Musculoskeletal Extremity Injuries in School-aged Children

with special focus on overuse injuries, seasonal variation and body composition

An investigation based on an observational prospective school based cohort study
The Childhood Health, Activity and Motor Performance School Study Denmark

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Contents

Preface

This thesis was conducted at the Faculty of Health Sciences, Centre of Research in Childhood Health, Research Unit of Exercise Epidemiology, Department of Sport Science and Clinical Biomechanics, University of Southern Denmark, in the period 2008 – 2013.

This PhD thesis presents results obtained from The Childhood Health, Activity and Motor Performance School Study, Denmark – The CHAMPS Study-DK. In 2007 the city council of the municipality of Svendborg, Denmark, decided to create sports schools with the intention to improve physical health of children (the Svendborg Project). The CHAMPS Study-DK was made responsible for the scientific evaluation of this project. The study is ongoing since August 2008 and has the overall aim to investigate the effect of additional physical education in a school based curriculum on children's health. The studies of this thesis have focus on musculoskeletal extremity injuries in children during 2.5 years from 2008 to 2011. The author of this thesis contributed full time to the data collection for the entire study period.

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List of studies

This thesis is based on the following four studies, which will be referred to by their roman numerals in the text:

I. Jespersen E, Holst R, Franz C, Rexen CT, Klakk H, Wedderkopp N. **Overuse and traumatic extremity injuries in school children surveyed with weekly text messages over 2.5 years.** Scand J Med Sci Sports (2013) (Epub ahead of print)

II. Jespersen E, Rexen CT, Franz C, Møller NC, Froberg K, Wedderkopp N. **Musculoskeletal extremity injuries in a cohort of school children aged 6-12: A 2.5 year prospective study.**
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III. Jespersen E, Holst R, Franz C, Rexen CT, Wedderkopp N. **Seasonal variation in musculoskeletal extremity injuries in school children aged 6-12 followed over 2.5 year.** BMJ Open (2014) (Epub ahead of print)

IV. Jespersen E, Verhagen E, Holst R, Klakk H, Heidemann M, Rexen CT, Franz C, Wedderkopp N. **Total body fat percentage and body mass index and the association with lower extremity injuries in children: a 2.5-year longitudinal study.** British Journal of Sports Medicine (2013) (Epub ahead of print)

Thesis at a glance

Study	Objectives & participants	Methods	Conclusions
|I	To report the incidence, prevalence and duration of traumatic and overuse injuries. To estimate the odds of injury types when looking at sports participation in school and leisure time as a risk factor, adjusting for gender, age, previous injuries, and seasonal variation. 1259 children (661 girls, 598 boys). Baseline mean age: 8.4 (5.4 - 11.6)	SMS-track (automated text messaging) reports on: • Musculoskeletal pain • Leisure time sports participation Telephone consultation identifying injuries and a clinical examination diagnosing injuries	Close to twice as many overuse as traumatic extremity injuries were registered, with 2.5 times more overuse than traumatic injuries in lower extremities. A reverse pattern was found for upper extremities, with 3.1 times more traumatic than overuse injuries. Grade level, school type, leisure time sport, and seasonal variation were associated with the risk of sustaining lower extremity injuries. Only grade level was associated with upper extremity injuries.
II	To describe the epidemiology of diagnosed musculoskeletal extremity injuries and to estimate the injury incidence rates in relation to different settings, different body regions and injury types. 1259 children (661 girls, 598 boys). Baseline mean age: 8.4 (5.4 - 11.6)	SMS-track (automated text messaging) reports on: • Musculoskeletal pain • Leisure time sports participation • Sports Telephone consultation identifying injuries and a clinical examination diagnosing injuries Accelerometer	A total of 1229 injuries were presented with apophyses and soft tissue injuries being the most common overuse injuries in lower and upper extremity. Ligament sprains were the most common traumatic injury. Injury rates of traumatic injuries were found to be highest for injuries sustained in sports and lowest for injuries sustained in physical education lessons. The shoulder/upper arm and the heel were the most common region of overuse injury in upper and lower extremity. The hand/wrist and the ankle were the most common regions of traumatic injury.
III	To determine the seasonal variation in extremity injuries in children. 1259 children (661 girls, 598 boys). Baseline mean age: 8.4 (5.4 - 11.6)	SMS-track (automated text messaging) reports on musculoskeletal pain. Telephone consultation identifying injuries and a clinical examination diagnosing injuries.	There are clear seasonal differences in the occurrence of musculoskeletal extremity injuries among children with almost twice as high injury incidence and prevalence estimates during autumn, summer and spring compared to winter.
IV	To examine two different measures of overweight, BMI and TBF%, as risk factors for lower extremity injuries in a school-based cohort, while considering potential confounding effects of gender, age, fitness levels and exposure times in physical education and leisure time sports participation. 632 children (321 girls, 311 boys) Baseline mean age: 9.6(7.7 - 12.0)	SMS-track (automated text messaging) reports on musculoskeletal pain and leisure time sports participation Telephone consultation identifying injuries and a clinical examination diagnosing injuries DXA scan providing body fat percentage BMI Aerobic fitness	The risk of lower extremity injuries increased in overweight children. When comparing two different measures of overweight, a body composition of proportional high levels of %BF is a higher risk factor, than overweight as measured by BMI. This suggests that a high proportion of adiposity explains injury risk better than being heavy for reasons that could also include a high proportion of lean muscle mass.

Description of contributions

	Study design	Data collection	Data analysis	Manuscript writing	Manuscript revision
Study I	EJ, NW	EJ, CF, CTR, HK, NW	EJ, RH, NW	EJ	EJ, RH, CF, CTR, HK, NW
Study IV	EJ, NW	EJ, CF, CTR, NCM, NW	EJ	EJ	EJ, CF, CTR, NCM, KF, NW
Study III	EJ, RH, NW	EJ, CF, CTR, NW	EJ, RH, NW	EJ, NW	EJ, RH, CF, CTR, CY-L, NW
Study II	EJ, EV, NW	EJ, HK, ML, CF, CTR, NW	EJ, EV, RH, NW	EJ	EJ, EV, RH, HK, MH, CF, CTR, NW

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RH	René Holst

Introduction

Why is it important to focus on musculoskeletal health in children?

Participation in physical activities promotes health in children. It has been shown that regular physical activity is associated with numerous physical health benefits, improved cognitive function, mental well-being, higher self-esteem and social skills in children [1-4]. A drawback of physical activity is the risk of related musculoskeletal injuries, both in adults and children. Injuries sustained during physical activity have been established as a leading cause of paediatric injuries in western countries [5-7]. Physical activity-related injuries in children constitute a significant public health burden, leading to high direct and indirect costs for both children and parents [8]. Injuries may cause short-term disability, absence from school and sport, loss of enthusiasm for participating in physical activities, and long-term consequences such as osteoarthritis resulting in pain and a decrease in physical activity [9-12]. A lowering of the physical activity level could have serious personal and public health implications, such as increased risk of cardiovascular disease and type II diabetes [13]. Thus from both an individual and a public health point of view it is important to prevent injuries.

Physical activity-related injury problems in general populations of children

A majority of published studies in the area of physical activity-related injuries in children have presented selected study populations and selected injury types, due to extracting data from selected settings (i.e. emergency departments, specific sports) or selected clinical conditions (i.e. ankle-ligament sprains, anterior cruciate ligament ruptures). Although all studies are informative it would seem that only part of the total injury problem is revealed, and that the less severe injuries and overuse injuries are under-represented. Previously pointed out as the “tip-of-the-iceberg” phenomenon by Dutch and Norwegian injury research groups [14-17].

A few descriptive epidemiology studies have looked into the general injury incidence in children and adolescents. The National Centre for Health Statistics conducted a large household survey in the US population and found that annually an estimated 7 million Americans received medical attention for sports and recreation related injuries (25.9 injury episodes per 1000 persons). The highest average annual medically attended sports and recreation injury episode rates were found in children aged 5-14 years (59.3 per 1000 persons) [6]. A Canadian survey of sport participation and sport injury high school students, aged 14-19, reported 65.7 injuries per 100 adolescents per year. When accounting for only those injuries that required medical attention the rate was 40.2 injuries per 100 adolescents per year [18]. The Childhood Injury Prevention Study followed a sample of 774 randomly selected Australian school children aged 4 to 12 years over 12 months. The overall injury incidence represented a 12-month physical activity-related injury incidence of 53.2 per 100 children. Child-based injury rates were calculated both in and out of the school setting, thus school injuries accounted for 10.8 injuries per 100 children per year, while non-school injuries accounted for 42.6 injuries per 100 children per year. The study also presented exposure rates based on time-at-risk for non-school injuries, namely 5.9 per 10.000 hours of exposure for injuries sustained outside school hours [19]. The Dutch iPlay-study, an injury prevention school study, was carried out in a cluster-randomised sample of 996 children aged 10-12 years followed over 12 months. The overall injury incidence rate was 0.48 per 1.000 hours of exposure, with leisure time physical activities having the lowest injury rate (0.39), followed subsequently by physical education lessons (0.50) and sport (0.66) [20].

Injury definitions and impact on the study outcomes

The above-mentioned surveys/ studies were carried out in population-based settings, but still reporting mostly severe and traumatic injuries due to the choice of injury definitions. Physical activity-related injuries are commonly defined by one of three possible criteria: the criteria of all physical complaints regardless of their consequences (‘any physical complaint’ definition), the criteria of needing medical care seeking (‘medical attention’ definition) or by the criteria of being unable to fully participate in normal activities (‘time-loss’ definition) [21].

It has been commonly acknowledged that different injury definitions identify different types of injuries in terms of injuries being severe or less severe and/or if they are traumatic or have a more gradual onset as overuse injuries [15 16, 22]. Traumatic injuries are those resulting from a single, specific, and identifiable event whereas overuse injuries are caused by repeated micro trauma without a single, identifiable event responsible for the injury [21].

The ‘time-loss’ injury definition has been questioned in the context of measuring overuse injuries as symptoms often have a vague and gradual onset, generating pain, but not necessarily causing time-loss from physical activities. This was illustrated in a study using beach volleyball as an example of how different injury definitions and recording methods led to different conclusions regarding the rate and severity of overuse injuries [16]. Beach volleyball is a technical sport with minimal contact between opposing players and few traumatic injuries [23], but a nature that calls for overuse injuries due to a lot of repetitive over-head and jumping activities. Bahr (2006) showed that using a traditional cohort study approach, the time-loss definition suggested that injury risk was very low, but using a survey of past and present pain problems in the shoulder, knees and low back demonstrated that overuse injuries were indeed prevalent [16]. The study was used to provide recommendations for a standardized methodology to quantify overuse injuries in sports and points out the advantage of frequent and prospective measurements, using sensitive scoring instruments to measure pain symptoms and define injuries by other means than time lost from sport or the need for medical attention [16].

The choice of an injury definition that embraces any physical complaint serve as a fine-meshed method for the recording of all symptom-giving injuries, independent of whether these injuries requires medical care or causes time loss from school and physical activities. Reporting of all injuries causing physical complaints seem relevant in the case of the young, growing and playing child. Musculoskeletal pain in children can be disabling and is not in all cases a self-limiting phenomenon [11, 24, 25]. Musculoskeletal pain and disability in adults are a major problem in modern society, and there has been an increasing amount of studies showing patterns of tracking of back pain from childhood into adulthood [26-28]. Only few studies have looked at extremity pain as a predictor and found associations between self-reported extremity pain and later extremity pain disorders. These studies were limited to a retrospective study design possibly inducing recall bias or cohort studies still awaiting long-term follow-up [24, 29, 30]. Results from these studies describe symptoms according to body area, frequency and duration, but leave causes uncertain. When Bishop and colleagues (2012) asked parents, what they thought was the cause of their child's extremity pain, a large number chose to state that the reason was unknown and the most often cited cause of extremity pain was referred to as growing pains [29].

Though it seems that musculoskeletal pain complaints should not be ignored in children through the years of growth, the injury definition 'any physical complaint' will yield a high rate of non-specific conditions if generated by self-report by child or parents and not by clinical assessments. Clinically diagnosed injuries give detailed information on the kind of tissue damage that is causing the physical complaints. Furthermore it gives an understanding of injury mechanism in terms of tissue damage being a result of a traumatic event or a result of accumulated micro-traumatic stress over time. An insight into the magnitude and nature of childhood musculoskeletal injuries allows for better planning and tailoring of preventive and treatment strategies.

Aetiology of physical activity-related injuries

An efficient preventive approach of musculoskeletal injuries in children also requires an insight in the circumstances in which they arise. The understanding of injury aetiology is another step to reduce physical-activity related injuries. Meeuwisse and colleagues (2007) developed a dynamic and cyclical model for injury causation, illustrating that injuries are not just the result of one specific inciting event but a complex interaction between intrinsic and extrinsic risk factors leading to the event that incites injury (figure 1) [31]. Risk factors are not considered stable, but may change through preceding cycles of participation and circumstances, for example a cohort of athletes will have a changing risk factor profile during a season. The recursive nature of the model also illustrates the cause of overuse injuries as it is not one single, identifiable event, but multiple exposures to the same risk factors that causes maladaptation and eventually tissue damage resulting in an overuse injury [21].

