left) and acute traumatic (right) back pain (results given as percentage (%) of all back pain according to time-loss days)

TABLE 3 Hazard ratios for non-traumatic low back pain (ntLBP) and all low back pain (aLBP)

		Adjustement factors							
Variable	**Risk factor**	**Age**	**Sex**	**BMI**	**Nicotine use (yes)**	**Family history of LBP (yes)**	**Starting age**	**Other sports participation**	**Previous 12 mo LBP (yes)**
HR for ntLBP (95% CI)									
Leg press 1RM	1.00 (0.99, 1.00)	N/A	N/A	N/A	**3.60** (1.23, 10.54); No 1	1.94 (0.84, 4.47); No 1	1.06 (0.94, 1.20)	N/A	1.54 (0.77, 3.06); No 1
Hip Abduction strength asymmetry	0.86 (0.64, 1.15)	N/A	N/A	N/A	**3.18** (1.11, 9.06); No 1	1.92 (0.87, 4.23); No 1	1.05 (0.94, 1.19)	N/A	1.42 (0.73, 2.77); No 1
Iliopsoas flexibility	0.99 (0.96, 1.03)	N/A	N/A	N/A	**3.32** (1.15, 9.56); No 1	2.03 (0.87, 4.73); No 1	1.01 (0.89, 1.15)	N/A	1.53 (0.75, 3.11); No 1
Quadriceps flexibility	1.01 (0.97, 1.04)	N/A	N/A	N/A	**3.35** (1.16, 9.66); No 1	1.99 (0.86, 4.60); No 1	1.01 (0.89, 1.14)	N/A	1.54 (0.76, 3.13); No 1
Hamstring flexibility asymmetry	1.02 (0.97, 1.09)	N/A	N/A	N/A	**3.02** (1.05, 8.67); No 1	1.93 (0.87, 4.26); No 1	1.06 (0.94, 1.19)	N/A	1.43 (0.74, 2.80); No 1
Hamstring flexibility	0.99 (0.97, 1.01)	0.87 (0.71, 1.07)	N/A	N/A	**4.19** (1.38, 12.74); No 1	2.16 (0.98, 4.77); No 1	N/A	N/A	N/A
Beighton-Horan Laxity index[a] (normal)	0.95 (0.41, 2.18); Hyperflex 1	0.87 (0.71, 1.07)	N/A	N/A	**4.24** (1.40, 12.91); No 1	2.19 (0.98, 4.87); No 1	N/A	N/A	N/A
HR for aLBP (95% CI)									
Leg press 1RM	1.00 (0.99, 1.00)	N/A	N/A	N/A	2.71 (0.94, 7.77); No 1	2.08 (0.99, 4.37); No 1	1.10 (0.99, 1.23)	N/A	1.66 (0.89, 3.12); No 1
Hip Abduction strength asymmetry	0.88 (0.67, 1.14)	N/A	N/A	N/A	2.53 (0.90, 7.09); No 1	**2.30** (1.16, 4.56); No 1	1.10 (0.99, 1.23)	N/A	1.49 (0.82, 2.71); No 1
Iliopsoas flexibility	0.99 (0.96, 1.03)	N/A	N/A	N/A	1.67 (0.87, 3.20); No 1	1.10 (0.98, 1.24); No 1	1.89 (0.86, 4.15)	N/A	2.65 (0.94, 7.51); No 1
Quadriceps flexibility	1.01 (0.98, 1.04)	N/A	N/A	N/A	2.73 (0.96, 7.77); No 1	1.84 (0.84, 4.00); No 1	1.10 (0.98, 1.23)	N/A	1.69 (0.88, 3.23); No 1
Hamstring flexibility asymmetry	1.01 (0.96, 1.07)	N/A	N/A	N/A	2.46 (0.88, 6.92); No 1	**2.31** (1.17, 4.59); No 1	1.11 (0.99, 1.23)	N/A	1.49 (0.82, 2.71); No 1
Hamstring flexibility	0.99 (0.97, 1.01)	N/A	N/A	N/A	2.41 (0.86, 6.78); No 1	**2.36** (1.19, 4.67); No 1	1.11 (1.00, 1.24)	N/A	1.45 (0.81, 2.69); No 1
Beighton-Horan Laxity index[a] (normal)	1.14 (0.55, 2.38); Hyperflex 1	N/A	N/A	N/A	2.49 (0.89, 6.97); No 1	**2.32** (1.17, 4.59); No 1	1.11 (0.99, 1.23)	N/A	1.49 (0.82, 2.72); No 1

[a]Normal range 0-3, hyperflexibility 4-9.

N/A, Not included in the final model.

Statistically significant ($P < .05$) findings are indicated with bold type.

Considering the recurrence and severity of the reported back pain, it is therefore unsurprising that it has been argued LBP has a detrimental effect on athletic performance.[13]

In cross-sectional studies focusing on athletic populations, LBP has been reported to be associated with the function of the trunk and pelvis muscles,[23,24] as well as spinal movements during walking and running.[25] Hip muscle strength and asymmetry have been reported to be associated with other lower extremity injuries.[26,27] However, it is unclear if the deficits in neuromuscular function in the lumbar–pelvic area are the cause or effect of back complaints. In the prospective setting, we did not find lower extremity strength or hip abduction strength asymmetry to be a risk factor for time-loss low back pain in young athletes. Pain has been shown to inhibit maximal voluntary muscle force in experimental studies[28] and the results of this current study indicate that deficits in neuromuscular function in the lumbar-pelvic area might be more of an effect than a cause of LBP.

General joint hypermobility in children has been associated with decreased proprioception and muscle performance,[29] and therefore, it could be hypothesized to be a possible risk factor for back complaints. Previous studies have not found an association between back pain and general hypermobility in adults,[30,31] and according to our results, it is not a risk factor for back pain in young athletes either. Hamstring extensibility has been found to be associated with LBP in adolescents.[32] Nevertheless, only a few studies have investigated the association between hamstring[33,34] and quadriceps[33] extensibility and LBP prospectively in the adolescent population. Only one of the two studies found a significant association between hamstring extensibility and LBP. According to our results, hamstring extensibility is not associated with the incidence of LBP in young athletes, and the result supports the findings of a previous study involving young athletes.[34] We also noticed that neither iliopsoas nor quadriceps extensibility were associated with the incidence of LBP in young athletes. Similar findings regarding the quadriceps in young people have been reported previously Feldman et al,[33] but contrary findings have also been reported by Kanachanomai et al.[35] The difference between the findings could be due to the differing definitions of LBP, and/or the different measurements used. Kanachanomai et al[35] measured hamstring extensibility using the active knee extension test. Feldman et al[33] used the knee extension test in a similar manner as we did in our study, but they failed to mention if active knee extension was used or if the endpoint of the knee extension was determined by the subjective feeling of a stretch or a standardized pulling force.

There are some strengths and limitations to this study. To our knowledge, this study is among the largest prospective studies assessing risk factors for back pain in young athletes. However, in cohort studies with a follow-up, the investigated factors may change over time, especially in cohorts with young people. Thirty-nine of the first low back pain periods occurred during the players' first study year, eight during the second year, and one during the third study year, meaning that in most cases (81%), the time between the baseline test and the first low back pain period was 1 year or less. The lack of inclusion of psychosocial factors in the LBP risk factors is a limitation, as they have been shown to be associated with LBP in young people[36] and LBP becoming chronic in athletes.[37] In addition, we were unaware of the time spent in everyday physical activity or inactivity by the athletes outside their sport or the training characteristics of other sports they might play. For example, screen time has been shown by Rossi et al[2] and Hakala et al[38] to be associated with LBP. In addition, we did run the analysis with players without previous history of back pain. However, the number of events was too small for complicated models. The analysis of the subgroup, without any adjusting factors, did not find significant risk factors for LBP. Therefore, in the final analysis we decided not to exclude players with previous back complaints, but we adjusted for previous LBP in the risk factor analysis. As we did not find predisposing factors for back pain, the prolonged back pain could be associated with anatomic changes in the growing spine due to high loading. These changes may include vertebral end plate and ring apophysis changes[14] and posterior vertebral arch stress fractures.[39] However, our study protocol did not include systematic imaging studies to find out the possible structural reasons for back pain.

In summary, back pain seems to result in considerable time-loss from training and competing among young basketball and floorball players, and the pain tends to reoccur. According to this 3-year prospective follow-up study, lower extremity extensibility, general hypermobility, lower extremity strength, and hip abduction strength asymmetry are not associated with the incidence of time-loss low back pain in young basketball and floorball players.

5 | PERSPECTIVE

As measured in this study, the investigated factors cannot be used to assess the risk for low back pain in young team ball game players. However, the association between low back pain and functional tests assessing neutral zone control and neuromuscular movement control of the low back and pelvis area require further studies.

