INJURY AND ILLNESS IN YOUTH ELITE ATHLETES

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by

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List of papers

This dissertation is based on the following papers, addressed in the text by their Roman numerals:

I. Moseid CH, Myklebust G, Fagerland MW, Clarsen B, Bahr R.
The prevalence and severity of health problems in youth elite sports: A 6-month prospective cohort study of 320 athletes. Scand J Med Sci Sports. 2018; 28: 4: 1412-1423. doi: 10.1111/sms.13047. Epub 2018 Feb 19.

II. Moseid CH, Myklebust G, Fagerland MW, Bahr R.
The association between early specialization and performance level with injury and illness risk in youth elite athletes. Scand J Med Sci Sports. 2019 Mar; 29: 3: 460-468. doi: 10.1111/sms.13338. Epub 2018 Dec 6.

III. Moseid CH, Myklebust G, Slaastuen MK, Bar-Yaacov JB, Kristiansen AH, Fagerland MW, Bahr R.
The association between physical fitness level and number and severity of injury and illness in youth elite athletes. Scand J Med Sci Sports. doi: 10.1111/sms.13498. Epub 2019 Jun 17.

Summary in English

Introduction

The health benefits associated with youth sports participation are well recognized. At the elite level, however, are these advantages in fact outweighed by an increased risk of injury and illness? There are strong opinions in the public debate regarding how best to achieve success in youth sport, but research is limited. Specialized sport academy high-schools enable youth athletes to combine high-school and sports at the elite level. There is no consensus, however, regarding when intensive, sport-specific training programs need to start, what the requirements are for youth elite athletes to improve skills vs. minimizing injury and illness risk, and how physical and mental overload can best be avoided.

The purpose of this thesis was to increase the level of knowledge about the magnitude of health problems in youth elite athletes (*Paper I*) and to conduct studies analyzing potential risk factors for injury and illness expressed through (i) early single-sport specialization, (ii) performance level (*Paper II*), and (iii) level of physical fitness (*Paper III*).

Methods

This was a 26-week prospective cohort study. The study included youth elite athletes (n=260) newly enrolled into three selected specialized sport academy high-schools in Norway, representing a variety of endurance, technical, and team sports, as well as a convenience sample of their teammates (n=60) attending regular high-schools. At baseline, they completed a questionnaire covering anthropometrics, medical history, and sport history and performed physical fitness tests related to endurance, strength, agility, and speed. Both the athletes and their coaches were asked to evaluate performance levels at baseline.

To assess weekly injuries and illnesses, we used the Oslo Sports Trauma Research Center Questionnaire on health problems.

Main results

At any given time, 43% (95% CI 37% to 49%) of the youth elite athletes reported a health problem, and 25% (95% CI 20% to 31%) reported a substantial health problem. Girls reported more health problems than did boys (53%, 95% CI 42% to 64% vs. 39%, 95% CI 32% to 46%). Most injuries were reported in team sports (37%, 95% CI 29% to 45%) and technical sports (36%, 95% CI 25% to 48%), whereas most illnesses were reported among the endurance athletes (23%, 95% CI 15% to 35%). Team sport athletes reported more substantial injuries vs. their teammates (22%, 95% CI 16% to 30% vs. 10%, 95% CI 5% to 20%) *(Paper I)*. In *Paper II,* we demonstrated

that youth elite athletes with a sport history of early and single-sport specialization were not at a greater risk of incurring injury and illness after enrollment into a specialized sport academy high-school environment, nor were the best-performing youth elite athletes. The athletes with performance level ratings within the top 10%, who reported more overuse injuries compared to the other athletes (1.0, 95% CI 0.9 to 1.2 vs. 0.8, 95% CI 0.6 to 1.0), were an exception. In *Paper III,* we demonstrated that the least fit youth elite athletes were not at a greater risk of injury or illness compared to the other athletes. The least fit girls, who reported more overuse injuries compared to the other girls (0.9, 95% CI 0.1 to 1.7 vs. 0.3, 95% CI 0.1 to 0.6), were an exception. There was also a trend wherein the least fit endurance athletes reported more illnesses than did the other endurance athletes.

Conclusions

Nearly half of the youth elite athletes attending specialized sport academy high-schools reported a health problem every week, and 25% weekly reported a substantial health problem. In our study, neither early specialization nor single-sport specialization appeared to represent risk factors for injury and illness among the youth elite athletes. Similarly, neither high performance level nor low physical-fitness level appeared to represent risk factors for injury and illness among the youth elite athletes. The great burden of health problems applied to these youths, however, is a concern, and further preventative work is warranted.

Sammendrag (Summary in Norwegian)

Introduksjon

Mange unge drømmer om å bli toppidrettsutøvere, og det er mange som mener mye om hvordan de best kan nå dette målet. I flere idretter kreves det i dag at unge utøvere tidlig velger bort andre idretter til fordel for kun én idrett. Idretter som før var sesongbasert er i dag helårsidretter, og den naturlige sesong-vekslingen mellom ulike idretter er forsvunnet. Mange barn og unge trener derfor mye og kanskje mindre differensiert enn tidligere fra svært ung alder. I tillegg er det etablert mange nye arenaer der "de beste" unge utøverne plukkes ut til å være med. Disse unge utøverne deltar både på kamper, i turneringer, stevner og treninger i ulike årsklasser/nivå, er ofte utøvere som har mest spilletid og konkurranser, og som konsekvens får liten tid til restitusjon.

I de skandinaviske landene er det etablert en rekke offentlige og private toppidrettsgymnas. Gymnasene tilrettelegger for at unge idrettsutøvere skal kunne kombinere skole og idrett på høyt nivå. Disse toppidrettsgymnasene er populære, men for noen utøvere øker treningsmengden dramatisk i overgangen fra ungdomsskole til toppidrettsgymnas. Ungdommene er fremdeles i vekst og utvikling både mentalt og fysisk, og denne overgangen med rask økning i treningsbelastning, kan gi økt risiko for sykdom og skade. Mange av ungdommene opplever også stor totalbelastning, der både skole, trening, konkurranse, venner og familie krever sin plass.

Formålet med denne avhandlingen var å øke kunnskapsnivået rundt omfang og risikofaktorer for sykdom og skade hos unge toppidrettsutøvere, for på sikt å kunne ivareta dem på en bedre måte enn i dag.

Metode

Doktoravhandlingen er basert på et forskningsprosjekt der vi prospektivt gjennom en 26-ukers periode kartla sykdommer og skader hos 260 unge toppidrettsutøvere fra tre ulike toppidrettsgymnas i Norge. Hver uke rapporterte utøverne sykdom og skade via "Oslo Sports Trauma Research Center Questionnaire on Health Problems." Ved studieslutt ble det gjennomført retrospektive intervju. En kontrollgruppe bestående av 60 lagkamerater som drev lagidrett på samme lag som toppidrettsungdommene men gikk på vanlig videregående skole var også inkludert i studien. Alle deltakerne fylte ut et spørreskjema ved studiestart som kartla idrettsbakgrunn, prestasjonsnivå (både egenevaluert og trenerevaluert), tidligere sykehistorie og gjennomførte fysiske tester (Ironman Jr)

Hovedresultat

Gjennomsnittlig ukentlig prevalens av helseplager blant unge toppidrettsutøvere på toppidrettsgymnas var på 43% (95% CI 37% til 49%), mens 25% (20% til 31%) rapporterte om betydelige helseplager *(Artikkel I).* Jenter rapporterte mer helseplager enn gutter (53%, 95% CI 42% til 64% vs. 39% (32% til 46%). Det var ikke signifikant forskjell i prevalens av belastningsskader mellom ulike idrettskategorier (17%, 95% CI 13% til 22%), men størst andel av skader ble registrert blant lag- og tekniske utøvere og størst andel sykdom blant utholdenhetsutøverne. Det var høyere prevalens av betydelige belastningsskader hos lagidrettsutøvere på toppidrettsgymnas vs. deres lagkamerater (22%, 95% CI 16% til 30% vs. 10%, 95% CI 5% til 20%). *Artikkel II* viste at de som hadde spesialisert seg tidlig i én idrett ikke var mer utsatt for sykdom eller skade i løpet av det første skoleåret. Utøverne med høyest prestasjonsnivå (egenevaluert og trenerevaluert) var heller ikke mer utsatt for sykdom eller skade. Et unntak var at utøverne med høyest egenevaluert prestasjonsnivå rapporterte noe mer belastningsskader i forhold til resten av utøverne (1.0, 95% CI 0.9 til 1.2 vs. 0.8, 95% CI 0.6 til 1.0). *Artikkel III* viste at de som scoret dårligst på fysiske tester generelt sett ikke var mer utsatt for flere (3.7, 95% CI 3.0 til 4.0 vs. 3.6, 95% CI 3.2 til 3.9) eller mer alvorlige (median kumulativ severity 304 (Q1, Q3:153, 741) vs. 304 (Q1, Q3:157, 643) helseplager enn de som presterte best. Et unntak var blant jentene i dårligst form som rapporterte mer alvorlige belastningsskader enn de øvrige jentene (0.9, 95% CI 0.1 til 1.7 vs. 0.3, 95% CI 0.1 til 0.6). De dårligst trente utholdenhetsutøverne rapporterte også noe mer sykdom enn resten av utholdenhetsutøverne (3.2, 95% CI 2.2 til 4.2 vs. 2.3, 95% CI 1.9 til 2.7).

Konklusjon

Litt under halvparten av unge idrettsutøvere på toppidrettsgymnas rapporterte om ukentlige helseplager, og 25% rapporterte at sykdom eller skade påvirket prestasjon eller treningsmengde i betydelig grad. Til tross for at vi ikke fant signifikante sammenhenger mellom de undersøkte risikofaktorene; tidlig spesialisering, spesialisering i én enkelt idrett, høyt prestasjonsnivå eller de dårligst trente utøverne, viser den høye sykdom- og skadeprevalensen blant unge toppidrettsutøver, at videre oppfølging av denne gruppa er viktig for å kunne forebygge og redusere sykdom og skade.

Thesis at a glance

Questions	Methods	Results	Conclusion
What is the magnitude of health problems in youth elite athletes attending specialized sport academy high-schools? How does this compare to teammates attending regular high-schools?	*Participants:* 260 youth elite athletes and 60 team sport teammates *Data collection:* OSTRC-Q on health problems *Outcomes:* Prevalence & severity of health problems	*Weekly prevalence of health problems (mean):* All 43% and substantial 25% *For sub-group (means):* *All health problems:* boys 39% & girls 53% *Illness:* endurance 23% *Injury*: technical 36% and team sport 37% *Substantial injury:* Team sport 22% and teammates 10%	43% weekly reported a health problem and 25% a health problem with a substantial negative impact on training and performance. Pattern and magnitude of health problems differed between sport categories and sexes. Elite team-sport athletes reported more substantial injuries compared to their teammates.
Do early or single-sport specialization or high performance level increase the risk of health problems in youth elite athletes?	*Participants:* 259 youth elite athletes *Risk factors:* Early & single-sport specialization & high performance level *Data collection:* OSTRC-Q on health problems *Outcomes:* Number & severity of health problems	*Number of all health problems between groups (mean):* *Early vs. late specialization:* 3.5 vs. 3.6 *Single-sport vs. multisport:* 3.5 vs. 3.7 *Self-evaluated top 10% performance level:* 3.5 vs. 3.6 and overuse injuries 1.0 vs. 0.8 *Coach-evaluated top 50% performance level:* 3.5 vs. 3.2	Neither early nor single-sport specialization was associated with more health problems in youth elite athletes, nor was high performance level. An exception was observed in some of the highest-performing athletes (self-evaluated), who reported more overuse injuries.
Is the least fit quartile of youth elite athletes at greater risk of becoming injured or ill after sport academy high-school enrollment?	*Participants:* 166 youth elite athletes *Risk factor:* Physical fitness *Data collection:* OSTRC-Q on health problems *Outcomes:* Number & severity of health problems	The least fit quartile of athletes reported 3.7 (mean) health problems vs. 3.6 in the rest of the cohort. The least fit girls reported more substantial overuse injuries, 0.9 vs. 0.3 among the other girls. The least fit endurance athletes reported more illness (only a trend).	Overall, the least fit athletes were not at a greater risk of becoming injured or ill after enrollment into specialized sport academy high schools, except for the least fit girls, who reported more overuse injuries.

Abbreviations

AAP	American Academy of Pediatrics
ACL	Anterior cruciate ligament
AMSSM	American Medical Society of Sports Medicine
AOSSM	American Orthopedic Society of Sports Medicine
Approx	approximately
CGS sports	Sports measured in centimeters, grams and seconds
CI	Confidence interval
cm	centimeter
e.g.	exampli gratia
GH	Growth hormone
h	hours
HPs	Health problems
IGF-1	Insulin-like growth factor 1
IGF-2	Insulin-like growth factor 2
i.e.	id est
IOC	International Olympic Committee
LTAD	Long-Term Athlete Development
min	minute
no	number
NTG	Norges Toppidretts Gymnas
OR	Odds ratio
OSTRC	Oslo Sports Trauma Research Center
OSTRC-Q	Oslo Sports Trauma Research Center Questionnaire on Health Problems
s	seconds
SD	Standard deviation
TRIPP	Translation Research into Injury Prevention Practice
yrs	years
vs.	versus

Introduction

"Youth sports is about winning the race to the right finish line"

John O'Sullivan, "Changing the game project"

The why – thesis rationale

Across nations, youths engage in organized and unorganized sport at all levels. Through sport, youths experience enjoyment and develop confidence and empowerment. They also improve their health and develop physical fitness and peer relations, often of lifelong importance. Youths have a natural inclination toward learning skills and are under physiological and psychological development, rendering them well suited to physical fitness training and skill development in sports. A relevant question, however, concerns whether or not youth sport at the elite level remains healthy. Is it healthy, or is it merely a race to weed out the weak from the strong, nurturing only the survivors, without thoughts of enjoyment, empowerment, or health benefits? Are the health benefits associated with youth sports in fact outweighed by the risk of injury and illness when performing at the elite level *(Paper I)*?

Early single-sport specialization, early talent identification, overscheduling, and increasing training loads at an early age represent potential risk factors for injury and illness in youth athletes *(Paper II)*. A short-term focus on performance rather than on long-term athlete development and empowerment, failing to consider the different developmental stages of youths, might increase youth athletes' risk of incurring injury and illness (Jayanthi et al., 2013; Jayanthi et al., 2015). At increasing rates, youth sports are becoming hypercompetitive, deselecting late developers who do not show talent at a young age, children participating in more than one sport at young ages, and children partaking in sports merely for enjoyment and peer socialization (Gregory, 2017). At the same time, the gifted youth athletes are overloaded with scheduled practices and competitions from a very young age. Some of these athletes have scheduled training for more than 16 hours weekly while completing a full-time school curriculum (Rose et al., 2008).

In recent years, medical societies around the world have expressed concern regarding this trend. Potential medical risks of high-intensity training and sports specialization during pre-adolescent years, related to the high physiological and psychological demands, are highlighted (American Academy of Pediatrics, 2000). Year-round inappropriate training and a high competition load, potentially overloading and overscheduling gifted youth athletes, without concern for maturational aspects, represent a global concern in youth sports (Bahr, 2014; DiFiori et al., 2014). Youth athletic development projects, predicated on the observed need to transform the youth sport culture, have emerged (Côté et al., 2009; Côté and Vierimaa, 2014; DiFiori et al., 2014; Bergeron et al., 2015; Mountjoy and Bergeron, 2015; LaPrade et al., 2016; DiFiori et al., 2018). Unfortunately, there remains a lack of real-life implementation of these postulates, statements, and development criteria throughout most youth sport communities.

There are strong opinions in the public debate regarding how best to achieve success in youth sport, but research is limited, resulting in a reliance on anecdotal evidence. As stated by Coté and Vierimaa (2014), it is evident that in order to be internationally competitive and successful as an adult athlete, at some point during adolescence, future expert athletes need to adopt intensive, sport-specific training programs. There is a divide, however, regarding when the intensive, sport-specific training programs need to start, what the requirements are for youth elite athletes to improve skills vs. minimizing injury and illness risk, and how physical and mental overload can best be avoided. In this thesis, we illuminate the magnitude of health problems that are imposed on youth elite athletes (*Paper I*) and internal risk factors for injury and illness expressed through (i) early single-sport specialization, (ii) performance level (*Paper II*), and (iii) level of physical fitness (*Paper III*).

Background

Growth and maturation of adolescent athletes

General principles of maturation

Given the trends toward extensive training, early sport specialization, and participation in a large number of high-level tournaments at young ages, there appears to be an increased emphasis on early competitive success for youth athletes. As a result, several consensus statements, editorials, and review articles have underlined the importance of incorporating into the adolescent athlete's training appropriate adjustments to his/her biological and physiological maturational process (Mountjoy et al., 2008; Armstrong and McManus, 2011; Bergeron, 2015; Bergeron et al., 2015; Emery et al., 2015; Malina et al., 2015; Mountjoy and Bergeron, 2015; Suppiah et al., 2015).

The physical changes of puberty typically dominate early adolescence (10-13 years), whereas mid-adolescence (14-16 years) and late adolescence (16-19 years) are dominated by cognitive, psychosocial, and behavioral development (McKay et al., 2016). Successful performance in sports during adolescence depends on a variety of physiological and psychological variables related to sex, age, and maturational level. Inter-individual differences in both timing and tempo, as well as normal variations in pubertal hormones, result in pronounced differences in body size, physiological capabilities, and behavior for adolescents of the same chronological ages. These variations can potentially influence their selection into athletic development programs. Adolescents exhibiting early maturation are overrepresented in strength- and power-based sports, whereas adolescents exhibiting late maturation are overrepresented in aesthetic sports, such as gymnastics, dance, and figure skating (McKay et al., 2016).

The phenomenon of differences in biological maturation represents one of the great challenges in youth sport (Gabbett et al., 2014). Armstrong and McManus (2011) describe how boys who mature earlier are generally taller and heavier and have higher mass-to-stature ratios than those who mature at a later age. Differences are most pronounced between 12 and 15 years of age, coinciding with peak elite youth sports participation. In addition to greater body size, the early maturing boys benefit from changes in body composition and shape that are advantageous in most popular youth sports (e.g., football and ice hockey).

Background

Girls differ from boys in their growth and development during maturation, resulting in substantial differences in body size and composition between the sexes. Girls are smaller in stature, have shorter legs, lower muscularity, and greater relative fatness, and are consequently not as strong or as fast as their male counterparts. Another important aspect related to sex differences is the predisposition to an increased risk of skeletal and reproductive health problems, particularly in endurance and aesthetic sports, where intense training is coupled with a focus on leanness. Finally, some responses to exercise are not solely explained by differences in body size and body composition between sexes. There is evidence of qualitative sex differences due to training responses (Mountjoy et al., 2008; Armstrong and McManus, 2011).

Hormonal changes during maturation

Puberty is the defining biological event of adolescence. The sex hormones alongside the pituitary hormones, GH and IGF-1, are the major hormones of puberty. These hormones both improve physical performance and influence somatic growth, body composition, and bone development. The sex hormones, predominantly estradiol in females and testosterone in males, both drive and develop secondary sex characteristics. By the end of puberty, there has been a 20-to-30-fold increase in testosterone for males and a 10-to-20-fold increase of estradiol for females (Richards et al., 1992; Bordini and Rosenfield, 2011; McKay et al., 2016).

Musculoskeletal changes during maturation

Armstrong and McManus (2011) describe musculoskeletal changes during adolescence as marked increases in muscle strength and power. The muscle enzyme profile needed for optimal anaerobic energy generation to support high-intensity exercise improves as children progress through adolescence. Aerobic fitness and maximal oxygen uptake benefit from increases in muscle mass, stroke volume, and hemoglobin concentration. This greater strength, power, anaerobic fitness, and aerobic fitness of early maturing girls and boys enhances their sport performance, advancing them from the less successful performers at the same age.

Muscle metabolism: Youth athletes accumulate less lactate than adults during exhaustive exercise; consequently, they are better equipped for aerobic than anaerobic exercise (Armstrong et al., 2015). The exact maturational effects on blood lactate accumulation during exercise, however, have not yet been established (Armstrong and McManus, 2011; Bergeron et al., 2015). Youths, as compared to adults, oxidize a higher percentage of lipids and a lower percentage of carbohydrates during exercise. This renders them well suited for long-duration, moderate-intensity sporting activities. In sports involving short-duration, high-intensity events fueled by glycogenolysis/glycolysis, however, youths appear to be at a disadvantage compared to young adults (Armstrong and McManus, 2011; Bergeron et al., 2015). The transition in fuel utilization from lipid-based oxidization into an adult fuel-utilization status occurs in mid to late puberty. Operationally, this means that early maturing athletes are favored in high-intensity sports, such as football, handball, and certain athletics exercises, due to the earlier development of the anaerobic metabolism capacity (Armstrong et al., 2015).

Muscle strength

Muscle strength increases in a relatively linear manner through childhood, with few differences between males and females. During puberty, sex differences emerge, and muscle strength accelerates from 13 to 14 years through late adolescence for boys, while girls continue to develop at a similar rate as during pre-puberty. On average, by late puberty, there is a sex difference in the expression of strength of approximately 50%, being both muscle-group (individual strength or composite measurements from several groups) and muscle-action (isometric, concentric, or eccentric) specific (Armstrong and McManus, 2011; Bergeron et al., 2015). Armstrong and McManus (2011) describe how peak strength development occurs approximately one to one-and-a-half years after peak height velocity. During adolescence, a greater percentage of motor units can be voluntarily activated, the proportion of type II muscle fibers is increased, and the size of the muscle fibers is also increased (4-to-5-fold). For males, these differences are most pronounced between the ages of 13 and 16 years. Consequently, early maturing athletes also have greater strength and muscle mass than their later maturing peers, with the accompanying advantages apparent in most youth sports (Armstrong and McManus, 2011; Malina et al., 2015; Cumming et al., 2017).

Bio-banding in youth sport

The selection of youth athletes follows, in many cases, a maturity-related gradient. To counteract this, a process called bio-banding places youth athletes into groups based on physical characteristics rather than chronological age. This practice has been tried out in youth-academy football competitions, with suggested benefits to both early maturing adolescents and late maturing adolescents (Cumming et al., 2018). Bio-banding does not, however, preclude consideration of technical and tactical skills, as well as psychosocial factors, and further research is needed to determine its effectiveness (Malina et al., 2015; Cumming et al., 2017).

Background

Bone and skeletal changes

Linear growth is driven by cartilage cells (chondrocytes) within the growth plates, resulting in bone formation and longitudinal growth of the skeleton (Wood et al., 2019). The epiphyseal and apophyseal growth plates represent regions of particular structural vulnerability in the youth athlete. This vulnerability is amplified during adolescence under the influence of not only pubertal hormones but also insulin-like growth hormones, growth factors (IGF-1 and IGF-2), insulin, and thyroid hormones, promoting longitudinal bone growth throughout. In the later stages of puberty, high estradiol levels complete linear growth by inducing epiphyseal fusion through direct effects on the growth plate when the growth plate becomes replaced by bone. In adolescent males, this occurs through aromatization of testosterone to estradiol (Rogol et al., 2002; Armstrong and McManus, 2011; Wood et al., 2019).

During puberty, an increase in bone mineralization occurs, with approximately 25% of estimated adult bone accrued during this period. Estrogen enhances this process, which is also both sex- and maturity-dependent. Consequently, in terms of optimizing bone mineralization, the early pubertal years and pre-menarche years are particularly important for young girls (Armstrong and McManus, 2011). Muscle enlargement and strength also play a pivotal role in bone development. In some data, these are reported as the primary determinants of bone structure and strength (Armstrong and McManus, 2011).

During the period of peak linear growth, there is a transient decrease in bone strength and bone mineral density, explaining the observed association between peak fracture rate and peak height velocity during adolescence (Bailey et al., 1989; Faulkner et al., 2006; McKay et al., 2016). This is counteracted by both weight-bearing exercise and nutritional status. Consequently, an excessive focus on low caloric intake and leanness in certain aesthetic and endurance sports appears particularly unfavorable during puberty. Too low an intake of calcium and vitamin D, together with an already-predisposed reduction in bone mineral density, might negatively affect bone health (Armstrong and McManus, 2011).

Aerobic and anaerobic fitness during maturation

Maximal oxygen uptake (i.e., the highest rate a child/adolescent can consume oxygen during exercise) is recognized by Armstrong and McManus (2011) as the best single indicator of a young person's aerobic fitness. It rises almost linearly from 8 to 18 years of age. Values tend to plateau somewhat earlier for girls than for boys. During adolescent years (12 to 17 years of age), maximal oxygen uptake increases approximately 25% in girls vs. 70% in boys. Maximal oxygen uptake is highly correlated to body size. The progressive increase in muscle mass for boys accounts for an increased difference between the sexes. Additionally, an increase in hemoglobin concentration is related to changes in testosterone concentration. For boys, the largest annual increase in maximal oxygen uptake occurs between 13 and 15 years of age, accompanying the years before and after the peak height velocity; for girls, the largest annual increase in maximal oxygen uptake occurs somewhat earlier (Armstrong and McManus, 2011; Bergeron et al., 2015). Youth elite athletes in some endurance sports tend to have higher maximal oxygen uptake compared to athletes in other sports and non-athletes. Whether this is due to selection or subsequent training is unknown (Armstrong and McManus, 2011; Armstrong et al., 2015).

Anaerobic fitness also increases (almost) linearly between 7 and 12 years of age in both sexes; boys then have a more pronounced increase through to young adulthood. Girls experience an increase in anaerobic performance of approximately 65% between the ages of 12 and 17 years, whereas this increase is 120% for boys. As such, both sexes experience a more pronounced increase in anaerobic performance compared to aerobic performance during maturation (Armstrong and McManus, 2011; Bergeron et al., 2015).

Neurocognitive changes during maturation

There are major changes in brain structure and function during adolescence. The grey matter changes in the same sequence in boys and girls, with the sensory and motor regions maturing first. There is a suggested link to hormonal status, as these changes peak approximately one year earlier for girls than for boys and hormonal status and puberty correspond to the behavioral changes of adolescence (Wood et al., 2019). Neuromuscular injury prevention programs might take advantage of the fact that the motor cortex develops early during adolescence.

Later changes in brain structure are the most obvious in the prefrontal cortex. This area is responsible for executive function, decision making, and risk assessment and is possibly related to typical risk-taking behavior during mid to late adolescence as a result of the adolescent hyper emotionality and sensation seeking driven by other brain areas. Increasing maturity of the prefrontal cortex moderates this impulsivity and risk taking upon entry into young adulthood. Nevertheless, there are other moderators of risk-taking behavior during adolescence, such as performance-based incentives and the presence or absence of peers. Finally, the ability to understand consequences and complex events is a cognitive function that is not fully developed until adulthood. If these properties are developed early, they might have a positive impact on performance, perhaps particularly related to highly technical sports and skills (Huijgen et al., 2015; McKay et al., 2016).

Exercise-induced fatigue and recovery – differences between children and adults

Exercise-induced fatigue and recovery in children and adolescents remain under-researched. The current status is that children recover faster from exercise exhaustion than do adults. It has been suggested that the difference in recovery rates is primarily explained by children having less muscular output and producing fewer metabolic by-products and possibly lower neuromotor activation. Thus, they have less from which to recover. The cardiorespiratory recovery rate is, however, faster in children. Muscle fibers are smaller, resulting in higher capillary density. The distance of circulation is shorter. Children produce less lactate, although studies disagree on whether the elimination rate of lactate differs between children and adults. Children have a faster re-synthesis of intramuscular energy substrate (i.e., creatine phosphate), possibly due to their greater reliance on oxidative rather than glycolytic metabolism, as previously discussed. There are also data suggesting that children recover faster from neuromotor exhaustion as compared to adults (Falk and Dotan, 2006; Bergeron et al., 2015). During adolescence, adult-level recovery is established by mid puberty in females and somewhat later in males (Armstrong and McManus, 2011; Bergeron et al., 2015).

Fatigue and recovery are not only related to performance, however, but also to psychological and cognitive factors, which are suggested to be particularly important in youth athletes (Patikas et al., 2018). Illness is also suggested to be related to an inadequate stress-recovery balance (Brink et al., 2010; van der Does et al., 2017). In a recent IOC statement, published in 2015 by Bergeron et al. (2015), adequate rest and recovery are highlighted as important factors in youth athletes. In the work of maintaining healthy youth elite athletes, minimizing injury and illness risk, a two-sided perspective is important. The overall training, psychological and cognitive load, considering both training and competition load and environmental aspects (e.g., eating, sleeping, travelling), must be balanced with adequate recovery regimens (Schwellnus et al., 2016; Soligard et al., 2016).

Overreaching, overtraining syndrome and burnout

Excessive fatigue with overreaching, overtraining, and burnout conditions is a recognized vulnerability of adolescence. Overreaching and overtraining arise when there is an imbalance between training fatigue and/or non-training stressors and recovery. Overreaching is a continuum between a functional and non-functional state and is also accompanied by psychological and neuroendocrine symptoms. Full recovery is expected after a rest period. More specifically, overreaching is an accumulation of training and non-training stressors that result in short-term decrements in performance. It can take from days to several weeks to recover from overreaching.

Overtraining can be considered the next step in this continuum, resulting from an accumulation of both training and non-training stressors that result in "prolonged maladaptation." Numerous contributing factors to overtraining syndrome appear to exist. Both environmental factors and personal characteristics seem to be of importance (McKay et al., 2016). Several biological, neurochemical, and hormonal regulation mechanisms (Meeusen et al., 2013) induce detrimental long-term effects on performance, and a recovery period may last from several weeks to several months (Halson and Jeukendrup, 2004; Malina, 2010a; Armstrong and McManus, 2011). In short, overtraining produces the same symptoms as overreaching, but the symptoms are more severe, and the decrease in performance lasts longer (> 2 months) (Meeusen et al., 2013; DiFiori et al., 2014).

Commonly identified symptoms associated with overreaching and overtraining include increased perception of effort and performance stagnation or decrement, persistent fatigue, frequent upper respiratory tract infections, muscle soreness, sleep disturbances, feelings of muscular heaviness, loss of appetite, and mood disturbances (e.g., increased tension, depression, anger). Symptoms reported by young athletes during periods of overtraining include increased conflicts with family, partners, coaches, or friends, decreased interest in training and competition, increased frustration with training, decreased self-confidence, inability to concentrate on a particular task, short temper, depression, sadness, and elevated levels of perceived stress (Malina, 2010a; Armstrong and McManus, 2011; Meeusen et al., 2013).