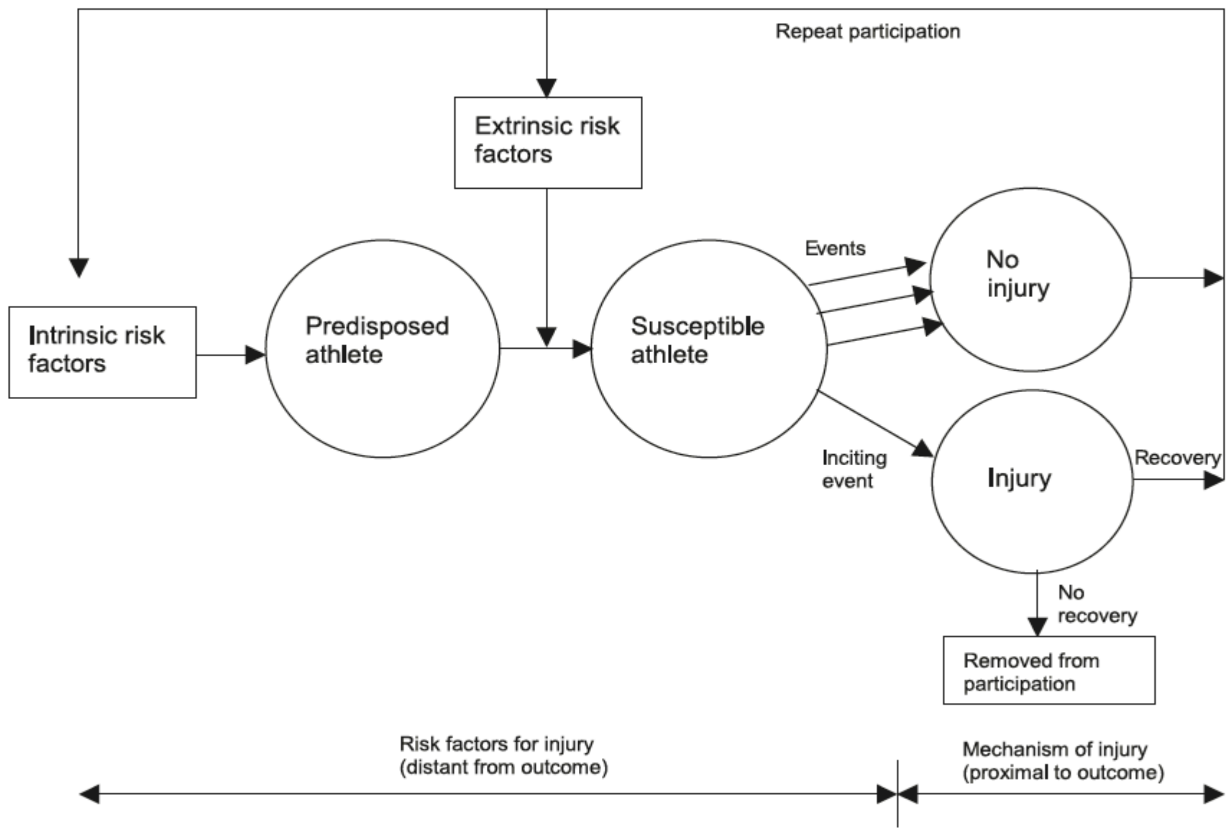


Figure 1. A dynamic, recursive model of aetiology in sport injury by Meeuwisse et al, 2007 [31]

Risk factors for injuries are factors that increase the potential risk for injury and can be divided into two categories: Intrinsic risk factors related to the individual (e.g. age, gender, previous injury, strength, fitness etc.) and extrinsic risk factors not related to the individual (e.g. time of season, playing surface, equipment, sport played, rules, etc.) [32]. Another consideration is whether risk factors are modifiable and can be altered by injury prevention strategies to reduce injury rates. Non-modifiable risk factors (e.g. gender, age, time of season) may affect the relationship between modifiable risk factors and injury and assists in defining high-risk groups [32].

Injury risk factors are a common set of factors that influence injury risk in all age groups, but in some fields they might have different influence in children /adolescents than later in adulthood and some factors are unique to the growing individual.

Intrinsic risk factors in children

Skeletal growth and musculoskeletal concerns

In the years of growth skeleton tissue develops from cartilage to bone tissue during processes of ossification occurring in several stages for different bones and continuing into the mid-20s [33]. The growing zones of the long bones include the physis and the epiphysis, and are sites vulnerable to musculoskeletal pain and injuries, commonly described as physeal injuries or growth plate injuries [34, 35].

Two types of epiphyses are found in the extremities: traction epiphyses and pressure epiphyses [34]. Traction epiphyses (or apophyses) are located at the site of attachment of major muscle tendons to bone (e.g. the attachment of the quadriceps muscle to the apophyses of the tibial tubercle). The apophyses contribute to bone shape, but not to the longitudinal growth. Consequently overuse apophyseal conditions, such as Osgood-Schlatter, Sinding-Larsen and Sever's are not generally associated with disruption of longitudinal bone growth, but may be a source of pain, discomfort and time lost from physical activities. Pressure epiphyses are situated at the end of long bones and are subjected to compressive forces (e.g. the epiphyses of distal femur and proximal tibia). In contrast with traction growth plates, injury to pressure epiphyses, such as physeal fractures may result in growth disturbance [34].

A decrease in bone strength appears to occur in the 2 to 3 years before peak height velocity in girls and boys (girls on average 12 y, boys on average 14 y) [33, 36]. It has been proposed that the time of rapid skeletal growth can temporarily increase muscle-tendon tightness and inflexibility because muscle development is thought to lag behind bone development [37]. However there is no evidence of this in the literature and one study found that adolescent growth were not associated with changes in flexibility [38].

To sum up, injuries that occur with similar mechanisms might result in different pathological conditions in children compared to adults. The immature skeleton is the weak link during growth, whereas soft tissue injuries (e.g. muscle strains, ligament sprains) are more prevalent in adults. One example is that while repeated contraction of the quadriceps muscle, typically from running -, jumping - and kicking sports, might result in pain at the apophyses of the tibial tubercle in children, the same mechanism might manifest as pain in the patellar tendon in adults [39].

Gender

Previous studies have found evidence that males are generally at higher risk of injury in child and adolescent sport (OR = 1.16 to 2,4) [32]. Possible explanations have included that boys are more likely to participate in vigorous exercise and sport, have a higher risk-taking attitude and have a larger body mass leading to greater forces generated on contact [32, 40]. Still, exceptions where girls are more at risk are easily found in sport specific studies (e.g. basketball, cross-country running, gymnastics, soccer and handball) or specific clinical conditions (e.g. knee injuries, especially anterior cruciate ligament ruptures) [41-44]. Many explanations have been given why girls suffer more serious knee injuries than boys, including anatomical variation, hormonal influences and neuromuscular factors [41, 42].

In heterogenic, more population-based cohorts, opposite results have been shown. Spinks and colleagues investigated 744 Australian school children aged 4-12 years and found that boys were injured at a higher rate than girls (62.9 vs. 41.5 injuries per 100 children per year) [19]. In contrast a Dutch school study, investigating 996 children aged 10-12 years, found that girls were at higher risk than boys (0.59 vs. 0.36 per 1000 hours of exposure) [20].

The possibility of gender differences in injury risk ‘crossing over’ between the ages 12 to 14, presumably due to the growth spurt appearing earlier in girls, has been suggested [20, 45]. A Danish study in 4619 children aged 6-17, treated in an emergency department, investigated age- and gender-specific incidence rates of sports injuries. They found girls had peak incidence rates at the age of 13 and boys at the age of 14, after which injury risk was observed to be substantially higher in boys [45].

Age

Risk of injuries generally increases with age across most studies when looking at specific sports [32, 41] even though some studies have shown the reverse or not found any association between age and injury [42]. Possible explanations are increasing hours of participating in sport, higher levels of competition and adolescents generating more force on contact than younger children, given that they are faster, heavier and stronger [32, 41].

Children of the same chronologic age may vary considerably in biologic maturity status, and individual differences in maturity status influence measures of growth and performance during childhood [33]. It has been speculated that early- and late-maturing children are at different injury risks. Findings from studies on the relationship between biologic maturity and injuries in sport are ambiguous and lack information on individual variation in exposure time, leaving the possibility that results are more an expression of time participating in sport than maturity [41].

Body composition

Body composition, defined as the relationship between bone tissue, lean muscle and fat mass, has received some attention as a potentially modifiable risk factor on sport injury risk [32, 41]. Major changes in body composition occur during childhood and especially in adolescence when gender differences are established [33].

There has been a focus on the particular association between overweight and injuries [46]. The importance is emphasized as overweight and obesity are affecting an increasing proportion of children globally [47]. Hence the paradox is, that while physical activity is associated with numerous health benefits, including reducing the levels of overweight and obesity[13], overweight might at the same time cause a rise in injury rates as the prevalence of overweight and obesity increases.

Overweight youth are generally considered as being at increased risk of sustaining lower extremity injuries in sports, due to a corresponding increase in the forces that bones, ligaments, tendons and muscular structures must endure [42, 46, 48]. However findings in studies about the association between body composition and injuries are inconclusive, and choices of measures of body composition have been different, such as height and weight, lean muscle mass, body fat content and most commonly body mass index (BMI) [42].

Overweight and obesity should be defined as excess body fat. The most widely used measurement to define obesity is BMI. It is an indicator of overweight and obesity from a population perspective, but has limitations on an individual level and is only a proxy measurement of body fat [49]. Not all individuals with excess weight are fat, because muscle mass and other non-fat tissues may contribute to the increase in weight [33]. Especially in athletes, the association between BMI and body fat has shown to be lower than in non-athlete controls [50-53].

In view of this, the common use of BMI as a criterion measurement may be an issue when it involves physically active children. A high BMI might in that case be an expression of a high proportion of lean muscle mass, rather than overweight or 'unhealthy' weight. Generally, caution should be taken when using BMI in growing individuals with changing relationship between body proportions (e.g. increased stature relative to weight) [33]. Body fat percentage is a measure of adiposity and in the area of sports it has proven to be a more precise measure for classification of overweight [51-54].

Previous injury

Evidence is provided in the literature that previous injuries combined with inadequate rehabilitation are risk factors for re-injury of the same type and location in adults, especially in the ankle [42, 55, 56]. A previous injury may lead to an increased risk of sustaining future injury, possibly due to persistent symptoms and underlying physiologic deficiencies (i.e. muscular weakness and imbalance, low endurance, impairment of ligaments, proprioception and fear of re-injury) [42, 57].

Few studies have addressed the problem in a childhood population. In a Dutch school cohort study, 38% of injuries were considered re-injuries, but criteria for classifying injuries as re-injuries were not stated [58]. When using the criteria of same body part, injury type, nature of onset and a history of injury the previous year a study in young (mean age: 12.6) female gymnasts showed a percentage of re-injuries of 32.7% [59]. It seems that re-injuries are an existing problem in childhood, but whether previous injuries leads to increased risk of sustaining a new injury has to our knowledge not been demonstrated in a child population.

Extrinsic risk factors in children

Time-at-risk

The time participating in physical activities, whether in physical education lessons, different sports or in unorganized physical activities in leisure time, is the time at risk of physical activity-related injuries.

Injury risk can be expressed as the number of new injuries that occur in a defined population during a specific period of time; i.e. injury incidence rates [60]. The most common approach to calculate incidence rates in the sports injury literature is to report the number of incident injuries divided by the total time at risk and is usually multiplied by a value expressing the chosen period of observation (e.g. 1000 hours) [61]. Other units of time-at-risk are ‘athlete exposures’, defined as one athlete participating in one practice or game where there is the possibility of sustaining an athletic injury and ‘element-exposures’, defined as one athlete participating in one element of activity (e.g. pitches, plays, bike trips) [61]. Finally, an incidence rate expressing the number of injuries divided by the total number of individuals and usually multiplied by a chosen number of individuals (e.g. 100) has served as an indicator of clinical resource use and therefore named a clinical incidence, but is not considered a valid estimator of risk nor a true rate as it does not take exposure time into account [60].

Using the ‘time-exposure’ accounts for the potential variance in exposure of individuals to risk of injury and makes comparison between studies possible if the same units of time-at-risk are used (e.g. minutes, hours) [61]. However, some authors have pointed out that a time-based exposure measure is meaningless in sports with constant interruptions (e.g. American football) leaving players inactive during significant proportions of game time [62] or in activities where it is more the specific elements (e.g. number of bicycle rides) that associates with risk of injury than the time [63].

Seasonal variation

Different times of the year invite different types and intensities of physical activities and different types of physical activities engender different types of injuries [64-68]. A review of the literature reveals that very little information is available on the injury pattern in children over the calendar year. Only data on more serious injuries from emergency room treatments and hospitalized children are available and show an indication of seasonal pattern to the incidence and type of injuries [65-68]. Literature on the seasonal injury pattern among children in the general population, which would be necessary in order to obtain proper incidence and prevalence data including also less serious injuries and overuse injuries, was not found. A Dutch school cohort study used a correction factor to account for seasonal effects on physical activity participation throughout the follow-up period (12 months) [20]. It seems reasonable that a proper survey of a possible variation in incidents of injuries across seasons necessitate frequent injury recording.

Injury incidence and prevalence

Basic epidemiology applied to sports and other physical activity-related injuries presents incidence as the number of new injuries that occur over a specific period of time, whereas the prevalence of injury is the proportion of athletes who have an existing injury at any given point in time [60]. Traditionally, the main focus has been on issues related to estimating injury incidence in sports injury research [60], but prevalence measures have been found more appropriate in the area of valid recording of overuse injuries [16]. The proportion of individuals affected by an overuse problem at any given time will capture the magnitude and severity of overuse injuries better, as symptoms might persist for several seasons and may exist before the injury recording has started. Thus the latter might not be registered as an incident injury, even though it is very long lasting and performance limiting [16]. Duration of injury affects the prevalence, but needs prospective and serial measurements of symptoms to get valid information on the severity of injury in terms of duration [22]. In the case of the growing child, the registration of injury incidence, injury prevalence and duration of injury are all important information. To date, however, there has been a lack of studies reporting childhood injury prevalence and duration of injuries, and there have been limited studies on childhood injury incidence and associated risk factors in general populations.

This thesis is based on information gathered in a large cohort of Danish schoolchildren aged 6 to 12 followed closely with mobile phone text messaging data on symptoms indicative of musculoskeletal injuries, with real time data on injuries diagnosed by clinicians and level and type of physical activity. This provided an opportunity to obtain estimates of the incidence, prevalence and duration of physical activity-related, musculoskeletal injuries occurring during a period of 2.5 years in a population-based sample of children. The thesis also looks into the above-described risk factors and the association with injury risk in children.

Aim and objectives of the thesis

Aim

To investigate the patterns of musculoskeletal extremity injuries in school children.

Objectives

1. To report the incidence, prevalence and duration of traumatic and overuse injuries in a cohort of school children using weekly assessments for 2.5 years and to estimate the odds of injury types when looking at sports participation in school and leisure time as a risk factor, adjusting for gender, age, previous injuries, and seasonal variation (study I).
2. To report diagnosis of all musculoskeletal extremity injuries and injury incidence rates in a cohort of school children aged 6-12 followed during 2.5 years (study II).
3. To examine the seasonal variation in extremity injuries in children (study III).
4. To examine two different measures of overweight, BMI and %BF, as risk factors for lower extremity injuries in a school-based cohort, while considering potential confounding effects of gender, age, fitness levels and exposure times in physical education and leisure time sports participation (study IV).

Methods

Setting

The studies in this thesis are all based on data from the Childhood Health, Activity, and Motor Performance School Study Denmark (CHAMPS Study–DK) August 2008 to July 2011 [69]. This investigation is a large prospective controlled school-based study in Denmark using the design of a natural experiment [70] to evaluate the effect of increased physical education on childhood health in general. Six schools were assigned to become sport schools with six physical education lessons per week and four normal schools served as control with two physical education lessons per week. The project is extensively described elsewhere (Wedderkopp et al., 2012).

This thesis is not an evaluation of the effect of increased physical education, but an investigation of musculoskeletal injuries in children taking exposure to physical activities, seasonal variation, body composition and other explaining factors into consideration.

Participants

All boys and girls from pre-school to fourth grade in ten public schools participating in the CHAMPS Study-DK also agreed to participate in the registration of musculoskeletal pain and injuries. The overall participation rate was 697 (90%) for the sport schools and 521 (71%) for the normal schools. The study was kept open, with the opportunity for new children to enter. Due to the novel data collection method of automated mobile phone text messaging (SMS-track), the ten schools were included gradually over eight months in order to allow for a phasing-in process.

Collection of injury data

SMS-track – surveying musculoskeletal problems using mobile phone text messaging

The method

The underlying theory to mobile phone short message service (SMS) surveying has been described by Schiffman[71] as an Ecological Momentary Assessment, a method well suited to assess how events change over time and across contexts in subjects' natural environments. Ecological Momentary Assessment was introduced in 1994 as a method to avoid memory lapse and recall bias, by repeated assessments using technologies ranging from diaries, telephone interviews, palm-top computers and lately SMS. The aim is to get real world information in real time about a subject's current state, thus maximizing validity of data as opposed to data collected retrospectively [71].