ACKNOWLEDGEMENTS

This study was financially supported by the Finnish Ministry of Education and Culture, and the Competitive State Research Financing of the Expert Responsibility Area of Tampere University Hospital (Grants 9N053, 9S047, 9T046, 9U044).

ORCID

M. K. Rossi http://orcid.org/0000-0002-5714-6436
K. Pasanen http://orcid.org/0000-0002-0427-2877
A. Heinonen http://orcid.org/0000-0002-3681-9953
G. Myklebust http://orcid.org/0000-0002-0692-7494
P. Kannus http://orcid.org/0000-0002-3324-3872
U. M. Kujala http://orcid.org/0000-0002-9262-1992
K. Tokola http://orcid.org/0000-0002-6466-4100

REFERENCES

1. Trompeter K, Fett D, Platen P. Prevalence of back pain in sports: a systematic review of the literature. *Sports Med*. 2017;47:1183.
2. 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 Musculoskel Dis*. 2016;17:263.
3. van Hilst J, Hilgersom NFJ, Kuilman MC, Kuijer P, Paul FM, Frings-Dresen MHW. Low back pain in young elite field hockey players, football players and speed skaters: prevalence and risk factors. *J Back Musculoskelet Rehabil*. 2015;28:67-73.
4. Schmidt CP, Zwingenberger S, Walther A, et al. Prevalence of low back pain in adolescent athletes: an epidemiological investigation. *Int J Sports Med*. 2014;35:684-689.
5. Kokko S, Mehtälä A. Lasten ja nuorten liikuntakäyttäytyminen Suomessa, LIITU-tutkimuksen tuloksia 2016. [Physical Activity Behaviour of Children and Adolescents in Finland, Results from LIITU-Study 2016] Publications of the National Sports Council. 2016.
6. FIBA Basketball Overview - Facts and Figures. www.fiba.com/presentation#|tab=element_2_1. Accessed 7.7.2017.
7. IFF - Number of Licensed Players 2015 – 09.03.2016. http://www.floorball.org/news.asp?tyyppi=kohdennettu&alue=204&id_tiedote=4836. Accessed 7.7.2017.
8. Pasanen K, Rossi M, Parkkari J, et al. Low back pain in young basketball and floorball players: A retrospective study. *Clin J Sports Med*. 2015;16:376-380.
9. Hestbaek LDC, Leboeuf-Yde C, Kyvik KO, Manniche CDMS. The Course of Low Back Pain from Adolescence to Adulthood: eight-year Follow-up of 9600 Twins. *Spine*. 2006;31:468-472.
10. Ståhl M, El-Metwally A, Rimpelä A. Time trends in single versus concomitant neck and back pain in finnish adolescents: results from national cross-sectional surveys from 1991 to 2011. *BMC Musculoskelet Disord*. 2014;15:296.
11. Nguyen A, Shultz SJ, Schmitz RJ, Luecht RM, Perrin DH. A preliminary multifactorial approach describing the relationships among lower extremity alignment, hip muscle activation, and lower extremity joint excursion. *J Athl Training*. 2011;46:246.
12. Zazulak BT. Deficits in neuromuscular control of the trunk predict knee injury risk: a prospective biomechanical-epidemiologic study. *Am J Sports Med*. 2007;35:1123-1130.
13. Nadler SF, Moley P, Malanga GA, Rubbani M, Prybicien M, Feinberg JH. Functional deficits in athletes with a history of low back pain: a pilot study. *Arch Phys Med Rehabil*. 2002;83:1753-1758.
14. Kujala UM, Taimela S, Erkintalo M, Salminen JJ, Kaprio J. Low-back pain in adolescent athletes. *Med Sci Sports Exerc*. 1996;28:165-170.
15. Bahr R, Krosshaug T. Understanding injury mechanisms: a key component of preventing injuries in sport. *Br J Sports Med*. 2005;39:324-329.
16. Pasanen K, Rossi MT, Parkkari J, et al. Predictors of lower extremity injuries in team sports (PROFITS-study): a study protocol. *BMJ Open Sport Exerc Med*. 2015;1:e000076.
17. Kuorinka I, Jonsson B, Kilbom A, et al. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. *Appl Ergon*. 1987;18:233-237.
18. Bahr R, Andersen SO, Loken S, Fossan B, Hansen T, Holme I. Low back pain among endurance athletes with and without specific back loading–a cross-sectional survey of cross-country skiers, rowers, orienteerers, and nonathletic controls. *Spine*. 2004;29:449-454.
19. Fuller CW, Ekstrand J, Junge A, et al. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. *Scand J Med Sci Sports*. 2006;16:83-92.
20. Olsen O, Myklebust G, Engebretsen L, Bahr R. Injury mechanisms for anterior cruciate ligament injuries in team handball: a systematic video analysis. *Am J Sport Med*. 2004;32:1002-1012.
21. R Core Team. *R: a language and environment for statistical computing*. Vienna, Austria: R Core Team; 2016.
22. Therneau TM. *coxme: mixed Effects Cox Models*. R package; 2015. 2.2-5. https://CRAN.R-project.org/package=coxme
23. Hides J. Magnetic resonance imaging assessment of regional abdominal muscle function in elite AFL players with and without low back pain. *Man Ther*. 2011;16:279-284.
24. Hides JA. A magnetic resonance imaging investigation of the transversus abdominis muscle during drawing-in of the abdominal wall in elite Australian Football League players with and without low back pain. *J Orthop Sports Phys Ther*. 2010;40:4.
25. Müller R, Ertelt T, Blickhan R. Low back pain affects trunk as well as lower limb movements during walking and running. *J Biomech*. 2015;48:1009-1014.
26. Niemuth PE, Johnson RJ, Myers MJ, Thieman TJ. Hip muscle weakness and overuse injuries in recreational runners. *Clin J Sport Med*. 2005;15:14-21.
27. Nadler SFDO, Malanga GA, DePrince M, Stitik TP, Feinberg JH. The relationship between lower extremity injury, low back pain, and hip muscle strength in male and female collegiate athletes. *Clin J Sport Med*. 2000;10:89-97.
28. Graven-Nielsen T, Lund H, Arendt-Nielsen L, Danneskiold-Samsøe B, Bliddal H. Inhibition of maximal voluntary contraction force by experimental muscle pain: a centrally mediated mechanism. *Muscle Nerve*. 2002;26:708-712.
29. Fatoye F, Palmer S, Macmillan F, Rowe P, van der Linden M. Proprioception and muscle torque deficits in children with hypermobility syndrome. *Rheumatology*. 2009;48:152-157.
30. Tobias JH, Deere K, Palmer S, Clark EM, Clinch J. Joint hypermobility is a risk factor for musculoskeletal pain during adolescence: findings of a prospective cohort study. *Arthritis Rheum*. 2013;65:1107-1115.
31. Harreby M, Nygaard B, Jessen T. Risk factors for low back pain in a cohort of 1389 Danish school children: an epidemiologic study. *Eur Spine J*. 1999;8:444-450.

32. Sjolie AN. Low-back pain in adolescents is associated with poor hip mobility and high body mass index. *Scand J Med Sci Sports*. 2004;14:168-175.
33. Feldman DE, Shrier I, Rossignol M, Abenhaim L. Risk factors for the development of low back pain in adolescence. *Am J Epidemiol*. 2001;154:30-36.
34. Kujala UM, Taimela S, Salminen JJ, Oksanen A. Baseline anthropometry, flexibility and strength characteristics and future low-back pain in adolescent athletes and nonathletes. *Scand J Med Sci Sport*. 1994;4:200-205.
35. Kanchanomai S, Janwantanakul P, Pensri P, Jiamjarasrangsi W. A prospective study of incidence and risk factors for the onset and persistence of low back pain in Thai University students. *Asia Pac J Public Health*. 2015;27:NP115.
36. Kamper SJ, Yamato TP, Williams CM. The prevalence, risk factors, prognosis and treatment for back pain in children and adolescents: an overview of systematic reviews. *Best Pract Res Clin Rheumatol*. 2017; 30:1021-1036.
37. Heidari J, Mierswa T, Hasenbring M, et al. Low back pain in athletes and non-athletes: a group comparison of basic pain parameters and impact on sports activity. *Sport Sci Health*. 2016;12:297-306.
38. Hakala PT, Rimpelä AH, Saarni LA, Salminen JJ. Frequent computer-related activities increase the risk of neck-shoulder and low back pain in adolescents. *Eur J Public Health*. 2006;16:536-541.
39. Kujala UM, Kinnunen J, Helenius P, Orava S, Taavitsainen M, Karaharju E. Prolonged low-back pain in young athletes: a prospective case series study of findings and prognosis. *Eur Spine J*. 1999;8:480-484.

SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

How to cite this article: Rossi MK, Pasanen K, Heinonen A, et al. Incidence and risk factors for back pain in young floorball and basketball players: A Prospective study. *Scand J Med Sci Sports*. 2018;00:1–9. https://doi.org/10.1111/sms.13237

IV

PERFORMANCE IN DYNAMIC MOVEMENT TASKS AND OCCURRENCE OF LOW BACK PAIN IN YOUTH FLOORBALL AND BASKETBALL PLAYERS

by

Rossi Marleena K, Pasanen Kati, Heinonen Ari, Äyrämö Sami,
Räisänen Anu M, Leppänen Mari, Myklebust Grethe, Vasankari Tommi,
Kannus Pekka, Parkkari Jari

BMC Musculoskeletal Disorders 21, 350 (2020)

https://doi.org/10.1186/s12891-020-03376-1

Published under CC BY 4.0 license

Rossi *et al. BMC Musculoskeletal Disorders* (2020) 21:350
https://doi.org/10.1186/s12891-020-03376-1

BMC Musculoskeletal Disorders

RESEARCH ARTICLE Open Access

Performance in dynamic movement tasks and occurrence of low back pain in youth floorball and basketball players

M. K. Rossi[1,2*], K. Pasanen[1,3,4,5], A. Heinonen[2], S. Äyrämö[6], A. M. Räisänen[3], M. Leppänen[1], G. Myklebust[7], T. Vasankari[1], P. Kannus[1,8] and J. Parkkari[1,9]

Abstract

Background: Prospective studies investigating risk factors for low back pain (LBP) in youth athletes are limited. The aim of this prospective study was to investigate the association between hip-pelvic kinematics and vertical ground reaction force (vGRF) during landing tasks and LBP in youth floorball and basketball players.

Methods: Three-hundred-and-eighty-three Finnish youth female and male floorball and basketball players (mean age 15.7 ± 1.8) participated and were followed up on for 3 years. At the beginning of every study year the players were tested with a single-leg vertical drop jump (SLVDJ) and a vertical drop jump (VDJ). Hip-pelvic kinematics, measured as femur-pelvic angle (FPA) during SLVDJ landing, and peak vGRF and side-to-side asymmetry of vGRF during VDJ landing were the investigated risk factors. Individual exposure time and LBP resulting in time-loss were recorded during the follow-up. Cox's proportional hazard models with mixed effects and time-varying risk factors were used for analysis.

Results: We found an increase in the risk for LBP in players with decreased FPA during SLVDJ landing. There was a small increase in risk for LBP with a one-degree decrease in right leg FPA during SLVDJ landing (HR 1.09, 95% CI 1.02 to 1.17, per one-degree decrease of FPA). Our results showed no significant relationship between risk for LBP and left leg FPA (HR 1.04, 95% CI 0.97 to 1.11, per one-degree decrease of FPA), vGRF (HR 1.83, 95% CI 0.95 to 3.51) or vGRF side-to-side difference (HR 1.22, 95% CI 0.65 to 2.27) during landing tasks.

Conclusions: Our results suggest that there is an association between hip-pelvic kinematics and future LBP. However, we did not find an association between LBP and vGRF. In the future, the association between hip-pelvic kinematics and LBP occurrence should be investigated further with cohort and intervention studies to verify the results from this investigation.

Level of evidence: Prognosis, level 1b.

Keywords: Low back pain, Lumbar spine, Team sports, Youth athletes, Risk factors

* Correspondence: marleena.k.rossi@student.jyu.fi
[1]Tampere Research Center of Sports Medicine, UKK Institute, 33501 Tampere, Finland
[2]Faculty of Sport and Health Sciences, University of Jyväskylä, Jyväskylä, Finland
Full list of author information is available at the end of the article

© The Author(s). 2020 **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by/4.0/. The Creative Commons Public Domain Dedication waiver (http://creativecommons.org/publicdomain/zero/1.0/) applies to the data made available in this article, unless otherwise stated in a credit line to the data.

Key points

Findings Based on the results of this study, peak vGRF is a poor risk factor for LBP in youth team sport players. Hip-pelvic kinematics are associated with increased risk for LBP; smaller angle between the femur and pelvis increases the risk for all LBP and non-traumatic gradual onset LBP.

Implications One cannot discriminate players with future LBP based on the femur-pelvic angle during SLVDJ landing alone. The association between hip-pelvic kinematics and other movement patterns, such as trunk kinematics, and risk for LBP in athletes merits further investigations.

Caution The data recording and statistical analyses in this study did not take into account the temporal nature of physical abilities during the follow-up nor did it include psychosocial factors. Statistical power might not have been enough to reveal small to moderate associations. The results should be verified by future cohort and intervention studies.

Background

Back pain is common among youth athletes [1]. Our previous findings show that nearly half of floorball players (45%) and 64% of basketball players have had LBP during the preceding 12 months [2]. Furthermore, lower extremity injuries (LEI) resulting in time loss are common among these players [3]. Association between LEI and back pain has been suggested by previous research [4–6]. It has been speculated that changes in lower extremity function after an injury, or shared risk factors, might explain the association between LEI and LBP and that plausible mechanisms behind this relationship should be investigated [5]. Sports injury studies have investigated the association between LEI and lower extremity kinetics and kinematics, such as ground reaction forces and lower extremity movement patterns, but they have not considered how these factors might contribute to the cause of LBP.

Previous studies investigating intrinsic risk factors for LBP in youth have focused mostly on lower extremity and trunk muscle strength and endurance, flexibility and anthropometric measures [1, 7]. Prospective investigations into association between LBP and movement patterns in youth athletes are scarce [8] and most of the previous studies investigating back pain in athletes have been largely cross-sectional [9].

It has been stated that the trunk, including lumbo–pelvic–hip complex, is the central point of kinetic chains of most sports activities and essential in decreasing back injuries [10]. Furthermore, it has been suggested that for the functional evaluation of the trunk and lumbo–pelvic–hip complex, dynamic hip-pelvic movement patterns should be investigated [10]. Previous research has identified differences between youth athletes with and without LBP on lumbo–pelvic–hip complex movement patterns [11–14] and an association between LBP and frontal plane hip-pelvic movement patterns has been observed in single-leg dynamic tasks in youth cricket players [15] and in adults with LBP [16].

Basketball and floorball (an indoor team ball sport that resembles floor hockey) are sports that include running, sudden direction changes and stops. In addition, basketball players perform lots of jumping and landing [17]. These movements produce large ground reaction forces (GRF) [18, 19] that transfer to the lumbar spine and thus may pre-dispose players to LBP. Yet, to our knowledge, the association between LBP and peak vGRF nor lumbo–pelvic–hip complex movement patterns, using kinematic measures, have not been investigated in youth floorball and basketball players.

The aim of this exploratory prospective study was to investigate if hip-pelvic kinematics, measured as femur-pelvic angle (FPA), and peak vGRF during landing tasks, are associated with LBP incidence in a large cohort of youth basketball and floorball players. The prospective design and consideration of the individual training and game exposure hours adds to the novelty value of this study. The hypotheses were that [1] decreased FPA in frontal plane during single-leg vertical drop jump (SLVDJ) landing and [2] higher or asymmetric peak vGRF during vertical drop jump (VDJ) landing increase the risk for LBP plausibly due to increased load and strain in the lumbo-pelvic area.

Methods

Study design and data collection

This study is part of the large Finnish PROFITS study (Predictors of Lower Extremity Injuries in Team Sports) carried out between 2011 and 2015 [20] and the descriptive results regarding LBP have been reported already in previous reports [1, 2]. This study was approved by the Ethics Committee of the Pirkanmaa Hospital District (ETL-code R10169) and carried out in accordance with the Declaration of Helsinki and the guidelines for good scientific practice. Written informed consent was acquired from the participants (and a legal guardian if the player was under 18 years old).

Ten female and male basketball and 10 floorball teams were recruited from six sports clubs in Tampere, Finland. Players older than 21 and younger than 12 at baseline were excluded. Data were collected at baseline in April or May of 2011, 2012, or 2013 as the player entered the study, and at the beginning of each study year in which the player participated. The players were followed prospectively for up to 3 years. Data from all players entering the follow-up were included in the analyses for the time they participated.

The baseline questionnaire covered the following demographics: age, sex, dominant leg, nicotine use, family history of musculoskeletal disorders, and training and playing history during the previous 12 months.

The players' history of back pain was recorded using the Standardized Nordic questionnaire of musculoskeletal symptoms (modified version for athletes) [21, 22]. History of previous LBP was determined based on the question: How many days have you had LBP during the past 12 months: 'none' (recorded as no LBP history), '1 to 7 days', '8 to 30 days', '>30 days but not daily' and 'daily' (recorded as a history of LBP). The questionnaire has been validated among adults [23]. The baseline questionnaire was completed during the same day as the baseline tests.

The baseline tests were performed at the UKK Institute over 1 day at the beginning of every follow-up year. The test procedures are outlined in more detail in previous reports [20, 24–29] and Table 1 and only briefly described below. Players with an ongoing injury at the time of the baseline test and players who did not have a valid number of test trials were excluded from the risk factor analyses.