Numerous contributing factors appear to exist, resulting in prolonged recovery, performance decrement, and, ultimately, athlete burnout (Matos et al., 2011; Meeusen et al., 2013; DiFiori et al., 2014). Burnout in a young athlete has been defined as "a response to "chronic stress" that results in the athlete ceasing to participate in a previously enjoyable activity"(Cahill and Pearl, 1993). For adolescent athletes, psychological factors play a particularly important role in the overreaching-overtraining-burnout continuum (DiFiori et al., 2014). Overwhelming physiological and psychological demands might result in youth athlete burnout and attrition from sport, whereof sport specialization might be an associated factor.

Background

Relative Energy Deficiency in Sport (RED-S)

RED-S is characterized by impaired physiological function in different organs, including bone health, menstrual function and hormonal imbalance, metabolic rate, immunity, protein synthesis, and cardiovascular health. RED-S is due to an energy deficiency relative to the balance between nutritional dietary intake and daily energy expenditure (Mountjoy et al., 2014). RED-S was formerly known as the female athlete triad, defined as the presence of one or more of low energy availability (with or without disordered eating), amenorrhea, and/or osteoporosis (Nattiv et al., 2007). Lately, however, it has been acknowledged that male athletes also experience relative energy deficiency related to energy expenditure, particularly in weight-sensitive sports, such as cycling, running, and ski jumping (Mountjoy et al., 2014; Mountjoy et al., 2018). In a recent study on young elite athletes, a high prevalence of eating disorders existed in both male (3%) and female (14%) elite adolescent athletes (Martinsen and Sundgot-Borgen, 2013). The existence of RED-S among adolescent elite athletes is worrying given their greater need for energy intake (American Academy of Pediatrics, 2000). Reduced dietary intake might result in inadequate calcium intake, which is of concern given that this is a time when substantial amounts of bone should be accrued (Armstrong and McManus, 2011; Campbell and Peebles, 2014; Bergeron et al., 2015). Secondary amenorrhea as a result of inadequate nutritional status and intense athletic training is also of concern due to the potential negative effects on other long-term health outcomes, such as infertility or cardiovascular health (American Academy of Pediatrics, 2000).

Youth athletic development

General principles

It has been stated that early sport specialization leads to success for a few and physical inactivity for many (Mostafavifar et al., 2013). A growing number of coaches and parents believe that the best way to produce superior young athletes is to have them participate in only one sport from a young age (Suppiah et al., 2015; Feeley et al., 2016). Children and youth athletes tend to be selected into talent programs at an ever earlier age to undergo more specialized training (Brenner, 2007; Malina, 2010a; Jayanthi et al., 2013; Mostafavifar et al., 2013; LaPrade et al., 2016), much like adult elite athletes. Working with youth athletes stands in great contrast to working with mature, fully developed elite athletes, however, in several ways (LaBella, 2014; Malina et al., 2015; Mountjoy and Bergeron, 2015; Weissensteiner, 2015). In youth athletic development, different ethics apply. Youth athletes are fully dependent on their stakeholders, their parents, coaches, and teachers. They participate in a full-time school curriculum and might spend several hours daily travelling between home and training facilities. Youths are "under construction," and in the work of developing youth athleticism, multiple factors encompassing growth and maturation need to be considered continuously. Youths should not be categorized as "small adults".

Two main pathways in youth athletic development work

The path of early specialization

In sports literature, youth athletic development is described by either deliberate practice or deliberate play from a young age. The path of deliberate practice emphasizes the association between structured hours of training for the acquisition of expert performance skills and advancement into peak elite performance. This pathway, also known as early specialization, was first described by Ericsson and co-workers (1993) with relation to highly selected elite musicians and chess players. This model has since been transferred into the field of sports performance and embraced by several stakeholders in youth elite athlete development systems (Ericsson et al., 1993; Ericsson, 2013).

Early sport specialization most likely originated in Eastern Europe, with activities such as gymnastics, diving, and figure skating (Malina, 2010a). Some reports consider early specialization helpful in achieving long-term success, at least in aesthetic or highly technical sports, where peak performances tend to appear at a younger age and strength gain and aerobic capacity are not dependent on post-pubertal development (Feeley et al., 2016). For the development of youth athletes in general, however, the success of a selected few in pre-adolescent years has proved to be of limited value (Bergeron et al., 2015).

The path of early specialization is controversial, at least in the western world. Still, this pathway is becoming more common as the competitive pressure in youth sport intensifies. More children play one sport year-round, fewer participate in several sports across the year, and unorganized sport participation or free play are overrun by scheduled trainings. Consequently, there is a risk that the same muscles, tendons, and bones are overtaxed due to high amounts of repetitive, unbalanced movement patterns and too little time for recovery (Myer et al., 2015a). Lack of time off from scheduled sports or high internal and external expectations might also appear as a consequence (DiFiori et al., 2014). In sum, accumulation of both training and non-training stressors might result in "prolonged maladaptation" and a possibility of overreaching and overtraining, as previously discussed.

Background

The path of early diversification

Another pathway to youth athletic development involves promoting deliberate play and sampling different sports at young ages while maturing into a deliberate practice regimen, which typically begins at the age of around 16 years in this pathway (Moesch et al., 2011). This is called the path of early diversification. There are several models embracing youth athlete development and late rather than early specialization. In two systematic reviews by Bruner and colleagues (2009; 2010), the Developmental Model of Sport Participation is deemed the most prominent conceptualization of athlete development within the sports literature (LaPrade et al., 2016). This model provides a framework of sports involvement, prescribing early sampling of different sports as the foundation for further sport participation, toward both the elite level and the recreational level (Côté et al., 2009; LaPrade et al., 2016; Myer et al., 2016). The model, which has been researched and refined over the past 15 years, is based upon seven postulates describing the process, pathways, and outcomes associated with youth sport development, integrating performance, participation, and personal development as the three principal outcomes (Côté et al., 2009).

Postulate 1: Early diversification (sampling) does not hinder elite sport participation in sports where peak performance is reached after maturation

Postulate 2: Early diversification (sampling) is linked to a longer sport career and has positive implications for long-term sport involvement

Postulate 3: Early diversification (sampling) allows for participation in a range of contexts, which most favorably affects positive youth development

Postulate 4: High amounts of deliberate play during the sampling years build a solid foundation of intrinsic motivation through involvement in activities that are enjoyable and promote intrinsic regulation

Postulate 5: A high amount of deliberate play during the sampling years establishes a range of motor and cognitive experiences, which children can ultimately bring to their principal sport of interest

Postulate 6: Around the end of primary school (at approximately age 13), children should have the opportunity to either choose to specialize in their favorite sport or to continue in sport at a recreational level

Postulate 7: Late adolescents (around age 16) have developed the physical, cognitive, social, emotional, and motor skills needed to invest their efforts into highly specialized training in one sport*

**The seven postulates associated with the Developmental Model of Sport Participation (Côté et al., 2009; Côté and Vierimaa, 2014).*

The first five postulates address how sampling of several sports and free play influence youth participation, performance, and personal development in sports, while postulates 6 and 7 focus on important transition ages within sports (Côté et al., 2009; Côté and Vierimaa, 2014). Based on this model, Long-Term Athlete Development programs, aiming to promote physical literacy across different ages and maturational levels of youth athletes, have been developed in Canada, the United States, Norway, and several other industrialized countries (e.g. Australia, the UK, and Portugal).

The Canadian model has refined a Long-Term Athlete Development program to promote adjusted and adequate training, competition, and recovery programs through seven different stages. These are based on the developmental age of the athlete rather than the chronological age and are meant to embrace both emotional and cognitive development, as well as physical and physiological development, of children and adolescent athletes (Côté et al., 2009; SportforLife, 2014). Each step reflects different points in the natural skill development of young athletes, outlined as follows (age cut-off years vary between the sexes and between individuals):

1) Active start 2) FUNdamentals (6-12 years) 3) Learn to Train (8-11 years) 4) Train to Train (10-14 years) 5) Train to Compete (13-18 years) 6) Train to Win (>17 years) (7) Active for Life

The first three steps form the basis for further physical literacy, upon which the next four steps are built.

The US Olympic Committee, along with American National Governing Bodies, built the American Developmental model on the same long-term athlete development principles, creating a five-stage American Development model (UnitedStatesOlympicCommittee, 2014):

1) Discover, Learn and Play (0-12 years) 2) Develop and Challenge (10-16 years) 3) Train and Compete (13-19 years) 4) Excel for High Performance OR Participate and Succeed (ages > 15 years) 5) Mentor and Thrive (for Life)

To demonstrate the developmental foci of these programs, the steps involving the adolescent athlete will be discussed further. These steps involve athletes of the same age as the participants in this thesis. Further details of the program are considered beyond the scope of this thesis but can be found on the web (SportforLife, 2014; UnitedStatesOlympicCommittee, 2014).

The Train to Train/Develop and Challenge stages involve athletes in early and mid-adolescence (age differs between sexes and countries). At these stages, the primary goal is to learn basic skills and how to train, rather than to compete (a ratio of 75% training to 25% competition is recommended) (Brenner, 2016). Both physical and cognitive skills are considered important. Developing major fitness factors (e.g., aerobic capacity, speed, power, and strength) as well as integrated mental, cognitive, and emotional development is recommended. Major biological markers at this age include the onset of the growth spurt, peak height velocity (i.e., the fastest rate of growth before growth decelerates), and, for most girls, menarche. At this stage, the Long-Term

Athlete Development program allows for talent identification and selection and sport-specific training between six and nine times per week, including complementary sports.

The Train to Compete/Train and Compete stages involve mid- to late adolescence. At these stages, recommendations are that 50% of the time should be spent on developing technical and tactical skills while the other 50% should be spent on competition-specific training (Brenner, 2016). At these stages, specific physical conditioning is related to sport, event, and position played. Technical-tactical preparation and development of technical and playing skills under competitive conditions are recommended. Integrated mental, cognitive, and emotional skills and advanced mental preparation are advised, as are specialization in a single sport and sport-specific technical, tactical, and fitness training. Training between 9 and 12 hours per week is advised at this stage.

Early specialization vs. early diversification for attaining future athletic success

In contrast to what a growing number of coaches and parents believes, studies have demonstrated that specialization at an older age may result in better athletic achievements (Barynina and Vaitsekhovskii, 1992; Lidor and Lavyan, 2002). Russian swimmers who specialized before age 11 spent less time on a national team and retired earlier than late specializers (Barynina and Vaitsekhovskii, 1992). Lidor and Layan (2002) evaluated elite and sub-elite athletes across a variety of sports, finding that the elite group was more likely to have played more than one sport during developmental years and practiced intense training after the age of 12. In a large German study encompassing more than 1 500 Olympic athletes, the elite athletes started intense training and competition later and participated in more than one single sport at an older age compared to sub-elite athletes (Vaeyens et al., 2009; Jayanthi et al., 2013). Several other studies have also demonstrated that elite athletes began intense training at later ages vs. near-elites and trained less during childhood (Moesch et al., 2011; Jayanthi et al., 2013; Feeley et al., 2016); some also report that practicing a single sport from a young age might in fact be considered a limiting factor (Barreiros et al., 2014; Suppiah et al., 2015).

Nevertheless, the association between engaging in various sports at younger ages and future athletic success might depend on sport category. The transferring of technical skills among sports might be more valuable in certain sports; indeed, some believe it might be more important in team sports as compared to technical sports. In line with this, no advantage was reported for athletes sampling different sports in a Danish study on CGS sports (i.e., sports measured in centimeters, grams, and seconds, such as athletics or swimming) (Moesch et al., 2011). This finding was also supported in a study on triathletes (Baker, 2003).

Consequently, evidence is equivocal regarding future athletic success and early sport specialization. One could argue that early and single-sport specialization do no harm. There is also insufficient evidence to conclude that it is beneficial for future high-caliber athletic performance, however, and it might be a riskier path (LaPrade et al., 2016).

The Norwegian youth athlete developmental model

Olympiatoppen is responsible for the development, training, and support of the majority of Norwegian youth elite athletes. Olympiatoppen defines elite sports for young athletes as "tomorrow's performers of varying ages, participating on different levels, working on extensive quality improvement through a long-term progression plan that will normally lead to performance at the international elite sport level" (www.Olympiatoppen). The philosophy of Olympiatoppen embraces the same developmental stages for youth athlete development as the Long-term Athlete Development program. Even though some of the developmental stages differ slightly, the developmental focus is similar. Important factors for success that are highlighted in working with young elite athletes are the values of learning, coping, and development. Mastery of skills and personal development, rather than focusing on competition and winning, are considered key steps. Promoting longevity and sustainability in all activities performed by youth athletes is advised and should be managed through both organized and unorganized activities. Finally, personal involvement and ownership are deemed mandatory for all youth elite athletes that are involved in high-level activities through Olympiatoppen (www.Olympiatoppen).

Specialized sport academy high-school programs

The specialized sport academy high-school programs in Norway provide youth athletes with the opportunity to practice their sport at the highest level (elite) while obtaining a college-entry senior high-school diploma. Lately, there has been a large increase in the number of such high-school programs in Norway, and today there are 29 programs (both private and community based) (www.Utdanning.no). Some of the requirements for these programs are as follows (as decided by Olympiatoppen and mandated by the Norwegian Ministry of Education) (www.Olympiatoppen):

- To promote independence and responsibility in youth athletes, regarding both educational and athletic aspects.
- To promote long-term athlete development both for the individual athlete and for their teams, and to develop future athletes competing at a high level.

- To cooperate closely with the athlete's home clubs to maintain enjoyment and further sports participation for youth athletes.
- Responsibility for the educational program for the athletes leading to fulfillment of the requirements for a senior high-school diploma and further educational opportunities.

Two of the predominant stakeholders within specialized sport academy high-schools in Norway are Wang and Norges Toppidrettsgymnas (NTG), both recognized by Olympiatoppen as specialized sport academy high-schools. Wang and NTG strive to develop youth elite athletes at the highest level and to provide surrounding sports clubs and Olympiatoppen with elite athletes. All athletes attending these schools compete for their local sports clubs, which are not affiliated with the schools. To attend these schools, athletes must pass multiple admission tests, demonstrate excellent skills in their sport, and compete at the highest level (national or international). A large proportion of the athletes attending these schools are members of regional and national representative teams.

The sequence of prevention research model in sport

Considering the specific maturational and developmental aspects that apply to youth elite athletes, epidemiological data on health problems in this population are needed. Likewise, data addressing their specific risk factors for injury or illness (Steffen and Engebretsen, 2010) are needed. For such purposes, a recommended research model has been described by van Mechelen et al. (1992). Four main research steps are outlined, constituting a "sequence of prevention", as follows:

In the first step, the extent of the problem needs to be determined. The second step is to assess possible associations, risk factors, or mechanisms for injury. The third step is to implement suggested preventive measures, and the fourth step is to assess the impact of the suggested strategy by determining the magnitude of the problem once again (Figure 1, white boxes) (van Mechelen et al., 1992).

This research model has since been extended with two steps (step 5 and 6) by Finch (2006) (Figure 1, shaded boxes) addressing the importance of translating injury prevention research into practice, highlighting implementation strategies. Step 5 describes the intervention context (beliefs, behavior, and barriers among athletes and stakeholders), and step 6 addresses real-life implementation by intended users, and assessment of their effectiveness is described.

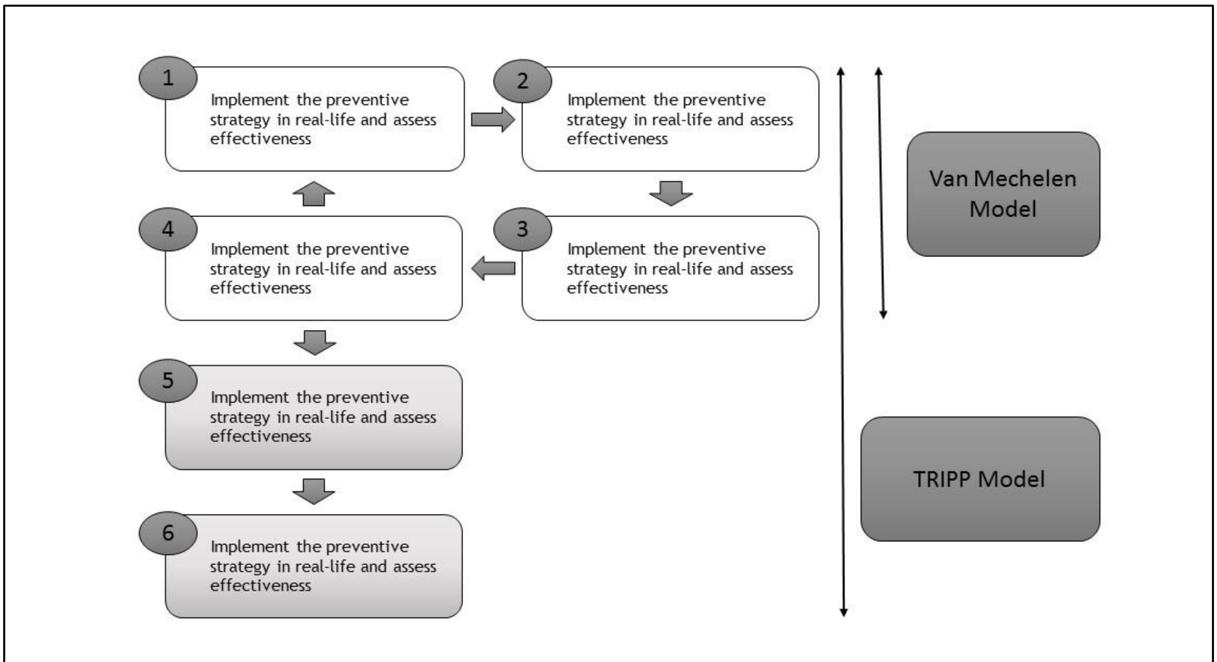

Figure 1: *The sequence of prevention research model for sports injuries (van Mechelen et al., 1992) and the model of translating research into sport injury prevention practice (the TRIPP model) (Finch, 2006).*

Injury and illness in surveillance studies

According to step 1 in van Mechelen's (1992) sequence of injury prevention research model, the extent of the problem first needs to be determined. For this purpose, uniform definitions are needed. When estimating the extent of health problems among youth elite athletes, research outcomes will depend on uniform definitions of all outcomes: health problems, injuries, and illnesses (Orchard et al., 2005; Fuller et al., 2006a; Fuller et al., 2007c; Bahr, 2009; King et al., 2009; Pluim et al., 2009; Turner et al., 2012; Clarsen and Bahr, 2014; Timpka et al., 2014; Mountjoy et al., 2016; Orchard et al., 2016).

In the following section, aspects related to the definition of health problems, injury, and illnesses within the sports medicine context are considered.

Classifications and definitions in surveillance studies

Classification of health problems, injury and illness

Today's recommended injury definitions are based on consensus statements made by Orchard et al. (2005) in cricket, Fuller et al. (2006b) in football (later developed for other team sports), and Junge et al. (2008) in multi-sport events. Further consensus statements covering both injury and illness definitions were developed in 2009 for tennis (Pluim et al.), in 2014 for athletics (Timpka et al.), and in 2016 for aquatic sports (Mountjoy et al.), and the term "medical conditions" was adopted to cover both injury and illness.

Based on these consensus statements, the IOC has made the following recommendations on how to define health problems, injuries, and illnesses in surveillance studies (Junge et al., 2008; Clarsen et al., 2013; Clarsen et al., 2014b):

Health problems are classified as injuries if they were disorders of the musculoskeletal system or concussions. They are classified as illnesses if they involved other body systems, such as (but not limited to) the respiratory, digestive, and neurological systems, as well as non-specific/generalized psychological or social problems. Injuries are further subcategorized into acute and overuse injuries. Acute injuries are those whose onset can be linked to a specific injury event, whereas overuse injuries are those that cannot be linked to a clearly identifiable event (Clarsen et al., 2014b).

Injury and illness definition

Throughout the sports medicine literature, there are primarily three classes of injury and illness definitions in use (Orchard et al., 2005; Fuller et al., 2006b; Fuller et al., 2007c; Hodgson et al., 2007; Orchard and Hoskins, 2007; Pluim et al., 2009; Timpka et al., 2014; Mountjoy et al., 2016;

Orchard et al., 2016), originating from the consensus statements made by Fuller et al. (2006b) in football:

A "time loss" injury is an injury that results in a player being unable to take full part in future football training or match play.

A "medical attention" injury is an injury that results in a player receiving medical attention.

An "any physical complaint" injury is an injury sustained by a player that results from a football match or football training, irrespective of the need for medical attention or time loss from football activities.

A time loss definition is expected to result in the fewest captured injuries and illnesses, while the broader definition, of any physical complaint, is expected to yield a higher rate (Bahr, 2009; Clarsen and Bahr, 2014). This relates to the fact that most athletes continue to participate (fully or to a moderate extent) despite the presence of minor health problems. Consequently, when using the time loss definition, the magnitude of health problems can be underestimated, which is particularly relevant for overuse injuries and illnesses (e.g., allergies, cold, asthma) (Bahr, 2009; Clarsen and Bahr, 2014).

The medical attention definition captures a greater number of conditions, and provides a more complete picture of the true burden of injury and illness (Hodgson et al., 2007), but depends upon the athlete's access to medical support. As this is not uniform, underreporting of health problems might occur. The medical attention definition is used most widely during competitions, where healthcare personnel are readily available. Still, underreporting of chronic illnesses, overuse injuries, or not fully rehabilitated acute injuries from outside of competition periods might underestimate the true burden of health problems when using this definition (Clarsen and Bahr, 2014).

Finally, when using the any physical complaint definition, all health problems, as perceived by the athlete, are captured. There is a concern, however, that reliability may be suspect. Athletes may differ in their interpretations of what constitutes a health problem (Clarsen and Bahr, 2014). Consequently, between-athlete comparisons may be questionable when using this definition.

Summarized, this implies that the choice of injury and illness definition depends on the study setting as well as on the type of health problem of interest. Recommendations have been made, however, for during out-of-competition periods, where medical personnel are less readily available, and if athletes are expected to not only suffer from new health complaints but also overuse injuries and chronic illnesses:

Background

If the goal is to capture the total burden of health problems applied to the athlete, an any physical complaint definition is to be used, as the medical attention or time loss definitions have proven to exclude a significant amount of both illnesses and overuse injuries (Bahr, 2009; Clarsen and Bahr, 2014; Bahr et al., 2018).

Acute vs. overuse injuries

Acute and overuse injuries can be differentiated by the nature of the energy that causes them (Mountjoy et al., 2016). An acute injury occurs when the external forces applied exceed the normal tolerance of the tissue at a certain point in time (macro trauma), while an overuse injury occurs when repetitive forces are accumulated over a longer period of time and, in this way, overload the regenerative qualities of the tissue (micro trauma). Distinguishing between the two is often obvious. It may be clinically difficult in certain cases, however, such as if an overuse injury occurs instantly (e.g., a stress fracture).

Recurrent medical conditions

In injury and illness surveillance studies, the methodology for how to report recurrent medical conditions might represent a challenge. Most previous reports are in accordance with the definitions and framework first outlined by Fuller (2007a):

A re-injury is a repeat episode of a fully recovered index injury.

An exacerbation is a worsening in the state of a non-recovered index injury.

In several IOC consensus statements, a recurrent medical condition is defined as a medical condition of the same type and at the same site linked to an index medical condition or incident and which occurs after an athlete's return to full function and participation ("full recovery") from the index condition (Pluim et al., 2009; Timpka et al., 2014).

Recent recommendations include both illness etiology and differentiation between new onset, recurrent, and pre-existing illness (Mountjoy et al., 2016). Repeat episodes of illness, such as skin infections, exercise-induced asthma, or upper respiratory tract infections, should be recorded as recurrences (Pluim et al., 2009). It is not specified as to whether they should be counted as single or multiple cases for the purpose of analysis, however, and there is a risk of misclassification.

Consequently, in sports injury and illness surveillance studies, difficulties arise when trying to differentiate between illness/injury exacerbations, re-injuries, and new illnesses/injuries.

Several papers have suggested methods for differentiating between these injuries and illnesses (Bahr, 2009; Hamilton et al., 2011; Clarsen et al., 2013; Finch and Cook, 2013; Clarsen et al., 2014b; Shrier et al., 2016). It is considered beyond the scope of this thesis, however, to provide further details on this issue.

Methodology in surveillance studies

When attempting to describe the true burden of health problems applied to youth elite athletes, the result will depend not only on factors related to classification and definition of the health problem but also on the applied research design and methodology (van Mechelen et al., 1992).

The traditional measure of injury in sports medicine surveillance studies has been incidence: the number of new cases during a specific period of exposure, well suitable to report acute injuries during in-competition settings. Severity of health problems has traditionally been reported as days of absence, measured from the onset date of the medical condition until the date when full sports participation is re-established (Junge et al., 2008; Pluim et al., 2009; Timpka et al., 2014; Mountjoy et al., 2016). Based on these measures, however, injuries and illnesses occurring outside of competition have been mostly ignored, and health problems not leading to time loss have been underestimated (Bahr, 2009; Clarsen et al., 2013).

To achieve a better description of the extent of health problems that are applied to athletes both within and outside of competition, the following recommendations have been given regarding how to report data in injury and illness epidemiology studies:

If the whole burden of health problems is to be captured within a cohort of athletes (both acute and overuse injuries as well as illnesses), studies should be prospective, with serial measurements of health-related symptoms conducted over successive seasons, also including non-seasonal and out-of-competition periods (Bahr, 2009).

When the purpose is to study not only acute injuries but also overuse injuries and more chronic illness conditions, which is particularly important during out-of-competition periods, a prevalence measure should be used, defined as the proportion of athletes affected by problems at any given time (Bahr, 2009).

Severity of health problems should be based on functional level, not related to time loss from sports only (Fuller et al., 2006b; Bahr, 2009; Clarsen et al., 2013).

The burden of health problems should reflect the relationship between incidence or prevalence and severity of each problem (Bahr et al., 2018).

Background

Studies are recommended to include both physical and psychological complaints resulting from participation in sports (match/training/competition) and physical activity (Pluim et al., 2009; Timpka et al., 2014; Mountjoy et al., 2016).

Finally, when the intention is to capture the whole burden of health problems applied to athletes both within competition and outside of competition, it becomes evident that health problems are not always sports-related, and they do not always occur during sport participation. Such problems may also be appropriate to record, as they affect the overall health of the athlete (Bahr, 2009).

In a recently developed surveillance method within the field of sports medicine, injury and illness are reported by symptoms and consequences on training volume, sports participation, and performance. This method also reflects the total burden of health problems during both in- and out-of-competition periods as well as within and outside of a sport setting. All problems are self-reported as experienced by the athlete. Consequently, all health problems that affect the athlete at any given time are reflected and can be approached and treated in a more comprehensive way (Clarsen et al., 2014b).

The Oslo Sports Trauma Research Center Questionnaire on Health Problems

Until recent years, health monitoring of youth elite athletes outside major competitions was rare in most sports. This could be related to methodological challenges when developing the studies and validated questionnaires required to conduct such surveys. The Oslo Sports Trauma Research Center (OSTRC) recently developed a method to monitor an athlete's total health over longer periods of time, independent of the athlete partaking in competition and also independent of medical personnel being available (Clarsen et al., 2013; Clarsen et al., 2014b). The method is validated and has been successfully used by adolescent elite athletes in handball, volleyball, cross-country skiing, and tennis (Clarsen et al., 2014a; Pluim et al., 2015). The method has shown superior performance when describing the prevalence and burden of injury and illness, during both in- and out-of-competition periods (Bahr, 2009; Clarsen et al., 2013).

The OSTRC method was primarily developed as a tool for assessment of overuse injuries, but it has since proven useful in monitoring illnesses as well. The method applies the "all health complaint" injury and illness definition. It reports the consequences of health problems for sports participation, training volume, and sports performance, as well as the injury type (acute vs. overuse), injury location, and the degree to which the athlete has experienced illness symptoms. The method is considered useful when examining a heterogeneous cohort of athletes and when a wide array of health problems are expected (Clarsen et al., 2014b).

Background

The OSTRC method enables calculation of a weekly severity score as a measure of the athlete's own assessment of the impact that every health problem has on performance, training load, and participation (Clarsen et al., 2013). This is in contrast to most previous methods, which often expressed severity as the number of days taken from injury occurrence until resumption of full training and competition (i.e., days of time loss from sports) (van Mechelen et al., 1992).

The OSTRC severity score also allows for a calculation of the burden that each health problem imposes on the athlete over time, a cumulative severity score (i.e., the weekly severity score for each problem summarized over the study period). The cumulative severity score reflects the fact that for the individual athlete, a problem of mild severity but long duration may be perceived as a more severe problem (receiving a higher cumulative severity score) than a more severe problem of a very short duration (receiving a lower total score) (Clarsen et al., 2013; Richardson et al., 2017; von Rosen et al., 2017).

Finally, the OSTRC method enables the distinction of more severe health problems through the categorization of substantial health problems, defined as health problems affecting the athlete's training volume or performance in a moderate way or worse or leading to complete time loss from sports.

Epidemiology

To identify previous studies examining health problems among youth elite athletes, a systematic literature search of three electronic databases was performed in February 2019. PubMed, SPORTDiscus, and Web of Science were searched using the following search terms: (youth OR adolescent OR adolescents) AND (athlete OR athletes) AND (elite OR "young professionals") AND (injury OR injuries OR illness OR illnesses) AND (prevalence OR incidence). Studies were included if they met the following criteria: (1) epidemiological study and (2) full text available in English. The following studies were excluded: (1) review/book chapters (9), (2) not relevant sport (10), (3) studies examining only one specific injury or illness (23), and (4) outside scope of study (e.g., few participants, outdated study, injury prevention) (22).

A total of 356 studies were identified as potentially relevant articles (Pub Med n=226, SPORTDiscus n=61, and Web of Science n= 69), of which 214 were discharged after reviewing the titles and abstracts, and 57 were discharged as duplicates. The final 85 articles were assessed in detail and screened in full text. An additional 21 studies were identified from related citations and author knowledge. The final 106 articles were assessed in detail, and 42 met the inclusion criteria.

Background

The characteristics of the available articles are shown in Tables 1 through 4, summarizing the incidence, prevalence, number, type, and location of injuries and illnesses among youth elite athletes across different sports. Ten articles included both injury and illness data (Tables 1 and 2), whereas 32 studies included only injury data (Tables 3 and 4). Thirteen articles were restricted to in-competition data only (Tables 1 and 3), whereas 29 reported epidemiological data, covering both in- and out-of-competition periods (Tables 2 and 4).