Using SMS in research is still a novel method, but has so far proven that it is possible to collect accurate data of fluctuating conditions by obtaining detailed information on changes over time [72, 73]. Moreover the method has shown to be an inexpensive, feasible and user-friendly method for collecting data, with high compliance rates [72-76].

Studies on validity and reliability are still needed, but in one study construct validity was moderate to strong when comparing weekly responses on low back pain with the initial pain score and two self-rated health measures collected during and after completion of the study [77]. In another study a comparison between real time data captured by SMS and retrospective telephone interview showed low agreement between 1-year recall and weekly reports, whereas 1-week and 1-month agreement was high [75]. In this study the SMS-Track reporting where validated against verbal reporting. The sensitivity for the SMS-track data was 0.98, specificity 0.87, positive predictive value 0.94 and the negative predictive value 0.95, indicating high validity of data [78].

The technology

SMS-Track is a web-based program (Software-as-a-Service) that enables use of text messages as a means to perform surveys. The service has been used within research projects with a focus on frequent monitoring and iterative data gathering, which has transformed the service to contain a series of industry best practices within SMS surveying. The technology enables data from a large number of respondents to be gathered at frequent intervals and yield real time information through two-way messaging. Data from the text message can be viewed instantly, making it possible to identify non-responders and recognize misunderstandings. The data are automatically transferred to an electronic data file which is readily available for download in various formats, making import to statistical programs possible [79].

SMS-track as a method in this study

Data on musculoskeletal complaints were collected weekly during 2.5 school years using SMS-track. Collection of data was suspended during the six weeks of summer holiday and one week of Christmas holiday.

Parents were used as informants on behalf of the child, as self-reported data from young children may be inaccurate [80, 81]. Every Sunday, text messages were automatically sent to the parent's mobile phone asking the following question:

> "Has [NAME OF CHILD] during the last week had any pain in:
> 1. Neck, back or low back
> 2. Shoulder, arm or hand
> 3. Hip, leg or foot
> 4. No my child has not had any pain."

The parents were asked to type the relevant number in a return text message.

If parents forgot to answer, reminders were sent twice with an interval of 48 hours. If parents did not answer at all, or answered in text or other invalid ways, research assistants contacted them by telephone to clarify facts. If there was no contact, the answer was coded as a missing value. All the answers were stored directly in a database, thus making it possible for researchers to extract information instantly.

The answers served to investigate the fluctuations in musculoskeletal symptoms and duration of pain over time, but was at the same time a weekly screening, leading to the identification of new incidences of musculoskeletal related injuries. The procedure was to identify all new reports on musculoskeletal pain by listing the parents, who had answered 1, 2 or 3, giving the information that the child had experienced pain and in which anatomical region (back, upper extremity or lower extremity). Further information on the origin, nature and course of pain, was captured by clinicians contacting the parents by telephone.

Telephone consultation

Two physiotherapists and two chiropractors were responsible for the follow-up of children reporting pain. Every Monday they telephoned parents whose children had musculoskeletal problems in the past week. During the telephone consultation a standardised questionnaire was completed. This collected information about whether the pain had a traumatic, a more gradual or an unknown cause, if it occurred during PE-lessons, in sport or leisure time physical activities and the specific anatomic location. The nature of pain was not defined in the instructions to parents, leaving the broadest possible interpretation open to the parents, when they had to decide what to report. The possibility of parents reporting burns, cuts etc. was present, but only musculoskeletal symptoms were registered for later analysis. If the pain was non-musculoskeletal, had disappeared or was well explained by an earlier medical history, there would be no more intervention before next pain reporting (if any). If the pain was still present and unexplained, a clinical examination was scheduled.

Clinical examination

Physiotherapists, chiropractors and a medical practitioner were responsible for the clinical examination and diagnosing of injuries within the next fortnight at the respective schools of the child in need of examination. A standard medical record was performed and a standardised questionnaire was also completed for research use.

If necessary, the child was referred for examination at a sports medicine clinic and seen by the research leader, who is an orthopaedic surgeon, leader of the sports medicine clinic and professor in clinical biomechanics. If needed, the child would be referred for para-clinical examination procedures, such as x-ray, ultrasound or MRI-scans.

Information on children being seen or treated elsewhere (e.g. emergency department, GP) during the study period was collected concurrently to get a complete data collection on injuries.

An injury was not registered as a new injury if the condition was determined to be an exacerbation of a non-recovered index injury.

Classification of injuries

Injuries were diagnosed using the International Classification of Diseases (ICD-10) [82]. Furthermore injuries were classified according to injury causation; whether they were traumatic or overuse injuries. Injuries were classified into these two categories by looking at diagnosis and medical records, where the injury mechanisms were documented.

Overuse injuries are complex to describe when looking for the context in which they occur in a general, non-sports specific, cohort. The tissue damage is a result of repetitive demands over the course of time and probably an accumulation of different types of physical activities across different settings. Thus only the traumatic injuries were categorized and presented according to whether they happened during physical education lessons, sports, or during leisure time physical activities.

Explaining risk factors

Injury rates - exposure time

Injury rates, where exposure time is taken into consideration, are useful when comparing risks of injury between groups. In this study exposure data were collected in three different settings of being physically active; physical education lessons, organised leisure time sports and leisure time physical activity.

School – physical education lessons

Weekly amount of physical education lessons was 4.5 hours for sport schools and 1.5 hours for normal schools, corresponding to three and one double lesson per week respectively. Children at sport and normal schools were therefore assigned three and one physical activity exposure unit per week respectively. The recording of non-attendance was attempted, but finally omitted as teaching records were not consistent.

Sports

The weekly amount of organised leisure time sport was assessed using SMS-track. Every Sunday, text messages were automatically sent to each parent's mobile phone as a second question after the "pain question", asking the following:

> "How many times did [NAME OF CHILD] participate in sports in leisure time the previous week?"

The parents were instructed to type the relevant number between 0 and 8. The answers 0 to 7 represented the unique number of times engaging in sports, whereas 8 stood for 'more than 7 times'. If the answer was different from zero, meaning that the child had participated in organized sport during the previous week, a third question asking about the type of sport was automatically sent:

> " Which type of sports?"

The parents had 10 answer options: 1. Soccer, 2. Handball, 3. Basketball, 4. Volleyball, 5. Rhythmic gymnastics, 6. Tumbling gymnastics, 7. Swimming, 8. Horse-riding, 9. Dancing, 10. Other sports. The parents were instructed to type the relevant number(s).

For feasibility reasons, the parents were asked to report how many times their child had participated in leisure time sport and not the exact amount of minutes/hours. Therefore the injury rates were expressed in the form of injuries per 1000 physical activity units, instead of injuries per 1000 hours. The time spent in different sports per training or per match typically varies from 30 minutes (i.e. swim training) to 90 minutes (i.e. soccer and handball training) for Danish children aged 6 to 12.

Leisure time physical activity

There were no weekly measures of the amount of physical activity besides organised sport and PE lessons, hereafter named leisure time physical activity. Instead data from accelerometer measurements was used to estimate the amount of exposure in terms of leisure time physical activity. Accelerometer assessments were performed from November 2009 to January 2010, when the children attended 1st - 5th grade, using an Actigraph GT3X accelerometer (Pensacola, Florida, USA), designed to monitor human activity. The children were instructed to wear the device from the time they woke up in the morning until bedtime in order to capture the entire amount of physical activity for each day. The only exception was to remove the monitor when showering or swimming in order to prevent damage to the device. The children were asked to wear the accelerometers for 7 full consecutive days, thus potentially including all weekdays and a full weekend. After the measurement period the accelerometers were recollected and data downloaded to a computer.

A customized software program (Propero, version 1.0.18, University of Southern Denmark, Odense, Denmark) was used to process the accelerometer data using information on physical activity for every 10 seconds. In order to distinguish between true intervals of inactivity and "false intervals of inactivity" recorded when the monitor had been taken off, consecutive strings of zeros of 30 minutes or longer were interpreted as "accelerometer non-worn". Activity data were included for further analyses if the child had accumulated a minimum of 10 hours of activity per day for at least four days. Cut-off points for four activity intensity levels; sedentary, light, moderate, vigorous, were used according to Evenson et al [83].

For estimates of exposure time in relation to leisure time injuries, calculations of time spent in moderate and vigorous activity were chosen, as this activity type was regarded as the "risk of injury activity". For study II data were used on sample-level, meaning that a mean estimate of the total number of exposure units was extracted. An exposure unit was arbitrarily chosen to equal 60 minutes of moderate and vigorous activity. Exposure time for the amount of physical activity outside organised sport and physical education lessons is thus the number of exposure units in physical education and organised sports subtracted from the total number of exposure units as estimated from accelerometer measurements.

Body composition measures

Total Body Fat Percentage (TBF%)

Total body fat percentage (TBF%) was measured by Dual Energy X ray Absorptiometry (DXA), (GE Lunar Prodigy, GE Medical Systems, Madison, WI), ENCORE software (version 12.3, Prodigy; Lunar Corp, Madison, WI). The procedure took place at Hans Christian Andersen Children's Hospital, Odense, Denmark. Children were instructed to lie still on the scanner table in a supine position wearing underwear, a thin T-shirt, stockings and a blanket for the duration of the DXA scan. The typical scan duration was 5 min, depending on child's height. If quality was not acceptable a new scan was performed. All scans were performed and analysed by two different operators only and analysed by one. The DXA machine was calibrated daily, following standardized procedures.

TBF% was calculated for each participant from the equation: [(FM (g) x 100)/ Total body weight (g)]. Cut-offs to classify children as normal-weight or overweight was defined using the cardiovascular health- and gender-related TBF% standards according to Williams et al. Cut-off for overweight boys was ≥ 25 TBF% and similar cut-off for girls was ≥ 30 TBF% [84].

Body Mass Index (BMI)

Weight was measured to the nearest 0.1 kg on an electronic scale, (Tanita BWB-800S, Tanita Corporation, Tokyo, Japan). Height was measured to the nearest 0.5 cm using a portable stadiometer, (SECA 214, Seca Corporation, Hanover, MD). Both anthropometrics were conducted without shoes.

Body Mass Index (BMI) was calculated as [weight (kg)/height2 (m)]. BMI classifications for normal-weight, overweight and obese were defined using age- and sex specific cut-offs as recommended by the International Obesity Taskforce recommendations [85]. Dichotomized categories were made for weight classes normal-weight or overweight/obese (hereon referred to as overweight) for easier comparison with the dichotomous variable of normal-weight vs. overweight as described above for TBF%.

Aerobic fitness

Aerobic fitness was used to explain associations between the risk of lower leg injuries and overweight in study IV. Aerobic fitness was assessed by the Andersen test. This is a 10 minutes intermittent running test to estimate maximal oxygen uptake and indicate aerobic fitness [86]. The test was carried out indoors on 20-m running lanes marked by cones. Children were urged to run as quickly as possible for 15 seconds, then stopped for the next 15 seconds and repeating this pattern for 10 minutes. The total distance measured in meters was the test result. This field test was tested and described thoroughly for the age group of our cohort in a study by Ahler et al.[87], thus validity was $r^2 = 0.85$ compared to VO_2 treadmill test and reliability was $r^2 = 0.86$ test/retest.

Ethics

The study was approved by the Ethics Committee for the region of Southern Denmark before the start of the project (ID S20080047), and registration in the Danish Data Protection Agency was made, as stipulated by the law J.nr. 2008-41-2240. No person referable data are available in the main data set. Written informed consent was obtained from the child's parent. All participation was voluntary with the option to withdraw from parts of, or the entire project, at any time. Prior to every clinical examination, an additional verbal agreement was obtained from both child and parent to allow the recording of information on the injury. All clinical examinations were conducted with respect to every child's personal integrity.

Ethical considerations were applied in relation to the fact that children being examined often experienced some level of pain and functional limitations. Clinicians gave advice as a natural implication of the duty to alleviate symptoms, and referred to specialists and further examinations as needed.

Data analysis

The collection of data on injury incidence and prevalence and risk factors every week for 2.5 years in a school setting provides a multitude of observations. The challenge is to correctly analyse and exploit data and at the same time make clinical sense. Some considerations were common, some concerned the outcome variables and some the explaining variables – all are presented in the following paragraphs.

Common considerations

Start-up-phase

When looking at injury incidences across weeks, there were suggestions of a larger diversity and lack of stability in the first period, approximately first four weeks, of sending out mobile phone text messages (figure 1 in appendences). Weeks relative to each school inclusion was used, thus week one is the first week for all ten schools even though the inclusion of schools to participate in SMS-track was gradual. The purpose was to distinguish if the higher rates of incidence were a phenomenon connected to a start-up-phase as also empirical experience would suggest.

To investigate if the difference between the start-up-phase and the rest of the period was influencing the estimates from other explanatory effects, a binomial variable was generated, indicating if this was start-up-phase or not, and used as an explanatory variable in a logistic regression model. Analysis showed this to be significant in all cases, indicating that we could expect the estimates to be affected by the diversity of the two periods. We looked at estimates in analysis with, and without, the first four weeks relative to each school and found results to be different. Consequently observations from the first four weeks relative to each school were excluded for modelling of the final analysis, as the high levels of injury incidences in the start-up-phase were considered to be unrepresentative and a possible effect of injuries accumulated over time and not yet seen by other clinicians.

Missing

Repeated data collection inevitably implies missing data. SMS-track data presented with four kinds of missing: 1. Parents replied, but in a non-valid manner, 2. Parents replied, but with an empty SMS, 3. Parents received SMS, but did not answer, 4. Parents never received SMS because of wrong or changed mobile numbers. Missing values because of practicalities concerning wrong or changed mobile numbers were dropped for analyses. Potential patterns for the missing values were addressed by a logistic regression analysis, controlling for gender, age, school type, and leisure time sports effects.