The SLVDJ was used to investigate hip-pelvic kinematics. In the SLVDJ the player dropped off from a 10-cm box followed by a maximal vertical jump. Hip-pelvic angles were estimated from a still video image by an investigator using Java-based software (ImageJ, National Institutes of Health), and FPA, outlined in Fig. 1, was chosen for risk factor analysis. The FPA measured in a similar, but not identical 2D single-leg landing task has shown good correlation with 3D measurements [31]. Using the same methods as this study, Stensrud et al. observed moderate to excellent reliability when they measured lower extremity kinematics during the SLVDJ (ICC range = 0.58–0.89) [26].

The VDJ was used to investigate the vGRF during landing. During a valid VDJ test the player stood on the 30-cm box, dropped off the box and immediately after landing the player performed a maximal vertical jump. Absolute and weight adjusted peak vGRF and side-to-side asymmetry were investigated as potential risk factors. The same methodology has been used previously by, for example, Nilstad et al., Mok et al. and Krosshaug et al. [27–29]. They also demonstrated good to excellent reliability for peak vGRF measure in athletes (ICC range = 0.60–0.91) [28, 29].

Table 1 Description of selected baseline tests and the investigated variables

SINGLE-LEG VERTICAL DROP JUMP (SLVDJ)

Preparation Small pieces of sports tape were placed on the left and right side of the upper anterior iliac tubercle (ASIS) and tuberositas tibiae.

Equipment A high-definition digital camera (Sony® Digital HD Video Camera Recorder HXR-NX70E, Sony Corporation, Tokyo, JAPAN).

Warm up No separate warm-up was performed, as the SLVDJ immediately followed a previous test (not included in this study). One practice trial on each leg was allowed.

Test performance During the test the player stood in front of the video camera, on a 10-cm box. Using one leg, the player dropped off the box and landed on one leg. Immediately after landing, the player performed a maximal jump straight up with the same leg. (The test was performed three times.) An overhead goal was used for maximum effort [30] and the test started with the right leg. Trials with jumping, a leg touching the ground or falling/clear loss of balance, were considered invalid. Two valid trials was considered acceptable.

Measurements/Calculations The frontal plane knee and pelvic angles were estimated by a physiotherapist by marking the knee joint centre and ASIS in the still image captured from a video. Joint angles were estimated at the point of maximum knee flexion during initial landing. *Femur-pelvic angle (FPA)* described the angle between the femur and pelvis and was calculated from the intersection of a line created by ASIS and the knee joint centre. A smaller angle indicates increased femur adduction and/or pelvic drop.

VERTICAL DROP JUMP (VDJ):

Preparation A static calibration trial was performed.

Equipment The 3D motion analysis consisted of eight cameras (Vicon T40, Oxford, UK), 16 lower body markers (Plug-In Gait, Vicon, Oxford, UK) and two force plates (AMTI, Watertown, Massachusetts) where data were recorded synchronously at 300 fps and 1500 Hz. A 30-cm box was used.

Warm up Players performed a standardised warm-up (5 min of cycling) before testing. One practice trial was allowed.

Test performance The player stood on the 30-cm box, dropped off the box and landed symmetrically on both feet on the force plates. Immediately after landing the player jumped as high as possible. An overhead goal was used for maximum effort [30] and the player tried to touch the goal with their head. Three valid trials were collected. The trials were accepted if the entire foot landed on the force plate and the markers stayed tightly on the athlete's skin throughout the task.

Measurements/Calculations Vicon Nexus Plug-in Gait model was used for the analyses. Peak vGRF and vGRF asymmetry were investigated as potential risk factors. Three trials from both legs were averaged and the side with the larger value was chosen for analyses as peak vGRF. Peak vGRF was normalized by bodyweight. The vGRF asymmetry was calculated as the difference between the right and left legs. GRF was filtered using a fourth-order Butterworth filter with cutoff frequencies of 15 Hz and the landing phase was defined as the period when the unfiltered ground reaction force exceeded 20 N.

Injury and sport exposure registration

The primary outcomes were traumatic and non-traumatic LBP. LBP was defined as pain in the lower back area that prevented the player from taking full part in team practices and games for at least 24 h. LBP that resulted from a specific identifiable event, such as falling, was referred to as acute traumatic LBP. Non-traumatic LBP had gradual onset, without an identifiable event of trauma. Acute traumatic LBP events were categorised as "contact", "indirect contact", and "non-contact" [32]. A contact injury was defined as an injury sustained by the injured body region because of direct contact with another player or object and were excluded from this investigation. An indirect contact and non-contact injury were defined as occurring without direct contact to the injured body region.

Once a week one of the two study physicians contacted the teams to interview the injured players. A structured injury questionnaire (Supplementary Table 1)

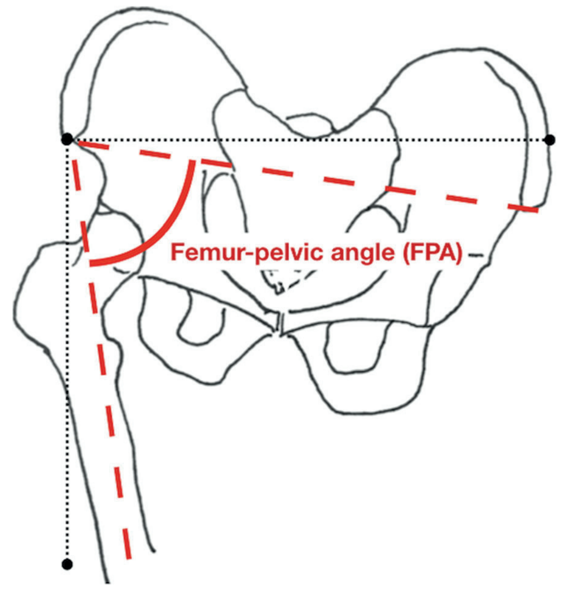

Fig. 1 Femur-pelvic angle (FPA) measured from the still-video image in single-leg vertical drop jump (SLVDJ) test

was used to register the injury/pain location, cause, type, time of onset and the suspected mechanism (acute traumatic vs. non-traumatic gradual onset) based on recommendations of Fuller et al. [33]. During the follow-up, the coaches collected all hours in games and team practices for each player on a monthly basis. Individual practice performed outside the scheduled team events was not included in the exposure data.

Statistical methods

IBM SPSS Statistics (v. 23–24.0) and Chi-square test and the t-test (Mann-Whitney test when appropriate) were used for descriptive statistical analyses and the results were reported as the mean and standard deviation (SD). Cox's proportional hazard models with mixed-effects were used to investigate the associations between potential risk factors and LBP (yes/no). This method accounts for the sports exposure and variance in follow-up time between the players. Mixed effects were used to account for the sports club as a random effect. Time-dependent variables were used, when possible, due to the tendency of changes in investigated variables over time. The individual game and practice hours from the start of the follow-up until the first event (LBP) or the end of follow-up (if no event) were included in analyses. For players reporting more than one LBP after the baseline, only the first was included. Data from all eligible players entering the follow-up were included in the analyses for the time they participated.

R (v 3.1.2; R Foundation for Statistical Computing [34]) package coxme [35] was used for the risk factor analyses. Univariate analyses were followed by multivariable analyses, where the number of adjusting variables was dependent on the number of events (10 per variable) included in the analysis, as recommended by Peduzzi et al. [36, 37]. The adjusting variables were selected from the following factors: age, sex, BMI, nicotine use, leg dominance, family history of LBP, and history of LBP. Leg dominance was used as a two-category variable: the categories 'left' and 'right' were merged into 'unilateral leg dominance' and the category 'don't know/both' into 'bi-lateral/unknown leg dominance'. The adjusting factors were selected by dropping factors from the model one by one, based on their statistical significance. Only nicotine use, a history of LBP and leg dominance showed a statistically significant association with LBP. The analyses were performed using continuous and dichotomized variables. Variables were dichotomized into 'high' and 'low' using the median. The results are presented as hazard ratios (HR), 95% CIs and p-values. The player was considered as the unit of analysis, but in unilateral tasks the right and left sides were investigated separately.

Results

Nine teams of both sports agreed to participate (Fig. 2), with a mean follow-up time of 16.5 months (range 1 to 36 months). Player demographics and baseline test results from each study year are presented in Table 2. There were some differences between the players included and excluded from the tests (Supplementary Table 2). For example, more male players and heavier players were excluded from the SLVDJ test due to ongoing injuries and for not having a valid test result. The players excluded from the VDJ test were older and heavier than those that were included.