In the following section, comparisons are made and discussed between (1) studies collecting both injury and illness data, either in-competition (Table 1) or out-of-competition (Table 2) and (2) studies collecting injury data only, either in-competition (Table 3) or out-of-competition (Table 4).

Injury and illness data in and out of competition

Until recent years, only a few studies have evaluated the total burden of health problems in youth elite athletes as recommended. There is now a handful of studies reporting injury and illness data in this population across several sports, however, during both in-competition periods (Table 1) and out-of-competition periods (Table 2). All studies were prospective. Four studies have reported in-competition data for both injury and illness (2012-2017) (Table 1). Six studies have reported similar data out-of-competition (2009-2018) (Table 2).

Some important differences between the in- and out-of-competition study settings need to be highlighted. The in-competition surveillance studies applied the "medical-attention" definition, well suited in these settings due to easy access to medical personnel and a short study period (5-10 days). In contrast, the out-of-competition studies were of longer duration (32 weeks to 2 years) and defined health complaints by using either the "any physical complaint" or, in two studies, the "time loss" definition. While the in-competition studies consisted of large multi-sport events (900-2000 participants), the out-of-competition studies represented between one and six sports, and in three studies, they were restricted to one sport only (football, tennis, or alpine skiing). Also, the out-of-competition studies attained fewer participants with greater age diversity.

Table 1 summarizes in-competition injury and illness surveillance studies. In these studies, injury incidence per 1000 athletes per event varied between 4-11%, whereas illness incidence varied between 2-8%. During the winter championships (Ruedl et al., 2012; Ruedl et al., 2016; Steffen et al., 2017), the risk of sustaining an injury was greater in high-speed and technical sports (e.g., snowboarding, freestyle and alpine skiing, and ice hockey), whereas illnesses dominated in lower-impact sports and endurance sports (e.g., curling, biathlon, figure skating, and Nordic combined) and were predominantly respiratory tract infections (Ruedl et al., 2012; Ruedl et al., 2016; Steffen et al., 2017). Infections related to the gastrointestinal system were more common in the summer events (van Beijsterveldt et al., 2015). In these studies, girls and older athletes were at a higher risk of sustaining an illness (Ruedl et al., 2012; Steffen et al., 2017). Finally, across all sports, the most common injury sites were the lower extremities, followed by injuries to the head and lower back. Time loss severity varied from primarily mild injuries in football (<1 week of absence) to more severe injuries in alpine skiing (1-4 weeks of absence from sports).

In the studies reflecting out-of-competition periods (Table 2), outcome measures were expressed as incidence per 1000 exposure hours and by prevalence. While the incidence measure reflected only new injuries and illnesses, the prevalence measure suggested a more complete picture of both new and chronic health problems. In the out-of-competition studies, the average prevalence of all health problems varied between 15% in tennis (in younger athletes) and 48% in adolescent female football players (Pluim et al., 2009; Richardson et al., 2017; von Rosen et al., 2017; von Rosen et al., 2018). The average illness prevalence varied between 6% and 15%. Finally, injury severity in these studies, as expressed by the prevalence of substantial injuries, varied between 8% and 31% (Pluim et al., 2015; Richardson et al., 2017; von Rosen et al., 2017; von Rosen et al., 2018).

Table 1. Overview of youth in-competition injury and illness studies.[1]

Author	Championship	Duration (days)	Participants (n) (F/M)	Age (mean)	Sports	Number (n)		Incidence per 1000 athletes		Most frequent injury (%)		Illness characteristics affected system & cause[2]	
						Injury	Illness	Injury	Illness	Location	Type		
Ruedl (2012)	Winter Youth Olympic Games 2012 (YOG)	5	1021 (45%/55%)	16.6	Alpine skiing Ice hockey Ice-track sports Nordic skiing Skating Snowboard	111	86	109 (11%)	84 (8%)	Knee (14%) Pelvis (11%) Head (10%) Lower back (10%)	Contusions (39%) Ligament sprain (18%) Muscular strain (10%) Concussion (7%)	Respiratory (61%) Gastrointestinal (9%)	Infections (50%) Exercise-induced (16%) Environment (13%)
Van Beijsterveldt (2015)	European Youth Olympic Festival 2013 (EYOF)	5	2272 (48%/52%)	16	Athletics Basketball Cycling Gymnastics Handball Judo Swimming Tennis	207	46	91 (9%)	20 (2%)	Knee (12%) Ankle (11%) Thigh (11%)	Sprains (22%) Contusions (20%) Lacerations (16%)	Respiratory (26%) Gastrointestinal (44%)	Infections (57%)
Ruedl (2016)	Winter European Youth Olympic Festival 2015 (EYOF)	5	899 (37%/63%)	17.1	Alpine skiing Curling Ice hockey Ice-track sports Nordic skiing Skating Snowboard	38	34	42 (4%)	38 (4%)	Lower back (16%) Pelvis (13%) Knee (11%) Face (11%)	Contusions (41%) Muscle-cramp (11%) Concussion (8%) Sprain (8%)	Respiratory (53%) Gastrointestinal (27%)	Infections (77%) Exercise-induced (9%) Environmental (6%)
Steffen (2017)	Winter Youth Olympic Games 2016 (YOG)	10	1083 (46%/54%)	16.6 (F) 16.9 (M)	Alpine skiing Ice hockey Curling Sliding sports Nordic skiing Skating sports Snowboarding Freestyle	108	81	95 (10%)	72 (7%)	Knee (18%) Head (12%) Spine (11%)	Contusion (21%) Sprain (17%) Strain (17%) Concussion (11%)	Respiratory (82%) Gastrointestinal (6%)	Infections (71%) Exercise-induced (3%) Environmental (9%)

[1] *All prospective studies using the medical attention injury definition* [2] *Proportion (%) of all illnesses*

Table 2. Epidemiological injury and illness data[1] (prevalence and incidence) for youth elite athletes across multiple sports.

Author	Population (n) F/M	Age	Sport	Study period[2]	Definition	Injury					Illness		
						n	Prevalence[3] (%)	Incidence[4]			n	Incidence[4]	Prevalence[3] (%)
								Total	Training	Competition			
Brink (2010)	Dutch football players (0/53)	15-18	Football	2 s	Time loss	320			11.1	37.6	82	5.3	
Pluim (2015)	Dutch national tennis program (29/44)	11-14	Tennis	32 w	Any physical complaint	113	15 (all) 11 (sub)	1.2 (a)[5]			67		6 (all) 4 (sub)
Richardson (2017)	Dutch talent development program (60/0)	16.6	Football Basketball Gymnastics	1 s	Any physical complaint	440	48 (all)* 31 (sub)*	8.6			85		9 (all) 4 (sub)
von Rosen (2017)	Swedish national sport high schools (76/74)	16-19	Orienteering (O) Running (R) X-country skiing (XC)	52 w	Any physical complaint	155	O: 26 (all) R: 32 (all) XC: 21 (all) O: 8 (sub) R: 17 (sub) XC: 9 (sub)	O: 5.7 R: 4.0 XC: 2.5					O: 15 R: 14 XC: 15
Müller (2017)	Austrian ski boarding school (31/51)	9-14	Alpine skiing	2 y	Time loss	69			0.9 (t)[5] 0.3 (o)[5]		197		2.4[6]
von Rosen (2018)	Swedish national sport high schools (137/147)	15-19	Athletics Skiing (X-country Alpine Freestyle) Handball Orienteering	52 w	Any physical complaint	326	31 (all) 15 (sub)	4.1	2.8	23.8			12.1

[1]Only prospective data available (i.e. no retrospective data met search-criteria) [2]s=seasons, w=weeks, y=years [3]Average (bi)weekly prevalence [4]Per 1000 h exposure to sport, reported as all or substantial (sub) [5]a=acute t=traumatic o=overuse [6]Illness per athlete*

Background

Injury data, in and out of competition

In Table 3, in-competition injury surveillance studies from several youth elite championships are summarized. All studies were prospective, and the majority were on football (Junge et al., 2004; Walden et al., 2007; Junge et al., 2008; Hagglund et al., 2009; Junge and Dvorak, 2013). In Table 4, out-of-competition epidemiological injury studies on youth elite athletes are listed. Again, the majority were on football players (Price et al., 2004; Le Gall et al., 2006; Merron et al., 2006; Le Gall et al., 2008; Johnson et al., 2009; Nilsson et al., 2016; Renshaw and Goodwin, 2016; Read et al., 2018). For the listed out-of-competition studies (Table 4), prospective data collection varied between 26 weeks and up to 10 seasons for elite French youth football players reported by Le Gall et al. (2006). The medical attention injury definition was mostly used for in-competition surveillance studies (Table 3), whereas the time loss definition was mostly used for out-of-competition studies (Table 4). Injury risk was mostly reported as injury incidence, which was, however, inconsistently defined as either number of injuries per match, number of injuries per athlete, or number of injuries per 1000 hours of exposure to training or competition. Only three of the out-of-competition studies reported injury prevalence (Table 4).(Jacobsson et al., 2012; von Rosen et al., 2016; von Rosen et al., 2018)

Overall findings in these studies were that more injuries occurred during competition than in training (Tables 3 and 4), and during competition, older athletes were at a higher injury risk compared to younger athletes (Price et al., 2004; Emery and Meeuwisse, 2006). In most out-of-competition studies (Table 4), injury incidence per 1000 exposure hours was <10 during training and between 10 and 20 during competition. In contrast, injury incidence was higher in the in-competition studies summarized in Table 3 vs. out-of-competition studies in Table 4. For example, an injury incidence of 51 and 88 per 1000 competition hours was reported by Junge et al. (2004) for U17 football players during the Men's World Championships. These differences in injury incidence might relate to the injury definition used.

In the literature summarized in Tables 3 and 4, most injuries were located in the lower extremities. Injury location depends on the sport practiced, however. For example, youth elite football players report mostly ankle sprains, muscle strains, and contusions to the thigh and lower leg (Junge et al., 2004; Hagglund et al., 2006; Junge and Dvorak, 2007; Hagglund et al., 2009; Junge and Dvorak, 2013), whereas youth elite ice-hockey players report predominantly acute injuries to the head and face (Tuominen et al., 2017).

In the out-of-competition studies enumerated in Table 4 (using the time loss injury definition), the majority of injuries in team and endurance sports were categorized as mild or moderate (Le Gall et al., 2006; Le Gall et al., 2008; Smoljanovic et al., 2009; Moller et al., 2012). Conversely, in high-speed technical sports, such as alpine skiing, more injuries were classified as severe (Westin et al., 2012).

The epidemiological research gap

As demonstrated in Tables 1 through 4, it is evident that valid and reliable data regarding the total burden of health problems among youth elite athletes are rare, with the exception of studies in youth football. Although several studies present data on injury incidence in youth elite football players, however, data on the total burden of health problems are missing in this population as well.

As previously discussed, youth athletes are under continuous development, and multiple factors encompassing both growth and maturation might increase their risk of incurring injury and illness. Until the past two years, however, there was a complete lack of evidence regarding the true impact of health problems on youth elite athlete health. During the past two years however, four studies have addressed this question by applying the OSTRC Questionnaire on health problems to evaluate both in- and out-of-competition periods (Bahr, 2009; Clarsen et al., 2014b; Bahr et al., 2018).

In *Paper I*, we applied the OSTRC Questionnaire on health problems to assess the prevalence and severity of health problems in youth elite athletes attending different sport academy high schools in Norway, across both sexes, between different sport categories, and compared to teammates attending regular high-schools.

Table 3. Injury incidence during youth elite championships[1]

Author	Championship	Season	Participants (n) Age	Sport	Definition	Injuries (n)	Injury incidence per 1000 h		Injury incidence per	
							Training	Competition	Match (mean)	Athlete
Hutchinson (1995)	Boys' National US Tennis Championships	1986 To 1992	(1440) U16 U18	Tennis	Medical attention	304		U16 & U18: 21.5[2]		U16 & U18: 0.1[3]
Junge (2004)	Men's World championship	1999 2001	U17 U20	Football	Any physical complaint	456		U17: 51, 88 U20: 109, 144	U17: 1.7, 2.9 U20: 3.6, 4.7	
Junge (2007)	FIFA Women's World Championships	2002 2004 2006	U19 U20	Football	Medical attention			U19: 85, 68 U20: 89	U19: 2.8, 2.2 U20: 2.9	
Waldén (2007)	Men's European Championship	2005	(144) U19	Football	Time loss	17	U19: 2.9	U19: 30.4		
Hägglund (2009)	Women's and Men's European Championships	2006 2007 2008	U19 F (433) U17 M (433) U19 M (436)	Football	Time loss	43 40 38	U19 F: 7.4, 1.1, 1.8 U17 M: 1.2, 1.5, 5.6 U19 M: 0, 1.5, 2.1	U19 F: 28.2, 22.9, 11.7 U17 M: 20.7, 21.0, 28.6 U19 M: 16.3, 27.8, 25.8	U19 F: 0.9, 0.7, 0.4 U17 M: 0.6, 0.6, 0.9 U19 M: 0.5, 0.5, 0.9	
Edouard (2012)	Male & female French National Championship	2010	Youth (34) 16.4 Junior (29) 18.2	Athletics	Medical attention	17 13		Youth F: 59[2] Youth M: 59[2] Junior F: 41[2] Junior M: 60[2]		Youth F: 0.4 Youth M: 0.6 Junior F: 0.3 Junior M: 0.6
Junge (2013)	FIFA World cup for females and males	1999 to 2012	U17 F U19/20 F U17 M U20 M	Football	Medical attention	225 445 680 991			U17 F: 2.3 U19/20 F: 2.6 U17 M: 2.5 U20 M: 3.0	
Tuominen (2017)	Ice hockey male World Junior Championships	2006 To 2015	(10518) U18 U20	Ice hockey	Medical attention	633		U18 & U20: 40 U18: 36 U20: 43		
Furlong (2018)	Females and male European Hockey Championship	2016	U18 F U18 M	Field hockey	Medical attention observed by personnel	44 27		U18 F: 86 U18 M: 53	U18 F: 2.2 U18 M: 1.4	

[1]Only prospective studies identified [2]Injury per 1000h athlete exposure [3]Injury prevalence per 100 athlete 21%

Table 4. Epidemiological injury data (prevalence and incidence) for youth elite athletes across multiple sports.

Author	Population (n)	Participants (n) F/M	Age	Sport	Design[1]	Duration[2]	Definition	Number (n)	Injury prevalence (mean) (%)	Injury incidence per 1000 h of exposure			Injury incidence pr athlete per season
										Total	Training	Competition	
Kirialanis (2002)	Greek artistic gymnasts	87/100	12-13	Gymnastics	P	1 y	Time loss	248			1.4		1.3
Price (2004)	English academy football	4773	9-19	Football	P	2 s	Time loss (> 2 days)	3805					0.4
Le Gall (2006)	French national institute of football	0/528	14-16	Football	P	10 s	Time loss	1152		4.8	3.9	11.2	2.2
Merron (2006)	English premiere league football players	0/112	16-18	Football	P	4 y	Time loss	236		8.07	6.1	25.0	
Emery (2006)	Canadian hockey players	NA	13-14 (B)[3] 15-16 (M)[4]	Ice hockey	P	1 s	Time loss	45 81		4.8 5.7	1.0 1.8	6.2 9.0	
Le Gall (2008)	French football players	119/0	15-19	Football	P	8 s	Time loss	619		6.4	4.6	22.4	5.2/3 s[2]
Johnson (2009)	Manchester United academy	0/292	9-16	Football	P	6 y	Medical attention	476		2.2	1.4	10.5	
Soltanovich (2009)	International rowers	167/231	18 (MD)[5]	Rowing	R	1 s	Time loss	393			2.1[6]		1.0
Rishiraj (2009)	State team field hockey players	75/0	18	Field hockey	R	5 y	Time loss	198		70[3]	68[3]	67.5[3]	
Jacobsson (2012)	Swedish top athletic athletes	65/49	17	Athletics	R	1 y	Time loss (> 3 weeks)	NA	44% (F) 29% (M)				
Westin (2012)	Swedish ski high school students	216/215	16.7	Alpine skiing	P	5 y	Any physical complaint	312		1.7 1.8 (F) 1.6 (M)			

Moller (2012)	Danish handball players	142/69	U16 F U16 M U18 F U18 M	Handball	P	31 w	Time loss	NA		6.8 4.2 4.7 6.9	2.9 1.7 2.1 3.2	10.8 11.5 13.0 17.2	
Jacobsson (2013)	Swedish top athletic athletes	71/55	17	Athletics	P	52 w	Time loss	NA		3.1 (F) 3.9 (M)			
McKay (2013)	Canadian hockey players	0/316	13-14 (B)[3] 15-16 (M)[4]	Ice hockey			Time loss	143			3.6 (B)[3] 4.0 (M)[4]		
Woollings (2014)	Canadian climbers/ boulderers	19/31	15.5	Sports climbing/ bouldering	R	1 y	Any physical complaint	84		4.4			1.7
Saluan (2015)	Gymnasts 1985-2005		Precoll.	Gymnastics	R	21 y	Medical attention	875			2.9		
Roos (2015)	Swiss orienteering	15/16	18-19	Orienteering	R		NA	61			2.2		
Renshaw (2016)	Premier league UK football academy	181	U9-U18	Football	P	1 s	Medical attention	127			U9-U11: 0.7 U18: 6.0	U9-U11: 0.7 U15: 80 U16: 32 U18: 28	
Nilsson (2016)	Swedish football players	0/43	17.7	Football	P	2 s	Any physical complaint	61		6.8	5.6	15.5	0.7
von Rosen (2016)	Swedish sport high schools	33/31	17	Orienteering	P	26 w	Any physical complaint	109	37% (all) 18% (subs)		18		
Von Rosen (2018)	Swedish sport high-school athletes	155/185	17	16 sports	P	52 w	Any physical complaint		39% (all) 18% (subs)				
Read (2018)	UK football academies	0/608	11-18	Football	P	1 s	Time loss	804					1.3
Mónaco (2018)	Spanish handball-players	0/133	14-18	Handball	P	2 s	Time loss	142		6	3.7	14.9	

[1]P=Prospective R=Retrospective [2]y=years, s=seasons, w=weeks [3]Bantam [4]Midget [5]Median [6]injuries are reported per 1000 training sessions, practice or game (not h)

Injury causation models

Athletes in general

An important step in van Mechelen's (1992) four-step injury prevention surveillance model is to identify associations, risk factors, or mechanisms for injury and illness in athletes. This includes obtaining information on why a particular athlete may be at risk of incurring injury as well as on how injuries happen. According to the risk factor model of Meeuwisse (1994), certain factors may influence the risk of sustaining an injury. This conceptual model was further expanded by Bahr and Krosshaug (2005). The model (Figure 2) illustrates the multifactorial nature of sports injuries, emphasizing the relationship between intrinsic risk factors, extrinsic risk factors, and injury mechanisms, all of which are important along the chain of events that finally results in injury. This model was originally developed for acute injuries but seems likewise applicable to overuse injuries, where cumulative and multifactorial processes cause the problem.

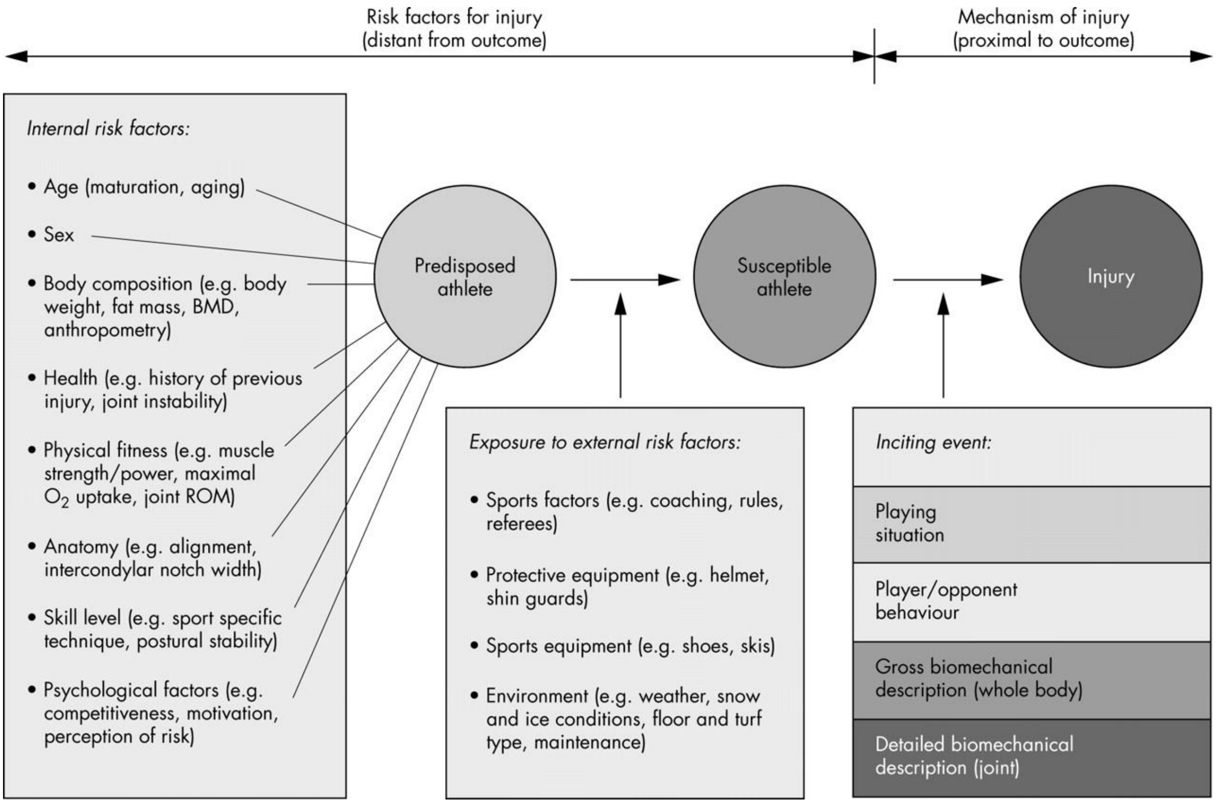

Figure 2. A model on a more comprehensive understanding of injury causation by Bahr and Krosshaug (Bahr and Krosshaug, 2005).

As expressed in the model, risk factors for sport-related injuries can be categorized as intrinsic or extrinsic. Intrinsic risk factors predispose the athlete to injury or illness due to internal characteristics, such as age, sex, height, weight, physical fitness, previous injury, or other individual-specific factors. Extrinsic risk factors are environmental factors that might predispose an athlete to injury, such as sports equipment, rules, or weather conditions. All risk factors may also be either modifiable (e.g., physical fitness) or non-modifiable (e.g., sex).

Youth elite athletes

Based on the original models by Meeuwisse (1994) and Bahr and Krosshaug (2005), a multifactorial approach can also be used to account for the different internal and external risk factors that apply specifically to youth elite athletes. Several maturational aspects related to growth and development may increase their risk of injury and illness (DiFiori et al., 2014), and the injury causation model can be adjusted accordingly (Figure 3).

The below model highlights some of the risk factors that might be specifically applicable to youth elite athletes. Several of these risk factors are only suggested risk factors (*), however, as solid evidence remains limited.

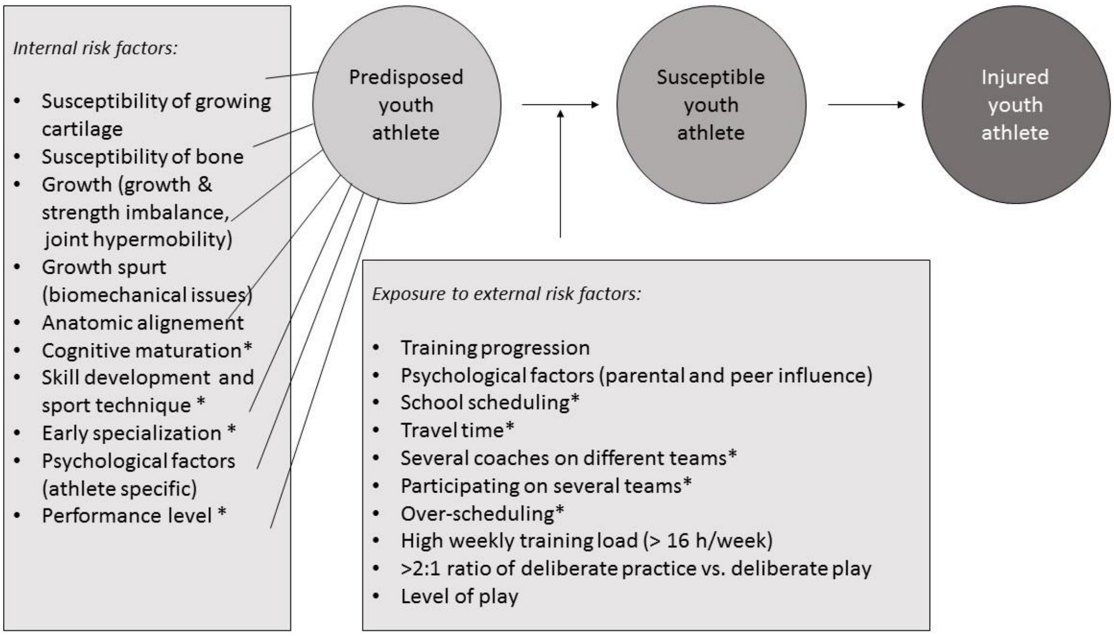

Figure 3. Additional internal and external risk factors specifically related to injury in adolescent athletes, developed from Bahr and Krosshaug (2005), Difiori et al. (2014), and LaPrade et al. (2016).

In terms of the original model, some of these factors can be considered modifiable and some non-modifiable. Growth-related factors are typically non-modifiable risk factors in the maturing youth elite athlete. A relative weakness and vascular susceptibility of the cartilage at the growth plates increases their vulnerability to repetitive stress, compression, and retraction forces. Consequently, injuries related to the epiphyseal plates and the apophyses might occur (Valovich McLeod et al., 2011b; DiFiori et al., 2014). A lower accrual of bone during adolescence can result in diminished bone mineral density and asynchronous growth patterns, which are also non-modifiable internal risk factors specifically related to the maturing athlete (DiFiori et al., 2014). Typical modifiable risk factors in youth elite athletes can include weekly training load, over-scheduling, playing on several teams with several coaches, or long-distance travel hours.

In the following section, previous knowledge related to the risk factors of early and single-sport specialization, high performance level, and physical fitness level, is discussed within the context of youth elite athletes and injury and illness risk. Considerations on how to define early sport specialization and existing knowledge about the association between injury and illness and early single-sport specialization, performance level, and physical fitness in youth elite athletes are highlighted.

Risk factors

Early specialization

A growing number of coaches and parents believes that the best way to produce superior young athletes is to have them play only one sport from a young age (Finley, 2006; Mostafavifar et al., 2013; Suppiah et al., 2015; Feeley et al., 2016). Successful stories about superstar athletes, like Tiger Woods, Andre Agassi, and Kjetil Andre Aamodt, featuring early introduction to a single sport, deliberate practice from a very early age, a dominating parent, a highly regulated life throughout childhood and adolescence, and eventual success in sports, have fueled the trend toward extensive training and early single-sport specialization (Malina, 2010a). Consequently, many youths participate in sports with aspirations toward achieving elite status and professional contracts or scholarships (Jayanthi et al., 2013). The evidence for the contribution of early sport specialization to achieving mastery of a specific sport is inconclusive, however, and research has not substantiated the importance of early single-sport specialization as a requirement for success

(LaPrade et al., 2016). There are confounding biological effects of maturation, and most likely also other yet-to-be-determined factors, that account for achievement in sports (Suppiah et al., 2015).

Medical concerns regarding early single-sport specialization

Medical communities around the world have expressed their concerns regarding this trend toward more specialized training at an early age and early selection into talent programs (ACSM, 1993; American Academy of Pediatrics, 2000; Brenner, 2007; DiFiori et al., 2014; Brenner, 2016; LaPrade et al., 2016). An increase in injury and illness rates among young athletes is observed (Brenner, 2007; Malina, 2010a; Jayanthi et al., 2013; Mostafavifar et al., 2013; Feeley et al., 2016; LaPrade et al., 2016), where several young athletes report persistent pain from overuse injuries (e.g., in the lower back, wrists, or shins, and sometimes associated with stress fractures) (DiFiori et al., 2014; Feeley et al., 2016), and several young athletes need surgery (e.g., Little-League's elbow or ACL injuries) (Petty et al., 2004; Olsen et al., 2006; Fleisig et al., 2011; Tyler et al., 2014).

Data are limited, however, on whether early and single-sport specialization might be associated with an increased risk of injury and illness. In a recent review, some evidence is presented that early sport specialization may increase the young athlete's risk of sustaining overuse injuries (Feeley et al., 2016). Practicing one sport exclusively from a young age is suggested to expose highly skilled youth athletes to repetitive monotonous movement patterns and unfavorable strain on an immature skeleton, ligaments, tendons, and muscles that are not yet fully developed. Additionally, excessive external and internal demands might promote unhealthy mental pressure and psychological burnout in a vulnerable phase of life (Malina, 2010a; Bahr, 2014; Feeley et al., 2016; LaPrade et al., 2016).

Nearly 20 years ago, the American Academy of Pediatrics (AAP) highlighted potential risks of high-intensity training and sport specialization at a young age related to the high physical, physiological, and psychological demands (American Academy of Pediatrics, 2000). In 2013, the American Medical Society for Sports Medicine (AMSSM) developed the AAP's recommendations into a position statement on overuse injury and burnout in youth sports, advising that specialization in a single sport should be discouraged before adolescence. The AMSSM also advocated limiting the weekly and yearly participation time in one single sport, adjusted according to age, growth and maturation, individual sport-readiness, and previous injuries. They also suggested scheduled rest periods and to monitor training load during the more injury-susceptible growth spurt period (DiFiori et al., 2014; Jayanthi et al., 2015). In 2015, the IOC developed a consensus statement emphasizing key considerations and challenges related to youth athlete development. Recommendations for children were to participate in a variety of sports, promoting variability and diversification of several sports. Therefore, talent development programs should be based on a long-term development context embracing all the different physiological, perceptual, cognitive, and tactical demands of sports (Bergeron et al., 2015).

Based on these recommendations from the AAP, AMSSM and IOC, the American Orthopedic Society of Sports Medicine (AOSSM) developed a consensus statement in 2016 (LaPrade et al.). This early sport specialization consensus statement identifies early sport specialization as damaging for future physical and mental health of the athletes and recommends closely monitoring for signs of overuse injury, burnout, and overtraining in young athletes who practice intense training for more than 16 hours per week or more hours per week than their age. Additionally, early sport specialization is defined as involvement of pre-pubertal children (roughly age 12 or younger), and it is emphasized that early sport specialization is not found to be beneficial to achievement of elite athletic performance at the national or international level (Jayanthi et al., 2013; LaPrade et al., 2016). An overview of previous early sport specialization definitions and recommendations is provided in Table 5.