Outcome variables

Analysis of injury incidence data

Observed incidence

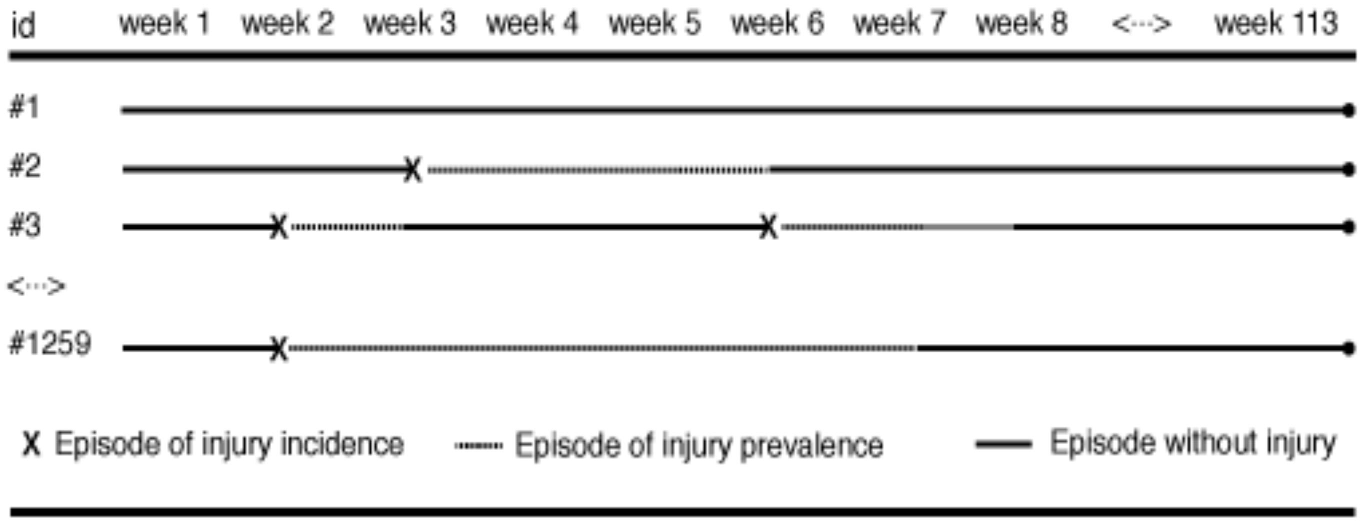
Unadjusted numbers of new incidences of injury were presented in different ways depending on the objective in the study. In study I, the results were presented as a weekly mean incidence with standard deviations for all individuals across all participating weeks shown for musculoskeletal pain and injuries in lower- and upper extremity, reporting overuse- and traumatic injury respectively (table 1). In study II, number of injuries was presented for all individuals according to diagnosis and body region (all injury types) and to different settings (only traumatic injuries) (table 1-4, study II). In study III, injury numbers and mean incidence rates (±SD) are presented by the four seasons for lower- and upper extremity (table 2; study III). In study IV number of lower extremity injuries are presented by gender (table 1, study IV).

Modelled incidence

Analyses on associations between possible explaining risk factors and injury incidence were carried out, but initially some general considerations for using injury incidence as outcome variable are explained.

Figure 2 gives a simplistic overview of the three events of main interest for regression analyses: The child sustaining an injury (episode of incidence), the child being in a state of injury (episode of prevalence) and the child being in a state without injury (episode without injury). The incidence models were based only on the data from the episodes without injury, as a child carries no information on the risk of injury when being in a state of injury. Consequently, an episode without injury was considered a risk episode.

Figure 2: Simple illustration of the observations of interest; the episodes of injury incidence, episodes of injury prevalence and episodes without injury.



Modelling the risk of injury incidence was done within the frame of logistic regressions with a binary outcome of interest: the absence or presence of extremity injury. In study I, looking at the risk of overuse - and traumatic injury incidence, the model was adjusted to handle three outcomes; absence of injury, presence of overuse injury and presence of traumatic injury. This was done using a multinomial logistic regression model, adequately taking the competing risk between the three types of events that could occur every week into consideration [88].

Analysis of injury prevalence data

Observed prevalence

Unadjusted injury prevalence was presented in different ways depending on objective in the study. In study I, the results were presented as a weekly mean prevalence with standard deviations for all individuals across all participating weeks shown for musculoskeletal pain and injuries in lower- and upper extremity, reporting overuse- and traumatic injury respectively (table 1). In study III, mean prevalence rates (±SD) were presented by the four seasons for lower- and upper extremity and extremity injuries combined (table 2, study III).

Modelled prevalence

The prevalence models (study III) were based on data from episodes of being without injury as well as episodes of being injured (figure 2). That is, a child was considered in risk of prevalence regardless of whether they were in a state with or without injury the week before. Modelling the risk of injury prevalence was done within the frame of logistic regressions with a binary outcome of interest: the absence or presence of pain being prevalent in relation to injury.

Analysis of injury duration

With prevalence data being available, it was possible to report mean injury duration (±SD) in terms of number of weeks with injury being prevalent for musculoskeletal pain and injuries in lower- and upper extremity, reporting overuse- and traumatic injury respectively (table 2, study I).

Explaining variables

Time-at-risk

Incidence rates using physical activity as exposure

Numbers of new incidences of injury, adjusted for the variations in time of being physically active were presented in different ways on either individual level or group level, depending on the objective in the study.

In study I, the calculation of injury incidence rates accounted for the total sum of exposure in injured children expressed in 1000 physical activity units. These comprised the physical education and sport exposures presented by grade and by injury type (overuse and traumatic) in mean incidence rates ±95%CI (table 1, study 1). In study IV, the total sum of physical education and sport exposures in injured children expressed in 1000 physical activity units, was likewise used to calculate incidence rates, this time by gender and in groups of children being normal weight or overweight (table 2, study IV). In study II, the calculation of injury incidence rates (IR) accounted for the total sum of exposure across all children expressed in 1000 physical activity units. These comprised the physical education, the sports and the leisure time PA exposures.

To sum up, study I and IV uses the individual data on injury numbers and exposure time in injured children, whereas study II injury rates are the sum of injuries across all individuals divided by the sum of exposure across all individuals.

Physical activity as an explaining covariate in regression models

While incidence rates calculated as the number of injuries divided by the number of exposures is a very common method of getting information on associations between injury risk and exposure time [22], other explaining risk factors were not taken into account. In order to examine the concurrent effect of all possible confounders explaining the injury risk, physical activity was included as an explaining covariate in multiple regression models. This was done in different ways, depending on the objective in the study.

In study I, the amount of physical education were accounted for by including school type as a covariate, i.e. the effect of being a child on a sport school (six physical education lessons per week) with children at normal schools (two physical education lessons per week) as reference. Sports participation was likewise included as an explaining covariate. The study looked at the weekly risk of sustaining overuse and traumatic extremity injury and the challenge was to capture a relevant period of sports participation, possibly influencing the risk of a new injury. Physiologically, there was no obvious cut point, as traumatic injuries could be sustained the first time a child participates, whereas overuse injuries typically would be a result of repetitive demands over the course of weeks or months.

An arbitrary timeframe of 8 weeks was chosen for the analyses, giving highest weight to the most immediate weeks before an incidence of injury when a child participated in sport. While study I was explorative in nature, outlining all covariates that could elucidate aetiology in overuse and traumatic extremity injury risk, the focal point of interest in study IV, was the exposure-outcome association between overweight and lower extremity injuries. Time-at-risk was adjusted for by a covariate expressing the mean physical education and sports participation per child and a covariate accounting for aerobic fitness as a proxy of how physically active children were.

Gender, age and previous injury

The selection of potential confounder effects for the analysis chosen a priori included gender, age, and previous injuries. These are commonly acknowledged modifying factors [32, 41].

Gender was used as an explaining covariate in study I, III and IV. Age was used as an explaining covariate in study I, III and IV. Grade level (0-6) was used as a proxy of age. The Danish 'grade 0' would correspond to pre-school and the age of 6 years, grade 1=7 years, grade 2=8 years, grade 3=9 years, grade 4=10 years, grade 5=11 years, grade 6=12 years. The same cohort of children was followed for 2.5 years, starting with them being pre-school to 4th grade pupils and ending with them being 2nd to 6th grade pupils. This explains the larger proportion of pupils in some grades in analysis.

Previous injury is a commonly acknowledged risk factor for sustaining new incidence of injury [32, 42]. From an analytic point of view the question is when to categorize a previous injury as an injury that could possibly influence the risk of a new injury. Consideration needs to be given to capture an aetiologically relevant time period, looking back from the time of injury, rather than forward from the beginning of the registration period. Timeframes for tissue recovery and rehabilitation (e.g. regaining muscular strength and balance, proprioception, aerobic fitness) are different and vary from weeks to months [89].

For study I a timeframe of 8 weeks was arbitrarily chosen for the analyses. Previous leg injury during the last 8 weeks was included as a covariate, when looking at the risk of new incidence of leg injury and likewise previous arm injury was included, when looking at risk of arm injury. It was considered clinically relevant to give most importance to the weeks just before the new incidence of injury by a Gaussian weighting.

Seasonal Variation

For an observational study, which is exploratory in nature, it is often not possible to completely specify all possible confounders of the exposure-outcome associations a priori [90]. Explorative plots of the observed injury incidence and prevalence for all injuries over the period of the study indicated an annual pattern, peaking during the autumn and spring seasons, and reaching a minimum injury incidence and prevalence during wintertime. Seasonal variation was therefore also included as a potential explaining covariate.

For study I, a dichotomous variable was included, indicating whether it was a high-risk period or a low risk period. In study III, the specific objective was to determine the seasonal pattern in extremity injuries. This was done by a harmonic regression model where the annual variation was accounted for by sine and cosine terms with periods of 52 weeks, representing the mathematical best fit of the data [91].

Prevalence history

To date, no studies have reported childhood injury prevalence using weekly information stating if the child is in a state of prevalence or no-prevalence. This gave reason for new hypotheses and explorative ways to address these by looking at crude data. Logically, it could be hypothesised that the risk of injury being prevalent would be higher if injury was prevalent the week before and vice versa.

Explorative plots, using the lorelogram were chosen to give information on a possible serial dependence between consecutive weeks in episodes of injury. A lorelogram is a plausible working correlation matrix used as a visual tool to illustrate the association between repeated measurements on the same individual. Different risks are expressed in terms of log odds ratios for 2x2 tables formed by the presence or absence of pain being prevalent on weeks separated by given distances/lags in time: lag1=the distance of one week, lag2=the distance of two weeks, etc. The value of zero implies independence, whereas values above zero imply positive associations [92 93].

Looking at prevalence data on leg pain as an example in the present study, the hypothesis about a serial dependency is confirmed (figure 2 in appendences). There are some main features to this plot. At lag 1, the log odds ratios are very high (3.8 => odds ratio=44.7), indicating that weeks with leg pain tend to follow each other. The lorelogram then decays very quickly for about 10 weeks, possibly reflecting the injury episode effect (duration of injury). After that the mean is stable at a level considerably above 0 (log(OR) approximately 1.5 => odds ratio=4.5). This long-term association is thought to occur as a result of heterogeneity between children, essentially a frailty effect: some children are prone to have frequent episodes of injury and some children are prone to have few episodes of injuries or none [93]. Summing up, serial dependency between weeks of injury being prevalent was obvious, leading to the necessity of allowing for this explaining effect in prevalence models.

The risk of injury prevalence were modelled in study III and the serial correlation between consecutive weeks in episodes of injury were accounted for by a covariate expressing if pain was prevalent the week before and also expressing the current duration of injury episode. This was considered of clinical relevance as the 1st week of injury being prevalent might associate differently to risk compared to for example the 7th week of injury being prevalent, as also indicated by explorative plots (figure 2 in appendences). The prevalence models in study III also accounted for the different risks when being in an episode of injury prevalence and when being in an episode without injury.

Overweight as exposure

In study IV, the risk of getting injured according to baseline BMI and TBF% was explored. Furthermore the potential effect of children changing body composition through the 2.5 years of injury monitoring was evaluated by separate regression analyses for BMI and TBF% using a variable with “no change”, “change to elevated BMI/TBF%” and “change to normal BMI/TBF% values” as categories.

Concerns about children being underweight were addressed, as injury patterns could possibly be different in this group [50, 94]. For this reason the prevalence of underweight was determined in the baseline population, using recommended cut-offs [95 96]. An initial analysis excluding the group of underweight children did not change estimates of risk of injury or the estimated effect of other covariates. Underweight children were therefore not considered different from normal weight children regarding the risk of injury and thus categorized as normal weight children for analysis.

A multilevel mixed-effects Poisson regression was used to estimate incidence rate ratios (IRR) with BMI and TBF% as primary risk factors. BMI and TBF% were used as dichotomized variables (0=normal values, 1=elevated values) in separate regression analyses. For identification of groups of potential clinical interest, the four combinations of normal and elevated BMI with normal and elevated TBF% were likewise tested in a regression analysis, with normal BMI and normal TBF% being the reference group.

Finally BMI and TBF% were tested as continuous variables and used for illustrating the adjusted risk of lower extremity injuries in relation to the two measures of body composition.

Analysis of clustered data

Observations in a school study are clustered, assuming that observations in one cluster tend to be more similar to each other than in another cluster in the same sample [90]. In the present study three levels of clustering were defined; schools, classes and children, acknowledging a hierarchical structure allowing for potential variation between schools, between classes within schools and between children within classes. Thus, each level in this structure added to the random variation in the data and therefore the choice of using random effect models was made. The sources of variation (e.g. different environments, teacher’s enthusiasm, atmosphere) in themselves were not of interest and were therefore deemed to be random effects in multilevel models.

Statistical software:
All data from SMS-track and data on diagnosed injuries were analysed using STATA 12.1, StataCorp, College Station, Texas, USA. Stata statistical software is a complete, integrated statistical software package that provides data management, data analysis and graphics. For study III the statistical software program; R 2.15.197, was also used.

Main results

This section consists of three parts. First, the data on descriptive and analytic injury epidemiology is presented (Study I & II). In this part the overall picture of musculoskeletal extremity injuries in a sample of school children aged 6-12 followed during 2.5 years is shown. Second, the seasonal variation in injuries is described (Study III). Finally, overweight as an independent predictor of lower extremity injuries is presented (Study IV).

Study I and II

There was a gradual inclusion of schools, starting with 231 children from three schools, including one school per month thereafter, and ending eight months later with children from all ten schools being included. Thus all the schools participated from the start of the 2009-2010 school year. In total 1259 children took part during the study period. The range of participation time was 1-113 weeks with an average of 90.2 weeks. Dropouts were due to children moving away from the municipality or changing to a non-project school, but were counterbalanced by new children moving to project schools. Fifteen children dropped out for other reasons, the main one being that answering SMS questions every week was too bothersome. An average weekly response rate of 96.2% was recorded during the study period of 113 weeks of parents answering text messages concerning musculoskeletal pain. A total number of 109.245 observations were recorded and 4.297 (3.8%) were missing. Analysis of missing data did not show any patterns when looking at gender, age, school type, and leisure time sports.

Some children experienced more than one injury; the range was from zero injuries and up to nine episodes of lower extremity injuries and up to three episodes of upper extremity injuries. On average the children participated 1.5 times per week (range 0 to 7.2) in leisure time sport. Third and fourth grade had a significantly higher mean sports participation in leisure time, compared to pre-school, first and second grade.

Musculoskeletal extremity injuries – the general picture

In the participating 1259 children a total of 1229 injuries were registered, of these 180 were upper extremity injuries and 1049 were lower extremity injuries.

The overall weekly injury incidence and prevalence rates were 1.2% and 4.6% respectively with a mean duration of 4.9 weeks and an incidence rate of 1.59 injuries per 1000 physical activity units. The number of injuries, the weekly incidence, prevalence and duration of injuries and incidence rate of injuries per physical activity units are shown in table 1.

Looking at injury types, 794 were overuse injuries and 435 were traumatic injuries. The ratio of overuse lower extremity injury to traumatic lower extremity injury was 2.5:1. The reverse applied for upper extremity injuries, with the corresponding ratio being 1:3.1.