During the follow-up, altogether 566 athlete-years were recorded. Fifty-four percent of players (n = 205) reported no history of LBP at baseline. Of the 383 players, 13% (n = 48) sustained LBP during the follow up, 35% of them (n = 17) had not had back pain prior to the study. Half of the players developing LBP during the follow-up

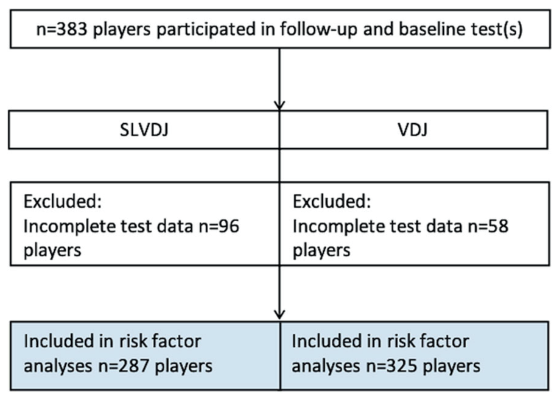

Fig. 2 Study participant flow

Table 2 Baseline characteristics, baseline test results, and practice and game exposure during the follow up for players with and without LBP

	LBP during follow-up	Study year 2011–2012				Study year 2012–2013				Study year 2013–2014			
		n	Mean	SD	***P* value**	n	Mean	SD	***P* value**	n	Mean	SD	***P* value**
Age, years	No	106	**16.2**	**1.7**	**0.009**	138	16.7	2.0	0.659	266	16.1	2.0	0.109
	Yes	6	18.0	1.5		10	16.3	2.2		32	15.5	2.0	
Sex, %		100	20.3	5.2	0.743	128	19.3	4.4	0.569	228	**18.8**	**3.9**	**0.043**
Female	No	80	95.2			85	92.4			107	88.4		
	Yes	4	4.8			7	7.6			14	11.6		
Male	No	26	92.9			53	94.6			159	89.8		
	Yes	2	7.1			3	5.4			18	10.2		
Height, cm	No	106	170.4	8.5	0.138	138	173.2	9.1	0.609	259	174.2	9.4	0.929
	Yes	6	175.8	10.9		10	171.7	10.1		32	174.1	7.7	
Weight, kg	No	106	63.8	9.8	0.646	138	66.9	10.5	0.124	259	66.3	11.0	0.598
	Yes	6	67.3	12.4		10	62.1	8.4		32	65.1	9.0	
BMI	No	106	21.9	2.6	0.776	138	22.2	2.6	0.140	259	21.8	2.8	0.633
	Yes	6	21.6	2.0		10	21.0	1.6		32	21.4	2.1	
Sport, %													
Basketball	No	58	96.7		0.307	58	96.7		0.717	133	88.1		0.504
	Yes	2	66.7			2	3.3			18	11.9		
Floorball	No	48	92.3			80	90.9			133	90.5		
	Yes	4	7.7			8	9.1			14	9.5		
Nicotine use, %													
No	No	103	94.5		0.676	134	93.7		0.230	257	89.9		0.103
	Yes	6	5.5			9	6.3			29	10.1		
Yes	No	3	100.0			4	80.0			9	75.0		
	Yes	0	0.0			1	20.0			3	25.0		
Peak vGRF, N/kg	No	100	20.3	5.2	0.743	128	19.3	4.4	0.569	228	**18.8**	**3.9**	**0.043**
	Yes	5	19.7	4.2		6	18.0	3.7		29	**20.2**	**4.2**	
Absolute Peak vGRF, N	No	100	1289.1	392.3	0.774	128	1269.1	357.4	0.224	228	1216.7	321.3	0.122
	Yes	5	1316.5	345.5		6	1077.4	118.5		29	1298.2	308.7	
Peak vGRF asymmetry, N/kg	No	100	2.5	2.0	0.584	128	2.0	1.8	0.464	228	2.1	1.8	0.641
	Yes	5	2.1	2.0		6	2.4	1.8		29	2.1	2.0	
Absolute Peak vGRF asymmetry, N	No	100	161.2	131.6	0.662	128	131.1	123.4	0.572	228	133.6	119.4	0.735
	Yes	5	143.5	144.3		6	143.1	95.9		29	132.9	125.8	
Left leg femur-pelvic angle, degrees	No	85	80.9	4.5	0.375	103	79.9	4.4	0.303	202	80.5	5.0	0.740
	Yes	6	78.9	5.4		7	79.1	7.2		20	80.1	5.3	
Right leg femur-pelvic angle, degrees	No	91	77.5	4.9	0.905	95	76.9	4.5	0.587	199	**77.1**	**4.7**	**0.033**
	Yes	6	77.6	5.4		7	75.6	5.4		22	**74.6**	**4.9**	
Team practice hours during the follow-up, mean hours	No	106	238.1	104.5	0.341	138	201.1	89.4	0.356	266	229.0	114.6	0.923
	Yes	6	279.6	77.7		10	227.8	60.2		32	227.0	101.5	
Game hours during the follow-up, mean hours	No	106	7.1	6.0	0.597	138	8.4	5.8	0.247	266	9.1	6.0	0.240
	Yes	6	5.8	4.8		10	10.6	4.8		32	7.8	4.4	

vGRF vertical ground reaction force, *N* newton, *cm* centimetres, *kg* kilograms, *LBP* low back pain, *SD* standard deviation
Statistically significant results are indicated with **bold**

were females (52%, n = 25). Fifty-four percent of floorball players and 46% of basketball players had LBP during the follow-up. Most of the players who developed back pain during the follow up did so during their first follow-up year (81%) and only one player was followed for 3 years before developing LBP. LBP incidence was addressed in a previous publication [1].

Risk factor analyses

Our results showed that the players who had a smaller FPA during SLVDJ when landing on their right leg were at increased risk for all LBP and for gradual onset non-traumatic LBP (Table 3). The analysis using dichotomous risk factors showed that players with 80° FPA or less during right leg landing, had 2.2 times higher risk for LBP during the follow-up, than players with more than 80° FPA. There was no statistically significant association between risk for LBP and FPA during left leg landing from the SLVDJ.

In the third study year, mean peak vGRF was significantly higher in players who developed LBP during the follow-up (20.2 vs. 18.8 N/kg, p-value 0.033), but no significant differences were observed between previous study years (Table 2). The Cox risk factor analyses showed no association between peak vGRF measures and LBP incidence in young floorball and basketball players (Table 4).

Discussion

The aim of this study was to investigate whether hip-pelvic kinematics and peak vGRF during landing tasks were associated with LBP incidence in youth floorball and basketball players. The first hypothesis was that the movement pattern, where the FPA is decreased during SLVDJ landing due to increased movement of the hip in the direction of adduction and contralateral pelvis drop might predispose for LBP. The second hypothesis was that players with higher or asymmetric peak vGRF during VDJ landing are at increased risk for LBP. Contrary to our second hypothesis, we did not find a statistically significant association between LBP and peak vGRF. However, our results suggested that there is an association between hip-pelvic kinematics and LBP.

The lumbo-pelvic function is an essential part of successful athletic performance [10]. According to a conceptual framework of the kinetic chain [38], a decreased or increased movement somewhere in the kinetic chain is compensated for elsewhere along the chain. This has also been suggested by Garci et al. (2015), who observed that a change in frontal plane knee kinematics resulted in changes higher in the kinetic chain [39]. It has also been shown that stability in inferior segments, such as the lower leg, is significantly correlated with superior segments, such as pelvis and back, and therefore trunk stability may be dependent on the stability of lower segments [40]. Thus, based on the kinetic chain theory it

Table 3 Cox regression analysis results for femur-pelvic angle (FPA) during single-leg vertical drop jump

Continuous variables[b,c]	Univariate			Adjusted		
	HR	95% CI	***P*** value	HR	95% CI	***P*** value
All LBP						
Femur-pelvic angle, left side ([a])	1.04	(0.97 to 1.11)	0.240	1.04	(0.97 to 1.11)	0.310
Femur-pelvic angle, right side ([a])	**1.09**	**(1.02 to 1.17)**	**0.011**	**1.09**	**(1.02 to 1.17)**	**0.014**
Gradual onset non-traumatic LBP						
Femur-pelvic angle, left side ([a])	1.04	(0.96 to 1.11)	0.370	1.03	(0.95 to 1.11)	0.480
Femur-pelvic angle, right side ([a])	**1.10**	**(1.02 to 1.18)**	**0.013**	**1.09**	**(1.01 to 1.18)**	**0.021**
Dichotomous variables [d]						
All LBP						
Femur-pelvic angle, left side (low vs high)	1.80	(0.91 to 3.57)	0.094	1.86	(0.94 to 3.71)	0.076
Femur-pelvic angle, right side (low vs high)	**2.15**	**(1.10 to 4.21)**	**0.026**	**2.19**	**(1.12 to 4.30)**	**0.023**
Gradual onset non-traumatic LBP						
Femur-pelvic angle, left side (low vs high)	1.72	(0.79 to 3.73)	0.170	1.80	(0.83 to 3.90)	0.140
Femur-pelvic angle, right side (low vs high)	**2.25**	**(1.07 to 4.72)**	**0.033**	**2.30**	**(1.09 to 4.84)**	**0.028**