Table 5. Early specialization in youth athletes - position & consensus statements, definitions, and recommendations related to early specialization in sports.

Organization	Title	Definition	Recommendations
American Academy of Pediatrics, 2000	Intensive training and sports specialization in young athletes	-	1. Children are encouraged to participate at a sports level consistent with their abilities and interests 2. Collaborating with parents to ensure coaches with appropriate knowledge 3. Physicians and coaches should strive for early recognition, prevention, and treatment for overuse injuries 4. Regular physical and emotional monitoring is advised and being alert for signs of overtraining, anorexia, sleep loss, and stress 5. Ongoing assessment of nutritional intake 6. Educate about heat injury and its prevention
National Athletic Trainers` Association Position Statement 2011, McLeod et al.	Position statement: Prevention of pediatric overuse injuries	-	1. Participate in multiple sports and recreational activities. 2. Take time off between sport seasons and enjoy 2-3 nonconsecutive months away from a specific sport. 3. Follow guidelines related to cumulative time/count of pitches 4. 1-2 days off per week from competitive sports 5. Participation on only one team if more teams involve more than 5 days/week
American Orthopedic Society for Sports Medicine: Sports Health 2013, Jayanthi et al.	Sport specialization in young athletes: Evidence-based recommendations	Intense, year-round training in single sport with the exclusion of other sports.	1. Intense single-sport specialized training is necessary for elite skill development. For most sports, this training should begin in late adolescence to optimize sports success. 2. Intense single-sport specialized training in most sports should be delayed until late adolescence to reduce the risk of injury and adverse psychological stress.
American Medical Society for Sports Medicine 2014, DiFiori et al.	Position statement: Overuse injuries and burnout in youth sports	Intensive training in a single sport at the exclusion of other sports.	1. Limit weekly and yearly participation time and sport-specific repetitive movements, adjusted for age, sport, growth, sport readiness, and previous injury. 2. Schedule rest periods 3. Monitor training load during growth spurt.
International Olympic Committee 2015, Bergeron et al.	Consensus statement on youth athletic development	-	1. Encourage deliberate play and age-appropriate sport-related activities to develop athletic and social skills. 2. Design youth athlete development programs with diversity and variability of athletic exposure. 3. Talent development programs should be based on a long-term individually variable development context and physiological, perceptual, cognitive, and tactical demands of the sport. 4. Promote variability and diversification 5. Sufficient rest and recovery 6. Age- and skill-appropriate competition formats

American Orthopedic Society for Sports Medicine: Sports Health 2015, Myer et al.	Sport specialization part 1: Does early sport specialization increase negative outcomes and reduce the opportunity for success in young athletes.	Year-round training (greater than 8 months per year), choosing a single sport, and/or quitting all other sports to focus on one sport.	1. Youth should be given opportunities for free, unstructured play to improve motor-skill development, and parents and educators should encourage child self-regulation to help limit the risk of overuse injuries. 2. Parents and educators should help provide opportunities for free, unstructured play to improve motor-skill development during the growing years, which can reduce injury risk during adolescence. 3. Youth should be encouraged to participate in a variety of sports during growth to influence development of motor skills and identify sports they enjoy.
American Orthopedic Society for Sports Medicine: Sports Health 2015, Myer et al.	Sport specialization part 2: Alternative solutions to early sport specialization in youth athletes.	Year-round participation in one sport only from an early age.	1. Children who participate in more hours/week than their age, and for more than 16 hours/week in intense training, and who are specialized in sport activities, should be closely monitored for indicators of burnout, overuse injury, or potential decrements in performance due to overtraining. 2. All youths benefit from periodized strength and conditioning (e.g., integrative neuromuscular training) 3. Youth who specialize should plan periods of isolated integrative neuromuscular training to enhance motor skill development and reduce injury risk factors.
American Academy of Pediatrics 2016, Brenner et al.	Sport specialization and intensive training in young athletes	Focus on one sport only, usually at the exclusion of any other and often year-round.	1. Have fun and learn lifelong physical skills 2. Participate in multiple sports until puberty 3. Late specialization recommended (late adolescence) 4. Late specialization and early diversification provides greater chance of lifetime or elite sport involvement 5. Promote the athlete's own goals 6. 3 months off throughout the year 7. 1-2 days off weekly 8. Close monitoring of psychological and physiological parameters if pursuing intensive training
American Orthopedic Society for Sports Medicine 2016, LaPrade et al.	Consensus statement: Early sport specialization	1. Participation in intensive training and/or competition in organized sports greater than 8 months per year (essentially year-round). 2. Participation in 1 sport to the exclusion of participation in other sports (limited free play overall). 3. Involving pre-pubertal children (seventh grade or roughly age 12 years).	Recommend current recommendations by Myer et al. 2015 (Sport spec. Part 2). Further recommendations are as follows: 1. A public health message that multisport participation will not diminish the athletic capabilities of athletes 2. Effort toward the importance of physical education as an opportunity for noncompetitive play 3. Increased emphasis on the economic impact of a lack of physical fitness to healthcare costs presented in obesity and various medical comorbidities. 4. Recognition that each sport has its own distinct loading pattern and a distinct overuse injury to accompany it. 5. Identification of the optimal level of exposure to maximize training effect with minimal risk of injury needs to be identified. 6. Early sport specialization has not been shown to be beneficial for high-caliber athletic performance and may be detrimental.

Background

Definition of early single-sport specialization

To date, early single-sport specialization remains poorly defined, perhaps related to the fact that it is still unclear as to which factors are the most critical for inclusion in such a definition and where the tipping point lies for an individual athlete to become "overspecialized" (Buckley et al., 2017). Jayanthi et al. (2013; 2015) have suggested a commonly used definition of early sport specialization, which is "year-round intensive training in a single sport at the exclusion of other sports." In accordance with this definition, a 3-point scale has been suggested to categorize the degree of specialization as low, moderate, or high, depending on the fulfillment of one or more of the following three criteria: 1) year-round training (more than 8 months per year), 2) choosing a single sport, and 3) discontinuing all other sports to focus on a single sport (Jayanthi et al., 2015; Myer et al., 2015e). Nevertheless, some challenges need to be recognized if using this definition. First, the particular age of what is considered early for sport specialization is not specified. Second, level of performance is not covered. Third, sport volume is related solely to year-round training, not weekly volume or intensity. Finally, in recent years, the ratio between organized and unorganized activities has also emerged as an important factor when considering early specialization in youth athletes. In the section below, each of these points is discussed.

Age

The suggested graded definition of early sport specialization did not originally define what is considered an early age. Likewise, recent studies regarding early sports specialization have focused more on the degree of specialization than on the age (Hall et al., 2015; Jayanthi et al., 2015; Myer et al., 2015e; Bell et al., 2016; Myer et al., 2016; Pasulka et al., 2017; Post et al., 2017). It is clear that what is considered early will vary depending on the type of sport practiced. For most sports, however, pre- or early-adolescent years can be considered early. Specialization in a single sport at this age might foster in children over-dependence and social isolation from age-matched peers, potentially causing them to miss out on opportunities for important non-sport developmental experiences (Malina, 2010a; Bergeron et al., 2015). Also, motor skill development during the growing years will, for most sports, benefit from free, unstructured play activities alongside diverse neuromuscular training and experiences across different sports. Skill transfer between sports might in fact be beneficial in the long run for those pursuing the elite level as an adult athlete (Malina, 2010a; Armstrong and McManus, 2011; Bergeron et al., 2015; Myer et al., 2015a; Feeley et al., 2016; LaPrade et al., 2016; Myer et al., 2016). Nevertheless, there remains no consensus regarding the age or developmental stage to which early specialization refers. The recent statement by

LaPrade and co-workers (2016), however, suggests that the term "early specialized" in most sports refers to an age of specialization of 12 years or younger, or to pre-adolescence.

Performance level

The graded definition of sport specialization fails to consider performance level. A high performance level is usually an assumption when discussing sports specialization, which also reflects high training and competition volume. From a clinical perspective, performance level is an important issue in relation to training and competition load among youth athletes. At young ages, talented or highly skilled athletes are often selected by parents or coaches to attend local, regional, and "all-star" teams, all of which require their own practice sessions and games. High training and competition load, coupled with inadequate rest and recovery and returning too early to sport if injured, might increase injury and illness risk in youth athletes, particularly those at the highest performance levels (Bahr, 2014; Feeley et al., 2016; LaPrade et al., 2016).

Sport volume

At least in Scandinavia, not only elite athletes but also recreational youth athletes participate in one main sport for more than 8 months per year. Consequently, a majority of youth athletes would fulfill the requirement of sport specialization, according to this point of the graded definition. Nevertheless, there is no doubt that the volume of training and competition is a major concern regarding youth elite athletes. Whether or not year-round participation in one sport inherently increases the risk of injury or illness is not known. There are, however, other, more specific factors of interest when considering sport volume recommendations: participation in more hours per week than the athlete's age, more than 16 hours of weekly practice, or a >2:1 ratio of organized sport to recreational free play (Rose et al., 2008; Jayanthi et al., 2013; Jayanthi et al., 2015; Myer et al., 2015a; Bell et al., 2016; Myer et al., 2016). A recent study on adolescent athletes demonstrated that youth athletes exceeding the sport volume recommendations in months per year and hours per week reported a 26-85% higher probability of incurring injury compared with athletes meeting these recommendations (Post et al., 2017).

Organized vs. free play ratio and choosing a primary sport

The criteria of choosing a single or primary sport is also a problematic measure, as children who have only ever played one sport are defined as specialized according to this criterion. In the recent consensus statement by AOSSM, this criterion is combined with the criterion of discontinuing other sports and also with that of limited free play. In our opinion, this defines early sport specialization more specifically and is operationally useful (Jayanthi et al., 2013; Jayanthi et al., 2015; LaPrade et al., 2016).

To summarize, in extant literature, there remains no consensus regarding what precisely defines early single-sport specialization. For future use, there is a need to define this term.

Early sport specialization and risk of injury and illness

The existing literature on early single-sport specialization and injury and illness risk is limited, yet, as presented in Table 5, it contains strong opinions on the question. Data on the effect of early single-sport specialization on illness risk are non-existent to date, and studies presenting solid evidence evaluating the effect of early single-sport specialization on injury risk have either been of a very short duration (Jayanthi et al., 2011), retrospective (Hall et al., 2015; Buckley et al., 2017), or case-control based (Jayanthi et al., 2015).

Previous studies on early or single-sport specialization present data on youth elite tennis players (Jayanthi et al., 2011; Jayanthi et al., 2015), female team-sport players (Hall et al., 2015) or a variety of team and individual sports, comparing single-sport specialization in high school, collegiate, and professional athletes (Buckley et al., 2017).

Jayanthi et al. (2011) monitored a cohort of 10- to 18-year-old tennis players (n=519) during a 4-week summer tournament and found that playing only tennis was associated with injury during the past year but not with medical withdrawal from the tournament. In a case-control study, also by Jayanthi et al. (2015), injured athletes (7 to 18 years of age, n=822) treated at hospital-based sports-medicine clinics were compared to athletes undergoing pre-season physicals in affiliated primary-care sports-medicine clinics (n=368). Injured athletes were older and spent more total hours training and more time in specialized training than controls, leading to the conclusion that single-sport specialization represented a risk factor for injury. An explanation for their findings, however, could be that these athletes were more dedicated and therefore more likely to seek medical care when injured. In a retrospective study by Hall and coworkers (2015), an association between single-sport specialization and an increased risk of developing anterior knee pain was demonstrated in adolescent female athletes playing basketball, football, or volleyball, comparing multisport athletes (n=357) with single-sport athletes (n=189). The authors failed to consider, however, that single-sport athletes were older, taller, and heavier than the multisport athletes. Finally, in a retrospective cross-sectional study comparing athletes participating at the high school, collegiate, and professional levels (n=3090), high-school athletes recalled a higher incidence of injury that they attributed to specializing in one sport when compared with current collegiate and current professional athletes. Based on this, the authors suggest that early sport specialization can be a potential factor in the occurrence of early sport-related injury. Nevertheless, associations in injury data comparing specialized vs. non-specialized athletes were not explored, and data were based on a reflection of the athlete's ability to recall an injury that interrupted sports participation and required specific treatment rather than on actual injury data.

In other words, existing literature on sport specialization is limited. Recall bias and response bias represent limitations in both the prospective (Jayanthi et al., 2011) and the retrospective (Hall et al., 2015; Buckley et al., 2017) studies, possibly overestimating their findings. In the case-control study (Jayanthi et al., 2015), which was not population based, oversampling of injured athletes might also have biased the statistical analyses.

The need for early single-sport specialization is currently under debate because of the increasing training loads and specialized training in young athletes and the successive potential risks of increased injury and illness, burnout, and high drop-out rates. Although recent reports and position statements assert that specialized training in young athletes increases the risk of serious overuse injury (American Academy of Pediatrics, 2000; Jayanthi et al., 2011; Valovich McLeod et al., 2011a; Jayanthi et al., 2013; Jayanthi et al., 2015; Myer et al., 2015e), however, this relationship has yet to be clearly demonstrated (Feeley et al., 2016). To date, there are no studies tracking the long-term implications of early or single-sport specialization for current risk of incurring injury and illness in youth elite athletes (Fabricant et al., 2016; Reider, 2017).

In *Paper II*, we address the association between a history of early and single-sport specialization and injury and illness risk. Based on extant literature and clinical knowledge, we defined early sport specialization as having occurred if the athlete had defined one sport as being more important than other sports at 12 years of age or younger. We also evaluated whether the athletes had been practicing a single sport or multiple sports during the past 2 years.

Background

Performance level

Overconsumption of talented youth athletes

In recent years, youth elite athletes have been seemingly training and competing at an increased intensity, duration, and level of difficulty. National and international competitions are organized, possibly in an attempt to identify, foster, and develop sporting talent at a higher rate. The question has been raised as to whether the most talented youth elite athletes sustain an increased risk of incurring injury and illness. Several external risk factors might apply to these athletes, such as higher volumes of training and competition, higher match exposure, superior performance factors, better technical skills, and holding the more exposed positions (Bahr, 2014).

In Norway, some of the most highly skilled youth athletes attend specialized sport academy high schools to combine a 3-year educational high-school program with an elite training program. To attend these schools, athletes must demonstrate excellent skills and compete at the highest level (national or international) in their sport. Additionally, among these athletes, the most talented often train and compete with local, regional, and national teams, and might be exposed to an increased risk of injury and illness through inappropriate training and competition programs. In an editorial in 2014, Bahr (2014) discusses the fact that many gifted young athlete careers have been halted or ruined by what seem like inappropriate training and competition programs after entering such specialized sport academy high schools. Visnes et al. (Visnes et al., 2013; Visnes and Bahr, 2013) addressed this concern, showing that training volume, match exposure, and superior physical ability, in this case jumping ability, acted as injury risk factors among high-performing youth elite athletes attending specialized sport academy high-schools.

Whether or not the most gifted athletes face a greater risk of incurring injury and illness is discussed further in the following section, which addresses key factors that apply to this population.

Finding balance (LaBella, 2014)

As previously discussed, the balance between damage and recovery might be more fragile for youth athletes than for adults (Bahr, 2014; DiFiori et al., 2014). There is a fine-tuned homeostatic balance between tissue loading and regeneration. If overloaded through excessive stress and inadequate recovery, the ability of the tissue to remodel is exceeded, and structures are damaged (Brink et al., 2010; Bahr, 2014). Youth athletes, holding an immature musculoskeletal system and remaining under cognitive and psychological development, might be at an increased risk due to high internal and external demands and expectations possibly exceeding this balance of regeneration (DiFiori et al., 2014; LaBella, 2014). In a systematic review on adult and elite youth football players (Pfirrmann et al., 2016), youth players reported a higher incidence of training injuries than did professional adult football players. A high percentage of these were re-injuries, and most were overuse injuries, possibly reflecting the high demands of intensive training that are applied to youth athletes at the highest level.

Training volume

Higher training volumes have been reported to increase injury risk across multiple sports in youth athletes (Emery, 2003; Visnes and Bahr, 2013; Arnold et al., 2017; Post et al., 2017; Sugimoto et al., 2019). For youth athletes at all levels of play, injury risk increases as the hours of participation per week increase. More specifically, training more than 16 hours/week has been associated with a significant increase in injury risk (Rose et al., 2008).

Match exposure

The most talented youth athletes are often selected to play more matches and are more exposed in every match. Because injury risk during competition is higher than injury risk during training (demonstrated in Tables 2 and 4 of this thesis), this might place the most talented athletes at an increased risk compared to their less skilled peers. Additionally, available data on competition frequency and injury risk seem to demonstrate that a congested competition calendar increases injury risk during competition (Soligard et al., 2016).

Whether or not this association also applies for illnesses is not known.

Injury risk in talented youth athletes

A uniform definition of talent or "high performance level" has not been provided in youth sports. Previous studies addressing talent or high performance level as risk factors in youth elite athletes, however, have addressed this through either technical skills or level of play. In the following section, the association between injury risk and performance level in different sports (e.g., football, ice hockey, baseball, track and field, and rugby) is discussed. Reports demonstrating a positive association are described, followed by reports demonstrating no such association.

In youth football, several previous studies indicate an association between injury risk and high performance level. Soligard and coworkers (2010a) demonstrated that in female amateur football (aged 13-17 years) (n=1665), players with high levels of football skills were at greater risk of sustaining injuries than their less skilled teammates. Similarly, level of play was investigated by Emery et al. (2005), who demonstrated that injury risk was greater in higher divisions of play in

Canadian adolescent football players (n=344). Playing on more than one football team has also been demonstrated to be associated with a 2.5-fold increase in knee overuse injury risk in US female youth football players (ages 12-15) (n=351) (O'Kane et al., 2017). Time spent in match play and training were also independent injury predictors in male youth elite football players attending the Manchester United Football Club Academy (ages 9-16) (n=292) (Malina, 2010j).

In ice hockey, there are studies supporting an association between injury risk and high performance level. Emery and Meeuwisse (2006) reported that players in the highest skill division were at the greatest injury risk in 11- to 12-year-old ice-hockey players, although no increase in injury risk by skill level was demonstrated in other age groups. In a systematic review on injury in youth ice hockey, however, increased skill level was highlighted as an injury risk across all age groups (Emery et al., 2010).

In baseball, the incidence of injury to the ulnar collateral ligament has increased dramatically among adolescent athletes, possibly associated with overuse from an early age (Petty et al., 2004). In a case-control study on adolescent pitchers requiring shoulder or elbow surgery (n=95), injured pitchers played more months per year, more games per year, more innings per game, and more pitches per game compared with adolescent pitchers without a history of arm injury (n=45) (Olsen et al., 2006). Injured players were more often starters, pitched with higher velocity, and more often with arm pain. These findings are corroborated by other studies on high-school baseball players (Fleisig et al., 2011), and they align with the previously discussed findings in volleyball pointing toward an overconsumption of talented youth athletes (Visnes et al., 2013; Visnes and Bahr, 2013).

Finally, an Australian retrospective study on track and field athletes (n=103) demonstrated that injured youth elite athletes reported higher yearly training volumes at higher intensities compared to non-injured athletes (Huxley et al., 2014).

Associations between injury risk and technical skills or more elite level of play are not always demonstrated, however. In a review on football injury incidence in children and adolescents by Faude et al. (2013), injury incidence in the elite vs. sub-elite youth players was mostly in the upper range; medical service in elite players was more comprehensive compared to sub-elite players, however, and the authors conclude that elite and sub-elite players have similar injury risk. In a prospective 1-year study, Peterson et al. (2000) demonstrated that high-level youth football players had less injuries and half as many severe injuries as low-level players (14 to 18 years old) (n=264). Finally, in a 2-season cohort study within the English youth rugby union comparing two levels of play in 16- to 18-year-old males (n=492) (professional academy players vs. school rugby players), training injury incidence tended to be lower for the academy group vs. the school rugby players

(Palmer-Green et al., 2015). Likewise, injury severity did not differ between academy and school rugby players. In the same study, however, match injury incidence was 34% higher in the academy group compared to school rugby players.

Illness risk in talented youth athletes

Previous literature addressing illness risk and performance level in youth elite athletes is limited. Previous epidemiological studies on illnesses in youth elite athletes are presented in Tables 1 and 2. As previously discussed, most of these illnesses were caused by infections (mostly respiratory or gastrointestinal related), and in a study evaluating associations between heavy exercise and illness in junior elite swimmers (n=29), prolonged vigorous training was associated with an elevated risk of airway infections due to compromised immune cells (Morgado et al., 2012). Another study addressing illness risk in youth elite athletes was conducted by Brink and coworkers (2010). They demonstrated that both physical and psychosocial stress were associated with greater odds of illness in youth elite football players. Based on these reports, it seems reasonable to assume that high work- and competition-load, as well as excessive external and internal demands, might put skilled youth elite athletes at an increased illness risk.

Finally, previous literature has suggested that youth athletes competing at the highest level are at a particular risk of overreaching and burnout. Environmental factors, such as high training volumes, high time demands, demanding performance expectations, frequent intense competitions, and inconsistent coaching practices are heralded as key risk factors (DiFiori et al., 2014). No previous reports, however, have addressed talent, performance level, or skill level specifically as risk factors for illness in youth elite athletes.

In *Paper II,* we explore whether, among youth elite athletes attending specialized sport academy high schools, those with the greatest talent or highest performance level were at a greater risk of incurring injury or illness during their first school year after enrollment.

Physical fitness

Well-developed qualities in aerobic and anaerobic endurance, muscular power, strength, and agility are all essential components of athletic performance. Youth elite athletes strive to improve these qualities daily, and, courtesy of physiological development and natural inclination toward learning new skills during maturation, they are well suited to develop physical fitness and technical skills (Gabbett et al., 2014). The divide between what is required to maintain and improve skills vs. minimizing injury and illness risk in youth athletes, however, is not well understood.

Background

The evidence examining the link between physical fitness properties and injury and illness risk in youth elite athletes is limited and conflicting. In the following section, we discuss current knowledge about the association between a lower physical fitness level and injury risk in youth athletes.

Physical fitness level and injury and illness risk

Physical fitness relates to a set of qualities necessary for athletes to perform their sport. Muscular strength and power, anaerobic and aerobic fitness, as well as explosive efforts during sprints, duels, cutting maneuvers, or jumps, are all sport-specific qualities affecting athletic performance. In contrast, if the required demands of the sport are not met by the athlete's fitness qualities, a lower physical fitness level may contribute to an increased injury risk. This has been demonstrated in several studies on the adult elite athlete population (Arnason et al., 2004; McCall et al., 2014; Gabbett, 2016; Malone et al., 2017; Gabbett, 2018; Malone et al., 2018). Previous evidence considering physical fitness level and injury and illness risk in youth athletes, however, is mostly related to the general youth population participating in sports at the recreational level. Only limited data apply to youth athletes at the elite level. Both are discussed below.

The general youth athlete population

At the recreational level, most previous literature agrees that a low level of physical fitness is associated with an increased injury risk in sports. In a previous systematic review addressing risk factors for sport injuries in children and adolescents at the non-elite level, poor endurance capacity and lack of preseason training were highlighted as important risk factors for injuries (Emery, 2003). This finding has support in several other papers (Carter and Micheli, 2011). For example, in a study on female adolescent football players, preseason aerobic fitness was a predictor of the number of injuries and illnesses sustained during the season (Watson et al., 2017). Likewise, muscular weakness in the shoulder of adolescent baseball pitchers (Tyler et al., 2014), in the hamstrings of young female athletes (Myer et al., 2009), and in the middle trapezius of swimmers (Tate et al., 2012) has been associated with increased injury risk. Slower running speed, less cardiorespiratory endurance, and less muscular strength have also been associated with more ankle sprains in young adult males (17-28 years of age, mean age 18 years) (Willems et al., 2005). Finally, in army trainees, several studies have reported an association between lower extremity injury and physical fitness (particularly cardiovascular fitness) (Bell et al., 2000; Knapik et al., 2001; Bedno et al., 2013; Teyhen et al., 2015). The applicability of these findings to youth elite athletes is, however, questionable.

Background

Youth athletes at the elite level

Few prior studies have addressed associations between physical fitness levels and injury and illness risk in the youth elite athlete population. These studies are either suggestive of an association between lower physical fitness level and injury (Raschner et al., 2012; Chalmers et al., 2013; Moller et al., 2017; Muller et al., 2017), or they are reluctant to claim such associations (Emery et al., 2005; Frisch et al., 2011; Newton et al., 2017).

Existing literature has evaluated youth elite athletes partaking in alpine skiing, football, or handball. Several fitness components have been tested, but only a few have demonstrated an association with injury risk. For example, poor core strength and reactive leg strength have demonstrated an association with injury risk in youth elite alpine skiers (Raschner et al., 2012; Muller et al., 2017). Also, lower aerobic endurance has demonstrated an association with in-season injury in Australian elite junior football players (n=382) (Chalmers et al., 2013), although this finding was not reproduced in a later study (Chalmers et al., 2018). Finally, an association between decreased external rotational shoulder strength and shoulder injury was demonstrated in youth elite handball players (14-18 years of age) (n=679) by Møller et al. (2017).

Contradicting these results is a study on male athletes (13-19 years of age) attending a regional football high school in Luxembourg (n=67). The sole factor associated with an increased injury risk in this study was physical fatigue (Frisch et al., 2011). In a Canadian football study (girls and boys ages 12-18, levels 1-4), there was likewise no association between preseason physical fitness tests and in-season injury (Emery et al., 2005). Finally, pre-season physical fitness tests were not associated with injury in football players attending an English Premier League youth academy (n=84) (Newton et al., 2017).

Based on this, the previous literature demonstrates conflicting evidence on the associations between physical fitness levels and injury risk in youth elite athletes.

A rapid increase in training load

There is emerging evidence that a rapid increase in training load results in an increased risk of injury and illness, and that adult athletes accustomed to high training loads have lower risk of incurring injuries than athletes training at lower workloads and of lower physical fitness (Gabbett et al., 2014; Drew and Finch, 2016; Gabbett, 2016; Schwellnus et al., 2016; Soligard et al., 2016; Malone et al., 2017; Gabbett, 2018; Malone et al., 2018). Data remain limited as to whether this also applies to youth elite athletes. Nevertheless, a few studies have addressed associations between a rapid increase in training load and injury risk in this population (Malisoux et al., 2013; Soligard et al., 2016; Watson et al., 2016; Moller et al., 2017).

In a report on 679 youth elite handball players (14-18 years of age), Møller et al. (2017) demonstrated that a large (>60%) increase in weekly handball load, relative to the weekly average amount of handball load in the preceding 4 weeks, was associated with an increase in shoulder injuries. Likewise, in a prospective 20-week study on 75 US female youth football players, a rapid increase in training load was associated with increased in-season injury risk (Watson et al., 2016). Finally, in a 41-week prospective study on youth elite athletes practicing team, racket, or individual sports (12-19 years of age) (n=154), there was a trend wherein the number and intensity of weekly training sessions increased immediately prior to injury (Malisoux et al., 2013).

Despite the limited evidence, it seems reasonable to believe that rapid increases in training load are also associated with increased injury risk in youth athletes across several sports. Youth elite athletes entering specialized sport academy high schools might experience a great increase in training volume. Consequently, the least fit athletes might be overloaded, with negative adaptations, such as injury and illness, as a result.

Exercise-based injury prevention in youth elite athletes

There is solid evidence to support the preventative effect of global, as well as specific, injury prevention programs. Across all levels of youth sports, injury prevention programs focusing on developing neuromuscular properties, muscular strength, plyometrics, agility, and proprioception have proven effective (Abernethy and Bleakley, 2007; Frisch et al., 2009; Soligard et al., 2010e; Myer et al., 2011; Steffen et al., 2013; Emery et al., 2015; Faigenbaum et al., 2016; Myer et al., 2016; Zouita et al., 2016). An overall effect size of over 40% on injury risk in youth sport has been estimated (Rossler et al., 2014).

At the other end of this spectrum is performance enhancement through the same fitness components (endurance, speed, agility, strength and power), all of which are essential in youth athlete development programs (Gabbett et al., 2014; SportforLife, 2014; UnitedStatesOlympicCommittee, 2014; Granacher et al., 2016). In a narrative review, Faigenbaum et al. (2016) suggest that integrative training programs grounded in resistance training and motor-skill development can optimize sporting performance in young athletes while minimizing sport-related injuries (Myer et al., 2011). Based on this, one would assume that optimizing physical fitness levels while minimizing sport injury seems to be a two-in-one deal.

Finally, it seems reasonable to believe that stronger and fitter youth elite athletes are better prepared to sustain the high training and competition load applied after enrollment into specialized sport academy high schools, and that youth elite athletes attaining a lower physical fitness level could be at an increased risk of incurring injury or illness. Ultimately, it is the load to which the youth athlete is exposed, relative to the load for which he or she is prepared, that might place the athlete at an increased risk of incurring injury or illness (Soligard et al., 2016).

This was the question we addressed in *Paper III*: whether the least fit youth elite athletes were at an increased risk of incurring injury or illness after enrollment into a specialized sport academy high school.

Aims of the dissertation

General aim

The main aim of this study was to evaluate the magnitude of, and some potential risk factors for, health problems in a population of youth elite athletes newly enrolled into specialized sport academy high-schools.

Specific aims

Paper I

The aim was to describe the prevalence and severity of health problems in a cohort of elite athletes representing a variety of endurance, team, and technical sports, as well as in a group of their sub-elite teammates.

Paper II

The aim was to evaluate a sport history of early and single-sport specialization or current performance level as risk factors for injury and illness in youth elite athletes attending specialized sport academy high-schools.

Paper III

The aim was to evaluate the association between a lower level of physical fitness and the risk of injury and illness in youth elite athletes newly enrolled into specialized sport academy high-schools.

Methods

Study design

All papers in this thesis are based on one prospective cohort study within the same study population. *Paper I* is a descriptive, prevalence study. *Papers II and III* are risk factor studies.

All participants were included in August 2014. These were: 1) youth elite athletes from three selected sport academy high-schools in Norway (n=260), 2) team sport teammates attending regular high schools (n=60), and 3) 16-year-old adolescent controls attending the same high-school as the youth elite athletes but without the specialized sport curriculum (n=20).