Injury incidence rate according to body region and injury type, using the total amount of physical activity exposures (774362 units) during 2.5 years, was 1.03 per 1000 physical activity units (95% CI 0.95 to 1.10) for overuse injuries in total and 0.56 per 1000 physical activity units (95% CI 0.51 to 0.61) for traumatic injuries in total.

Injury rates of traumatic injuries and the setting in which they occur was highest for injuries sustained in sports; 1.57 per 1000 sport exposure units (95% CI 1.3 to 1.8), followed by injuries sustained in leisure time PA; 0.57 per 1000 leisure time PA exposure units (95% CI 0.5 to 0.6) and lowest for injuries sustained in PE; 0.14 per 1000 PE exposure units (95% CI 0.1 to 0.2).

Injury rates of traumatic injuries and the specific sports in which they occur was highest for injuries sustained in basketball; 4.61 per 1000 basketball exposure units (95% CI 0.92 to 8.3), but injury numbers were only 6 with a total number of physical activity exposures being 1301. In handball, the total number of physical activity exposures was 16822 and incidence rate was 2.9 per 1000 handball exposure units (95% CI 2.1 to 3.7). In soccer, the total number of physical activity exposures was 25982 and incidence rate was 2.3 per 1000 soccer exposure units (95% CI 1.7 to 2.9). Finally, for the non-ballgame sport having the highest incidence rate, tumbling gymnastics had an incidence rate of 2.4 per 1000 tumbling gymnastics exposure units (95% CI 1.2 to 3.5).

Upper extremity injuries

For upper extremity injuries the overall weekly incidence and prevalence rates were 0.2% and 0.5% respectively with a mean duration of 3.8 weeks and an incidence rate of 0.2 injuries per 1000 physical activity exposures (table 1). The body region most commonly injured was the hand and wrist (n=66) followed by shoulder/upper arm, fingers and elbow/underarm in declining order (table 4, study II).

Overuse injuries in upper extremity

For upper extremity overuse injuries the overall weekly incidence and prevalence rates were 0.04% and 0.2% respectively with a mean duration of 5.2 weeks and an incidence rate of 0.06 injuries per 1000 physical activity exposures (table 1).

A total number of 44 overuse injuries were diagnosed in upper extremities, with soft tissue injuries being the most common (n=31). Shoulder and upper arm was the most common region of overuse injury: n=26, IR=0.03 per 1000 physical activity units (95% CI 0.02 to 0.05).

Traumatic injuries in upper extremity

For upper extremity traumatic injuries the overall weekly incidence and prevalence rates were 0.1% and 0.3% respectively, with a mean duration of 3.3 weeks and an incidence rate of 0.18 injuries per 1000 physical activity exposures (table 1).

For traumatic injuries a number of 136 upper injuries were diagnosed, with ligament sprains being the most common (n=71). The hand and wrist was the most common region of traumatic injury: n=60, IR=0.08 per 1000 physical activity units (95% CI 0.06 to 0.10).

Injury rates of traumatic upper extremity injuries and the setting in which they occur was highest for injuries sustained in sports; 0.48 per 1000 sport exposure units (95% CI 0.4 to 0.6), followed by injuries sustained in leisure time PA; 0.19 per 1000 leisure time PA exposure units (95% CI 0.1 to 0.2) and lowest for injuries sustained in PE; 0.04 per 1000 PE exposure units (95% CI 0.01 to 0.06).

Injury rates of traumatic upper extremity injuries and the specific sports in which they occur was highest for injuries sustained in basketball; 1.54 per 1000 basketball exposure units (95% CI 0.00 to 3.4), but injury numbers were only 2 with a total number of physical activity exposures being 1301. In handball, the total number of physical activity exposures was 16822 and incidence rate was 1.07 per 1000 handball exposure units (95% CI 0.6 to 1.6). In soccer, the total number of physical activity exposures was 25982 and incidence rate was 0.4 per 1000 soccer exposure units (95% CI 0.2 to 0.6). Tumbling gymnastics presented with an incidence rate of 1.08 per 1000 tumbling gymnastics exposure units (95% CI 0.4 to 1.8).

Lower extremity injuries

For upper extremity injuries the overall weekly incidence and prevalence rates were 1.0% and 4.1% respectively, with a mean duration of 5.0 weeks and an incidence rate of 1.35 injuries per 1000 physical activity exposures (table 1). The body region most commonly injured was the knee (n=311) followed by heel, ankle, foot, thigh, achilles and hip in declining order (table 4, study II).

Overuse injuries in lower extremity

For lower extremity overuse injuries the overall weekly incidence and prevalence rates were 0.7% and 3.2% respectively with a mean duration of 5.3 weeks and an incidence rate of 0.97 injuries per 1000 physical activity exposures (table 1).

A total number of 750 overuse injuries were diagnosed in lower extremities. Apophysitis injuries at the growth plates of the heel (n=274) or the knee (n=189) were the most commonly diagnosed injuries. The heel was the most common region of overuse injury: n=275, IR=0.36 per 1000 physical activity units (95% CI 0.31 to 0.40).

Traumatic injuries in lower extremity

For lower extremity traumatic injuries the overall weekly incidence and prevalence rates were 0.3% and 1.1% respectively, with a mean duration of 4.8 weeks and an incidence rate of 0.39 injuries per 1000 physical activity exposures (table 1).

For traumatic injuries a number of 299 lower extremity injuries were diagnosed, with ligament sprains being the most common (n=178). The ankle was the most common region of traumatic injury: n=136, IR=0.18 per 1000 physical activity units (95% CI 0.15 to 0.21).

Injury rates of traumatic lower extremity injuries, and the setting in which they occur, was highest for injuries sustained in sports; 1.09 per 1000 sport exposure units (95% CI 0.9 to 1.3), followed by injuries sustained in leisure time PA; 0.38 per 1000 leisure time PA exposure units (95% CI 0.3 to 0.4) and lowest for injuries sustained in PE; 0.10 per 1000 PE exposure units (95% CI 0.06 to 0.14).

Injury rates of traumatic upper extremity injuries and the specific sports in which they occur was highest for injuries sustained in basketball; 3.07 per 1000 basketball exposure units (95% CI 0.1 to 6.1), but injury numbers were only 4 with a total number of physical activity exposures being 1301. In handball, the total number of physical activity exposures was 16822 and incidence rate was 1.84 per 1000 handball exposure units (95% CI 1.2 to 2.5). In soccer, the total number of physical activity exposures was 25982 and incidence rate was 1.92 per 1000 soccer exposure units (95% CI 1.4 to 2.5). Tumbling gymnastics presented with an incidence rate of 1.32 per 1000 tumbling gymnastics exposure units (95% CI 0.5 to 2.1).

Table 1: Musculoskeletal injuries presented in numbers, weekly mean incidence, prevalence and duration in weeks and incidence rates for total group of 1259 participants during 2.5 years of weekly registration.

	Numbers	Weekly mean incidence in percentage (±SD)	Weekly mean prevalence in percentage (±SD)	Mean duration in weeks (±SD)	Incidence rates per 1000 physical activity exposures (95% CI)
Upper extremity					
Injury	180	0.2 (±4.0)	0.5 (±7.2)	3.8 (±8.3)	0.23 (0.20 to 0.27)
Overuse injury	44	0.04 (±2.0)	0.2 (±4.9)	5.2 (±13.6)	0.06 (0.04 to 0.07)
Traumatic injury	136	0.1 (±3.5)	0.3 (±5.8)	3.3 (±4.6)	0.18 (0.15 to 0.21)
Lower extremity					
Injury	1049	1.0 (±9.7)	4.1 (±19.9)	5.0 (±7.1)	1.35 (1.27 to 1.44)
Overuse injury	750	0.7 (±8.2)	3.2 (±17.7)	5.3 (±7.7)	0.97 (0.90 to 1.04)
Traumatic injury	299	0.3 (±5.2)	1.1 (±10.4)	4.8 (±7.2)	0.39 (0.34 to 0.43)
Extremity combined					
Injury	1229	1.1 (±10.5)	4.6 (±21.0)	4.9 (±7.4)	1.59 (1.50 to 1.68)
Overuse injury	794	0.7 (±8.4)	3.5 (±18.3)	5.3 (±8.4)	1.03 (0.95 to 1.10)
Traumatic injury	435	0.4 (±6.2)	1.4 (±11.8)	4.4 (±6.6)	0.56 (0.51 to 0.61)

Risk of overuse and traumatic extremity injuries adjusted for explaining factors

The adjusted injury risk analyses showed a significant association between age and injuries across both injury types on both lower extremity and upper extremity injuries, with odds increasing for each grade level for both types of injuries. With normal school as reference the children in sport schools increased the odds significantly by 60% for traumatic lower extremity injury. No other differences were found between normal and sport schools. Each additional time a child participated in leisure time sport, the odds for an overuse and a traumatic lower extremity injury increased by 20%. The odds of sustaining an overuse lower extremity injury increased significantly by 90% in high-risk season. Only age was associated with upper extremity injuries, with odds for traumatic and overuse upper extremity injuries increasing by 20% and 60% respectively for each step in grade level (table 3, study I).

Study III

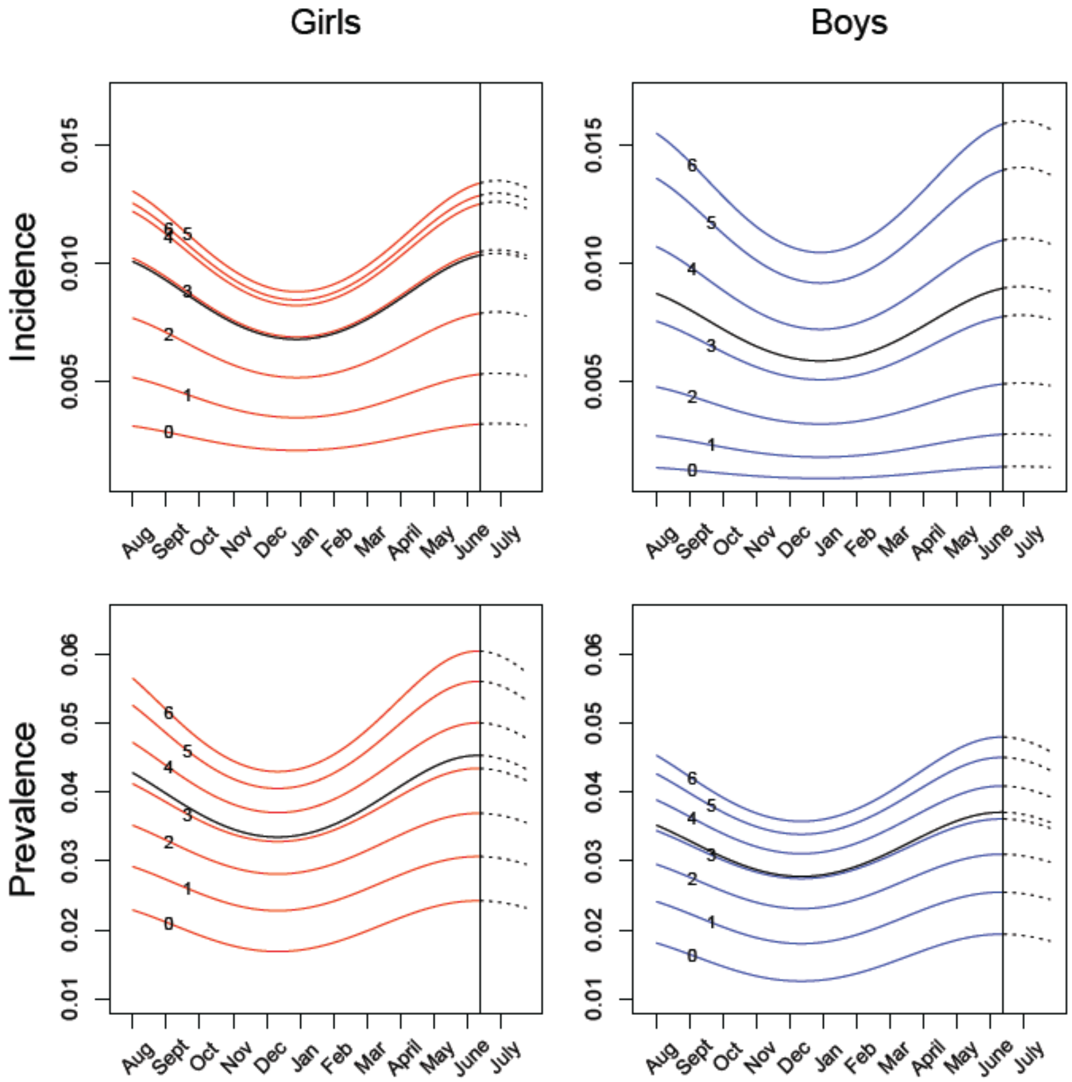
There was a clear seasonal variation in the observed incidences of extremity injuries. The highest injury incidence and prevalence rates for extremity injuries were observed for autumn; 1.3% and 5.1% respectively and for spring; 1.2% and 5.0% respectively, whereas they decreased to 0.8% and 3.6% in winter (table 2, study III)

The adjusted analysis showed a significant seasonal variation for extremity injuries on both incidence and prevalence. Other significant effects on the incidences were gender and grade, with different effects of grade for the two genders. The prevalence rates of extremity injuries showed significant effects of gender, class, the current duration of the injury and a state effect reflecting the difference between the risk- and the prevalence-states (table 3, study III).

The model based estimates of the incidence rates reached a maximum of 1.0% (girls) and 0.9% (boys) in week 29 (mid July) and a minimum of 0.7% (girls) and 0.6% (boys) in week 3 (mid January). The corresponding estimates for the prevalence rates reached a maximum of 4.5% (girls) and 3.7% (boys) in week 26 (late June) and a minimum of 3.4% (girls) and 2.8% (boys) in week 1 (early January).

Fitted curves illustrate the seasonal variation for the injury incidence and prevalence for extremity injuries by gender and age with grade level (0-6) as a proxy of age (figure 3). Corresponding results can be found in figures 2 and 3, study III, but now showing patterns separately for upper and lower extremity injuries.

Figure 3 Fitted curves for seasonal variation for extremity injury incidence and prevalence, showing curves in regard to gender and grade level (0-6) as a proxy of age. The thick, solid line illustrates the mean curve. The dotted lines illustrate the period of 6 weeks of extrapolated data.