HR Hazard ratio, *CI* confidence interval, *all LBP* acute traumatic and gradual non-traumatic low back pain
[a] degrees
[b]Adjusted with history of LBP, leg dominance
[c] HR calculated per one-degree decrease
[d]Adjusted with history of LBP
Femur-pelvic angle, left side high > = 80.0°, low< 80.0°
Femur-pelvic angle, right side high > = 76.3°, low< 76.3°
Statistically significant results are indicated with **bold**

Table 4 Association between peak vGRF measures and injury risk for all LBP and gradual onset non-traumatic LBP

	Univariate		Adjusted	
	HR 95% CI	***P*** **value**	HR95% CI	***P*** **value**
Continuous variables[a]				
All LBP				
Peak vGRF, N/Kg	1.03 (0.97 to 1.11)	0.340	1.03 (0.96 to 1.11)	0.380
Absolute Peak vGRF, N	1.00 (1.00 to 1.00)	0.760	1.00 (1.00 to 1.00)	0.870
Peak vGRF asymmetry, N/Kg	1.00 (0.85 to 1.18)	0.990	1.00 (0.85 to 1.18)	0.990
Absolute Peak vGRF asymmetry, N	1.00 (1.00 to 1.00)	0.970	1.00 (1.00 to 1.00)	0.940
Gradual onset non-traumatic LBP				
Peak vGRF, N/Kg	1.00 (1.00 to 1.00)	0.610	1.00 (1.00 to 1.00)	0.690
Absolute Peak vGRF, N	1.04 (0.96 to 1.12)	0.370	1.03 (0.96 to 1.12)	0.420
Peak vGRF asymmetry, N/Kg	1.03 (0.87 to 1.23)	0.720	1.02 (0.86 to 1.22)	0.810
Absolute Peak vGRF asymmetry, N	1.00 (1.00 to 1.00)	0.710	1.00 (1.00 to 1.00)	0.790
Dichotomous variables [b] **(high vs. low)**				
All LBP				
Peak vGRF, N/Kg	1.92 (1.00 to 3.68)	0.051	1.83 (0.95 to 3.51)	0.070
Absolute Peak vGRF, N	0.99 (0.53 to 1.83)	0.960	0.94 (0.51 to 1.76)	0.860
Peak vGRF asymmetry, N/Kg	1.23 (0.66 to 2.30)	0.510	1.22 (0.65 to 2.27)	0.530
Absolute Peak vGRF asymmetry, N	1.21 (0.65 to 2.25)	0.550	1.20 (0.64 to 2.23)	0.580
Gradual onset non-traumatic LBP				
Peak vGRF, N/Kg	1.47 (0.73 to 2.98)	0.610	1.41 (0.69 to 2.86)	0.340
Absolute Peak vGRF, N	0.98 (0.49 to 1.97)	0.370	0.94 (0.47 to 1.88)	0.850
Peak vGRF asymmetry, N/Kg	1.31 (0.65 to 2.64)	0.720	1.30 (0.64 to 2.61)	0.470
Absolute Peak vGRF asymmetry, N	1.28 (0.64 to 2.58)	0.710	1.26 (0.63 to 2.54)	0.510

HR Hazard ratio, *CI* confidence interval, *LBP* low back pain, *vGRF* vertical ground reaction force, *N* Newton;
[a]Adjusted with history of LBP, leg dominance and nicotine use
[b] All LBP: Adjusted with history of LBP and leg dominance. Gradual onset LBP: Adjusted with history of LBP
Peak vGRF high > = 18.5, low< 18.5
Absolute Peak vGRF high > = 1191.0, low< 1191.0
Peak vGRF asymmetry high > = 1.6, low< 1.6
Absolute Peak vGRF asymmetry high > = 103.3, low< 103.3
Statistically significant results are indicated with **bold**

could be hypothesised that the decreased FPA may result in movement compensations and increased load and strain up and down the kinetic chain, that is in the lumbo-pelvic area as well as in the knee and lower leg. The association of trunk, pelvis and hip kinematics in relation to lower extremity complaints has been discussed [41] and previous research suggests that dysfunction distal to the injury site can be associated with future injury occurrence [42, 43].

Our results showed a small increase in risk (8%) for LBP with a one-degree decrease in the right leg FPA during the SLVDJ landing. This means a 2.2-fold increase in risk in players with less than 80° FPA during the right leg landing, compared to the players with more than 80° FPA. However, no association was detected between the left leg FPA and the risk of LBP. The difference between the right and left leg results might be due to the test procedure where the starting leg was not randomized, that is, the test was always started with the right leg. Another explanation may be the fact that in most players the right leg was their dominant (kicking) leg and the left leg was their supporting leg. This may explain why the left side was more stable during the SLVDJ. Our results are in line with previous studies suggesting that hip-pelvic kinematics are associated with injuries in athletes [11, 44, 45]. For example, findings from Bayne et al. indicated that increased knee valgus and hip adduction movements might result in increased repetitive compensatory movements from the pelvis and trunk [45]. Frontal hip-pelvic kinematics have been linked with trunk kinematics, for example increased trunk lateral lean, during single-leg tasks [46]. Gluteal muscle dysfunction has been associated with LBP [47], and it could be speculated that gluteal muscle dysfunction could result in inability to control the movement of the hip-pelvic complex during single-leg landing. In addition, the hip-pelvic movement pattern observed in this study might also be a compensatory movement resulting from several other factors, such as decreased control of the trunk over the pelvis or even control of the ankle. Therefore, in future studies, it is important to study the kinematics of the entire kinetic chain and not just a part of it.

Our second hypothesis was that vGRFs that affect the lumbar spine [19] could potentially predispose for back pain. However, to our knowledge the association between peak vGRF and LBP incidence in youth athletes has not been studied previously. According to our findings, there was no association between LBP incidence and peak vGRF or vGRF side-to-side asymmetry, measured in VDJ landing. In a cross-sectional investigation, Müller et al. were also unable to find a difference in vGRFs of youth athletes with and without LBP [48]. Future studies should investigate if loading rate is associated with LBP, because it has been shown to be a stronger risk factor for lower extremity injuries than peak GRF [49].

Methodological considerations

The strengths of this study were the prospective design and the methods of LBP and playing exposure registrations. In addition, the sample size was relatively large. The length of follow-up varied across the sample and therefore we used Cox regression analysis. Cox regression analysis can adjust for variations in the amount of sport participation (follow-up time). Yet, due to the relatively low number of LBP events, we were unable to stratify the analyses by sex. However, it seemed that sex was not significantly associated with LBP in this sample.

Risk factors can change over time and therefore we used time-varying variables in the Cox analysis, when possible. In addition, over half (54.5%) of the players had a history of LBP at the beginning of the study and 35% (n = 17) of the LBP recorded during follow-up was first-time LBP. We compensated for this by adjusting the risk factor analyses with a history of LBP.

We should not overlook the fact that up to 25% of all players participating (n = 383) were not included in the risk factor analyses. In the SLVDJ 25% of the players and in the VDJ 19% of the players had incomplete baseline test data. The absence of these players might affect the results of this study. We are also unaware whether players refusing to participate differ from our sample. Another limitation is that we did not test the reliability of the selected tests during this study. However, the reliability of vGRF measurements has been demonstrated previously by Krosshaug and Mok and their colleagues [28, 29]. Herrington and others demonstrated in a similar test that frontal plane FPA is a reliable measurement [31]. One limitation is that in the SLVDJ test the starting leg was not randomized. The players performed the test first with the right leg and this might have had an effect on the results. When performing the test with the left leg, the players were more experienced.

The aetiology of LBP has been shown to be multifactorial [50], meaning that, in addition to external loading, internal loading such as psychosocial stress should also be recorded. The latter has been associated with the risk of sports injuries in general [51]. There are also several other risk factors that should be taken into account, such as trunk muscle symmetry [52], in addition to acknowledging the fact that risk factors are dynamic in nature and change over time [53].

Conclusions

Our results suggested that there is an association between hip-pelvic kinematics and LBP, as measured in this study. However, we did not find a statistically significant association between LBP peak vGRF or side-to-side asymmetry of vGRF during VDJ landing. In the future, the association between hip-pelvic kinematics and LBP incidence should be investigated further to verify the results from this study.

Supplementary information

Supplementary information accompanies this paper at https://doi.org/10.1186/s12891-020-03376-1.

Additional file 1 Supplementary Table 1. Data collected in the structured injury questionnaire.

Additional file 2 Supplementary Table 2. Differences between players with and without baseline test result.

Abbreviations

LBP: Low back pain; CI: Confidence interval; SLVDJ: Single-leg vertical drop jump; VDJ: Vertical drop jump; HR: Hazards ratio; FPA: Femur-pelvic angle; vGRF: Vertical ground reaction force; GRFs: Ground reaction forces; 2D: Two-dimensional; 3D: Three-dimensional; SD: Standard deviation; N: Newton; Kg: Kilograms

Acknowledgements

We are grateful to statistician Kari Tokola for his indispensable support with the statistical methods. We are also thankful to study physicians Jussi Hietamo and Teemu Ekola for injury data collection, and research assistant Irja Lahtinen for the collection of training and match data and keeping contact with the participating teams.