At baseline, we collected baseline data from all participants. Additionally, the coaches of the youth elite athletes were asked to rate their athletic performance levels (*Paper II*), and the elite athletes were invited to partake in physical fitness tests (*Paper III*). The youth elite athletes and their teammates reported injury and illness status weekly during the period from October 2014 until May 2015 through the OSTRC-Q on health problems. Supplementary retrospective interviews were carried out in May and June 2015 with most youth elite athletes and teammates.

Participants

Youth elite athletes

Before initiating the study, we contacted three well-established sport academy high-schools in the eastern part of Norway with an invitation to participate in the study. All three schools accepted. Prior to the study, we held meetings with the school management. Through school meetings, verbal and written information was given to the students and their parents about the purpose and procedures of the study.

All the youth elite athletes in this thesis were 15- and 16-year-old high-level athletes, enrolled into one of three selected specialized sport academy high-schools. Inclusion criteria of the study were first-year enrollment into one of these schools at the beginning of the school year 2014-15. There were no exclusion criteria for youth elite athletes at baseline. All first-year students were invited to join the study; 82% (n=260) agreed to participate (178 boys and 82 girls). Thirty different sport disciplines were represented and categorized into three sport categories: endurance sports (n=69), technical sports (n=62), and team sports (n=129). Two of the 260 athletes were lost to follow up at baseline; five were lost prospectively. In *Paper II*, 259 athletes were originally included (177 boys and 82 girls). One athlete was deleted from the teammate group and included in this group (due to sport academy high school enrollment). In *Paper III* (n=166), inclusion criteria included completion of a physical fitness test-battery performed at baseline during school hours. We excluded athletes who were absent on test day or who did not complete all tests.

Team sport teammates

In *Paper I*, we invited a convenience sample of teammates attending regular high schools, playing on the same teams as the elite team sport athletes, to participate in the study. A convenience sample of eight coaches representing four different team sports (football, handball, ice hockey, floorball) and 133 teammates were contacted for participation. We visited each team during practice and invited the players present to participate on an individual basis. Exclusion criteria included other sport academy high-school enrollment. Twenty-seven teammates were excluded based on this criterion. Of the 106 eligible teammates, 60 teammates (29 boys and 31 girls) from football (n=18), handball (n=28), ice hockey (n=3), and floorball (n=11) agreed to participate. During the study period, four were lost to follow up.

Adolescent controls

A convenience sample of same-aged non-athletes attending Wang sport academy high-school, but without the sport-specialization curriculum, were invited to participate in the study (*Paper I*). We visited two school classes during school hours, inviting students present to participate on an individual basis; 53 students were invited, and 21 agreed to participate (8 boys and 13 girls). There were no exclusion criteria. These participants were later excluded from the study due to low compliance.

Study procedures & data collection methods

Baseline questionnaire

Within 2 weeks of inclusion, all participants completed a baseline questionnaire. Youth elite athletes and non-athletes completed the questionnaire during school hours with the study administrator present. The teammates completed the questionnaire at home. The baseline questionnaire included information on anthropometrics, medical history, motivation for training (numeric scale, 1=very, very low to 7=very, very high), sport category, age when the athlete defined one sport as being more important than other sports (sport specialization), and self-evaluated performance level. They were also asked to report participation in other sports during each of the past 6 years (5th through 10th grade) and to report how many hours per week on average they had participated in training and competition during each of the past 12 months. As we were unable to find any existing questionnaire appropriate for our use, the baseline questionnaire was developed during a series of group meetings between the principal investigator, supervisors, and sports physiotherapists. Development of the questionnaire was based on clinical practice as well as on a questionnaire used in a project by Martinsen et al. (2010) evaluating sport history, sport debut, sport specialization, performance level, and nutritional pattern. A pilot of the final baseline questionnaire was tested on 10 athletes of different ages and performance levels, with subsequent adjustments based on their feedback before it was taken into use.

The Oslo Sports Trauma Research Center Questionnaire on health problems (OSTRC-Q)

In all papers, we used the OSTRC-Q on health problems to self-report injuries, illnesses, and training volume weekly through a smartphone application (Spartanova N.V., Gent, Belgium). The OSTRC-Q on health problems is validated for use in a heterogeneous cohort of elite athletes where both acute and overuse injuries, as well as illnesses, are of concern (Clarsen et al., 2014b). The questionnaire starts with four questions collecting information about the consequences of health problems on the athlete's (1) participation in training and competition, (2) training volume, (3) performance, and (4) symptoms. We modified the questionnaire for our use by including a question asking if injuries were classified as acute or overuse, and we added the total number of training and competition hours per week (0-25 hours).

When opening the questionnaire, a specific text initially informed the athlete that acute injuries were defined as those whose onset could be linked to a specific injury event (such as falling or being tackled), whereas an overuse injury could not be linked to a single clearly identifiable event (Fuller et al., 2006b). In the case of an injury, athletes were asked to register anatomical location. In the case of an illness, multiple predefined major symptoms, such as (but not limited to) fever, sore throat, fatigue, cough, or headache, could be registered. Instructions were that feelings such as sadness, depression, anxiety, or feeling troubled should be registered as illness. The questionnaire repeated itself up to four times for several health problems within the same week (Appendix I).

Methods

Questionnaire administration and follow-up

The questionnaire was distributed to participants every Sunday from October 30th 2014 until May 3rd 2015 (26 weeks). Reminders were sent to non-responders after 2, 4, and 6 days, both automatically through the application and manually via SMS, by the principal investigator. During the registration period, we had regular contact with all athletes and principal coaches. At the conclusion of the project, the principal investigator manually sifted through all reported health problems and checked for multiple registrations of the same health problem within the same week. If multiple registrations in the same week appeared, only the first registration was retained.

For recurrent health problems, we contacted the participants to evaluate the extent of the health problem and suggest further medical treatment. During the study period, medical advice was sought with the principal investigator by participants and parents as requested. To participants with the best weekly compliance, a small gift card was donated in December 2014.

Supplementation and verification of reported health problems

After the conclusion of the study, all available participants were interviewed by the principal investigator or sports physiotherapists to confirm or supplement the prospective data. The elite athletes and teammates with the lowest prospective compliance were prioritized for interviews. Nearly all interviews were conducted in person at school, in a few cases during a training session or by telephone. During the interviews, the prospective dataset, personal training diary, and competition schedules for all the different sports as reported by the coaches were available. For every athlete, one OSTRC-Q was completed for every health problem registered during the 26-week period. A standardized interview form was used, outlined as a week-by-week calendar based on the form used for injury surveillance in the FIS Injury surveillance system (Haaland et al., 2016) as well as the OSTRC-Q on health problems (Appendix II).

During the retrospective interviews, it was the interviewers (physician or physiotherapist), together with the athlete, who made the categorization of the health problems. In the case of injuries, when the same diagnosis was interspersed with periods of apparent recovery, the retrospective interview data were used as a backup check to determine whether the problem should be considered an exacerbation of an unresolved problem or a recurrence of a fully recovered problem (re-injury/new injury) in accordance with the definitions by Fuller et al. (2007a). Illnesses were treated in the same fashion, with repeated conditions in the near longitudinal period (close proximity) treated as a single case for the purpose of severity and duration analysis (Clarsen et al., 2013).

Definition of health problems

Health problems were defined as all self-reported injuries and illnesses, regardless of severity and consequences, as defined by the any physical complaint definition (Fuller et al., 2006b; Bahr, 2009; Pluim et al., 2009; Clarsen et al., 2014b).

Substantial health problems were defined as problems leading to moderate or severe reductions in training volume or performance or to complete time loss from sport (Clarsen et al., 2013).

Injury and illness definitions were in line with the previously discussed IOC recommendations (Junge et al., 2008), as suggested by Clarsen et al. (2013; 2014b).

Outcome measures

Primary and secondary outcomes

Primary outcomes in all papers were all and substantial health problems. Secondary outcomes were all and substantial acute injuries, overuse injuries, and illnesses, respectively.

In *Paper I,* we calculated the average weekly prevalence (mean with 95% CI) and cumulative severity score (median with IQR) of health problems. In *Paper II*, the average number and severity of health problems were calculated (mean with 95% CI). In *Paper III,* the average number (mean with 95% CI) and severity (median with IQR) of health problems were calculated.

Prevalence and number of health problems

The average weekly prevalence during the 26-week study period was calculated by dividing the number of athletes reporting any health problem by the number of questionnaire respondents for each week of the study, presented as proportions with 95% confidence interval averaged over the study weeks (*Paper I).* In *Papers II and III*, the average number of health problems for every athlete over the 26-week study period was calculated with the corresponding 95% confidence interval (Clarsen et al., 2013; Clarsen et al., 2014b).

Severity measures

A weekly severity score was registered for all athletes and all separate health problems, based on their responses to the four key questions. At the end of the study, we registered the cumulative severity score for each case by summing the weekly scores, and an average weekly severity score was calculated for all cases. In *Paper I*, the average weekly severity and cumulative severity for all illnesses, overuse injuries, and acute injuries were reported as medians with IQR. In *Papers II and III*, the cumulative severity score for all health problems, illnesses, acute injuries, and overuse injuries was calculated and reported as median with IQR in *Paper III*.

Risk factors

Early sport specialization

We defined sport specialization as the time when the athlete defined one sport as being more important than other sports. We asked the athletes: "At what age did you decide to focus on your sport?" Answers were classified into seven categories: ≤10 years, 11 years, 12 years, 13 years, 14 years, 15 years, or 16 years. This age of specialization was reported as proportions of athletes in *Paper I*. In *Paper II*, we dichotomized their responses as either early (≤12 years) or late specialization (>12 years).

Previous sports

Single-sport vs. multi-sport background. Previous and current involvement in different sports was asked for at baseline. We listed the 18 most common sports in Norway and related the different sport disciplines to the different school grades, giving the athletes multiple-choice alternatives from which to choose. The proportion of athletes practicing sports other than their primary sport in the previous two years was reported (*Paper I*). In *Paper II*, we classified athletes having participated in sports other than their main sport during the past two years (9th and/or 10th grade) as multi-sport athletes and those practicing only their primary sport during the past two years as single-sport athletes.

Performance level

Self-evaluated & coach evaluated performance level. At baseline, both athletes and coaches were asked to evaluate the athlete's current performance level. Neither the athletes nor the coaches were given any guidance or criteria on which to base their response to the questions about previous and current performance level. The athletes were asked to rate themselves compared to other same-age athletes (in the same sport) in Norway, based on six categories (top 1%, top 5%, top 10 %, top 25%, top 50%, and below 50%). The proportion of athletes rating themselves at or above 5% was reported in *Paper I*. The coaches were asked to rate athletic performance at the beginning of the school year by comparing between athletes within their training group, classified into quartiles

(Appendix III). For the risk factor analyses, we dichotomized the self-evaluations into above or below top 10% and the coach evaluations into above or below the top 50% (*Paper II*).

Physical fitness

In August 2014, all athletes were invited to perform physical fitness tests, either at the Norwegian School of Sport Sciences or at the sport academy high-school at Lillehammer. The same research team (physician and sports physiotherapists) coordinated the tests in the same order and with a 30-minute warm-up and 15-minute active breaks for all participants. Pilot testing of eight youth athletes was performed prior to the study, testing under the instruction of an experienced physical fitness trainer and the principal investigator. All test procedures were in line with the protocol of the Ironman Jr. test-batteries ("Attacking Vikings", Version 4.2, Aug 15th 2013, att. 7) (Appendix IV), except for the removal of the submaximal squat technique from the test-battery. For 110 athletes, a 1500 m run was substituted for the 3000 m run at the request of the sport academy high-schools. To provide a measure of general physical fitness level, all test components were weighted equally, independent of their relevance to the different sports. For each test, we ranked the athletes from 1 to 166, and we attained a composite score by summing these ranks. For the risk factor analyses in *Paper 3*, we dichotomized the composite score between the least fit quartile and the remainder of the cohort.

The Ironman Jr test-battery

The Ironman Jr test-battery was modified for our use, described below as performed.

1500 m and 3000 m runs

Performed on an outdoor 400 m running track, after a general warm-up and 10-15 minutes of running at increasing intensities.

Hexagonal obstacle

The athlete jumped as fast as possible with a two-foot landing across all obstacles. A warm-up of two to four rounds was performed. Athletes performed all clockwise attempts first, followed by the counter-clockwise attempts. The sum of the best time in minutes and seconds in both directions was retained.

Standing long jumps

Athletes were allowed a warm-up of four to five trials while feedback on technique and performance was given. A minimum of three trials was completed, and additional jumps were allowed as long as the length increased for every jump. The longest legal jump was registered.

Push-ups

Five- to ten-repetitions warm-up with feedback on correct technique and performance was performed. No time limit was given, but athletes were warned if they stopped for more than one to two seconds between repetitions. Athletes started in a prone position with their hands lifted off the floor. When extending their arms, the whole body had to be lifted rigidly off the floor with the chin, chest, hips, and thighs moving simultaneously from the floor until the arms were fully extended. The number of correctly performed push-ups was noted.

Chin-ups

Two- to five-repetitions warm-up with feedback on correct technique and performance was performed. No time limit was given, but athletes were warned if they paused for more than one to two seconds between repetitions. Athletes started hanging with the hands 10 cm wider than shoulder width. The number of correctly performed chin-ups was noted.

Crunches on a vaulting box

A warm-up of two to five repetitions with feedback on correct technique and performance was performed. Athletes started hanging upside down with knees flexed in a 90° position with hands held behind the head, holding a 5 cm rope ring. No time limit was given, but a warning was given if they paused for more than 1 second during the exercise. We noted the number of correctly performed crunches.

90-s bench jump test

A warm-up with 15-20 seconds of high-intensity jumping was performed. Athletes were asked to perform the maximum number of jumps possible within 90 seconds, starting on the top of the bench. The number of side-to-side jumps within 90 seconds was noted.

Covariates

Anthropometrics were self-reported by all participants at baseline (weight and height, *Papers I* and *III*). Date of birth was stratified as before and after July 1st (*Paper III*).

Methods

Sport category classifications of athlete participants aligned with a previous classification by Clarsen et al. (Clarsen et al., 2014b), dividing the athletes into three subgroups (endurance, technical, and team sports) (*Papers I, II, III*).

Baseline training load was self-reported as categories (0-5 hours, 6-10 hours, 11-15 hours, 16-20 hours, >20 hours) of weekly training and competition load from August 2013 until August 2014. Proportions of athletes in different categories of average weekly training load the previous year were presented in *Paper I* and used as an adjustment factor in *Papers II and III*.

Baseline variables not adjusted for

Medical history was collected at baseline, encompassing information about both previous illness and previous injury. We listed 13 different common illnesses, such as (but not limited to) asthma, mononucleosis, diabetes, attention deficit hyperactivity disorders, migraine, inflammatory bowel disease, and depression and included an open category. Allergy was reported elsewhere. The most common symptoms, time loss from sports during the past two years, and most recent illness episode were reported. Athletes reported injuries in the previous 2 years based on injury location (same as in the OSTRC-Q), time of injury, and duration of time loss from sports (*Paper III*).

OSTRC-Q at baseline: The baseline questionnaire also included the OSTRC-Q on health problems, covering health problems during the past week for all participants (*Paper I*), with a modified version for non-athletes, exchanging "sports" with "daily activities".

Ethical approvements and considerations

Protocols for the study were approved by the Norwegian Data Inspectorate (No. 38888) (Appendix V) and reviewed by the South-Eastern Norwegian Regional Committee for Research Ethics (2014/902/REK Sør-Øst) (Appendix VI). Written and verbal information was provided to all participants about the aims of the project, the procedures, and potential risks associated with participation (Appendix VII-VIII). Informed consent was obtained from all participants and legal guardians of those under 18 years of age (Appendix IX-X).

Statistical methods

Data were analyzed using SPSS for Windows (version 24) for all papers, vassarstats.net for Confidence interval of a proportion (Table 6) in paper I, www.socscistatistics.com Chi-Square test calculator for chi-square statistics, p-value, and statement of significance (Table 6). STATA version15 (StataCorpStataCorp LLC, College Station, TX) was used in paper III for calculations of CIs for medians. Matlab R2014a (Mathworks, Inc) was used to calculate the Fisher mid-P test. A (two-tailed) P-value <0.05 was considered statistically significant.

The analyses in this article were exploratory and were performed not to confirm or reject hypotheses but rather to suggest associations that might be of interest.

Statistical analyses applied

Table 6. An Overview of statistical analyses applied in the thesis

Statistical analyses	Variable category	Variables
Independent T-tests and CIs	Continuous	Anthropometrics(*Paper I*) FF test results, number of HPs (*Paper III*)
One-Way ANOVA	Continuous	FF test results, number of HPs (*Paper III*)
Pearsons chi-squared test (or Fisher mid-P)	Dichotomy	Sport history/baseline point prevalence of HP/weekly prevalence of HPs (*Paper I*)
Mann Whitney U-test	Skewed continuous	Duration and severity of HPs (*Paper I*) Cumulative severity between sex (*Paper III*)
Kruskal Wallis	Skewed continuous	Cumulative severity between sport categories (*Paper I*)
Univariable linear regression	Continuous	Early specialization(<12) Single-sport athlete previous 2 years Self-evaluated performance level above top 10% Coach-evaluated performance level above top 50% (*Paper II*) Lowest quartile of physical fitness level (*Paper III*)
Multiple linear regression	Continuous	Early specialization(<12) Single-sport athlete previous 2 years Self-evaluated performance level above top 10% Coach-evaluated performance level above top50% Sex, sport category, baseline training load (*Paper II*) Number of health problems, sex (*Paper III*) Lowest quartile of physical fitness level, birthdate, baseline training load, BMI (*Paper III*)
Univariable median regression	Skewed continuous	Cumulative severity score (*Paper III*)
Multiple median regression	Skewed continuous	Cumulative severity score, sex (*Paper III*) Lowest quartile of physical fitness level, birthdate, baseline training load, BMI (*Paper III*)

Independent t-tests and CIs (or one-way ANOVA) were used for continuous variables, such as anthropometrics (height and weight) in *Paper I* and Ironman Jr. test results and number of health problems in *Paper III*. This test was used to evaluate whether the means of the continuous variables were significantly different or not. For comparisons of means between sport categories, we used one-way ANOVA tests. Results were presented as P-values and means with 95% confidence intervals.

The Pearson's chi-squared test (or Fisher mid-P test) was used to explore associations between categorical data in *Paper I*. The Pearson's chi-squared test is a test of the null hypothesis that the probability of a binary outcome is equal in two independent groups. For this test to be valid, the expected frequency in all cells is required to be greater than or equal to five (Cohran's criterion) (Lydersen et al., 2009). Overall, for the few cases where the chi-squared test assumptions were violated, we used the Fisher mid-P test to explore associations between categorical data of small numbers (Fagerland, 2017).

The Mann Whitney U-test (or Kruskal-Wallis) is a non-parametric test. We used the Mann Whitney U-test for two independent samples due to data skewness regarding both duration and cumulative severity data, whereas Kruskal-Wallis was applied for more than two samples (*Paper I* Table 6). These tests do not assume a normal distribution of the residuals, but an assumption for these tests is same-sided skewness.

Regression analyses were used to evaluate associations between potential risk factors (independent variables) in *Papers II and III* with study outcomes (dependent variable, number and severity of prospective health problems). We used both *univariate linear regression analyses* for crude estimates (evaluated each risk factor separately), as well as *multiple analyses* for adjusted estimates. Before evaluating potential associations between exposure and outcomes, we evaluated all independent variables and their associations with exposure and outcome through directed acyclic graphs (DAG). We did this to identify confounders (need to adjust), colliders (do not adjust), and mediators (intermediate variables, possible to adjust). Some of the main assumptions for using these tests are linear associations, normally distributed residuals (evaluated with histograms), and correlations between independent variables (collinearity). The unstandardized coefficient (B) with associated 95% confidence interval was explored to evaluate the association between exposure and outcome and, finally, whether a significant effect of the model can be assumed. *Median regression* was used to compare medians (instead of means, as in linear regression).

Stratification vs. adjusting for sex and sport category: In *Paper III*, the cohort was stratified by sex and sport category because we could not assume that the effect of sex and sport categories were the same between covariates. Results were reported as the mean with 95% confidence intervals. Statistical significance was defined as p-value <0.05.

Sample size analyses

The sample size was based on previous studies by Clarsen et al. (Clarsen et al., 2013; Clarsen et al., 2014b). With 80% power and 5% significance level ($\alpha = 0.05$), the estimated number of main participants (n=300) and subgroups (n=50 to n=100) exceeded the previous power calculation for these studies and were also considered sufficient in this study, using the same methodology. For the teammates and the non-athlete controls, both were convenience samples.

Main results

Paper I

In *Paper I,* we documented the prevalence and burden of injuries and illnesses in youth elite athletes attending specialized sport academy high schools, representing a variety of endurance, team, and technical sports (n=258), as well as a convenience sample of their teammates attending regular high schools (n=60). Over the course of the study, a total of 912 unique health problems were reported by the youth elite athletes. Teammates reported 193 unique health problems. At any given time, an average of 43% (95% CI 37% to 49%) of youth elite athletes reported a health problem of some kind, whereas 25% (95% CI 20% to 31%) reported a substantial health problem (Table 7). All health problems were more common in girls than boys. Endurance-sport athletes reported more illnesses than technical- and team-sport athletes, while technical- and team-sport athletes reported more injuries compared to endurance-sport athletes. The elite team-sport athletes reported a higher prevalence of substantial injuries compared to their teammates. Finally, the total burden of health problems, reflecting both severity and duration, was evenly distributed between overuse injuries (37%), acute injuries (34%), and illnesses (30%) for all youth elite athletes.

Table 7. Average weekly prevalence during the 6-month observation period of all health problems and substantial health problems reported, as well as for subcategories of illness and injury in each subgroup of athletes. Data are shown as the percentage of athletes reporting at least one (substantial) health problem, with 95% confidence intervals.

	Elite sport athletes (n=258)						**Team sport teammates (n=60)**
	All (n=258)*	**Males (n=177)**	**Females (n=81)***	**Endurance sports (n=68)***	**Technical sports (n=62)**	**Team sports (n=128)***	
All health problems	43% (37,49)	39% (32,46)	53% (42,64)	38% (28,50)	45% (33,57)	45% (37,54)	37% (26,49)
Illness	12% (9,17)	11% (7,17)	16% (10,26)	23% (15,35)	10% (5,20)	8% (4,14)	14% (7,24)
Injury	31% (26,37)	28% (22,35)	37% (27,48)	15% (8,25)	36% (25,48)	37% (29,45)	23% (14,35)
- Acute injury	14% (12,20)	12% (8,17)	17% (11,27)	2% (0,8)	16% (9,27)	19% (13,26)	11% (6,22)
- Overuse injury	17% (13,22)	16% (11,22)	19% (12,28)	12% (6,22)	20% (11,31)	17% (12,25)	13% (7,24)
Substantial health problems	25% (20,31)	22% (17,29)	32% (23,43)	22% (14,33)	25% (17,38)	26% (19,34)	18% (11,30)
Illness	7% (4,11)	6% (4,11)	11% (6,20)	15% (8,25)	6% (3,15)	4% (2,9)	8% (4,18)
Injury	17% (13,22)	16% (11,22)	21% (14,31)	7% (3,16)	19% (11,31)	22% (16,30)	10% (5,20)
- Acute injury	10% (7,14)	9% (6,14)	12% (7,21)	1% (0,8)	11% (6,22)	14% (9,21)	6% (3,16)
- Overuse injury	8% (5,12)	7% (4,11)	9% (4,17)	6% (2,14)	8% (3,18)	9% (5,16)	4% (1,11)

*Indicates number of athletes at baseline.

Paper II

Early and single-sport specialization

In *Paper II*, we addressed the association between a background of early and single-sport specialization and injury and illness risk in youth elite athletes.

In our cohort, 47% of the team-sport athletes, 45% of the technical-sport athletes, and 20% of the endurance-sport athletes had decided to specialize in their sport at 12 years of age or younger (Figure 4).

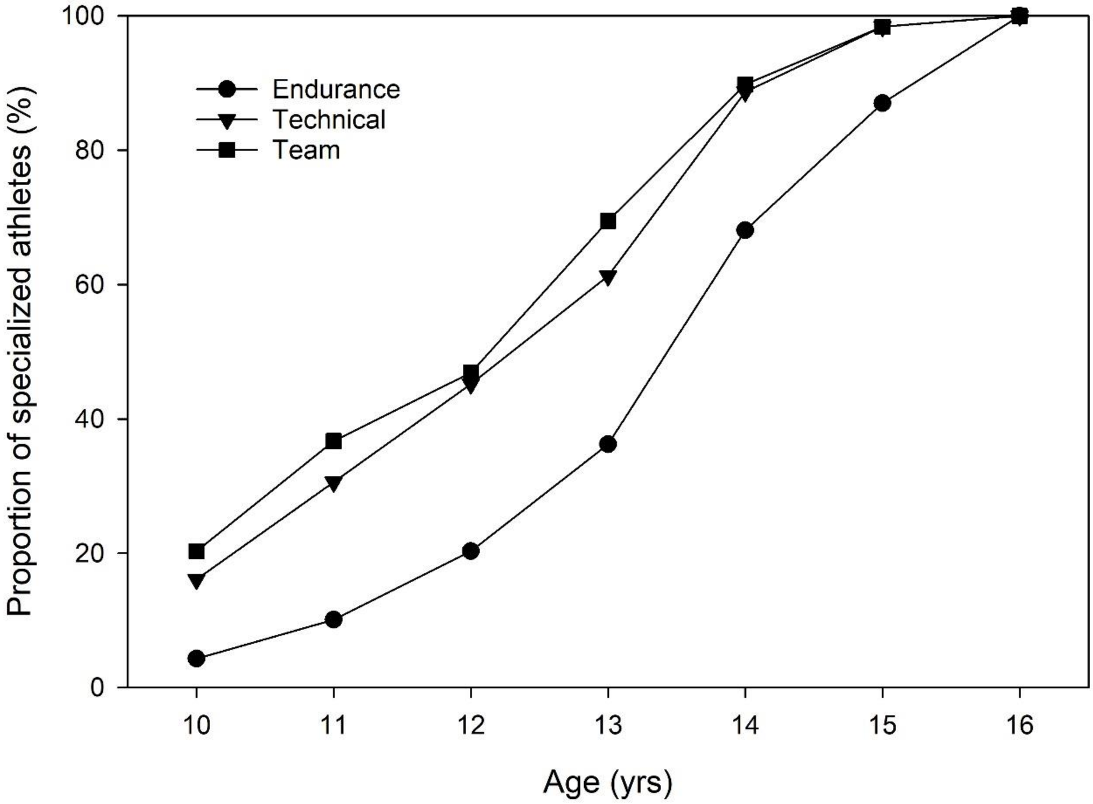

Figure 4. Proportion of specialized athletes at different ages.

Main results

The majority of team-sport athletes (60%) and a minority of endurance athletes (23%) reported that, during the previous 2 years, they had participated in their main sport only (Table 8).

Table 8. Baseline data on single-sport specialization. Data are shown as numbers with percentages.

	Endurance sports (n=69)		Technical sports (n=62)		Team sports (n=129)	
	Males (n=46)	**Females (n=23)**	**Males (n=43)**	**Females (n=19)**	**Males (n=89)**	**Females (n=40)**
Playing other sports previous two years						
No other sport	8 (17%)	8 (35%)	18 (42%)	10 (53%)	59 (66%)	19 (48%)
1 other sport	10 (22%)	1 (4%)	5 (12%)	4 (21%)	10 (11%)	11 (28%)
2 other sports	12 (26%)	10 (44%)	8 (19%)	3 (16%)	8 (9%)	5 (13%)
≥3 other sports	15 (33%)	4 (17%)	11 (26%)	2 (11%)	9 (10%)	4 (10%)

We showed that for youth elite athletes enrolled into specialized sport academy high-school programs, a background of early specialization did not increase their risk of incurring injury or illness, nor did being a single-sport athlete for the previous 2 years (Table 9).

Table 9. Relationship between the number of health problems (mean and 95% CI) and early single-sport specialization. Data are based on multiple linear regression analyses, adjusted for sport category, sex, and baseline training load.

	Number of health problems (mean)			Adjusted
	Yes**	**No****	**P-value**	**B (95% CI)**
Early specialization (≤12 years) (n=259)*	**n=102**	**n=157**		
All health problems	3.5 (3.1,3.9)	3.6 (3.3,3.9)	0.92	0.03 (-0.50,0.55)
Acute injuries	1.1 (0.8,1.3)	0.8 (0.6,0.9)	0.48	0.10 (-0.18,0.38)
Overuse injuries	0.8 (0.6,1.0)	1.0 (0.9,1.2)	0.10	-0.23 (-0.51,0.05)
Illness	1.6 (1.4,1.9)	1.8 (1.6,2.0)	0.45	0.13 (-0.21,0.48)
Substantial health problems	2.2 (1.8,2.5)	2.2 (1.9,2.4)	0.84	0.04 (-0.36,0.45)
Acute injuries	0.7 (0.6,0.9)	0.4 (0.3,0.6)	0.18	0.14 (-0.07,0.35)
Overuse injuries	0.4 (0.3,0.6)	0.6 (0.4,0.7)	0.06	-0.20 (-0.41,0.01)
Illness	1.0 (0.8,1.2)	1.2 (1.0,1.3)	0.47	0.10 (-0.17,0.36)
Single-sport athlete previous two years (n=251)*	**n=121**	**n=130**		
All health problems	3.5 (3.1,3.8)	3.7 (3.3,4.0)	0.66	-0.11 (-0.63,0.40)
Acute injuries	0.9 (0.8,1.1)	0.8 (0.6,1.0)	0.40	-0.12 (-0.39,0.16)
Overuse injuries	0.9 (0.8,1.1)	1.0 (0.8,1.2)	0.68	-0.06 (-0.34,0.22)
Illness	1.6 (1.4,1.8)	1.9 (1.6,2.2)	0.85	0.03 (-0.31,0.37)
Substantial health problems	2.2 (1.9,2.5)	2.2 (1.9,2.4)	0.56	0.12 (-0.28,0.52)
Acute injuries	0.6 (0.5,0.8)	0.5 (0.3,0.6)	0.92	-0.01 (-0.21,0.19)
Overuse injuries	0.6 (0.4,0.7)	0.5 (0.3,0.7)	0.41	0.09 (-0.12,0.29)
Illness	1.0 (0.8,1.2)	1.2 (1.0,1.4)	0.75	0.04 (-0.22,0.30)

* Numbers vary due to missing values
** Values are the number of athletes in each category (yes/no) for each exposure variable

Main results

Performance level

In *Paper II*, we also addressed the association between performance level and injury and illness risk in youth elite athletes.