Study IV

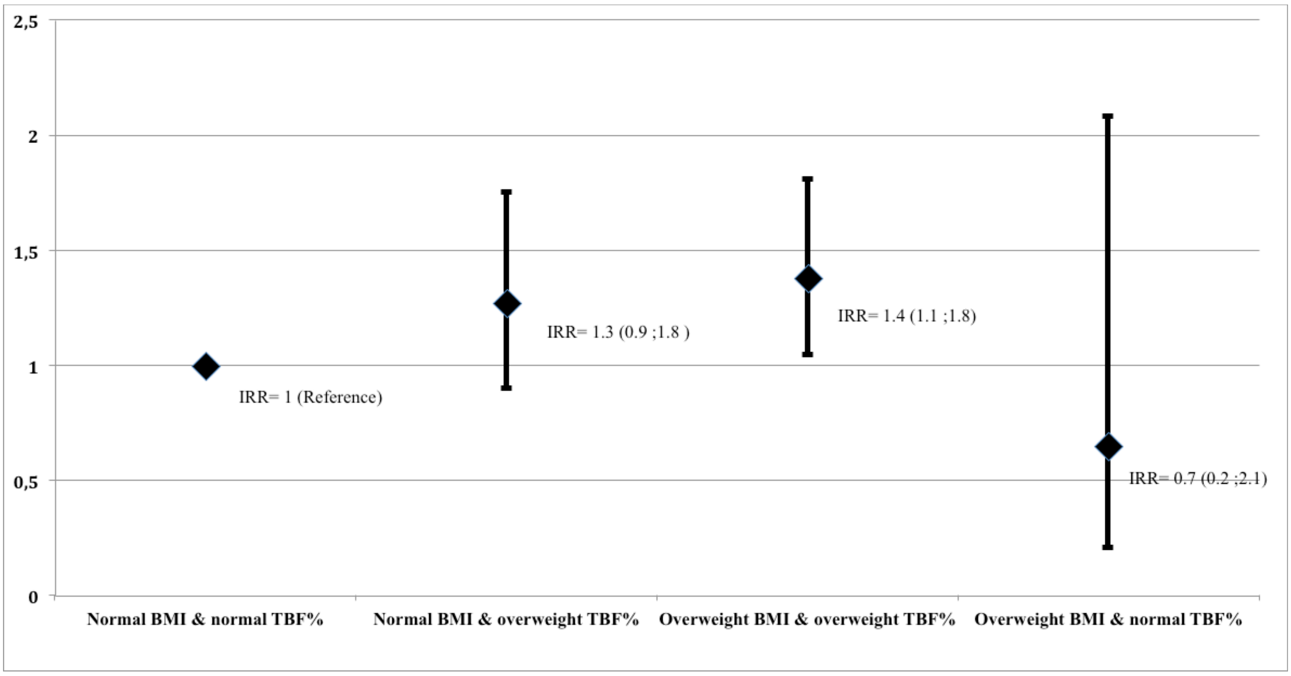
A total of 632 children, aged 7.7–12 years at baseline, participated at both baseline and follow-up DXA scan and in the registration of musculoskeletal injuries. Mean baseline BMI was 16.6 (± SD 2.1) and TBF% was 20.1% (± SD 8.0). A total number of 673 lower extremity injuries were diagnosed during the 2.5 years of follow-up. Mean weekly sport exposures units in PE and leisure time sport were 3.9 (± SD 1.3) and fitness level at baseline had a mean of 930.8 m (± SD101.9).

Injury rates per 1000 physical activity exposures showed a trend, albeit not significant, towards higher risk for children being overweight, whether defined by BMI or by TBF%. Injury rates, 95% CI and gender differences are described in Table 2, study IV.

The adjusted incidence-rate ratio (IRR) estimates suggested that children being overweight were generally at higher risk of sustaining lower leg injuries, by BMI: 1.28 (95% CI 0.98 to 1.66) and by TBF% 1.34 (95% CI 1.07 to 1.68), the latter being statistically significant.

Looking at the four combined groups of body composition, children with both elevated BMI and TBF% showed the highest risk of sustaining lower leg injuries: 1.38 (95% CI 1.05 to 1.81) relative to children having a normal BMI and a normal TBF% (figure 4).

Figure 4: Incidence-rate ratio estimates (95% CI) by four groups of body compositions, adjusted for age, gender, physical education/leisure time sport and fitness level.



The possible effect of children changing body composition during the 2.5 years of injury monitoring was also accounted for in the adjusted analysis, but did not explain the risk of lower extremity injuries, nor did it influence the estimated effects of other covariates.

Gender and age did not influence the risk, whereas the time participating in PE and leisure time sport and fitness level explained some of the lower extremity injury risk. The risk of injury significantly increased for each additional time a child participated in PE and leisure time sport from zero to 6.5 weekly exposure units. For the 18 children with a mean of more than 6.5 exposures a week, risk decreased again. A positive linear relationship was found between risk of lower extremity injuries and aerobic fitness.

The adjusted risk of lower extremity injuries in relation to the two measures of body composition measured on a continuous scale, are illustrated for girls and boys. A positive linear relationship was found between risk of lower extremity injuries and the continuous values of TBF% and BMI across the full range (figure 2, study IV).

Discussion

The main findings of this thesis is a fundamental understanding of injury epidemiology in school children aged 6 to 12 by describing incidence and prevalence of musculoskeletal extremity injuries and associated risk factors, thus giving new insight to injury aetiology. The following discussion will take the previously mentioned specific objectives of this thesis, including methodological considerations as the starting point.

Overuse injuries and traumatic injuries (Study I & II)

These studies are to our knowledge the first to report risk of overuse and traumatic extremity injuries by numbers, incidence, prevalence, duration and the association with physical activity, gender, age, previous injuries, and seasonal variation in a prospective cohort study of school children.

Clinical findings

Clinical findings were done using SMS-track to capture all symptoms indicative of musculoskeletal problems and having clinicians assigned to diagnose injuries, supplemented by data on injuries diagnosed in other clinical settings, prospectively during 2.5 school years.

A number of 1229 injuries were diagnosed; with close to twice as many overuse injuries (794) as traumatic injuries (435). The incidence and prevalence rates of overuse injuries were 0.7% and 3.2% respectively and the incidence and prevalence rates of traumatic injuries were 0.3% and 1.1% respectively. The average duration, measured as weeks with pain symptoms, was 4.4 weeks for traumatic injuries and 5.3 weeks for overuse injuries.

Approximately two decades ago authors started to think of overuse injuries as a new genre of paediatric sports injury and saw this as a consequence of the advent of regimented and repetitive sports training [98, 99]. Since then, there has been a concern with the issue of overuse injuries in children speculating that early specialization, increased intensity of training and competition in sport at younger ages, maybe on multiple teams simultaneously, and often year-round, could be a cause for an increased number of overuse injuries [100, 101]. Concerns have been raised that the consequences of overuse injury might be more serious to children and adolescents because the growing tissues are particularly vulnerable to stress [102, 103]. It has been suggested that approximately half of all sports-related injuries are in fact caused by overuse [104, 105]. Still actual epidemiologic investigations are scarce in the area of childhood overuse injuries. One British study from 1996 presented the results from a three-year retrospective survey of injuries to children and adolescents (5-17 years of age) treated at a sports injuries clinic. Out of a total of 394 injuries, 49.5% were characterised as being chronic and affecting mostly articular cartilage, epiphyseal and apophyseal growth plates [106]. In a group of 469 male and female elite figure skaters (13 to 20 years of age) 44.1% (a total of 469 injuries) reported overuse symptoms in a retrospective questionnaire survey [107].

The share of overuse injuries were 64.6% in the present study. The somewhat higher percentage may be explained by the fine-meshed method of frequent and prospective collection of injury data, capturing also overuse injuries. In the above-mentioned studies, percentages might be lower as injuries seen at a sports clinic might only be 'tip of the iceberg' and less severe overuse injuries might have been forgotten in retrospective questionnaires.

Diagnosis concerning traumatic injuries such as ligament strains, fractures, contusions and strains accounted for the largest part of the total number of upper extremity injuries. From studies in emergency departments, the same patterns of sprains, contusions, fractures and strains being the most frequent traumatic injury in children are seen [45, 108].

For lower extremity injuries a reverse pattern was found, as overuse injuries were by far the most common injury, with a notable high number of apophysitis injuries located at the heel or knee being diagnosed. Thus diagnosis as Sever's lesion, Sinding-Larsen and Osgood-Schlatter, accounted for 44% of all lower extremity injuries. These are injuries expected in this age group, where skeletal growth zones are still immature, yet the epidemiology of these injuries in prepubertal children have seldom been reported in school-based cohorts, which have focused mainly on traumatic injuries [20, 109]. These studies have included injuries that demanded first aid treatment, professional health treatment and/or time lost from PA and/or school. The 'time-loss' injury definition does not capture all overuse injuries [16] and the 'medical attention' injury definition overlooks less severe injuries [15].

We suggest that the benefit from the present studies is a broader insight into musculoskeletal physical activity-related injuries in children, including also less severe injuries and overuse injuries, by using a close and frequent method of monitoring musculoskeletal symptoms and with clinicians assigned to diagnose the injuries prospectively. It could be argued that the epidemiology of less severe injuries and overuse injuries has little relevance as they are less costly than severe injuries in terms of needing medical care or losing time from school and PA. Still it is noteworthy that even in the less severe injuries, pain is a present symptom that affects the child and might predict future pain [11, 24]. The duration of musculoskeletal pain in relation to overuse injuries was measured in a previous study on the same cohort and showed mean durations of 5.3 and 5.2 weeks for lower and upper extremity overuse injuries respectively [110]. Reporting of all injuries causing physical complaints is therefore advocated in the case of the young, growing and playing child.

Injury rates

Injury incidence rates were presented in relation to injury type, different body regions and different settings comprising physical education lessons, organized sports and leisure time PA.

In study I the reported injury rates were the sum of injuries across all injured children divided by the sum of exposure time in terms of physical education classes and organized sport across all injured children. This resulted in an incidence rate of 3.01 per 1000 units of physical activity for overuse injuries and 2.99 per 1000 units of physical activity for traumatic injuries. The lack of information on non-organized physical activity in leisure time was a limitation to this study.

In study II, the reporting of injury rates were strengthened with the inclusion of accelerometer measurements of leisure time physical activity. Thus injury rates are the sum of injuries across all participating children divided by the sum of exposure across all participating children, including exposure time from leisure time. This resulted in an incidence rate of 1.03 per 1000 units of physical activity for overuse injuries and 0.56 per 1000 units of physically activity for traumatic injuries.

While all information is important, the latter results are more comparable to existing studies, where injury incidence rates are collected at group level, including data from all children in a team [41, 111] or in a school cohort [19, 20] and including the total time of exposure across the relevant settings of being physical active.

A study on a Dutch school cohort of 10-12 year old children reported an traumatic injury incidence rate of 0.48 per 1000 hours of physical activity [20]. This finding corresponds to the incidence rate of

0.56 per 1000 units of physical activity for traumatic injuries in the present cohort, even though it should be noticed that exposure time were based on units of participation instead of hours. Exposure time based on exact hours instead of units of participation would have been more accurate to account for the variance in time-at-risk and has been the preferred measure of incidence rates in sports injury research studies [41, 111]. Still it has been argued that the content of e.g. a training/match session or a leisure time activity, just as much as the length of time is associated with injury risk [62, 63].

Another difference between the two studies was that data on leisure time physical were collected by accelerometers in the present study compared to parental reports in baseline and one year follow-up questionnaires in the Dutch study. Both methods are subject to uncertainty as extrapolated estimates from one week of accelerometer measurements might not reflect the child's activity level in general, as well as parental reports twice in 12 months might have resulted in a slight overestimation, as suggested by the authors [20]. Direct comparison between studies is hampered by differences in the aforementioned injury definition and in particular the injury data collection methods.

Looking at traumatic injuries, the injury incidence rate was highest in sport settings, with ball games and a high impact sport (tumbling gymnastics) being the most risky sports. Leisure time physical activity were less risky, but still with a higher injury incidence rate than physical education. It could be argued that in addition to being supervised by teachers, physical education lessons have a more pedagogic aim and are less competitive than most sports, thus resulting in the lowest injury IR for the three different types of setting.

In general, most injuries were sustained in the lower extremities (85%), of which the knee, heel and ankle accounted for 30%, 26% and 14% respectively. It is well established that injuries in weight bearing extremities are predominant, and of those, knee and ankle injuries present the majority [61]. The diagnosing of overuse injuries in the present study has added the heel to a body part commonly injured in this age group.

The reported incidence rate of 1.03 per 1000 units of physical activity for overuse injuries is a novel finding in the area of childhood musculoskeletal physical activity-related injuries.

Injury risk and explaining factors

Risk of injuries consistently increases with age across most studies when looking at specific sports (Caine et al., 2008; Emery, 2003). This pattern was reproduced in this cohort of children with a broad diversity in choice of sports, amount of participation, competitive levels etc. This suggests increasing age as a robust risk factor and though not modifiable, age should be considered when targeting groups of children and adolescents for injury prevention.

Previous studies have found evidence that males are generally at higher risk of injury in child and adolescent sport (Caine et al., 2008; Emery, 2003). We found no association between gender and overuse and traumatic injuries. This may be explained by the heterogeneity of the cohort and because it was not selected by any specific clinical condition or sports. Furthermore, it could be speculated that gender differences in injury patterns are more pronounced after puberty, because of the developmental differences in physique.

Previous injuries have shown to be one of the most consistent risk factors for sustaining new injuries, with relative risks ranging from 2.88 to 9.41 (Emery, 2003). These findings are from studies of adults where a previous injury has been defined as an incidence that has caused time lost from sport or the need of medical attention (Caine et al., 2008; Emery, 2003). This motivated the adjustment for previous injuries, but it appeared to have no influence on the risk of sustaining a new injury. Possible explanations could be that the chosen time period of two month was to short in the present study, the recovery of damaged tissue and rehabilitation might go beyond this. It could also be speculated that most children are not marked by potential implications of inadequate rehabilitation after an injury to the same extent as adults.

In study I, the risk of sustaining overuse lower extremity injuries almost doubled in high-risk periods of season (autumn and spring). Previous studies have suggested that the different levels of physical activity partly explain the variation in number of injuries across seasons (Tucker & Gilliland 2007). The proposition of seasonal variation being a proxy measurement for levels of sport participation were ruled out, as there were no indications of collinearity. Other potential extrinsic risk factors include weather conditions, training surface/field conditions, time of season in relation to level of physical fitness etc., which might explain the difference in risk.

Seasonal variation in injury risk (Study III)

This is the first prospective study presenting a seasonal variation in musculoskeletal extremity injuries in a cohort of school children followed closely during 2.5 years. The weekly data showed a 46% increase in injury incidence and a 32% increase in injury prevalence during summer compared to winter for extremity injuries.

There seem to be no studies on the overall incidence and prevalence of injury of the extremities in the general population. However, a few studies have looked at children hospitalized or treated in emergency rooms [66-68]. The present results are in accordance with Foltran et al. (2012) who looked at all serious paediatric injuries in an Italian region [68] and found a clear seasonal variation in serious injuries, with distinct peaks in prevalence of hospitalization of seriously injured children in the summer, and a low prevalence during the winter. Graham et al. (2005) also demonstrated this in a Scottish population of children with injuries needing emergency treatment [66]. The very large retrospective study of Loder et al. (2011) was also in agreement with the present results [67].

Proposed explanations of the variation in number of injuries across seasons vary across a broad spectrum of potential extrinsic risk factors, including weather and playing surface [112-114], venue being indoor or outdoor [58, 115], and time of season [116]. It also appears that the levels of physical activity vary with weather and season, hereby influencing the time-at-risk [64]. Thus, several mechanisms can be at play, e.g. the high injury incidence and prevalence in the autumn could have resulted from children starting organised sports participation without appropriate preparation. The results from the study of Wareham et al suggest that the overall physical activity and the use of outdoor recreational activities might be a significant factor, as they found that children have a clear increased prevalence of wrist fractures in spring and summer [65]. A Dutch school cohort study used a correction factor of 0.8 in order to account for the seasonal effects on physical activity participation throughout a 12 month follow-up period [20]. Although arbitrarily chosen, the correctional factor was in line with the decrease in physical activities during winter found in a previous review study [64].