Financial disclosure and conflict of interest

The authors affirm that we have no financial affiliation (including research funding) or involvement with any commercial organization that has a direct financial interest in any matter included in this manuscript, except as disclosed in an attachment and cited in the manuscript. Any other conflict of interest (i.e., personal associations or involvement as a director, officer, or expert witness) is also disclosed in an attachment.

Authors' contributions

All authors contributed to the study concept and design. KP was responsible for conducting the data acquisition. AMR was responsible for preparation of 2D video analysis data. ML was responsible for preparation of the 3D motion capture data. MR was responsible for the main data analysis, interpretation and writing the first draft of the manuscript. KP, AH, SÄ, AMR, ML, GM, TV, PK, and JP were significant manuscript revisers. All authors have approved the submitted version of the manuscript. KP is the guarantor.

Authors' information
Not applicable.

Funding
The PROFITS study was financially supported by the Finnish Ministry of Education and Culture, and the Competitive State Research Financing of the Expert Responsibility Area of Tampere University Hospital (Grants 9 N053, 9S047, 9 T046, 9 U044). The corresponding author was supported with research grants from the University of Jyväskylä and City of Kangasala (Björqkvist's fund).

Availability of data and materials
An anonymized form of the data can be made available from the corresponding author upon reasonable request.

Ethics approval and consent to participate
The Ethics Committee of Pirkanmaa Hospital District (ETL-code R10169). The study was carried out in accordance with the Declaration of Helsinki and the guidelines for good scientific practice. Written informed consent was acquired from the participants (and a legal guardian if the player was under 18 years old).

Consent for publication
Not applicable.

Competing interests
None declared.

Author details
[1]Tampere Research Center of Sports Medicine, UKK Institute, 33501 Tampere, Finland. [2]Faculty of Sport and Health Sciences, University of Jyväskylä, Jyväskylä, Finland. [3]Sport Injury Prevention Research Centre, Faculty of Kinesiology, University of Calgary, Calgary, Canada. [4]Alberta Children's Hospital Research Institute, University of Calgary, Calgary, Canada. [5]McCaig Institute for Bone and Joint Health, University of Calgary, Calgary, Canada. [6]Faculty of Information Technology, University of Jyväskylä, Jyväskylä, Finland. [7]Oslo Sports Trauma Research Center, Department of Sports Sciences, Norwegian School of Sport Sciences, Oslo, Norway. [8]Department of Orthopedics & Traumatology, Tampere University Hospital, Tampere, Finland. [9]Tampere University Hospital, Tampere, Finland.

Received: 16 December 2019 Accepted: 28 May 2020
Published online: 05 June 2020

References
1. Rossi MK, Pasanen K, Heinonen A, Myklebust G, Kannus P, Kujala UM, et al. Incidence and risk factors for back pain in young floorball and basketball players: a prospective study. Scand J Med Sci Sports. 2018;28(11):2407–15. https://doi.org/10.1111/sms.13237.
2. Pasanen K, Rossi M, Parkkari J, Kannus P, Heinonen A, Tokola K, et al. Low back pain in young basketball and floorball players. Clin J Sport Med. 2016; 26(5):376–80. https://doi.org/10.1097/JSM.0000000000000263.
3. Leppänen M, Pasanen K, Kujala UM, Parkkari J. Overuse injuries in youth basketball and floorball. Open Access J Sports Med. 2015;6:173–9. https://doi.org/10.2147/OAJSM.S82305.
4. Zazulak BT, Hewett TE, Reeves NP, Goldberg B, Cholewicki J. Deficits in neuromuscular control of the trunk predict knee injury risk. Am J Sports Med. 2007;35(7):1123–30. https://doi.org/10.1177/0363546507301585.
5. Seay J, Shing T, Wilburn K, Westrick R, Kardouni J. Lower-extremity injury increases risk of first-time low back pain in the US army. Med Sci Sports Exerc. 2018;50(5):987–94. https://doi.org/10.1249/MSS.0000000000001523.
6. Fuglkjær S, Vach W, Hartvigsen J, Wedderkopp N, Junge T, Hestbæk L. Does lower extremity pain precede spinal pain? A longitudinal study. Eur J Pediatr. 2018;177(12):1803–10. https://doi.org/10.1007/s00431-018-3235-6.
7. Potthoff T, de Bruin ED, Rosser S, Humphreys BK, Wirth B. A systematic review on quantifiable physical risk factors for non-specific adolescent low back pain. J Pediatr Rehabil Med. 2018;11(2):79–94. https://doi.org/10.3233/PRM-170526.
8. O'Sullivan K, O'Sullivan PB, O'Keeffe M, Forster BB, Qamar SR, van der Westhuizen A. Managing low back pain in active adolescents. Best Pract Res Clin Rheumatol. 2019;33(1):102–21. https://doi.org/10.1016/j.berh.2019.02.005.
9. Moradi V, Memari A, ShayestehFar M, Kordi R. Low back pain in athletes is associated with general and sport specific risk factors: a comprehensive review of longitudinal studies. Rehabil Res Pract. 2015;2015:1–10. https://doi.org/10.1155/2015/850184.
10. Kibler WB, Press J, Sciascia A. The role of core stability in athletic function. Sports Med. 2006;36(3):189–98. https://doi.org/10.2165/00007256-200636030-00001.
11. Roussel NA, Nijs J, Mottram S, Van Moorsel A, Truijen S, Stassijns G. Altered lumbopelvic movement control but not generalized joint hypermobility is associated with increased injury in dancers. A prospective study. Man Ther. 2009;14(6):630–5. https://doi.org/10.1016/j.math.2008.12.004.
12. Campbell A, O'Sullivan P, Straker L, Elliott B, Reid M. Back pain in tennis players: a link with lumbar serve kinematics and range of motion. Med Sci Sports Exerc. 2014;46(2):351. https://doi.org/10.1249/MSS.0b013e3182a45cca.
13. Ng L, Campbell A, Burnett A, Smith A, O'Sullivan P. Spinal kinematics of adolescent male rowers with back pain in comparison with matched controls during ergometer rowing. J Appl Biomech. 2015;31(6):459–68. https://doi.org/10.1123/jab.2015-0012.
14. Grosdent S, Demoulin C. Rodriguez de La Cruz, Carlos, Giop R, Tomasella M, Crielaard J, et al. Lumbopelvic motor control and low back pain in elite soccer players: a cross-sectional study. J Sci Med Sport. 2016;34(11):1021–9. https://doi.org/10.1080/02640414.2015.1085077.
15. Bayne H, Elliott B, Campbell A, Alderson J. Lumbar load in adolescent fast bowlers: a prospective injury study. J Sci Med Sport. 2016;19(2):117–22. https://doi.org/10.1016/j.jsams.2015.02.011.
16. Hernandez A, Gross K, Gombatto S. Differences in lumbar spine and lower extremity kinematics during a step down functional task in people with and people without low back pain. Clin Biomech (Bristol, Avon). 2017;47:46–52. https://doi.org/10.1016/j.clinbiomech.2017.05.012.
17. McClay IS, Robinson JR, Andriacchi TP, Frederick EC, Gross T, Martin P, et al. A profile of ground reaction forces in professional basketball. J Appl Biomech. 1994;10(3):222–36. https://doi.org/10.1123/jab.10.3.222.
18. Fuchs RK, Bauer JJ, Snow CM. Jumping improves hip and lumbar spine bone mass in prepubescent children: a randomized controlled trial. J Bone Miner Res. 2001;16(1):148–56. https://doi.org/10.1359/jbmr.2001.16.1.148.
19. Seay J, Selbie WS, Hamill J. In vivo lumbo-sacral forces and moments during constant speed running at different stride lengths. J Sci Med Sport. 2008; 26(14):1519. https://doi.org/10.1080/02640410802298235.
20. Pasanen K, Rossi MT, Parkkari J, Heinonen A, Steffen K, Myklebust G, et al. Predictors of lower extremity injuries in team sports (PROFITS-study): a study protocol. BMJ Open Sport Exerc Med. 2015;1(1):e000076. https://doi.org/10.1136/bmjsem-2015-000076.
21. Kuorinka I, Jonsson B, Kilbom A, Vinterberg H, Biering-Sørensen F, Andersson G, et al. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl Ergon. 1987;18(3):233–7. https://doi.org/10.1016/0003-6870(87)90010-X.
22. Bahr R, Andersen SO, Løken S, Fossan B, Hansen T, Holme I. Low back pain among endurance athletes with and without specific back loading—a cross-sectional survey of cross-country skiers, rowers, orienteerers, and nonathletic controls. Spine. 2004;29(4):449–54. https://doi.org/10.1097/01.BRS.0000096176.92881.37.
23. Takekawa KS, Gonçalves JS, Moriguchi CS, Coury H, de Oliveira Sato T. Can a self-administered questionnaire identify workers with chronic or recurring low back pain? Ind Health. 2015;53(4):340–5. https://doi.org/10.2486/indhealth.2014-0241.
24. Leppänen M, Pasanen K. Kulmala J-, Kujala U, Krosshaug T, Kannus P, et al. knee control and jump-landing technique in young basketball and floorball players. Int J Sports Med. 2016;37(4):334–8. https://doi.org/10.1055/s-0035-1565104.
25. Leppänen M, Pasanen K, Kujala UM, Vasankari T, Kannus P, Äyrämö S, et al. Stiff landings are associated with increased ACL injury risk in young female basketball and floorball players. Am J Sports Med. 2017;45(2):386–93. https://doi.org/10.1177/0363546516665810.
26. Stensrud S, Myklebust G, Kristianslund E, Bahr R, Krosshaug T. Correlation between two-dimensional video analysis and subjective assessment in evaluating knee control among elite female team handball players. Br J Sports Med. 2011;45(7):589–95. https://doi.org/10.1136/bjsm.2010.078287.
27. Nilstad A, Krosshaug T, Mok K, Bahr R, Andersen TE. Association between anatomical characteristics, knee laxity, muscle strength, and peak knee