The youth elite athletes reported that they participated at a high performance level within their sport at enrollment into the sport academy high-schools. Thirty-seven percent of them participated at the international level (junior or senior national team). Sixty-six percent of the athletes rated their performance level as within the top 10% nationally. The coaches ranked 46% of the youth elite athletes as above average and 54% below average within their training groups at the sport academy high-schools. Thirty-six percent of the athletes were rated in the top-performing category by both the athletes themselves and their coach.

In *Paper II,* we demonstrated that among the youth elite athletes newly enrolled into specialized sport academy high schools, those representing the highest performance level were not at a greater risk of becoming either injured or ill (Table 10). One exception was for the athletes rating themselves as within the top 10%. These athletes reported more overuse injuries compared to the rest of the cohort.

Table 10. Relationship between the number of health problems (mean and 95% CI) and self- and coach-evaluated performance levels. Data are based on multiple linear regression analyses, adjusted for sport category, sex, and baseline training load.

	Number of health problems (mean)		Adjusted	
	Yes**	No**	P-value	B (95% CI)
Self-evaluated top 10% performance level (n=259)*	**n=171**	**n=88**		
All health problems	3.5 (3.2,3.8)	3.6 (3.2,4.0)	0.91	0.03 (-0.49,0.55)
Acute injuries	0.8 (0.7,1.0)	1.1 (0.8,1.3)	0.09	-0.24 (-0.51,0.04)
Overuse injuries	1.0 (0.9,1.2)	0.8 (0.6,1.0)	0.03	0.31 (0.04,0.59)
Illness	1.7 (1.5,1.9)	1.8 (1.5,2.0)	0.71	-0.06 (-0.41,0.28)
Substantial health problems	2.1 (1.9,2.4)	2.2 (1.9,2.5)	1.00	0.00 (-0.40,0.40)
Acute injuries	0.5 (0.4,0.6)	0.6 (0.5,0.8)	0.23	-0.13 (-0.33,0.08)
Overuse injuries	0.5 (0.4,0.7)	0.4 (0.3,0.6)	0.13	0.16 (0.05,0.37)
Illness	1.1 (0.9,1.3)	1.1 (0.9,1.4)	0.80	-0.03 (-0.29,0.23)
Coach-evaluated top 50% performance level (n=210)*	**n=96**	**n=114**		
All health problems	3.5 (3.1,3.9)	3.2 (2.9,3.6)	0.22	0.32 (-0.19,0.82)
Acute injuries	0.9 (0.7,1.1)	0.8 (0.6,1.0)	0.70	0.05 (-0.22,0.33)
Overuse injuries	1.0 (0.7,1.2)	0.8 (0.7,1.0)	0.28	0.15 (-0.12,0.42)
Illness	1.6 (1.4,1.9)	1.6 (1.3,1.9)	0.57	0.10 (-0.25,0.46)
Substantial health problems	1.8 (1.6,2.1)	2.0 (1.8,2.3)	0.26	-0.22 (-0.62,0.17)
Acute injuries	0.5 (0.4,0.7)	0.5 (0.4,0.6)	0.78	-0.03 (-0.24,0.18)
Overuse injuries	0.4 (0.3,0.6)	0.5 (0.3,0.6)	0.73	-0.04 (-0.24,0.17)
Illness	0.9 (0.7,1.0)	1.1 (0.9,1.3)	0.24	-0.16 (-0.42,0.11)

* Numbers may vary due to missing values
** Values are the number of athletes in each category (yes/no) for each exposure variable

Paper III

In *Paper III*, we addressed the association between physical fitness level and injury and illness risk in youth elite athletes. We used physical fitness tests related to endurance, strength, agility, and speed to identify the least fit quartile among youth elite athletes newly enrolled into specialized sport academy high schools. Test results are presented in Table 11.

For the "all athlete" group, we demonstrated no difference in the number and severity of health problems reported between the least fit athletes and the rest of the cohort. Likewise, for groups stratified by sex and sport category, no statistically significant differences between the least fit athletes and the rest of the cohort emerged (Table 12). The least fit girls, who reported more substantial overuse injuries compared to the rest of the girls, were an exception. There was also a trend wherein the least fit endurance athletes reported more illnesses compared to the rest of the endurance athletes; this result did not reach a significant level.

Main results

Table 11. Ironman Jr test results according to gender and sport category. Data are shown as means with 95% CI.

Fitness test	Boys (n=119)	Girls (n=47)	Team sports (n=84*)	Technical (n=37**)	Endurance (n=45***)
1500 m (n=110)	5.2 (5.0 to 5.3)	6.0 (5.7 to 6.3)	5.4 (5.2 to 5.5)	6.1 (5.7 to 6.6)	5.0 (4.6 to 5.4)
3000 m (n=56)	11.5 (11.0 to 12.0)	13 (12.2 to 13.8)	13.0 (12.1 to 13.9)	12.7 (12.0 to 13.5)	10.7 (10.2 to 11.1)
Hexagon obstacle (s)	22.2 (21.9 to 22.5)	23.1 (22.4 to 23.7)	22.2 (21.9 to 22.6)	22.7 (21.9 to 23.6)	22.6 (22.1 to 23.1)
Standing long jumps (cm)	238 (235 to 241)	215 (211 to 220)	234 (230 to 238)	230 (223 to 236)	229 (223 to 236)
Push-ups (no.)	31 (29 to 32)	21 (18 to 24)	28 (26 to 30)	23 (20 to 27)	32 (28 to 36)
Chins (no.)	7 (6 to 8)	1 (0 to 2)	5 (4 to 6)	5 (4 to 7)	6 (5 to 8)
Crunches (no.)	14 (13 to 15)	14 (12 to 15)	14 (13 to 15)	14 (12 to 15)	15 (13 to 16)
Bench jumps 90 s (no.)	79 (76 to 81)	58 (54 to 62)	74 (70 to 77)	67 (59 to 74)	76 (73 to 80)

* Boys n=57 Girls n=27 **Boys n=28 Girls n=9 ***Boys n=34 Girls n=11

Table 12. The association between injury and illness (mean number of health problems with 95% CI) comparing the least fit athletes (lowest quartile according to composite score) to the rest of the cohort. Data are based on multiple linear regression analyses, adjusted for BMI, baseline training-load, and birth-date *.

	Number of health problems (mean)		**Adjusted**	
	Least fit	**Rest of cohort**	**P-value**	**B (95% CI)**
All athletes (n=166)	**n=42**	**n=124**		
All health problems	3.7 (3.0 to 4.4)	3.6 (3.2 to 3.9)	0.62	0.18 (-0.52 to 0.87)
Illnesses	1.9 (1.3 to 2.4)	1.7 (1.5 to 2.0)	0.49	0.17 (-0.31 to 0.65)
Acute injuries	1.0 (0.6 to 1.4)	0.9 (0.7 to 1.0)	0.38	0.18 (-0.22 to 0.57)
Overuse injuries	0.8 (0.5 to 1.2)	1.0 (0.8 to 1.2)	0.37	-0.17 (-0.54 to 0.20)
Substantial health problems	2.2 (1.8 to 2.7)	1.9 (1.7 to 2.2)	0.18	0.34 (-0.16 to 0.84)
Illnesses	1.1 (0.7 to 1.5)	1.1 (0.9 to 1.2)	0.83	0.04 (-0.33 to 0.42)
Acute injuries	0.6 (0.3 to 0.9)	0.4 (0.3 to 0.6)	0.24	0.16 (-0.11 to 0.42)
Overuse injuries	0.6 (0.3 to 0.8)	0.4 (0.3 to 0.5)	0.28	0.14 (-0.12 to 0.40)
Girls (n=47)	n=12	n=35		
All health problems	4.0 (3.1 to 4.9)	4.4 (3.8 to 4.9)	0.29	-0.54 (-1.55 to 0.47)
Illnesses	2.0 (0.9 to 3.1)	2.0 (1.6 to 2.5)	0.72	-0.18 (-1.15 to 0.80)
Acute injuries	0.8 (0.1 to 1.4)	1.2 (0.8 to 1.6)	0.28	-0.43 (-1.21 to 0.36)
Overuse injuries	1.3 (0.4 to 2.2)	1.2 (0.8 to 1.5)	0.87	0.06 (-0.70 to 0.83)
Substantial health problems	2.7 (1.8 to 3.5)	2.0 (1.5 to 2.5)	0.13	0.71 (-0.21 to 1.62)
Illnesses	1.3 (0.4 to 2.1)	1.1 (0.7 to 1.5)	0.91	0.04 (-0.76 to 0.84)
Acute injuries	0.5 (0.0 to 1.1)	0.5 (0.3 to 0.8)	0.95	0.02 (-0.49 to 0.52)
Overuse injuries	0.9 (0.1 to 1.7)	0.3 (0.1 to 0.6)	0.03	0.65 (0.05 to 1.24)
Boys (n=119)	n=30	n=89		
All health problems	3.5 (2.6 to 4.5)	3.3 (2.9 to 3.6)	0.35	0.41 (-0.45 to 1.27)
Illnesses	1.8 (1.2 to 2.5)	1.6 (1.4 to 1.9)	0.42	0.22 (-0.33 to 0.77)
Acute injuries	1.1 (0.6 to 1.6)	0.7 (0.5 to 0.9)	0.06	0.44 (-0.01 to 0.90)
Overuse injuries	0.7 (0.3 to 1.0)	0.9 (0.7 to 1.1)	0.23	-0.26 (-0.68 to 0.17)
Substantial health problems	2.1 (1.5 to 2.6)	1.9 (1.6 to 2.2)	0.58	0.17 (-0.44 to 0.77)
Illnesses	1.0 (0.6 to 1.5)	1.0 (0.8 to 1.2)	0.92	-0.02 (-0.44 to 0.40)
Acute injuries	0.6 (0.3 to 1.0)	0.4 (0.3 to 0.6)	0.18	0.22 (-0.1 to 0.55)
Overuse injuries	0.4 (0.2 to 0.6)	0.4 (0.3 to 0.6)	0.82	-0.03 (-0.32 to 0.25)
Team athletes (n=84)	n=21	n=63		
All health problems	3.0 (2.1 to 3.9)	3.8 (3.3 to 4.2)	0.09	-0.83 (-1.79 to 0.13)
Illnesses	1.3 (0.7 to 2.0)	1.6 (1.4 to 1.9)	0.36	-0.26 (-0.82 to 0.30)
Acute injuries	1.0 (0.5 to 1.4)	1.1 (0.8 to 1.3)	0.63	-0.12 (-0.63 to 0.38)
Overuse injuries	0.7 (0.3 to 1.2)	1.1 (0.9 to 1.3)	0.08	-0.45 (-0.95 to 0.05)
Substantial health problems	2.1 (1.4 to 2.8)	2.0 (1.6 to 2.4)	0.81	0.09 (-0.67 to 0.85)
Illnesses	0.9 (0.5 to 1.3)	0.9 (0.7 to 1.1)	0.87	-0.04 (-0.49 to 0.41)
Acute injuries	0.7 (0.2 to 1.1)	0.5 (0.4 to 0.7)	0.55	0.11 (-0.26 to 0.48)
Overuse injuries	0.6 (0.2 to 0.9)	0.5 (0.3to 0.7)	0.93	0.02 (-0.38 to 0.41)
Technical athletes (n=37)	n=8	n=29		
All health problems	5.0 (2.3 to 7.7)	3.3 (2.5 to 4.0)	0.24	1.02 (-0.71 to 2.75)
Illnesses	2.3 (0.6 to 3.9)	1.1 (0.6 to 1.7)	0.27	0.62 (-0.50 to 1.76)
Acute injuries	2.0 (0.5 to 3.6)	0.9 (0.4 to 1.4)	0.22	0.73 (-0.45 to 1.91)
Overuse injuries	0.8 (0.0 to 1.6)	1.2 (0.8 to 1.6)	0.47	-0.34 (-1.29 to 0.61)
Substantial health problems	2.4 (1.0 to 3.7)	1.7 (1.3 to 2.1)	0.35	0.48 (-0.54 to 1.50)
Illnesses	0.9 (0.0 to 2.0)	0.6 (0.3 to 0.8)	0.48	0.25 (-0.46 to 0.95)
Acute injuries	0.9 (0.2 to 1.6)	0.6 (0.3 to 0.9)	0.84	0.07 (-0.61 to 0.75)
Overuse injuries	0.6 (0.0 to 1.5)	0.5 (0.2 to 0.8)	0.65	0.17 (-0.56 to 0.90)
Endurance athletes (n=45)	n=11	n=34		
All health problems	3.8 (2.7 to 4.9)	3.5 (2.9 to 4.1)	0.47	0.42 (-0.75 to 1.59)
Illnesses	3.2 (2.2 to 4.2)	2.3 (1.9 to 2.7)	0.06	0.86 (-0.03 to 1.74)
Acute injuries	0.4 (0.0 to 0.7)	0.4 (0.1 to 0.6)	0.88	0.04 (-0.46 to 0.53)
Overuse injuries	0.3 (0.0 to 0.7)	0.8 (0.5 to 1.2)	0.15	-0.47 (-1.12 to 0.17)
Substantial health problems	2.3 (1.3 to 3.3)	2.0 (1.6 to 2.5)	0.59	0.27 (-0.73 to 1.27)
Illnesses	2.1 (1.1 to 3.1)	1.7 (1.3 to 2.0)	0.31	0.43 (-0.41 to 1.26)
Acute injuries	0.1 (0.0 to 0.3)	0.2 (0.0 to 0.4)	0.63	-0.09 (-0.47 to 0.28)
Overuse injuries	0.1 (0.0 to 0.3)	0.2 (0.0 to 0.4)	0.65	-0.07 (-0.37 to 0.24)

*Born before or after July 1st.

Discussion

Prevalence and severity of health problems in youth elite athletes (*Paper I*)

All youth elite athletes

In *Paper I*, we documented that overuse injuries, acute injuries, and illnesses all have a substantial impact on the health of youth elite athletes. In our study, 43% of the youth elite athletes reported a health problem at any given time, while 25% reported a more substantial health problem (Table 7).

Previous epidemiological studies regarding injury and illness data in youth elite athletes are scarce (summarized in Table 2). Our findings, however, are in line with existing reports suggesting that the prevalence of health problems among youth elite athletes is high (Pluim et al., 2015; Richardson et al., 2017; von Rosen et al., 2017; von Rosen et al., 2018), frequently exceeding 40%.

Our study also suggests that when taking both severity and duration of health problems into account, not only acute injuries but also overuse injuries and illnesses have a substantial impact on the health of youth elite athletes at any given time.

Girls vs. boys

Girls reported more health problems compared to boys in our study. A female predisposition for injury and illness has likewise been documented in several other reports, concerning both youth elite athletes (Mountjoy et al., 2008; Armstrong and McManus, 2011; Richardson et al., 2017; von Rosen et al., 2017; von Rosen et al., 2018) and adults (Engebretsen et al., 2013; Soligard et al., 2015; Soligard et al., 2017). In youth athletes, however, the complete picture of injury and illness differences by sex is complex. Literature from regular high schools comparing athletes at the non-elite level has also reported boys to be at a greater risk of incurring injuries (acute) than girls (Emery et al., 2006).

Across sport categories

We demonstrated a higher average weekly prevalence of injuries in team and technical sport athletes (37% and 36%) compared to endurance athletes (15%). We also demonstrated that endurance athletes reported more illnesses (23%) compared to technical and team sport athletes

(10% and 8%) (Table 7). This is consistent with findings from previous literature: that the type of health problem reported depends on sport category (Malisoux et al., 2013; Theisen et al., 2013; Richardson et al., 2017; von Rosen et al., 2017; von Rosen et al., 2018). The same trend has been observed for adult elite athletes (Engebretsen et al., 2010; Engebretsen et al., 2013; Clarsen et al., 2014b; Soligard et al., 2015; Soligard et al., 2017) and for youth athletes at the non-elite level (Emery et al., 2006; Emery et al., 2015). Our findings also demonstrate, however, that, even though acute injuries might seem to dominate within team and technical sports, if considering both severity and duration (i.e. the cumulative severity score), overuse injuries and illnesses are likewise important across sport categories.

Despite the overall finding that injuries were more common in team and technical sports compared to endurance sports, the prevalence of overuse injuries was high across all sport categories. These results align with data from both Richardson et al. (2017) and Pluim et al. (2015). In Richardson's study, the average weekly prevalence of overuse injuries varied between 10% (female football players) and 17% (gymnastics), while youth tennis players reported a 12% average weekly prevalence of overuse injuries in Pluim's study.

The average weekly prevalence of overuse injuries did vary slightly, albeit insignificantly, among sport categories in our study. It was a little surprising that endurance athletes reported a lower average weekly prevalence of overuse injuries (12%) compared to technical- (20%) and team-sport athletes (17 %). In a previous Swedish report on youth elite orienteerers, the average weekly prevalence was 36% (von Rosen et al., 2016).

A possible explanation concerns the variety of endurance sports in our cohort, of which the majority was cross-country skiers. Another possible explanation is that our method depended on the athletes providing honest information. Youth elite athletes might continue to train and compete despite overuse injuries, and underreporting might be a concern. There is little reason to believe, however, that underreporting would be more common among the endurance athletes compared to the technical- and team-sport athletes in our cohort.

Finally, our results were in line with data on adult elite endurance athletes (mean prevalence 15%) (Clarsen et al., 2014b). Due to maturational factors, however, a higher prevalence of overuse injuries among the endurance athletes in our cohort could have been expected.

Between elite team sport athletes and teammates

Differences in prevalence and severity of health problems did not reach significant levels between elite team-sport athletes and teammates, with one exception: we observed a trend of more injuries

(37% and 23%) and more substantial injuries (22% and 10%) in the elite team-sport athlete group compared to their teammates. Likewise, the duration of acute injuries was longer, and the cumulative severity score was higher among team sport athletes attending sport academy high-schools compared to their teammates.

This finding must be interpreted with caution for several reasons. Our method is based on self-reporting of health problems and does not provide an objective measurement of injury and illness. The same kinds of health problems might have a greater impact on elite team-sport athletes' sport participation and performance compared to their teammates because this method measures the consequences of each health problem. Youth athletes attending a specialized sport academy high-school environment may experience a greater loss of daily sport activities and self-esteem when injured compared to their teammates.

Nevertheless, our findings illuminate an important issue: that youth elite athletes in a specialized sport academy high-school environment do experience that injuries and illnesses have a substantial impact on their health.

Worries across medical communities

Medical communities have expressed concern due to the high rates of severe health problems among youth elite athletes. Until recent years, however, evidence has been missing. This study documents that injuries and illnesses are common among youth elite athletes. The specialized sport academy high-school model is unique to Scandinavian countries, but youth athletic development is an area of concern around the world. Multiple youth elite athlete developmental programs exist and are applied under different names and intentions. Our findings might be of interest to all who are concerned with youth elite athletes and athletic development because it provides solid evidence on the prevalence and severity of injuries and illnesses among youth elite athletes. As such, it addresses the first step in the recommended sequence of the injury prevention research model provided by van Mechelen et al. (1992).

Early and single-sport specialization and performance level and injury/illness risk in youth elite athletes *(Paper II)*

Early and single-sport specialization

In *Paper II*, we did not demonstrate any association between a history of early single-sport specialization and injury and illness risk in youth elite athletes. Even though crude data did indicate that early and single-sport specialization were associated with an increased risk of acute injuries, the higher prevalence of acute injuries among team and technical athletes compared to endurance athletes documented in *Paper I* necessitated adjusting for sport category in our analyses. The adjusted analyses demonstrated no association between a history of early or single-sport specialization and injury and illness in youth elite athletes (Table 8).

The literature is limited regarding early single-sport specialization and risk of injury and illness. In the few studies that exist, degree of specialization has been described as positively correlated with risk of injury (Jayanthi et al., 2015; Post et al., 2017), and overuse injuries in particular (Hall et al., 2015; Myer et al., 2015e). Nevertheless, there are methodological concerns related to these studies, as previously discussed (Hall et al., 2015; Jayanthi et al., 2015; Buckley et al., 2017). Also, because a uniform definition of the term "early specialization" is not in place, comparability across studies is difficult. An interesting finding is, however, that in the case-control study by Jayanthi et al. (2015), the initiation age of specialization (early vs. late) was not associated with an increased risk of injuries. This finding is in line with ours.

Across sport categories

The age of early and single-sport specialization differed between sport categories in our cohort; team- and technical-sport athletes tended to specialize earlier and were more likely to practice a single sport from an earlier age compared to endurance athletes (Figure 5, Table 9).

Although we used sport category as an adjustment factor, we did not explore early single-sport specialization associations with health problems across all the different sports in each sports category in our population. This heterogeneity between sports within each sport category might have underpowered our model and potentially masked between-group associations.

Discussion

Study design

In order to truly understand the impact of early sport specialization, one could argue that there is a need to monitor the athletes at the time they start to specialize in a sport and that the athletes selected to attend specialized sports academy high schools in our study might be the ones who have managed to avoid injury and illness. Athletes who have sustained severe injuries due to early or single-sport specialization might have withdrawn from sports participation at an earlier age.

Nevertheless, our method aligns with the aim of our study. We did not intend to evaluate what happens to the injury/illness risk of youth elite athletes at the time when they decide to specialize in sports. For this purpose, a large prospective cohort study monitoring a large group of young athletes from a very young age through adolescence would be ideal. Due to high attrition rates in youth sports, however, such a study would be difficult to complete, and this might explain why literature is scarce on the subject.

Our aim was to compare injury and illness risk during a period of transition into an intense, elite single-sport training program at age 16 between athletes with a single-sport vs. multi-sport background and/or an early- vs. late-specialized background.

We acknowledge that our retrospective design may have underpowered true associations, and recall bias as a limitation of this study is further discussed under methodological considerations at the end of this section.

The validity of the definition

We defined early specialization as when the athlete defined one sport as being more important than other sports at or before 12 years of age. Athletes who had participated in only their primary sport during the past 2 years were classified as single-sport athletes.

As previously discussed, a major challenge within this research field is the lack of a unified consensus on the term early single-sport specialization. In our opinion, there are several important factors to consider when addressing early single-sport specialization: age (both biological and chronological), performance level, training and competition volume, organized vs. free play, and the time when the youth athlete decides to participate in one single sport exclusively. We acknowledge that we did not address several of these issues appropriately in our study (e.g. organized vs. free play, training and competition volume, and biological vs. chronological age), which represents another limitation.

Ideally, future studies should be based on a survey tool considering key factors, as mentioned. The consensus statement by LaPrade et al. (2016) on early sport specialization embraces several of the key factors. For an even more operational definition and applicable survey tool, performance level needs to be included. Furthermore, placing such a survey tool within the context of specific sports would be ideal.

Injury and illness risk in the most talented youth elite athletes

In *Paper II*, we demonstrated no overall association between injury and illness risk and a higher performance level. This result was evident in both unadjusted analyses and analyses adjusted for sex and sport category (Table 10). This was in contrast to what we expected and in contrast to what most previous studies have reported: that due to risk factors, such as training volume, match exposure, and superior physical abilities, highly skilled athletes tend to be at a greater risk of incurring injury or illness (Emery et al., 2005; Emery and Meeuwisse, 2006; Olsen et al., 2006; Johnson et al., 2009; Soligard et al., 2010a; Faude et al., 2013; Visnes et al., 2013; Bahr, 2014).

The lack of association demonstrated in our study might relate to several factors. First, in order to be selected for a sport academy high-school, athletes must have attained a high skill level in their sport. This resulted in a relatively homogenous cohort, which might have underpowered our model. As a consequence, detecting an effect of performance level on injury risk might be difficult. In *Paper I,* however, we already demonstrated a high prevalence of health problems among youth elite athletes, a finding that substantiates the data from previous literature (Emery et al., 2005; Johnson et al., 2009; Soligard et al., 2010a; Visnes et al., 2013; Visnes and Bahr, 2013; Bahr, 2014).

A second factor is the heterogeneity within the sport categories applied in our study. We included participants from 30 different sports and categorized them into endurance, team, and technical sport categories. Nevertheless, performance levels did vary among the different sports within the same sport category. This was perhaps most evident within the technical sport category, where a diverse array of technical sports was included. Also, the alpine skiers in our cohort were possibly at a higher performance level compared to the other technical-sport athletes. This heterogeneity across different sports within the same category might have underpowered our prediction model.

Types of health problems

The athletes in our study are often selected to attend both regional and national representative teams. Consequently, inappropriate training and competition programs might expose them to an increased risk of injury, demonstrated in several previous studies (Emery, 2003; Emery et al., 2005; Emery and Meeuwisse, 2006; Olsen et al., 2006; Johnson et al., 2009; Emery et al., 2010; Soligard et al., 2010a; Faude et al., 2013; Visnes et al., 2013; Visnes and Bahr, 2013; Bahr, 2014).

In our study, however, only overuse injuries were associated with a higher performance level. We detected a 30% increased risk of overuse injuries among the athletes who evaluated themselves as within the top 10% in the country. This finding is in line with previous literature (Visnes et al., 2013; Visnes and Bahr, 2013; Bahr, 2014; Pfirrmann et al., 2016), but it must be interpreted with care. In all the univariate analyses applied, there were no other consistent associations between performance level and injury and illness risk. There is a risk of Type 1 error, as we did not adjust for multiple comparisons. We also analyzed the combination of the highest performance level evaluated by both athlete and coach (36% of the athletes). Again, no association was detected between overuse injuries and the subgroup of athletes who were rated in the top-performing categories both nationally (by themselves) and in their class (by their coaches).

Validity of performance level evaluation

We did not use a validated measure of performance level; rather, we asked both coaches and athletes to assess current performance level. Athletes and coaches compared performance levels among different groups. Athletes compared their performance levels with other age-matched Norwegian athletes in their sport; coaches only compared performance levels among athletes in their training group. This can be considered a limitation of this study. In our experience, however, most youth elite athletes have a sound understanding of their own performance level based on previous competitions, matches, talent camps, etc. Consequently, the face validity of their ratings seems high. The coaches were asked to compare athletes in the same training group based on quartiles. This approach was successful, resulting in 46% of the athletes assessed as being above average and 54% below. Consequently, in our opinion, both self- and coach-evaluated performance levels served as a solid foundation for selecting the highest-performing athletes within this heterogeneous cohort, independent of the specific sport practiced.

Physical fitness level and injury/illness risk after enrollment into specialized sport academy high schools *(Paper III)*

In *Paper III*, we addressed the association between physical fitness level and injury and illness risk in youth elite athletes. When entering a specialized sport academy high-school program, training and competition volumes are often greatly increased. Such a rapid increase in training and competition load relative to what the athletes are prepared for might overload the least fit athletes. We used physical fitness tests related to endurance, strength, agility, and speed to identify the least fit quartile of athletes. Due to test-performance differences between sexes, demonstrated in Table 11, and the greater prevalence of health problems among girls demonstrated in *Paper I*, we found it necessary to examine the a priori hypothesis separately among boys and girls.

We demonstrated that the least fit girls reported more substantial overuse injuries compared to the remainder of the girls. There was also a trend wherein the least fit endurance athletes reported more illnesses compared to the rest of the endurance athletes, but this result was not significant (Table 12). Other than this, we demonstrated no difference in the number and severity of health problems reported in the least fit athletes compared to the rest of the cohort.

These findings must, however, be interpreted with caution. First, as this was not a confirmatory study, we did not adjust for multiple comparisons, and there is a risk of Type 1 error. Second, due to the reduced sample size in the stratified subgroup analyses, statistical power is limited, which means that true relationships may be overlooked (Type 2 error).

Physical fitness level

We used physical fitness testing to provide a measure of general physical fitness levels among youth elite athletes. In our study, however, a lower level of physical fitness was not associated with an increased risk of injury and illness.

A consistent finding in the literature is that exercise-based injury-prevention programs reduce injury risk. Whether this is as a result of increased physical fitness is uncertain (Rössler et al., 2014). Nevertheless, it seems reasonable to believe that stronger and fitter youth athletes would be better prepared to withstand the high training and competition load applied after enrollment into specialized sport academy high schools compared to less fit athletes. Some reports support this, suggesting associations between specific fitness components, such as core or leg strength or endurance, and injury risk (Frisch et al., 2011; Raschner et al., 2012; Chalmers et al., 2013; Moller et al., 2017; Muller et al., 2017). Nevertheless, these reports are sport and injury specific. In contrast, we included 30 different sports, capturing both injuries and illnesses, and evaluated overall fitness levels. Consequently, in our study, methods and participants differ from those used in previous studies.

In line with our results, a lack of association between pre-seasonal physical fitness tests and injury risk has been previously reported in studies on youth elite football players from Canada, England, and Luxembourg (Emery et al., 2005; Frisch et al., 2011; Newton et al., 2017).

Based on this, it seems that previous data show inconsistent results, and it may be argued that when assessing injury and illness risk in youth elite athletes, physical fitness level is not a key factor. It is also possible, however, at least in our study, that a ceiling effect is introduced because of the relatively homogenous group of youth elite athletes participating, wherein all have attained a high level of physical fitness.

A rapid increase in training and competition load

We evaluated the association between physical fitness level and health problems in youth elite athletes. We did not intend to evaluate workload. Nevertheless, a rapid increase in workload might be considered a factor of great importance when addressing injury and illness risk in this population.

The athletes in our study reported previous years' training and competition volumes. This was used only as an adjustment factor in our study and was not considered an accurate measurement of previous workload (*Papers II and III).* If we had better addressed baseline and prospective workload, we could have established the exact increase in training and competition load. In light of today's knowledge on acute vs. chronic workloads, we consider this a limitation of our study.

In a previous report, a large increase in weekly handball load was associated with an increase in shoulder injuries in young elite handball players (Moller et al., 2017). Likewise, a high acute to chronic training load ratio has been associated with injury in female adolescent football players (Watson et al., 2016). In these reports, it was the sudden increase in acute training load, which we did not evaluate, that was associated with an increased injury risk. In the same studies, chronic workload was not considered a risk factor for injury. This is more in line with our findings.

Physical fitness testing

Face validity

A limitation of our study concerned the unknown reliability and validity of the test-battery that we applied. Still, face validity was high: the test-battery clearly evaluated physical fitness measures (endurance, upper and lower body strength, agility, coordination, and speed) that are generally agreed to be essential when practicing a variety of sports.

Demands and physical characteristics vary considerably between dissimilar sports, depending on sport-specific performance requirements. This also accounts for the characteristics of the training regimes traditionally used among different sports. Nevertheless, no sport-weighted scoring system was available for the physical fitness test applied. Moreover, for the purposes of the present study, we did not aim to provide a measure of sport-specific performance or fitness; rather, we aimed to provide a measure of the general physical fitness level of the athletes. Our own data also indicated that on the group level, the tests distinguished between boys and girls and between sport categories for factors expected to differ (Table 12).