The model based estimates for seasonal variation showed a noticeable and surprising difference between the highest and lowest incidence and prevalence rates respectively. A pattern was observed of the lowest prevalence rate early January preceding the lowest incidence rate 3 weeks later. Likewise, a pattern of the highest prevalence rate in late June was followed by the highest incidence rate 3 weeks later. Logically, high incidence rates should precede high prevalence rates and likewise with low rates. Prevalence of injury is the proportion of individuals who have an existing injury at any given point in time and is logically affected by the duration of injury [22]. Injury durations vary [110], possibly reflecting different types of injuries and time for tissue to heal. It can be speculated that high prevalence rates at certain time points are the result of accumulated severe and long-lasting injuries and vice versa for low prevalence rates.

Looking at adjusted estimates in the present study, all age groups followed the same pattern of seasonal variation for musculoskeletal extremity injury incidence and prevalence, but with more pronounced seasonal differences with increasing age. Risk of injury incidence consistently increases with age across most studies when looking at specific sports [32, 41]. This pattern was reproduced in this cohort of children with a broad diversity in choice of sports, amount of participation, competitive levels etc. [110].

The same patterns of higher injury incidence and prevalence estimates during warmer seasons than during winter were shown for both genders. A United States study, analysing all paediatric emergency department visits during four years from seven selected activities (bicycles/tricycles, scooters, playground equipment, swimming/water activities, skiing/snowboarding, trampolines and skating activities), found different peaks for girls and boys (mean age 9.5 years). Girls had the highest number of emergency department visits in the spring and boys in the autumn. This is explained by the most common activity by gender peaking at the same time (girls=playground equipment activities, boys= cycling) [67]. The present study did not look at seasonal risk by specific activities, which might have disclosed gender differences.

In this school-based cohort approximately half the children attended sports schools having three times as many physical education lessons as the rest of the children. This study has not taken the amount of physical activity into account, but it could still be speculated that the circumstances surrounding children being pupils at sports schools influences the injury risk. It is possible that not only the amount of physical education lessons makes a difference, but also that the form and content of physical education have a more pedagogic aim and are less competitive than sports participation in leisure time, hereby influencing injury rates and the seasonal variation in injury risk.

Data collection was put on hold during the six weeks of summer holiday. The predicted times of peak incidence and prevalence fall within this period. However, it seems plausible to assume a consistent pattern all year round. Children being more physically active during the warmer season may likely explain high rates of injuries at this time of the year. More activities take place outdoor, possibly under less rigorous supervision, than during the winter indoor activities. In relation to injury prevention, attention should therefore be focused on outdoor activities and leisure time sport during this time of the year.

This study confirms the need to look into the dynamic and cyclic nature of risk factors and causation to understand injury aetiology. Risk factors are not stable, but may change through preceding cycles of exposure, circumstances and season as suggested by Meeuwisse and colleagues (2007) [31].

Overweight and the association to injury risk (Study IV)

This study is the first to evaluate and compare two different measures of overweight as risk factors for lower extremity injuries in a school-based cohort of children. The risk of lower extremity injuries was observed to increase in overweight children. Being overweight measured by TBF% or the combination of elevated TBF% and BMI were more predictive than being overweight measured by BMI. This suggests that a high proportion of adiposity is more predictive of lower extremity injuries, possibly due to a lower proportion of lean muscle mass.

In contrast, Kaplan *et al* [117] found that body weight was a more powerful injury risk factor than adiposity, with no differences in injury risk between linemen and non-linemen in American football. This was shown in a study comparing different measures of body composition (body fat, BMI, weight, height) to injury risk in a group of 98 high school players with 28 injuries registered by trainers. This was reproduced in another American football study reporting injury rates by body fat, weight, BMI and lean body mass in high school football linemen.[118] Whereas in army cadets, adiposity expressed as TBF% was a stronger predictor of the magnitude and type (overuse/traumatic) of musculoskeletal injuries than BMI [119]. Direct comparisons may not be relevant because of differences in techniques to measure TBF%, injury registration methods, size of studies, ages and sports specific vs. more heterogenic settings. Still, it is possible that in some sports, the effect of increased mechanical loading during weight bearing or collisions have a more pronounced effect than in other sports.

Injury patterns might also differ in relation to different injury types. Traumatic injuries provoked and/or aggravated by greater collision forces due to heavy weight could be argued to be independent of the muscle/fat distribution to a greater extent than overuse injuries, where the quality of tissue (e.g. muscle strength and endurance) is important. The effect of overweight in relation to different injury types (overuse/traumatic), different diagnoses, different anatomical regions and different sports still needs to be clarified.

In this study, injury risk increased with increased participation in PE and leisure time sport. This is in accordance with the common understanding of the need to consider exposure time when estimating injury risk. Surprisingly, children with high fitness levels had a higher risk of sustaining lower extremity injuries. This is in contrast to earlier beliefs where lower fitness levels have been associated with muscle fatigue and subsequent injury [120]. A possible explanation could be that children with high aerobic capacities are also the children with the largest amount of exposure time.

Cut-offs to classify children as normal-weight or overweight were defined using cardiovascular health related and gender specific TBF% standards[84] and age- and gender-specific centiles from pooled international dataset, linked to adult cut-offs for BMI classifications.[85] It can be questioned if these criteria have the same relevance in injury risk research, but they permit comparison across studies and contribute to a general evaluation of health risk among overweight children.

The presentation of data in Figure 2 (study IV), does not suggest any obvious cut-off for a significant increase in risk of lower extremity injuries in relation to overweight. Specific overweight cut-offs for being at increased injury risk might be less important in the context of injury prevention, especially on an individual level where a more comprehensive screening of body composition involving an expression of TBF% would be more relevant. While DXA scans are expensive and not feasible in most settings, a measurement method such as waist circumference is cheap and easy to obtain.[121] Further research is needed into the proposed underlying mechanisms for overweight children being at increased injury risk. Previous suggested mechanisms have been poor postural control – leading to problems with balance and coordination, poor physical fitness – associated with muscle fatigue and subsequent injury and low pre-participation physical activity levels – associated with impaired neuromuscular and motor learning.[46]

Methodological considerations

Quantifying overuse injuries

The data collection method, using weekly text messages to gain knowledge about children possibly having sustained an injury might explain the relatively high number of injuries and injury rates found in this study. It could be argued that the inclusion of overuse injuries contributes to the high figure.

Previous recommendations for a standardized methodology to quantify overuse injuries in sports have mentioned the advantage of frequent and prospective measurements, using sensitive scoring instruments to measure pain symptoms and define injuries by other means than time lost from sport or the need for medical attention [16]. This study followed a cohort of school children for 2.5 years with weekly recordings on incidence and prevalence of musculoskeletal pain and injuries and severity based on diagnosis and duration of pain. This method allowed for a wider perspective on the area concerning musculoskeletal extremity injuries in school children aged 6 to 12, including severe and less severe injuries, traumatic and overuse injuries.

It could be argued that it was because of the particular method of prospective, frequent and sensitive monitoring that injury numbers and rates were high. The possible issue of parents reporting events that would normally be ignored was dealt with by a telephone consultation as a first screen between trivial complaints and persisting symptoms in relation to injury. If the latter was the case, a clinical examination, and if needed para-clinical investigations and/or further examination by medical specialists, was carried out before an injury was finally defined. It was a strength to this study that parental reports on pain and injuries were validated through objective examinations by clinicians.

Asking for pain for a long time

Two concerns emerge when using frequent data collection for a long period; an ethical concern and a methodologically concern.

The ethical question was whether it was sound to repeatedly ask for a negative outcome, such as pain. A study of adult individuals with rheumatic pain, assessed several times a day at random intervals for a month, did not induce a depressed mood [122]. However, the impact on healthy children with mostly temporary and self-limiting symptoms is to our knowledge unknown. In the present study proxy parent reports were considered appropriate, and we hoped to avoid unnecessary child focus on negative symptoms and attention bias in this way.

The methodological concern was whether reports were valid. More specifically, did we get exact measures on both positive responses (no pain) and negative responses (pain)? All negative responses (pain in back, arm or leg) were validated by a telephone consultation, which would identify possible fault reports and clarify if pain symptoms were trivial or indicative of injury. To validate if positive responses were indeed positive, the SMS-Track reporting were compared against verbal reporting and indicated high validity of data [78]. Another concern in this longitudinal setting was if gradual attrition would arise during the long survey period. Looking at response rates a notable high rate was seen throughout the study period, with a mean of 96.2%, confirming the feasibility of the method also seen in other studies [72-76]. One crucial reason for high compliance was believed to be the mutual benefit of parents getting their children clinically examined if required and researchers getting answers.

Injury durations

Duration of pain symptoms in relation to a diagnosed injury was interpreted as equivalent to duration of injury in the present study. This is an open discussion point and depending on the definition of when injury is considered recovered. In sport specific settings, the definition has often

been that injury was fully recovered with the athlete's return to competition or training [123]. A clinical approach weighting pain symptoms is advocated in this heterogeneous cohort of school children to make results comparable on this parameter.
For ethical reasons, the clinical staff assigned to the study gave advice to children and parents on how to alleviate symptoms. This might have influenced prevalence, thus biasing the duration in the direction of shortening injury durations.

Injury incidence rates

A general limitation to the presented injury incidence rates is the use of sample-level exposure data done for feasibility reasons. Taking the point estimate for the incidence rate in the sample as the sum of injuries across all individuals divided by the sum of exposures across all individuals, is the method used in most injury research, but this assumes that there is a fixed overall injury rate that is the same for every individual, which is rarely the case [22]. Another weakness is that with a follow-up of 2.5 school years both incidences of injury and exposure time might have varied in a way that makes causal inferences more uncertain, i.e. a child might have had no injuries and a low level of sports participation one year and several injuries and a high level of sports participation the next year or the reverse. Finally the uncertainty by extrapolating estimates from one week of accelerometer measurements must be mentioned, i.e. the physical activity patterns shown across one week in the winter might not reflect the child's activity level in general.

Lacking 6 weeks of injury data

A general weakness to the data collection was the lack of information on injuries and level of physical activity during 6 weeks of children's summer holiday. This was done to avoid parental attrition and for practical reasons, as children away on holiday could not be clinically examined.
Data collection was also put on hold for one week of Christmas holiday. This was not considered a significant methodological problem, as an injury would still be reported at the end of the holiday, with a maximum of two weeks delay.

Re-injury or exacerbation

The fact that some children experienced more than one injury in the study period, could suggest that some injuries were recurrent. It was not the focus of this study to define if an injury was in fact a re-injury (i.e. injuries occurring at the same site after the index injury has fully recovered [123]). However, an injury was not registered if the condition was clinically determined to be an exacerbation of a non-recovered index injury, thus avoiding over-reporting of the number of new injuries.

Commonly, in the context of sports injuries, an index injury is regarded as closed when the athlete return to full training or competition [123]. Fuller *et al* problematize this as many athletes often return to training or competition before they are completely recovered and suggest that clinicians should make the distinction between re-injuries and exacerbation of index injury [123]. It was a strength to this study that a clinical judgement distinguished between injuries being a new incidence or an exacerbation of a non-recovered index injury.

Conclusions

By presenting incidence and prevalence of musculoskeletal extremity injuries and associated risk factors possibly explaining aetiology, this thesis brings forward new and important knowledge concerning injury epidemiology in school children aged 6 to 12.

The main findings in relation to objectives:

1. **Study I:** Close to twice as many overuse as traumatic extremity injuries were registered, with 2.5 times more overuse than traumatic injuries in lower extremities. A reverse pattern was found for upper extremities, with 3.1 times more traumatic than overuse injuries. Grade level, school type, leisure time sport, and seasonal variation were associated with the risk of sustaining lower extremity injuries. Only grade level was associated with upper extremity injuries.
2. **Study II:** A number of 1229 injuries were presented, with apophyses and soft tissue injuries being the most common overuse injuries in lower and upper extremity respectively. Ligament sprains were the most common traumatic extremity injury. Injury rates of traumatic injuries and the setting in which they occur were found to be highest for injuries sustained in sports, followed by injuries sustained in leisure time physical activity and lowest for injuries sustained in physical education lessons. The shoulder/upper arm and the heel was the most common body region of overuse injury in upper and lower extremity respectively. The hand/wrist and the ankle was the most common region of traumatic injury in upper and lower extremities respectively.

3. **Study III:** There are clear seasonal differences in the occurrence of musculoskeletal extremity injuries among children with almost twice as high injury incidence and prevalence estimates during autumn, summer and spring compared to winter.

4. **Study IV:** The risk of lower extremity injuries increased in overweight children. When comparing two different measures of overweight, a body composition of proportional high levels of TBF% is a higher risk factor, than overweight as measured by BMI. This suggests that a high proportion of adiposity is more predictive of lower extremity injuries, possibly due to a lower proportion of lean muscle mass.

Perspectives

Future research

In the studies included in the present thesis we have addressed injury epidemiology in school children and associated risk factors possibly explaining aetiology. We have attempted to overcome methodological shortcomings in previous studies by using frequent and prospective measures. Nevertheless, limitations to the present study are still a concern and the following suggestions are given to future research.

To fully utilise the text messaging method of recurrent and frequent gathering of real time information, it is important to avoid gaps in data collection. Circumstances might necessitate that data collection is put on hold, but ways to compensate should be attempted. The obvious choice is to take advantage of the text messaging system and obtain the lost information retrospectively, e.g. after participants' holidays. This information will not have the same accuracy as weekly, prospective data, but still it will contribute to a more complete data collection.

Study III and IV investigated the particular association between injury risk and time of season and body composition respectively. While associations were found, further research into the underlying causation is still needed.

Injury severity in this study was presented only by the magnitude of diagnosed injuries and the related duration of pain. Other measures of severity might receive more attention on organisational levels, which can actual influence public health. Thus measures of e.g. days away from school, sports, parental costs and use of health services will be more compelling arguments and render possible economic evaluation. In advocating for increasing involvement of children in sports and physical recreation, it is important to be aware of the magnitude of the adverse health consequences that may be involved.

Policy implications

The understanding of injury epidemiology in children is fundamental to acknowledge that despite the many health benefits of physical activity, there are drawbacks in terms of related injuries. Emery *et al* (2006) developed a theoretical model (figure 5) that defines a responsibility hierarchy in preventing injuries in youth sport based on potential influence on different levels ranging from the child itself to policy-based strategies on governmental level [124]. The different levels will be taken as the starting point in placing the findings of this thesis into a broader perspective.