valgus during vertical drop-jump landings. JOSPT. 2015;45(12):998–1005. https://doi.org/10.2519/jospt.2015.5612.
28. Mok K, Petushek E, Krosshaug T. Reliability of knee biomechanics during a vertical drop jump in elite female athletes. Gait Posture. 2016;46:173–8. https://doi.org/10.1016/j.gaitpost.2016.03.003.
29. Krosshaug T, Steffen K, Kristianslund E, Nilstad A, Mok K, Myklebust G, et al. The vertical drop jump is a poor screening test for ACL injuries in female elite soccer and handball players. Am J Sports Med. 2016;44(4):874–83. https://doi.org/10.1177/0363546515625048.
30. Ford K, Myer G, Smith R, Byrnes R, Dopirak S, Hewett T. Use of an overhead goal alters vertical jump performance and biomechanics. J Strength Cond Res. 2005;19(2):394–9. https://doi.org/10.1519/15834.1.
31. Herrington L, Alenezi F, Alzhrani M, Alrayani H, Jones R. The reliability and criterion validity of 2D video assessment of single leg squat and hop landing Electromyogr Kinesiol 2017;34:80–85. doi: https://doi.org/10.1016/j.jelekin.2017.04.004.
32. Olsen O, Myklebust G, Engebretsen L, Bahr R. Injury mechanisms for anterior cruciate ligament injuries in team handball. Am J Sports Med. 2004;32(4):1002–12. https://doi.org/10.1177/0363546503261724.
33. Fuller CW, Ekstrand J, Junge A, Andersen TE, Bahr R, Dvorak J, et al. Consensus statement on injury definitions and data collection procedures in studies of football (soccer) injuries. Scand J Med Sci Sports. 2006;16(2):83–92.
34. R Core Team. R: A language and environment for statistical computing. Vienna; 2016.
35. Therneau TM. Coxme: mixed effects cox models. R package. 2015:2.2–5.
36. Peduzzi P, Concato J, Feinstein AR, Holford TR. Importance of events per independent variable in proportional hazards regression analysis II. Accuracy and precision of regression estimates. J Clin Epidemiol. 1995;48(12):1503–10. https://doi.org/10.1016/0895-4356(95)00048-8.
37. Peduzzi P, Concato J, Kemper E, Holford TR, Feinstein AR. A simulation study of the number of events per variable in logistic regression analysis. J Clin Epidemiol. 1996;49(12):1373–9. https://doi.org/10.1016/S0895-4356(96)00236-3.
38. Karandikar N, Vargas OO. Kinetic chains: a review of the concept and its clinical applications. PM&R. 2011;3(8):739–45. https://doi.org/10.1016/j.pmrj.2011.02.021.
39. Graci V, Salsich GB. Trunk and lower extremity segment kinematics and their relationship to pain following movement instruction during a single-leg squat in females with dynamic knee valgus and patellofemoral pain. J Sci Med Sport. 2014;18(3):343–7. https://doi.org/10.1016/j.jsams.2014.04.011.
40. Graham RB, Costigan PA, Sadler EM, Stevenson JM. Local dynamic stability of the lifting kinematic chain. Gait Posture. 2011;34(4):561–3. https://doi.org/10.1016/j.gaitpost.2011.06.022.
41. Powers CM. The influence of abnormal hip mechanics on knee injury: a biomechanical perspective. JOSPT. 2010;40(2):42–51. https://doi.org/10.2519/jospt.2010.3337.
42. Verrelst R, De Clercq D, Vanrenterghem J, Willems T, Palmans T, Witvrouw E. The role of proximal dynamic joint stability in the development of exertional medial tibial pain: a prospective study. Br J Sports Med. 2014;48(5):388–93. https://doi.org/10.1136/bjsports-2012-092126.
43. Dingenen B, Malfait B, Nijs S, Peers KHE, Vereecken S, Verschueren SMP, et al. Can two-dimensional video analysis during single-leg drop vertical jumps help identify non-contact knee injury risk? A one-year prospective study. Clin Biomech (Bristol, Avon). 2015;30(8):781–7. https://doi.org/10.1016/j.clinbiomech.2015.06.013.
44. Chaudhari AMW, McKenzie CS, Pan X, Oñate JA. Lumbopelvic control and days missed because of injury in professional baseball pitchers. Am J Sports Med. 2014;42(11):2734–40. https://doi.org/10.1177/0363546514545861.
45. Bayne H, Campbell A, Alderson J. Lumbar load in adolescent fast bowlers: a prospective injury study. J Sci Med Sport. 2015;19(2):117–22. https://doi.org/10.1016/j.jsams.2015.02.011.
46. Dingenen B, Malfait B, Vanrenterghem J, Verschueren SMP, Staes FF. The reliability and validity of the measurement of lateral trunk motion in two-dimensional video analysis during unipodal functional screening tests in elite female athletes. Phys Ther Sport. 2013;15(2):117–23. https://doi.org/10.1016/j.ptsp.2013.05.001.
47. Kankaanpää M, Taimela S, Laaksonen D, Hänninen O, Airaksinen O. Back and hip extensor fatigability in chronic low back pain patients and controls. Arch Phys Med Rehabil. 1998;79(4):412–7. https://doi.org/10.1016/S0003-9993(98)90142-3.
48. Müller S, Stoll J, Müller J, Cassel M, Mayer F. Trunk muscle activity during drop jump performance in adolescent athletes with back pain. Front Physiol. 2017;8. https://doi.org/10.3389/fphys.2017.00274.
49. van der Worp H, Vrielink JW, Bredeweg SW. Do runners who suffer injuries have higher vertical ground reaction forces than those who remain injury-free? A systematic review and meta-analysis. Br J Sports Med. 2016;50(8):659. https://doi.org/10.1136/bjsports-2015-094924.
50. Smith AJ, O'Sullivan PB, Beales D, Straker L. Back pain beliefs are related to the impact of low back pain in 17-year-olds. Phys Ther. 2012;92(10):1258–67. https://doi.org/10.2522/ptj.20110396.
51. Watson A, Brickson S, Brooks A, Dunn W. Subjective well-being and training load predict in-season injury and illness risk in female youth soccer players. Br J Sports Med. 2017;51(3):194. https://doi.org/10.1136/bjsports-2016-096584.
52. Linek P, Noormohammadpour P, Mansournia MA, Wolny T, Sikora D. Morphological changes of the lateral abdominal muscles in adolescent soccer players with low back pain: a prospective cohort study. J Sport Health Sci. 2018. https://doi.org/10.1016/j.jshs.2018.02.002.
53. Meeuwisse W, Tyreman H, Hagel B, Emery C. A dynamic model of etiology in sport injury: the recursive nature of risk and causation. Clin J Sport Med. 2007;17(3):215–9. https://doi.org/10.1097/JSM.0b013e3180592a48.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Ready to submit your research? Choose BMC and benefit from:

- fast, convenient online submission
- thorough peer review by experienced researchers in your field
- rapid publication on acceptance
- support for research data, including large and complex data types
- gold Open Access which fosters wider collaboration and increased citations
- maximum visibility for your research: over 100M website views per year

At BMC, research is always in progress.

Learn more biomedcentral.com/submissions

V

STANDING KNEE LIFT TEST IS NOT A USEFUL SCREENING TOOL FOR TIME-LOSS LBP IN YOUTH BASKETBALL AND FLOORBALL PLAYERS

by

Rossi Marleena K, Pasanen Kati, Heinonen Ari, Äyrämö Sami, Leppänen Mari, Myklebust Grethe, Vasankari Tommi, Kannus Pekka, Parkkari Jari

Request a copy from the author.