The relevance of the separate tests may differ among sports and sport categories, and a washout effect is possible. To adjust for this, we did stratify by sport category. We also explored the relationship between separate tests and health outcomes within each sport category. This failed to provide further information. Given the challenges presented by multiple testing, we refrained from including these results.

Finally, we used a composite score to distinguish between the least fit quartile of athletes vs. the rest of the cohort. The composite score weighted all tests equally. Nevertheless, some athletes might have been more familiar with the test-battery applied, possibly performing better on the tests and introducing the problem of a less valid composite score based on test results.

Timing

We performed all physical fitness tests in the month of August. This might have affected our results in various ways. First, as both summer and winter sports were included in our study, some athletes were tested in-season and some during pre-season. Pre-season athletes might attain higher levels of physical fitness compared to in-season athletes. Nevertheless, both pre-season and in-season athletes and sports were distributed across all sport categories. Also, pre-season training in youth elite athletes is not always a priority. Second, physical fitness in August might not be associated with injuries two months later. This applied to all participants on equal terms, however, and a selection bias in either direction due to the timing of the physical fitness tests is unlikely.

Maturation

Physical fitness during maturation is a challenging issue. As discussed more thoroughly in the introduction part of this thesis, both aerobic and anaerobic qualities improve during maturation. Aerobic fitness rises almost linearly between 8 and 18 years of age. Although we adjusted for chronological age, we did not adjust for maturational age. Diversities in biological maturation represent a major challenge in youth sport, and a selection bias of athletes placed in the least fit quartile toward late developers with poorer endurance, muscle strength, and power may have related more to maturational level than to a lower level of physical fitness (McKay et al., 2016).

Methodological considerations and limitations (*Papers I, II, III*)

Finally, there are some general methodological considerations that might have had an impact on the results of this study:

First, a surveillance study might increase awareness of health problems, possibly overestimating the outcomes.

Second, the investigators contacted the athletes suffering from recurrent health problems with medical advice, possibly affecting the outcomes of the study.

Third, athletes with long-term injury (e.g., ACL injury) or illness (e.g., mononucleosis) were possibly less willing to report weekly consequences for sports participation (due to response fatigue), possibly underestimating their results.

Fourth, all injuries and illnesses were reported, whether they occurred during training and competition or not, possibly overestimating the results by including injury/illness problems unrelated to sports.

Fifth, a lack of medical knowledge renders self-reporting of health problems difficult. It is difficult for adult athletes, and may be even more so for adolescents, to differentiate between acute and overuse injuries, between new subsequent injuries and recurrent subsequent injuries, and between illnesses of new etiology vs. exacerbations. Consequently, health problems might have been incorrectly categorized. Nevertheless, both contact between investigators and athletes during the prospective study and retrospective interview data were used to minimize this bias.

Sixth, one could argue that a duration of 26 weeks allows insufficient time for overuse injuries to occur. Because we used a prevalence measure rather than an incidence measure, however, all health problems were captured, including preexisting health problems as well as longer-lasting injuries, such as overuse injuries (Clarsen et al., 2013). Also, because we used the cumulative severity score as an outcome, the possibility of underestimating longer-lasting health problems was reduced.

Finally, the validity of both the performance level evaluations and the physical fitness tests represents a methodological consideration. This is further discussed in the previous discussion section for each paper.

Discussion

Recall bias

The most important limitation of our study concerns the low average compliance in the prospective study (mean 66%). This resulted in the implementation of retrospective interviews, which obviously introduces the problem of recall bias regarding study outcomes (*Papers I, II, and III).* Recall bias related to the supplemental interviews was minimized, however, by taking advantage of the available prospective datasets as well as the training diaries and competition schedules for each sport during the interviews. In our experience, all health problems lasting for more than 1-2 weeks were easily recalled by the athlete, especially when training camps, competitions, holidays, or personal major events were involved or affected.

Recall bias is also a concern regarding previous training load. In our experience, however, these young athletes were very cognizant of their training schedules, and most had an adequate sense of their training and competition load. Additionally, previous training load was not evaluated as an exact number but was only used as an adjustment factor.

Finally, recall bias is a concern regarding the principal exposure variables in *Paper II* (previous sports practiced and age of specialization). To minimize recall bias, we listed several sports, related the different sport disciplines to different school grades, and gave them multiple-choice alternatives. Again, it was clear in our experience that this group of youth athletes were organized with regard to which sports they had been practicing, at what times, how much, and when they decided to specialize in their primary sports.

Selection bias

A selection bias was possibly introduced at baseline because 18% of the athletes were absent due to international competitions when school started in August. These athletes were possibly some of the most talented athletes, with an increased risk of injury and illness through inappropriate training and competition programs, as addressed in *Paper II*. This introduces a selection bias that may have limited our opportunity to suggest associations between performance level and injury/illness risk.

A selection bias might also have been introduced when coaches failed to evaluate 49 of the participants. Among the athletes that the coaches failed to evaluate, however, 75% evaluated themselves as within the top 10% vs. 66% in the entire cohort. Additionally, neither sport category nor sex distribution was different between athletes evaluated by coaches and those not. Consequently, a selection bias in either direction based on this is unlikely. The proportions of athletes rated in each of the four risk-factor categories, as well as missing numbers, are presented in Table 12.

Previous injuries

We did not adjust for previous injuries, which is a limitation of our study. In previous literature, previous injury represents one of the few consistent internal risk factors for new injuries (Table 3) (Emery, 2003; Bahr and Krosshaug, 2005; Emery et al., 2005; Emery et al., 2006; Meeuwisse et al., 2007). In our study, previous injury can be considered a source of both selection bias and confounding bias: a selection bias between included and excluded athletes in all papers and a potential confounding factor, affecting both the independent variable (i.e. performance level in *Paper II* and level of physical fitness in *Paper III*) and the number and severity of health problems (outcome) in all papers.

Previous injuries were, however, equally distributed between included and excluded athletes in *Paper III* (85% in both), as well as between the least fit quartile (79%) compared to the rest of the cohort (88%) in this paper. Thus, a selection or confounding bias in either direction seems less likely.

Statistical considerations

Concerning the multiple testing procedures, there is a risk of Type I error in *Papers II and III.* We believe, however, that strict control of Type I error rates is necessary only for confirmatory analyses. The analyses in these articles were exploratory, and the aims were not to confirm or reject hypotheses but to suggest associations that might be of interest. We are therefore careful in our interpretations of the results, in light of the number of statistical tests and estimations, to account for the possibilities of false positive findings.

We dichotomized the results of the independent variables in *Papers II and III* and applied linear or median regression analyses to evaluate associations between the two. By creating two groups, we avoided the problem of trying to estimate the shape of the effect of the risk factor (e.g., age at specialization or fitness) as a continuous variable, which was likely to be non-linear. The power to estimate a non-linear curve would be very low in the subgroups, and gender and sport adjustments (*Paper II*) or stratification (*Paper III*) would have to be used in any case. This would not eliminate or reduce the risk of overfitting or too low power.

In all regression analyses performed between the four candidate risk factors and outcomes in *Paper II*, their lack of association was evident in both adjusted and unadjusted analyses.

Because of this lack of association, we did not perform a multivariate analysis including all the candidate risk factors. Moreover, we did not proceed with and report on more complex modeling of the data because, in our opinion, this would have led to an unnecessary increase in the number of analyses and statistical comparisons.

In *Paper III*, we elected to create two groups based on quartiles rather than treating fitness variables as continuous. This categorization of a continuous variable can result in significant loss of data and underpowered prediction models potentially masking other associations (also relevant in *Paper II*). Nevertheless, the dichotomization of the fitness variable most closely related the variable to the research question. A priori, we did not intend to investigate if there was a linear association between level of physical fitness and number or severity of health problems because, from clinical experience, this did not seem to be the most relevant question.

Conclusions

1. The magnitude of health problems is high among youth elite athletes newly enrolled into specialized sport academy high-schools. The average weekly prevalence of health problems was 43% (95% CI 37% to 49%), and that of substantial problems was 25% (95% CI 20% to 31%). Endurance athletes reported more illnesses, while technical- and team-sport athletes reported more injuries. Elite team-sport athletes reported a higher prevalence of substantial injuries compared to their teammates. The severity and duration of health problems were evenly distributed between overuse injuries, acute injuries, and illnesses among youth elite athletes.

2. There was no association between injury and illness risk and a sport history of early and single-sport specialization or current performance level in youth elite athletes attending specialized sport academy high-schools.

3. Among youth elite athletes newly enrolled into a specialized sport academy high-school environment, the least fit athletes were not at an increased risk of incurring injury or illness after enrollment.

Future perspectives

Future studies must be appropriately rooted within the sport-specific population of interest (e.g., specialized sport academy high schools, coaches, specific sport federations, athletes, and parents).

Youth athletes need to acknowledge the extent of the problem in order to be interested in preventative work. For successful acknowledgment within this group, the beliefs of coaches and parents and other potential barriers need to be addressed and dealt with.

Pronounced and detailed management strategies for both preventative and rehabilitation work through addressing all major platforms surrounding the youth athlete are necessary.

Approaching youth athletes throughout the school year, in order to help and guide youth athletes prospectively, seems to be of utmost importance.

Simple precautions, like easily accessible sinks and soap, are mandatory in illness preventive work, as are complete training and competition diaries to collect the overall picture of training and competition load, which is also useful for addressing the total burden of all life events.

The total psychosocial impact of life must be considered, as it is not only training and competition that might increase the youth athletes' risk of incurring injury and illness; other stressful life events also need to be acknowledged and addressed.

Early single-sport specialization remains poorly defined. A unified definition as well as continued research on the subject is necessary to provide a safe and healthy environment for youth athletes. Both clinical surveillance studies and basic science considering tissue properties of maturing athletes would be valuable (DiFiori et al., 2014; Myer et al., 2015a; LaPrade et al., 2016; Myer et al., 2016; Buckley et al., 2017). Guidelines also need to be sport specific.

It is important to recognize the busy schedules of youth elite athletes at the highest performance levels. Partaking in several national and international training camps and competitions is potentially counterproductive (Bjorndal et al., 2018). Educating youth elite athletes on balancing training and competition scheduling, family and friends, and school and recreational activities seems important (Côté et al., 2009; Bjorndal et al., 2018).

Sport diversity and deliberate play are important at young ages in preventing burnout, psychological stress, and high attrition rates across all sports. The seven postulates associated with the Long-Term Athlete Development model can be used when striving to achieve performance, participation, and personal development at the highest level possible for all youth partaking in sports. Or, as stated by a famous coach in the National Hockey League in a Washington Post article:

"Let your kids be kids. Let them enjoy all the sports. If they are meant to play pro ball...their natural ability will one day allow them the opportunity."

Doug Carpenter

"...it's not where you start that matters, it's where you finish"

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ORIGINAL ARTICLE

WILEY

The prevalence and severity of health problems in youth elite sports: A 6-month prospective cohort study of 320 athletes

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Little is known regarding the overall health of youth elite athletes. Our aim was to describe the prevalence and severity of health problems in a cohort of youth elite athletes representing a variety of endurance, team, and technical sports. Elite sport athletes (N = 260, 16.2 years) from different Sport Academy High Schools in Norway, and a group of their teammates (N = 60, 16.4 years) attending regular high schools, were included in the study. The Oslo Sports Trauma Research Centre (OSTRC) questionnaire on health problems was used to self-report injuries and illnesses for 26 weeks. At any given time, an average of 43% [95% CI: 37%-49%] of the elite sport athletes had some form of health problem and 25% [20%-31%] had substantial health problems. The prevalence of health problems was similar between the elite team sport athletes and their teammates, except for substantial injuries (22% [16%-30%] vs 10% [5%-20%]). Endurance sport athletes reported more illnesses (23% [15%-35%]) than technical and team sport athletes (10% [5%-20%] and 8% [4%-14%]). In contrast, technical and team sport athletes reported more injuries (36% [95% CI: 25-48] and 37% [95% CI 29-45]) compared to endurance sport athletes (15% [8%-25%]). The total impact of health problems was roughly split in thirds between overuse injuries (37%), acute injuries (34%), and illnesses (30%). This is the first prospective study to present self-reported injury and illness data in a large heterogeneous group of youth elite athletes, documenting a substantial impact of both injuries and illnesses on the health of this population.

KEYWORDS
adolescents, epidemiology, Illness, injury prevention, overuse injuries, sport academy high school, sporting injuries, subelite athletes

1 | INTRODUCTION

The health advantages of youth sports participation are well recognized. However, a relevant question is whether the health benefits of youth sport at an elite level are outweighed by the risk for injury and their potential long-term sequelae. Early single-sport specialization, early talent identification, overscheduling, and increasing training loads at an early age represent potential risk factors for injury or illness, possibly related to a short-term focus on performance.[1,2]

In recent years, there has been an increased focus on health monitoring and mapping of injuries affecting elite athletes.[3-5] Health surveillance programs have been established during major international competitions at the senior level,[4,6-12] and the value of monitoring elite athletes' health outside of major competitions has become increasingly recognized.[13-15] Unfortunately, this is not yet the case for the next-generation athletes, where the prevention of injury and illness has received less attention, in particular in out-of-competition periods.[3] Previous studies tend to be small or most often specifically related to only one sport, and until recently, most reports do not take the voice of the youth athlete into account.[16-24] The International Olympic Committee has recently published a consensus statement on this issue in an effort to promote a more unified and evidence-informed approach toward the medical care of youth elite athletes.[25,26]

Monitoring the overall health of elite athletes over-extended periods of time outside of major competitions is the first step in the care pathway, for both adult and adolescent athletes.[13,15] In this study, we used a recently developed method, useful for evaluating a wide array of health problems in a cohort representing multiple sports,[13,15] focusing on the young athlete's own experience of their health, and how it influences on their training, participation, and performance over time. Our aim was to describe the prevalence and severity of health problems in a cohort of young elite athletes representing a variety of endurance, team and technical sports, a group of their subelite teammates, as well as 16-year-old adolescents not participating in competitive sports.

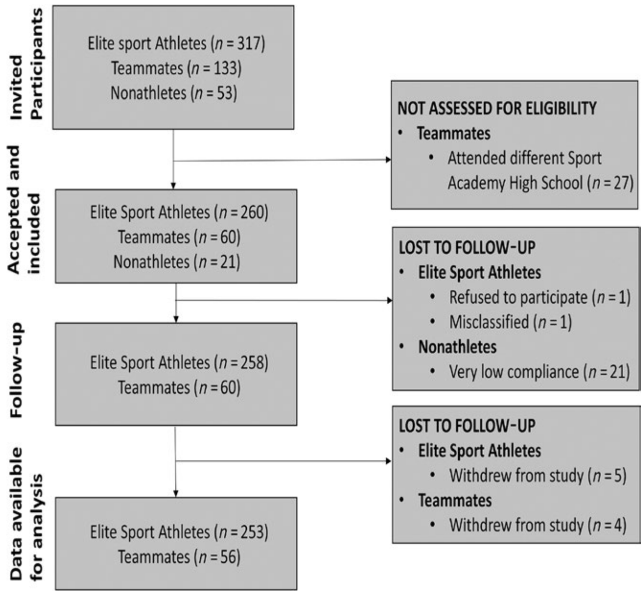

FIGURE 1 Study flowchart showing the number of participants invited, included, and analyzed

2 | METHODS

2.1 | Participants and recruitment

This cohort study involved 15- and 16-year-old boys and girls, enrolled in specialized Sport Academy High Schools in Norway (elite athlete group). A large proportion of these students are members of regional and national representative teams, and they all compete for sports clubs not affiliated with their sports high schools. All first-year students in three selected Sport Academy High Schools in Norway were invited to join the study, 82% accepted to participate (Figure 1). Thirty different sport disciplines were represented and categorized into three major categories (endurance, technical, and team sports) in accordance with a previous study on health problems in a heterogeneous group of athletes (Table 1).[15] We also invited a sample of teammates, playing on the same teams as the elite team sport athletes, but attending regular high schools and a convenience sample of nonathletes attending regular high school. The teammates were mostly at a slightly lower athletic level compared to the Sport Academy High School students, and thus considered a subelite group. In the subelite group, 133 athletes were invited to participate, but 27 of them attended other Sport Academy High Schools than the three we selected and could not be included. Of the 106 eligible athletes in the teammate group, 60 were included (56%). In the nonathlete group, 53 students were invited and 21 accepted to participate (Figure 1). Ninety-three percent of the teammates and 97% of the elite athletes completed the 26-week study. The nonathlete group was excluded from the study because of low compliance.

TABLE 1 Different sport disciplines in the Sport Academy High School group, categorized into three major categories

Endurance sports (n = 69)	Technical sports (n = 62)	Team sports (n = 129)
Athletics (3)	Athletics (4)	Basketball (9)
Biathlon (17)	Alpine skiing (10)	Floorball (7)
Cross-/Cycling (11)	Badminton (2)	Handball (38)
Cross-country skiing (18)	Climbing (3)	Ice hockey (31)
Nordic combined (3)	Fencing (1)	Soccer (40)
Orienteering (4)	Freeski (8)	Volleyball (4)
Paddling (3)	Golf (3)	
Swimming (10)	Gymnastics (3)	
	Luge (4)	
	Martial arts (6)	
	Motocross (3)	
	Sailing (4)	
	Skeleton (1)	
	Ski jumping (6)	
	Snowboard (2)	
	Tennis (2)	

Values represent the number of athletes in each sport.

Before initiating the study, we held meetings with the management of the schools to engage their support and to improve the chances of implementation of future recommendations based on our findings. Through school meetings, verbal and written information was given to the students and their parents about the purpose of the study, the importance of athlete commitment, and the procedures of the study. The same information was given to the teammates and their coaches during training sessions and by telephone. Parents of teammates were not present at these meetings.

The study was approved by the Norwegian Data Inspectorate (No. 38888) and reviewed by the South-Eastern Norwegian Regional Committee for Research Ethics (2014/902/REK Sør-Øst). Informed consent was obtained from the athletes and from the parents of those under 18 years.

2.2 | Data collection procedures

The study consisted of two main parts: (i) A prospective cohort study conducted from 1 August 2014 through 31 May 2015 and (ii) Supplemental interviews at the end of the study period (May/June 2015). Within 2 weeks of inclusion in the study (August-October 2014), all participants completed a web-based questionnaire which collected information on their anthropometrics, medical and sporting history, previous competition and training loads and performance level. The baseline questionnaire also included the Oslo Sports Trauma Research Center questionnaire on health problems (OSTRC questionnaire; [13,15]) covering the previous week.

2.3 | Prospective data collection

A smartphone application (Spartanova N.V., Gent, Belgium) was installed and used by the participants for weekly submission of the OSTRC questionnaire, training, and competition hours and days of time loss from training and/or competition. The questionnaire was distributed to participants every Sunday from 30 October 2014 until 3 May 2015 (26 weeks). Reminders were sent to nonresponders after 2, 4, and 6 days, both automatically through the application and manually through SMS by the principal investigator. During the registration period, we had regular contact with athletes, the school boards, and all principal coaches.

2.4 | Supplemental interviews

To supplement missing data from the prospective weekly registration and verify the accuracy of the prospective data, we conducted interviews at the end of the study period (May/June 2015). We interviewed all available participants still included in the study. All athletes brought their training diaries to the interview; we used all available prospective health data and we registered all major competitions in the interview form beforehand. One OSTRC questionnaire was completed for every health problem registered during the 26-week period, with the questionnaire responses applied to the entire duration of the problem. Most interviews were conducted in person at school or during a training session, in some cases by telephone.

During the athlete interviews, prospectively reported data were reviewed and quality controlled, and missing data were supplemented using interview data.

2.5 | OSTRC questionnaire on health problems; Registration of injury, illness, time loss, training, and competition hours

The OSTRC questionnaire consisted of four graded key questions about sport participation, training volume, performance, and health problems experienced during the previous 7 days (Clarsen et al 2014). Health problems were defined as all injuries and illnesses, regardless of severity and consequences. We did not specify that injuries had to be sports-related. We also specified that sadness, depression, anxiety, and feeling troubled could be registered as an illness. The responses to each of the four questions were allocated a numerical value from 0 to 25, were 0 represented no problems and 25 represented the maximum level for each question. The four response values were summed to calculate a severity score from 0 to 100 for each health problem. In sum, the OSTRC questionnaire records the consequences of the athlete`s health problems during the last week, as well as to what extent they had experienced symptoms. If the lowest score on each of the four key questions was recorded (no health problems or symptoms reported), the questionnaire was complete for that week. However, if any health problems were reported, athletes were asked to define whether the problem was an injury or an illness. In the case of an injury, they were asked to classify it as an acute injury (sudden event after for instance falling or a tackle) or an overuse injury (no particular injury situation) and thereafter to record the anatomical location of the injury. If illnesses were reported, athletes were asked to select the main symptoms they had experienced during the past week.[13] Multiple predefined symptoms could be registered. For both injuries and illnesses, they reported the number of whole days of time loss to training or competition the past week (defined as total inability to train or compete). In cases of multiple health problems during the same week, the questionnaire repeated itself up to four times. Participants were instructed to report all health problems every week, regardless of whether or not the problem had been registered the previous week. The total number of training and competition hours per week (0-25 hours) was added to the validated OSTRC questionnaire and recorded during the period.

2.6 | Data collection and classification

If an athlete reported the same health problem for more than 4-6 weeks, the principal investigator contacted the participant by telephone (call or SMS), to evaluate the extent of the health problem and suggest that further medical treatment was sought. If necessary, further follow-up by a physician or a physiotherapist at the Norwegian Olympic Training Center or with the school nurse was organized.

All participants and their parents could contact the principal investigator for medical advice through SMS or telephone calls at any time during the study.

In December 2014, we offered a small financial incentive (30€ gift card) to all participants that had reported every week since October.

Health problems were classified as an injury if affecting the musculo-skeletal system or concussions[13] and as an illness if affecting other organ systems such as respiratory, gastrointestinal, cardiac, dermatological, and psychological systems, as well as unspecified or generalized symptoms such as fever, dizziness, or fatigue. Injuries were further categorized into acute and overuse as reported by the athlete. An acute injury was defined as one which onset could be linked to a specific injury event, such as falling or being tackled, whereas overuse injuries were those that could not be linked to a single clearly identifiable event.[27] Illnesses were coded according to organ system affected.[15]

2.7 | Prevalence, severity, and relative impact of injury and illness

To calculate the prevalence of any and substantial health problems, we followed the methodology of Clarsen et al[13] Prevalence measures were calculated by dividing the number of athletes reporting any health problem by the number of questionnaire respondents for each week of the study. We calculated prevalence numbers for illness and injury (acute and overuse) and for subgroups of athletes (technical athletes, endurance athletes, team sport athletes, teammates, males, and females) for all health problems as well as for substantial health problems within these same categories. Substantial health problems were defined as those problems leading to moderate or severe reduction in training volume or performance, or complete time loss from sport. All prevalence measures are presented as proportions with 95% confidence interval [95% CI], averaged over the study weeks. We excluded data from the first 2 weeks of the prospective study (week 43 and 44), in accordance with previous recommendations[13] and also because we did not collect information from these weeks in the retrospective study.

Each week, we calculated a severity score from 0 to 100 for each of each health problem based on athletes' responses to the four key weekly questions.[13] At the end of the study, the cumulative severity score of each case was calculated by summing the score for every week it was reported. The average severity score was calculated for each case by dividing the cumulative score with the number of weeks that the health problem was reported.

In the case of injuries, where the same diagnosis was interspersed with periods of apparent recovery, the retrospective interview data were used as a backup check, to determine whether the problem should be considered as exacerbations of an unresolved problem or a recurrence of a fully recovered problem (re-injury/new injury) in accordance with the definitions by Fuller et al[27] Illnesses were treated in the same fashion, with repeated conditions in the near longitudinal period (close proximity) treated as a single case for the purpose of severity and duration analysis.[13]

To assess the relative impact from illnesses and injuries (acute and overuse) to the athletes` health, we summed the cumulative severity scores for these different types of health problems and the proportions of the three were determined.

2.8 | Statistical analysis

The sample size was based on previous studies by Clarsen et al[13,15] With 80% power and 5% significance level ($\alpha = 0.05$), the estimated number of main participants (n = 300) and subgroups (n = 50-100) exceeded the previous power calculation for these studies and was considered sufficient in this study as well, using the same methodology.

Our study design allowed for four different sets of group comparisons. We explored the differences between athletes and nonathletes (baseline prevalence only), elite team sport athletes and their teammates, endurance sport athletes vs technical sport athletes vs team sport athletes as well as between genders.

Potential group differences in baseline data were tested with t tests for continuous variables and Pearson chi-squared (or Fisher's mid-P) tests for dichotomous variables.

Differences in demographic variables between sporting groups were assessed using *t* tests for continuous variables and chi-square tests for categorical variables. To assess differences in prevalence of all health problems and substantial health problems between sporting groups, we used chi-square tests. We considered modeling changes over time; however, crude data analyses revealed only minor and inconsequential changes over time, and because our interest was limited to group averages over the entire period, we only analyzed summary measures of prevalence, not individual weekly prevalence. In addition, the inclusion of retrospective data into the prospective data decreased the precision of weekly estimates, which contributed to our decision to analyze summary prevalence measures.

To assess differences between groups in the duration and severity of health problems, we used Mann-Whitney *U* tests due to data skewness regarding both duration and cumulative severity data.

3 | RESULTS

3.1 | Participants

Baseline characteristics are shown in Table 2. In the elite sport athlete population, the majority were boys (68%), while

TABLE 2 Baseline characteristics of the participants

	Endurance sports (n = 69)		Technical sports (n = 62)		Team sports (n = 129)		Team sport teammates (n = 60)	
	Males	Females	Males	Females	Males	Females	Males	Females
Gender, n (%)	46 (67%)	23 (33%)	43 (69%)	19 (31%)	89 (69%)	40 (31%)	29 (48%)	31 (52%)
Age (yr), mean (SD)	16.2 (0.3)	16.1 (0.3)	16.2 (0.3)	16.2 (0.4)	16.2 (0.3)	16.2 (0.3)	16.6 (0.9)	16.2 (1.6)
Height (cm), mean (SD)	179 (6.9)	168 (4.9)	178 (6.7)	165 (6.7)	180 (6.7)	170 (6.7)	180 (5.5)	170 (5.6)
Body mass (kg), mean (SD)	67 (8.4)	59 (7.9)	67 (8.8)	57 (7.9)	72 (8.6)	61 (7.3)	71 (9.3)	60 (7.8)

the gender split was more even among teammates (48% boys). Age was similar between all athlete groups, while boys were taller ($P < .001$) and had greater body mass ($P < .001$) than girls.

3.2 | Sports history at baseline

Table 3 describes the sports background of all athletes by sports group and gender. Most athletes started playing their sport at an early age (team sports earlier than endurance sports and technical sports, $P < .001$) and the majority had decided to specialize in their sport by the age of 14 years. About 60% of all team sport athletes reported that during the previous 2 years, they did not play any other sports. In contrast, 76% of the endurance sport athletes played at least one other sport ($P < .001$).

Most of the athletes reported a high weekly training and competition load the year before the baseline registration, for the elite team sport athletes higher than their teammates ($P = .049$). The total weekly training and competition load was 11-15 hours for 47% of the elite sport athletes, while 25% reported training ≥16 hours.

The athletes also reported participation at a high-performance level; 37% of the elite sport athletes reported international participation (junior or senior national team) compared to 12% of the teammates ($P < .001$). Also, almost half (44%) of the elite sport athletes rated their performance as top 5% nationally, compared to 17% among teammates ($P < .001$).

3.3 | Prevalence of injury and illness at baseline

At baseline, more than 60% of all athletes in all groups reported having a current health problem ($P = .32$ between groups) (Table 4). Substantial health problems were reported by 24% of the elite athletes and adolescent controls and 30% of the teammates. There was no difference between sports groups ($P = .29$) or between genders ($P = .94$) (Table 4).

3.4 | Response to the weekly questionnaires

Prospectively, the response rate was 66% on average through all weeks for the elite sport athletes and 50% for the teammates. We interviewed 99% (n = 251) of the elite sport athletes and 55% (n = 31) of the teammates still included in the study. Thereafter, prospectively reported data were supplemented using interview data. This process resulted in a response rate of 99.4% from the elite sport athletes (adjusted for withdrawals (n = 5) during the period). The prospective data accounted for 66% and the supplemental interview data for 34% of the total registrations. For the teammates, the new total response rate was 82%, adjusted for withdrawals (n = 4), 61% prospective data and 39% supplemental interview data.

3.5 | Prevalence of injury and illness symptoms throughout the year

As shown in Table 5, the average weekly prevalence of all health problems was 43% [95% CI: 37%-49%] among elite sport athletes, with a prevalence of substantial health problems of 25% [95% CI: 20%-31%]. The differences between prospectively collected data and interview data were minimal for all health problems (44% [95% CI: 37%-52%] vs 40% [95% CI: 31%-51%]) and for substantial health problems (23% [95% CI: 17%-30%] vs 28% [CI: 20%-38%]). The maximum number of registered health problems per athlete per week was three. Health problems were more common among girls than boys ($P = .034$), while no significant gender difference was detected for substantial health problems ($P = .08$) (Table 5).

Endurance sport athletes reported a higher prevalence of illnesses compared to technical ($P = .035$) and team sport athletes ($P = .002$). In contrast, these groups reported a higher prevalence of injuries than did endurance sport athletes ($P = .006$ and $P = .001$ vs technical and teams sports, respectively). The prevalence of overuse problems did not differ between sports groups ($P = .47$).