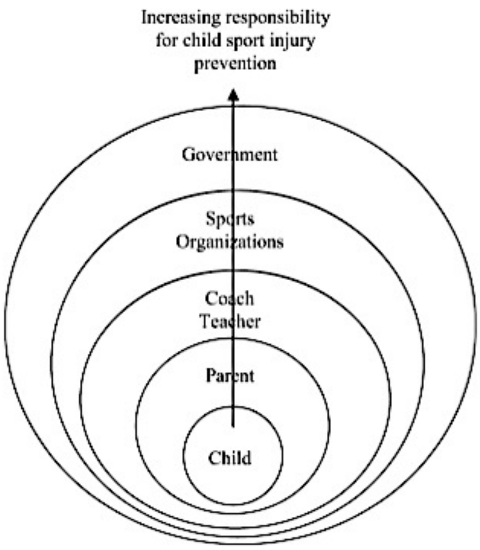


Figure 5 Responsibility hierarchy for child sport injury-prevention based on potential influence. Emery et al, 2006

The lowest level of responsibility has been assigned to the child because the extent of perceptual and cognitive development cannot be expected to adequately identify and recognize hazards in sports [124]. Our findings support this theory, as children in the case of overuse injuries, carry on being physical active in a way that aggravates symptoms. This can be caused by the individual lack of personal responsibility (e.g. not telling about overuse symptoms, not wearing appropriate shoes) or by externally imposed factors (e.g. content of physical education lessons and sports). Parents have a responsibility to support the child in avoiding risk behaviour e.g. ignoring pain, weight gain, but have no influence on the way that their children are trained and physically educated. Coaches and physical education teachers are strong moderators of behaviour and attitudes to sport, and their level of training skills and knowledge about the growing and physically active child is crucial. In relation to our findings on injury rates of traumatic injuries, risks were found to be highest for injuries sustained in sports and lowest for injuries sustained in physical education lessons. This suggests that appropriate interventions should target especially sport organisations and clubs as first choice for prevention of traumatic injuries, especially in ball game sports and high impact sports as tumbling gymnastics.

Overuse injuries is a result of repetitive demands over the course of time and probably an accumulation of different types of physical activities, which make it more complex to pinpoint settings for being most at risk. However, the findings of injuries being associated with time of season in relation to both traumatic and overuse injuries and across all settings, suggest preventive strategies before and during high-risk periods of children being physically active. Coaches and physical education teachers are in first-line to take this in charge, but sport organisations and teachers' colleges need to prioritise this in terms of education in age related training concepts and preparticipation sport-specific training.

Our results concerning overuse injuries and the risk factors involved, confirms the need for guidelines and recommendations on the prevention of overtraining, burnout and overuse injuries in children and adolescents as suggested by Brenner [100] and Valovich McLeod and colleagues [105]. The mentioned guidelines are primarily active strategies e.g. preparticipation physical screening, coach education, medical supervision, training and conditioning programs. The guidelines and recommendations address coaches, and health care professionals, but appropriate interventions on all responsible levels ranging from policy-based strategies to parents are important to prevent child sport injuries [124]. Emery *et al* suggest passive prevention strategies (e.g. legislation on bicycle helmets, bicycle paths, changing sport rules, optimizing surfaces, releasing binding for skiers) to be more effective than relying solely on active strategies and behaviour change [124]. Therefore Emery *et al* assign the highest level of responsibility to the governmental level to mandate policy-based strategies, ex safe playgrounds, money for maintenance of sports arenas (e.g., playing surfaces), safe roads with paths for cycles, legislation about helmet use for bicycling etc.

The findings in this thesis especially call for considering strategies to avoid overuse injuries. While the prevention and treatment of the severe 'time loss' and medical care needing traumatic injuries have been described to some extent [41, 125-129], a suitable approach towards less severe injuries and overuse injuries needs more attention. Efforts to keep the child physically active, but with consideration for the injury, are suggested to ensure continued fitness and social contact with the preferred activities, but further intervention research is needed to clarify best practice.

Summary in English

Background: Participation in physical activities promotes health in children, but a drawback is the risk of related injuries. Physical activity-related injuries have been established as a leading cause of paediatric injuries in western countries with high costs for children, parents and society. Previous studies have primarily presented severe and traumatic injuries; the “tip-of-the-iceberg” phenomenon. Information on the less severe injuries and overuse injuries is difficult to capture and quantify because symptoms might have a vague and gradual onset, their presence may not result in a measurable consequence and there has been a lack of valid and user-friendly methods for collecting this type of data. The common use of mobile phones now makes it possible to collect frequent data of self-reported symptoms indicative of musculoskeletal injuries for long periods in large cohorts.

Objectives: The objectives of this thesis were to investigate the patterns of musculoskeletal extremity injuries in a cohort of school children using weekly assessments for 2.5 years and to estimate the associations of possible risk factors such as exposure time, time of season and overweight measures.

Methods: To address these objectives, data from the Childhood Health, Activity, and Motor Performance School Study Denmark (CHAMPS Study–DK) August 2008 to July 2011 were used. In all, 1259 school children, aged 6-12, were surveyed each week with an automated mobile phone text message asking questions on the presence of any musculoskeletal problems. A telephone consultation served as a first screen between trivial complaints and persisting symptoms in relation to injury. If the latter was the case, clinicians assigned to the study examined the children and diagnosed injuries using the International Classification of Diseases (ICD-10). To get a complete recording of musculoskeletal extremity injuries in the sample, injuries diagnosed in other clinical settings (e.g. emergency departments) were collected in the same period. Physical activity was measured from text messaging and accelerometers.

Results: We found overall weekly rates of injury incidence and prevalence of 1.2% and 4.6% respectively. In the participating 1259 children a total of 1229 injuries were registered. Close to

twice as many overuse as traumatic extremity injuries were found, with 2.5 times more overuse than traumatic injuries in lower extremities. A reverse pattern was found for upper extremities, with 3.1 times more traumatic than overuse injuries. Grade level, school type, leisure time sport, and seasonal variation were associated with the risk of sustaining lower extremity injuries. Only grade level was associated with upper extremity injuries.

In general, most injuries were sustained in the lower extremities n=1049 (85%), with overuse injuries being by far the most common injury type with a notable high number of apophysitis injuries located at the heel or knee being diagnosed. Thus diagnosis as Sever's lesion, Sinding-Larsen and Osgood-Schlatter, accounted for 44% of all lower extremity injuries. A reverse pattern was found for upper extremity injuries (n=180) where traumatic injuries such as ligament strains, fractures, contusions and strains predominated.

The shoulder/upper arm and the heel was the most common body region of overuse injury in upper and lower extremity respectively. The hand/wrist and the ankle was the most common region of traumatic injury in upper and lower extremities respectively.

Injury rates of traumatic injuries and the setting in which they occur were found to be highest for injuries sustained in sports (1.57 per 1000 sport exposure units), followed by injuries sustained in leisure time physical activity (0.57 per 1000 leisure time PA exposure units) and lowest for injuries sustained in physical education lessons (0.14 per 1000 PE exposure units).

Seasonal variation in the patterns of injury incidence and prevalence was found with almost twice as high injury incidence and prevalence estimates during autumn, summer and spring compared to winter. Overweight by measures of BMI and total body fat percentage predicts lower extremity injuries suggesting that overweight children are at higher risk.

Conclusions and perspectives: This thesis has added an overall perspective to the area concerning musculoskeletal extremity injuries in school children aged 6 to 12, by using frequent and prospective measures to capture both traumatic and overuse injuries. Describing and analysing injury incidence and prevalence and associated risk factors possibly explaining aetiology, has broadened the understanding of injury epidemiology in children. The generic findings from this heterogenic cohort of school children especially call for considering strategies to avoid overuse injuries, suggestively on all responsible levels from children, parents, coaches, physical education teachers, sports health care professionals to policy-makers.

Summary in Danish

Baggrund: Fysisk aktivitet fremmer børns sundhed, men giver også en risiko for skader. Det er påvist at skader relateret til fysisk aktivitet er den største gruppe af skader blandt børn i vestlige lande medførende store omkostninger for både børn, forældre og samfund. Tidligere studier har fortrinsvist præsenteret alvorlige, traumatiske skader; det såkaldte ”toppen af isbjerget” fænomen. Det har været vanskeligt at opfange og kvantificere mindre skader og overbelastningsskader af flere grunde: For det første er symptomerne ofte diskrete og gradvist indsættende, for det andet medfører de ikke nødvendigvis at der søges hjælp hos sundhedsprofessionelle eller at deltagelse i idrætsaktiviteter stoppes, for det tredje har der været en mangel på valide og brugervenlige metoder at indsamle denne slags viden med. Den almindelige udbredelse og brug af mobiltelefoner og sms beskeder har muliggjort opsamling af selvrapporterede symptomer, som en første screening for eventuelle skader. Metoden muliggør hyppige registreringer over lange perioder i store kohorter.

Formål: Formålet med denne afhandling var at undersøge forekomsten af skader i bevægeapparatet i ekstremiteter og at estimere sammenhænge mellem mulige risikofaktorer så som eksponeringstid, årstidsvariation og overvægt i en kohorte af skolebørn undersøgt ugentligt over 2.5 år

Metode: Data fra the Childhood Health, Activity, and Motor Performance School Study Denmark (CHAMPS Study–DK) fra perioden august 2008 til juli 2011 blev anvendt. I alt blev 1259 skolebørn i alderen 6 til 12 år fulgt gennem ugentlige tilbagemeldinger på automatiserede sms spørgsmål om bevægeapparats problemer. En telefonkonsultation blev anvendt til at skelne mellem trivielle klager og vedvarende symptomer i relation til mulig skade. I sidstnævnte tilfælde, blev børn undersøgt af klinikere tilknyttet studiet og diagnosticeret i forhold til ICD-10 (the International Classification of Diseases). Skader diagnosticeret i andre kliniske sammenhænge (f.eks. skadestue) blev indsamlet i samme periode for at opnå en komplet skadesregistrering i kohorten. Fysisk aktivitet blev målt via sms spørgsmål og accelerometer målinger.

Resultater: Samlet set blev der observeret en ugentlig skadesincidens og skadesprævalens på henholdsvis 1.2% og 4.6%. Blandt de 1259 børn, der deltog blev der registreret 1229 skader. Der var nærved dobbelt så mange overbelastningsskader som traumatiske. I underekstremiteter var der

2.5 gange flere overbelastningsskader end traumatiske skader. Det modsatte gjorde sig gældende for overekstremiteter, hvor der var 3.1 gange flere traumatiske skader end overbelastningsskader. I forhold til risikoen for at pådrage sig underekstremitetsskader, blev der fundet en sammenhæng med klassetrin, skoletype, mængden af sport og årstid. I forhold til risikoen for at pådrage sig overekstremitetsskader, blev der kun fundet en sammenhæng med klassetrin.
De fleste skader var underekstremitetsskader, i alt 1049 (85%), hvoraf overbelastningsskader i form af apofysit skader svarende til hæl og knæ var langt det mest almindeligt forekommende. Således tegnede diagnoser som Sever's lesion, Sinding-Larsen og Osgood-Schlatter sig for 44% af alle underekstremitetsskader. For overekstremitetsskader, i alt 180, var det hovedsageligt traumatiske skader så som forvridninger, frakturer, kontusioner og forstrækninger der blev registreret.
For overbelastningsskader var det hyppigst skadede område i overekstremiteter skulder og overarm, imens det for underekstremiteter var hælen, der var mest skadet. For traumatiske skader var det hyppigst skadede område i overekstremiteter håndled og hånd, imens det for underekstremiteter var anklen, der var mest skadet.
De højeste skadesincidens rater for traumatiske skader forekom til sport i fritiden (1.57 per 1000 enheder sport). De næsthøjeste forekom i uorganiserede aktiviteter i fritiden (0.57 per 1000 enheder fysisk aktivitet i fritiden), imens den laveste risiko forekom i skoleidrætstimerne (0.14 per 1000 enheder skoleidræt).
Der blev fundet årstidsvariation i skadesincidens og skadesprævalens med næsten dobbelt så stor skadesrisiko henover forår, sommer og efterår, sammenlignet med vinter. Overvægt defineret med henholdsvis BMI og den totale andel af fedt i kroppen prædikterer forekomsten af underekstremitetsskader, hvilket indikerer at overvægtige børn er i øget risiko.

Konklusion og perspektivering

Denne afhandling har tilføjet en bredere indsigt i bevægeapparatsskader i ekstremiteter i en kohorte af 6-12 årige skolebørn ved at anvende hyppige og prospektive data indsamlings metoder til at opfange såvel traumatiske skader som overbelastningsskader. Den epidemiologiske viden omkring børns skader er udvidet ved at beskrive og analysere skadesincidens og skadesprævalens og de associerede risikofaktorer der bidrager til forklaringen af skadesætiologi. De generiske fund fra denne heterogene kohorte af skolebørn giver grund til især at gennemtænke strategier til at forebygge overbelastningsskader på alle ansvarlige niveauer fra børn, forældre, trænere, idrætslærere, sundhedsprofessionelle til beslutningstagere i sportsorganisationer og politik.

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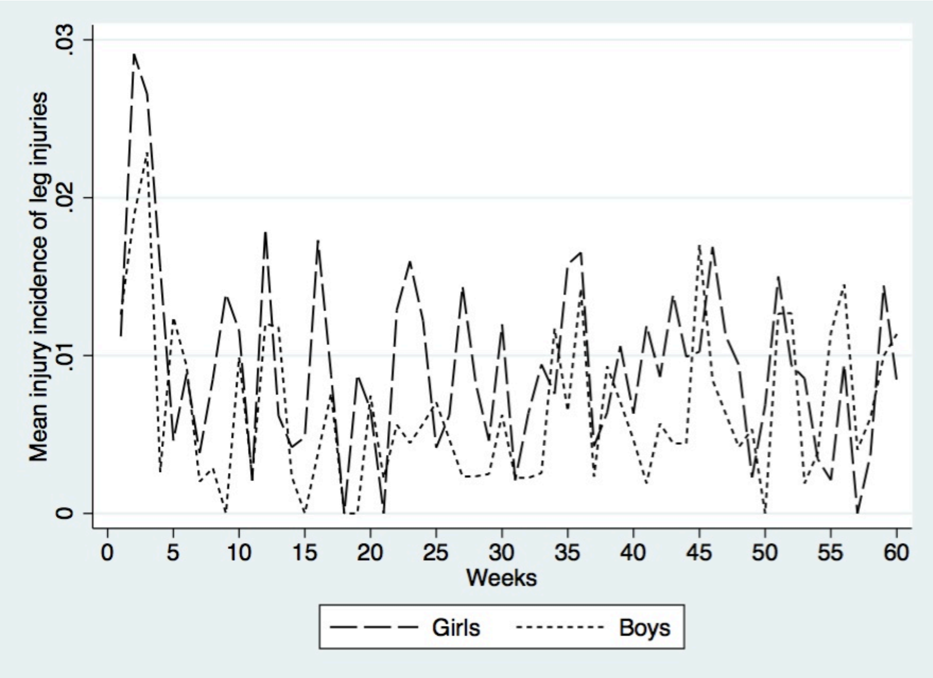
List of appendences

Figure 1: Mean lower extremity injury incidences by gender over time.



Weeks are relative to each school included in SMS-track, thus week 1 is the first week for all ten schools even though the inclusion of schools was gradual.

Figure 2: Lorelogram illustrating serial correlation in leg pain by gender