TABLE 3 Sports history at baseline

	Endurance sports (n = 69)[a]		Technical sports (n = 62)		Team sports (n = 129)		Team sport teammates (n = 60)	
	Males (n = 46)[a]	Females (n = 23)	Males (n = 43)[a]	Females (n = 19)	Males (n = 89)[a]	Females (n = 40)[a]	Males (n = 29)[a]	Females (n = 31)[a]
Age at primary sport debut								
≤8 yr	17 (37%)	14 (61%)	27 (63%)	11 (58%)	77 (87%)	28 (70%)	19 (66%)	24 (77%)
9-12 yr	20 (44%)	8 (35%)	13 (30%)	5 (26%)	11 (12%)	11 (28%)	9 (31%)	6 (19%)
13-15 yr	8 (18%)	1 (4%)	3 (7%)	3 (16%)	1 (1%)	1 (3%)	0 (0%)	0 (0%)
Age at specialization[b]								
≤10 yr	3 (7%)	0 (0%)	8 (19%)	2 (11%)	21 (24%)	5 (13%)	7 (24%)	5 (16%)
11-12 yr	4 (9%)	7 (30%)	12 (28%)	6 (32%)	23 (26%)	11 (28%)	8 (28%)	8 (26%)
13-14 yr	27 (59%)	6 (26%)	19 (44%)	8 (42%)	40 (45%)	16 (40%)	6 (21%)	14 (45%)
15-16 yr	12 (26%)	10 (44%)	4 (9%)	3 (16%)	5 (6%)	8 (20%)	8 (28%)	4 (13%)
Playing other sports 2 previous years								
No other sport	8 (17%)	8 (35%)	18 (42%)	10 (53%)	59 (66%)	19 (48%)	14 (48%)	23 (74%)
1 other sport	10 (22%)	1 (4%)	5 (12%)	4 (21%)	10 (11%)	11 (28%)	6 (21%)	1 (3%)
2 other sports	12 (26%)	10 (44%)	8 (19%)	3 (16%)	8 (9%)	5 (13%)	5 (17%)	4 (13%)
≥3 other sports	15 (33%)	4 (17%)	11 (26%)	2 (11%)	9 (10%)	4 (10%)	4 (14%)	2 (6%)
Average training load previous year (h/wk)								
>20 h	3 (7%)	5 (22%)	1 (2%)	5 (26%)	2 (2%)	0 (0%)	2 (7%)	1 (3%)
16-20 h	6 (13%)	3 (13%)	11 (26%)	0 (0%)	26 (29%)	2 (5%)	3 (10%)	4 (13%)
11-15 h	30 (65%)	9 (39%)	21 (49%)	9 (48%)	36 (40%)	18 (45%)	15 (52%)	11 (36%)
6-10 h	5 (11%)	6 (26%)	9 (21%)	4 (21%)	22 (25%)	20 (50%)	8 (28%)	9 (29%)
0-5 h	2 (4%)	0 (0%)	1 (2%)	1 (5%)	3 (3%)	0 (0%)	1 (3%)	6 (19%)
Current competition level								
International	4 (9%)	8 (35%)	21 (49%)	13 (68%)	33 (37%)	17 (43%)	0 (0%)	7 (23%)
National level	40 (87%)	15 (65%)	33 (77%)	15 (79%)	66 (74%)	30 (75%)	10 (35%)	14 (45%)
Performance level								
Top 5% nationally	21 (46%)	10 (44%)	24 (56%)	13 (68%)	40 (45%)	7 (18%)	5 (17%)	5 (16%)

Data are shown as numbers with percentages.
[a]Number of athletes at baseline.
[b]At which age they decided to focus on their sport.

TABLE 4 Baseline prevalence of all health problems and substantial health problems reported during the past 7 days, as well as for subcategories of illness and injury in each subgroup of athletes

	Elite Sport Athletes (n = 260)						Team sport team-mates (n = 60)	Adolescent controls (n = 21)
	All (n = 260)	Males (n = 178)	Females (n = 82)	Endurance sports (n = 69)	Technical sports (n = 62)	Team sports (n = 129)		
All health problems								
Total	155 (60%)	105 (59%)	50 (61%)	41 (59%)	33 (53%)	81 (63%)	37 (62%)	16 (76%)
Illness	49 (19%)	31 (17%)	18 (22%)	21 (30%)	11 (18%)	17 (13%)	12 (20%)	8 (38%)
Injury	106 (41%)	74 (42%)	32 (39%)	20 (29%)	22 (36%)	64 (50%)	25 (42%)	8 (38%)
Substantial health problems								
Total	61 (24%)	42 (24%)	19 (23%)	20 (29%)	10 (16%)	31 (24%)	18 (30%)	5 (24%)
Illness	14 (5%)	12 (7%)	2 (2%)	10 (15%)	1 (2%)	3 (2%)	3 (5%)	1 (5%)
Injury	47 (18%)	30 (17%)	17 (21%)	10 (15%)	9 (15%)	28 (22%)	15 (25%)	4 (19%)

Data are shown as the number and percentage of athletes reporting at least one (substantial) health problem.

TABLE 5 Average weekly prevalence during the 6-month observation period of all health problems and substantial health problems reported, as well as for subcategories of illness and injury in each subgroup of athletes

	Elite sport athletes (n = 258)						Team sport teammates (n = 60)
	All (n = 258)[a]	Males (n = 177)	Females (n = 81)[a]	Endurance sports (n = 68)[a]	Technical sports (n = 62)	Team sports (n = 128)[a]	
All health problems	43% (37, 49)	39% (32, 46)	53% (42, 64)	38% (28, 50)	45% (33, 57)	45% (37, 54)	37% (26, 49)
Illness	12% (9, 17)	11% (7, 17)	16% (10, 26)	23% (15, 35)	10% (5, 20)	8% (4, 14)	14% (7, 24)
Injury	31% (26, 37)	28% (22, 35)	37% (27, 48)	15% (8, 25)	36% (25, 48)	37% (29, 45)	23% (14, 35)
Acute injury	14% (12, 20)	12% (8, 17)	17% (11, 27)	2% (0, 8)	16% (9, 27)	19% (13, 26)	11% (6, 22)
Overuse injury	17% (13, 22)	16% (11, 22)	19% (12, 28)	12% (6, 22)	20% (11, 31)	17% (12, 25)	13% (7, 24)
Substantial health problems	25% (20, 31)	22% (17, 29)	32% (23, 43)	22% (14, 33)	25% (17, 38)	26% (19, 34)	18% (11, 30)
Illness	7% (4, 11)	6% (4, 11)	11% (6, 20)	15% (8, 25)	6% (3, 15)	4% (2, 9)	8% (4, 18)
Injury	17% (13, 22)	16% (11, 22)	21% (14, 31)	7% (3, 16)	19% (11, 31)	22% (16, 30)	10% (5, 20)
Acute injury	10% (7, 14)	9% (6, 14)	12% (7, 21)	1% (0, 8)	11% (6, 22)	14% (9, 21)	6% (3, 16)
Overuse injury	8% (5, 12)	7% (4, 11)	9% (4, 17)	6% (2, 14)	8% (3, 18)	9% (5, 16)	4% (1, 11)

[a]Indicates number of athletes at baseline.
Data are shown as the percentage of athletes reporting at least one (substantial) health problem, with 95% confidence intervals.

There were no significant differences in the prevalence of health problems in general between the two groups of team sport athletes (elite team sport athletes vs teammates: all health problems $P = .264$, substantial health problems $P = .261$). However, we found a significant difference in the prevalence of substantial injuries between the elite team sport athletes and their teammates ($P = .049$).

3.6 | Duration and severity of health problems

A total of 912 unique health problems were reported by 489 elite sport athletes over the course of the study (Table 6). Of these, 48% were illnesses, 26% were overuse injuries, and 25% were acute injuries. Illnesses represented the highest median weekly severity score. However, as illnesses were generally of shorter duration than injuries (Table 6), they only represented 30% of the total impact of all health problems, compared to 37% for overuse injuries ($P = .001$ vs illnesses) and 34% for acute injuries ($P = .007$ vs illnesses, $P = .54$ vs overuse injuries). Illnesses represented the highest median weekly severity score but also had the shortest duration (Table 6). Overuse injuries had the longest duration but the lowest median weekly severity score. Acute injuries had a higher weekly severity score than overuse injuries but were of shorter duration. Comparing all team sport athletes, the teammates report acute injuries with shorter duration and lower cumulative severity score than the elite team sport athletes ($P = .005$ and $P = .003$, respectively) (Table 6).

4 | DISCUSSION

This is the first prospective study of injuries and illnesses in young elite athletes representing a variety of endurance, team, and technical sports. We found that 43% of athletes reported a health problem any given time, with 25% of all young elite athletes reporting a substantial health problem. Furthermore, although patterns differed somewhat between sports groups, the total impact of health problems was evenly distributed between overuse injuries (37%), acute injuries (34%), and illnesses (30%).

The vast majority of previous epidemiological studies of injuries and illnesses among elite athletes have used a time-loss injury/illness definition. This has been shown to lead to an underreporting of overuse injuries in particular, which often do not lead to time loss from sports.[13,28,29] We used an "all health complaints" definition and a questionnaire intended to capture all sport-related injuries and illnesses, enabling us to estimate the true impact of all health problems regardless of the amount of time lost. However, as a consequence of differing definitions, direct comparison between our study and many previous studies is difficult.

In our study, the prevalence of health problems (43%) was higher than that observed in the only two prior studies using the same methodology. Clarsen et al[15] reporting a 36% prevalence and Pluim et al[30] reporting 21%. However, an important difference between these three studies is the participant profiles: Clarsen et al monitored adult Olympic athletes, while Pluim et al followed younger (11-14 year old) elite tennis players.

Our study design allowed for four sets of group comparisons: (i) athletes vs nonathletes (baseline prevalence only), (ii) elite team sport athletes attending sports schools vs teammates (subelite athletes) from the same clubs not attending sport school programs, (iii) endurance sports vs technical sports vs team sports, and (iv) males vs females.

First, as many as 76% of the nonathletes (both genders) reported having health problems of some sort at baseline, compared to 60% of the young elite athletes (females 61% and males 59%). Although a one-/first-time response to the OSTRC questionnaire should be interpreted with caution,[13] these data suggest that adolescents experience frequent health problems from time to time, regardless if they play sports or not. In a recent Norwegian National health report among 16 years olds, 22% of the girls and 8% of the boys reported daily physical complaints during the past month.[31]

Second, the prevalence of health problems was surprisingly similar between the elite team sport athletes attending sports schools, who on most days trained twice a day, versus subelite teammates from the same clubs not attending sports schools, who normally did not have training in the morning. One exception was that substantial injuries were more common in the elite team sport athlete group (22%) than among teammates (10%), although not at baseline (24% vs 30%). Previous studies show that young players with high levels of athletic skills (elite team sport athletes) are at greater risk of sustaining injuries than their less skilled teammates.[32-34] Higher training volumes, performance level, and a high competition load among the talented or more mature team sport athletes may exacerbate injury risk.[21,33,35] In contrast, the elite team sport athletes seemed to report less illnesses (8%) compared to their teammates (14%), but this difference was not significant ($P = .23$).

Third, sports group had an impact on the prevalence of injury and illness. In-competition surveillance studies have documented that different sporting groups report different patterns of injury and illness.[36-39] In the present study, endurance athletes had a higher illness prevalence, but a lower injury prevalence compared to technical and team sport athletes. The high illness prevalence among endurance athletes in our study (23%) was similar to that reported in a small prospective, Swedish study, on young elite orienteers (20%) using the same methodology.[40] In contrast, adult elite endurance athletes reported a somewhat lower illness prevalence (16%).[15]

TABLE 6 Number of incidents (n), duration, average weekly severity score and cumulative severity score of illnesses, overuse injuries and acute injuries in median (interquartile range Q_1, Q_3)

	Elite sport athletes (n = 258)						
	All (n = 258)	**Female (n = 81)**	**Male (n = 177)**	**Endurance (n = 68)**	**Technical (n = 62)**	**Team (n = 128)**	**Team sport teammates (n = 60)**
Illness							
Number of incidents	441	165	276	175	87	179	90
Duration (wk)	1 (1, 2)	1 (1, 2)	1 (1, 2)	1 (1, 2)	1 (1, 2)	1 (1, 2)	1 (1, 2)
Average weekly severity score	46 (22, 72)	50 (28, 72)	44 (20, 72)	51 (29, 72)	37 (16, 66)	46 (20, 74)	40 (17, 69)
Cumulative severity score	66 (29, 110)	72 (37, 128)	60 (28, 100)	72 (37, 140)	62 (27, 113)	61 (28, 100)	60 (20, 103)
Overuse injury							
Number of incidents	241	89	152	53	65	123	42
Duration (wk)	3 (1, 8)	4 (1, 9)	3 (1, 8)	3 (1, 8)	4 (1, 8)	3 (1, 9)	2 (1, 6)
Average weekly severity score	28 (19, 44)	28 (20, 40)	28 (16, 47)	29 (18, 44)	26 (18, 39)	28 (19, 48)	26 (15, 43)
Cumulative severity score	88 (28, 293)	100 (34, 354)	80 (22, 237)	71 (28, 276)	83 (25, 297)	96 (28, 301)	76 (27, 161)
Acute injury							
Number of incidents	230	81	149	26	66	138	61
Duration (wk)	2 (1, 4)	2 (1, 6)	2 (1, 4)	1 (1, 2)	2 (1, 4)	2 (1, 6)	1 (1, 3)
Average weekly severity score	37 (23, 58)	36 (22, 55)	41 (25, 60)	37 (22, 48)	37 (22, 54)	39 (26, 60)	34 (20, 59)
Cumulative severity score	74 (28, 187)	60 (26, 238)	86 (30, 185)	46 (27, 68)	79 (28, 162)	90 (33, 267)	53 (22, 107)

Surprisingly, although the majority of injuries affecting endurance athletes were related to overuse, athletes in team and technical sports tended to report more overuse injuries than endurance athletes (20% and 17% vs 12%), although this difference was not significant. It should be noted that about half of all injuries reported in team sports and technical sports were overuse injuries. The incidence of injury among elite youth athletes has been reported to be greater in technical and team sports compared to endurance athletes.[36,37,39] A two times higher injury risk has been reported in team sports compared to individual sports among young athletes attending sport schools.[41,42] However, in contrast to our data, these studies, which were based on a traditional time-loss definition, showed that the vast majority of injuries reported were acute, not related to overuse.

Finally, females reported a significantly greater prevalence of health problems during the school year (52%) than males (39%). A difference in illness incidence by gender has been reported in previous studies.[8,12,36,37,43,44] A greater risk of injuries among females compared to males was also shown in athletics[45] and snowboard cross,[38] but this is not a consistent finding in the literature.[36,37,46]

One novel finding in our study was that at any given time, not only acute injuries but also overuse injuries and illnesses constituted a substantial impact on the health of young elite athletes. In contrast, using a time-loss definition, previous studies have reported mainly acute injuries; illnesses as well as overuse injuries have been neglected.[15,28] Recent editorials emphasize a need for more evidence about overuse injuries in young elite athletes.[33,47-49] According to Bahr,[33] overuse injuries probably constitute a substantial problem among adolescent elite athletes. This view is supported by all the three studies on young elite athletes done using our methodology to date.[30,40]

Illnesses are also increasingly being included in surveillance studies during major youth championships.[36-38] In out-of-competition periods, evidence is still scarce. Our findings strongly suggest that at any given time, symptoms of illness have substantial impact on health, training, and performance. This was also suggested in a recent IOC consensus statement on load in sport and risk of illness.[50]

4.1 | Methodological considerations

The current method depends on comprehensive athlete responses,[15] and missing data constitute a challenge. The app-based questionnaires were meant to be easy to use and readily accessible at all times, but poor Wi-Fi coverage at times, generated low participation rates, as did holiday periods (Christmas, Easter) and multiple software upgrades. Therefore, we chose to use supplemental interview data to fill in the gaps. This obviously introduces the limitation of recall bias.

Declining response rates from athletes with long-term injuries as well as long-term healthy athletes is another factor to consider. This phenomenon was also described by Pluim et al[30] However, to complete missing data, to verify all health problems reported and to remove problems that may have been registered by mistake, we conducted interviews of all athletes within a few weeks after the end of the study period. Still, recall bias and underreporting of health problems is a possibility. To minimize this, we took advantage of the available prospective data sets, the training diaries, and competition schedules during the interviews. We calculated both data sets separately and found minimal differences. In this way, each data set served as a "control" for the other, and no systematic bias in either direction is anticipated. Nevertheless, a lower than expected response rate and subsequent inclusion of retrospective interview data into the prospective data decreased the precision of weekly estimates and limited which statistical analyses we could use.

Another limitation of the study is that injury/illness surveillance could affect awareness among athletes and parents. Previous studies applying this method have reported a slight reduction in the prevalence of overuse injuries and illnesses over time.[15] In contrast, our data show a stable prevalence of substantial health problems during the 26-week study course.

Some health-related problems may be expected when participating in high-level sports. The "all health complaints" definition covers most health issues, and even minor and transient cases such as muscle soreness and unspecific symptoms of illness (eg, light headache or tiredness) are likely to be registered.[13] This is a source of systematic bias, overestimating the true prevalence of sports-related health problems. Nevertheless, this is why we also used the "substantial problem" definition, which filters out the least consequential problems and may provide a better estimate of the impact of injuries and illnesses on the health of the young athletes.

5 | PERSPECTIVES

Nearly half of the young elite athletes reported symptoms from injury or illness at any given time, and one in four experienced health problems with a substantial negative impact on training and performance.

Our data suggest that the prevention focus should not only be on acute injuries but also on overuse injuries and illnesses among young athletes. Giving special attention to development and training techniques, rather than emphasizing competition and winning, may minimize or mitigate injuries. Superior athletic skills enable many of these young athletes to participate on a number of different teams and with older athletes, often having to relate to several different coaches. To this end, encouraging increased collaboration between coaches, promoting load management through individualized training programs and long-term personal goal setting seems reasonable.

To minimize illnesses, basic preventive measures such as hygiene education and frequent hand washing with soap and running water have proven effective among adult elite athletes.[51] The same preventive measures are relevant for youth elite athletes. An additional focus on how to prevent specific infectious diseases such as mononucleosis seems relevant. Adolescent-adapted education, with an overall focus on eating, sleeping, and other lifestyle factors (eg, managing stress and other nonsporting loads), is a key step.

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ORIGINAL ARTICLE

WILEY

The association between early specialization and performance level with injury and illness risk in youth elite athletes

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A trend is observed towards more specialized training and selection into talent programs at an early age for youth athletes. Little is known how this might influence the risk of illness and injury. The aim of the study was to assess whether, in a group of youth elite athletes, those specializing early or performing best were at increased risk of incurring injury or illness after entering a specialized Sport Academy High School program. We enrolled 259 16-year-old elite athletes. They completed a baseline web-based questionnaire covering their age at specialization, single- versus multi-sport involvement during the previous 2 years and current performance level (rated by themselves and their coach). Subsequently, the Oslo Sports Trauma Research Centre (OSTRC) questionnaire on health problems was used to self-report injuries and illnesses weekly for 26 weeks from October to May. In this specialized Sport Academy High School program, 39% of the athletes reported early specialization (at 12 years or younger). However, early specialization did not increase the risk of injury or illness during the 26 weeks, nor did being a single-sport athlete the previous two years increase this risk. The best performing athletes at the time of enrollment were not at greater risk of becoming injured or ill during the 26 weeks. In conclusion, in a group of youth elite athletes entering a specialized Sport Academy High School program neither early single-sport specialization nor performance level appears to represent risk factors for injury or illness after enrollment.

KEYWORDS
acute injury, adolescent, illness, overuse injury, performance level, single-sport specialization, sport academy, talent

1 | INTRODUCTION

Nearly 20 years ago, the American Academy of Pediatrics[1] pointed out the potential risks of high-intensity training and sports specialization at a young age, related to high physical, physiological and psychological demands. In 2013, the American Medical Society for Sports Medicine developed these recommendations into a position statement on overuse injury and burnout in youth sports, advising that specialization in a single sport should be discouraged before adolescence.[2,3] There is no universally accepted terminology regarding what is considered adolescents, but the World Health Organization defines it as young people between the ages of 10 and 19 years while youths can include the 15- to 24-year age group.[4] More recently, a consensus statement by the American Orthopedic Society of Sports Medicine recommends closely monitoring for signs of overuse injury, burnout and overtraining in young athletes who practice intense training for more than 16 hours per week or more hours per week than their age.[5,6] However, although recent reports claim that specialized training in young athletes increases the risk of serious overuse injury,[2,6-8] there are no prospective studies examining this relationship or the relationship between early single-sport specialization and acute injuries, illnesses or psychological stress and burnout.[9,10]

Despite great concerns expressed from the medical community, there is a trend towards more training, more specialized training and early selection into talent programs at an ever earlier age.[5,6,11-13] A growing number of coaches and parents believe that the best way to produce superior young athletes is to have them play only one sport from a young age.[14,15] Of particular interest is the transition from a regular club-based program to a specialized Sport Academy High School program, typically leading to a steep increase in training load, often doubling their training load over a short period and having to relate to multiple coaches both at school and in their club-based environment. Additionally, the most gifted young athletes among those selected for talent programs may be tempted by the opportunity to attend multiple practices and multiple levels of competition, as they are often selected for both regional and national representative teams. These are all factors that may put the best performing youth athletes at greater risk of injury or illness.[14,16]

In a recent paper, we documented that there was a substantial impact of both injuries and illnesses on the health of 16-year-old elite athletes after enrollment into intensive, specialized Sport Academy High School programs.[17] The aim of the current study was to examine whether among these, the early specialized or best performing athletes were at increased risk of injury or illness after enrollment.

2 | METHODS

2.1 | Study design

This study was based on data from a prospective cohort study involving youth elite athletes enrolled in three specialized Sport Academy High Schools in Norway.[17] Baseline data, including retrospective information on early specialization and performance level, were collected in August 2014, and the athletes reported their weekly injury and illness status prospectively for 26 weeks from October until May 2015, when supplemental interviews were done to complete the injury/illness recording. The study was approved by the Norwegian Data Inspectorate (No. 38888) and reviewed by the South-Eastern Norwegian Regional Committee for Research Ethics (2014/902/REK Sør-Øst).

2.2 | Participants

Inclusion criteria for the study[17] were all first-year students enrolled in three selected specialized Sport Academy High Schools in Norway 2014/-15. To attend these schools, athletes must demonstrate excellent skills in their sport, compete at a high level and pass multiple admission tests. There were no exclusion criteria. Verbal and written information was given to all 316 first-year students (11th grade, age 15 or 16 years) and their parents at the beginning of the school year about the purpose of the study. Of these, 259 accepted to participate. A large proportion of the participants were members of regional (76%) or national (37%) representative teams and competed at the national or international level.[17] Thirty different sport disciplines (both summer and winter sports from both individual and team sports) were represented and grouped into three major categories (endurance [n = 69], technical [n = 62], and team sports [n = 128]).[17] Further details of the flow of participants and characteristics of the study population have been reported previously.[17] Written consent was obtained from all participants and their parents.

2.3 | Baseline data collection

Within 2 weeks after inclusion, participants completed a web-based questionnaire with information on their anthropometrics, medical history, motivation for training (numeric scale, 1 = very, very low to 7 = very, very high), sport category, age when the athlete defined one sport as being more important than other sports (sport specialization) and self-evaluated performance level. The questionnaire was completed during school hours, without any assistance by parents. They were also asked to report participation in other sports during each of the past 6 years (5th through 10th grade). We related the different sport disciplines to the different school grades and gave them multiple-choice alternatives to choose from in order not to miss important sports. They also reported how many hours on average they had participated in training and competition during each of the past 12 months.

2.4 | Risk factor classification

2.4.1 | Early specialization

We defined sport specialization as the time when the athlete defined one sport as being more important than other sports and asked the athletes: "At what age did you decide to focus on your sport?" classified into seven categories: ≤10, 11, 12, 13, 14, 15 or 16 years. For the analyses, we dichotomized their response as early (≤12 years) or late specialization (>12 years).[5,12,13,18-22]

2.4.2 | Single-sport and multi-sport athletes

To assess previous and current involvement in different sports, we listed the 18 most common sports in Norway as well as an open category asking the athletes to describe their involvement in each of these during the past 6 years (excluding in physical education class). For the analyses, we classified athletes having participated in more than their main sport during the past 2 years (9th and/or 10th grade) as multi-sport athletes.

2.4.3 | Self-evaluated performance level

At baseline, all athletes were asked the following question: "In your opinion, how do you rate your own performance level compared to other same-age athletes in your sport in Norway?" classified into six categories: Top 1%, top 5%, top 10%, top 25%, top 50%, and below 50%. For the analyses, we dichotomized their responses into above or below top 10%.

2.4.4 | Coach-evaluated performance level

Their coaches were asked to rate athletic performance at the beginning of the school year based on the following question: "Compared to the average of the athletes in your training group, how do you rate this athlete's current performance level?" classified into quartiles from the top 25% to the lowest 25%. For the analyses, we dichotomized the coach evaluation into above or below the top 50%.

2.5 | Definition of injury and illness

Health problems were defined as all injuries and illnesses, regardless of severity and consequences.

Health problems were classified as an injury if affecting the musculo-skeletal system, as well as concussions,[23] and as an illness if affecting other organ systems such as respiratory, gastrointestinal, cardiac, dermatological and psychological systems, as well as unspecified or generalized symptoms such as fever, dizziness or fatigue.[24] Injuries were further categorized into acute and overuse as reported by the athlete. A definition of acute (linked to a specific injury event, such as falling or being tackled) vs overuse (those that could not be linked to a single clearly identifiable event) was shown each time the athlete opened the app for their weekly health report.[25] The instructions also emphasized that sadness, depression, anxiety, and feeling troubled should be registered as an illness. If an illness were reported, athletes were asked to select the main symptoms they had experienced during the past week.[23] Illnesses were coded according to organ system affected.[24]

Substantial health problems were defined as problems leading to moderate or severe reductions in training volume or performance, or complete time loss from sport.

2.6 | Prospective recording of injury and illness

The Oslo Sports Trauma Research Centre (OSTRC) questionnaire on health problems[24] was used to self-report injuries, illnesses and training load weekly through a smartphone application (Spartanova NV, Gent, Belgium). The OSTRC questionnaire records the consequences of any health problems the athlete may have experienced during the past week. It consists of four graded questions about sport participation, training volume, performance, and health problems experienced.[23,24] Each question is allocated a numerical value from 0 to 25, where 0 represent no problems and 25 the maximum level for each question. The four response values are summed, resulting in a severity score from 0 to 100 for each health problem reported. If the lowest score on each of the four key questions is recorded (no health problems or symptoms reported), the questionnaire is complete for that week. However, if any health problem is reported, the athletes are asked to define the problem as an injury or an illness. In case there are multiple health problems during the same week, the questionnaire repeat itself up to four times. Participants are instructed to report all health problems every week, regardless of whether or not the problem has been registered the previous week.

2.7 | Supplemental interviews

At the end of the study period, we conducted supplemental interviews with all available participants still included in the study. All athletes brought their training diaries to the interview. We used all available prospective OSTRC questionnaire data recorded, and we registered all major competitions in the interview form beforehand. Interviews were conducted in person at school or during a training session, in seven cases by telephone. During the athlete interviews, the data recorded prospectively using the smartphone app were reviewed and quality controlled, and missing data were supplemented using interview data. One OSTRC questionnaire was completed for every health problem registered during the 26-week period. Details about the injury and illness registration and the data collection procedures have been reported previously.[17]

2.8 | Outcomes

For every athlete, we calculated the number of all and substantial health problems during the 26-week period. The cumulative severity score of injuries and illnesses was calculated by summing the score for every week the health problem was reported, as previously described in detail.[17]

2.9 | Statistical methods

All data were analyzed using SPSS for Windows (version 24). The number of all and substantial health problems, illnesses, acute and overuse injuries, as well as their cumulative severity scores, were the main outcomes for the risk factor analyses. For each of the eight main outcomes, we generated four separate linear regression models, one for each candidate risk factor: (a) Early specialization, (b) Single-sport athlete previous 2 years, (c) Self-evaluated performance level above top 10%, and (d) Coach-evaluated performance level above top 50%. Crude linear regression analyses were made for all risk factors. We adjusted all models for the same set of factors, potentially influencing the number of health problems: sex, sport category, and baseline training load. Other risk factor variables (prospective training load, training motivation, main sport) were examined in separate univariable analyses and those with a *P*-value of <0.2 were investigated further in a multiple regression model.

We explored the differences in outcome measures (number of health problems and cumulative severity score) for all the four different risk factors. All four binary independent variables were included in unadjusted univariable linear regression models. Adjusted multiple regression models were based on clinical practice and literature review. Based on the unadjusted models, adjusted multiple linear regression analyses were also constructed for all candidate variables with a *P*-level <0.2. Results are reported as the mean with 95% confidence intervals. Significance was accepted at a *P*-level <0.05.

3 | RESULTS

We included 259 athletes in the study. Six athletes were lost to follow-up.[17] The response rate was 66% on average through all weeks for the prospective data collection. We interviewed all but two of the elite sport athletes still included in the study, supplementing the prospectively reported data. This process resulted in a final response rate of 99.4%.

3.1 | Early sport specialization, single-sport athletes and risk of injury and illness

Early specialization was reported by 39% of the athletes (n = 102), but only 23% (n = 57) of the athletes reported both early sport specialization and practicing a single sport (Table 1). The cohort was roughly split in halves between single- (48%) and multi-sport (52%) athletes the previous two years. We could not detect any association between being a single- or multi-sport athlete and the risk of injury (Table 2). In contrast, early sport specialization was associated with an increased risk of acute injuries, but this association was modified by sex, sport category and training load at baseline, and no longer significant after adjustment for these factors (Table 2).

TABLE 1 Numbers (proportions %) of early specializing athletes categorized by performance level and single-sport participation

		Early specialization (≤12 y)	
	n	Yes	No
Single-sport previous 2 y	251[a]	101	150
Yes	121	57 (23%)	64 (25%)
No	130	44 (18%)	86 (34%)
Coach-evaluated performance level	210[a]	78	132
Top 50%	96	42 (20%)	54 (26%)
Low 50%	114	36 (17%)	78 (37%)
Self-evaluated performance level	259[a]	102	157
Top 10%	171	76 (29%)	95 (37%)
Below 10%	88	26 (10%)	62 (24%)

[a]Numbers vary due to missing values

3.2 | Performance level and risk of injury and illness

When comparing themselves to all same-age athletes in the country in their sport, 66% of the athletes enrolled in the study (n = 171) rated their own performance within the top 10% in the country. Ninety percent (n = 234) of the athletes rated their performance within the top 25% and only 2% (n = 5) below 50% compared to other same-age athletes in their sport in Norway. The coaches rated 46% (n = 96) of the athletes as top 50% compared to their classmates at baseline (Table 2). The coaches failed to evaluate 19% (n = 49) of the athletes, of whom 75% rated themselves as top 10% in the country. For 36% (n = 75) of the athletes, there was a match between the highest self-rating (top 10% in the country) and coach-rating (top 50% in cohort). Crude analyses of the relationship between performance level and the number of health problems (injuries and illnesses) revealed no greater risk of getting injured or ill if categorized in the top performance athlete groups (Table 2). The 75 athletes (36%) categorized as being in the best performance group by both the athletes themselves and their coaches were also not at greater risk of injury or illness (*P* = 0.46). An exception was an increased risk of overuse injuries in the self-evaluated top 10% performance group when adjusting for sport category, sex, and baseline training load.

3.3 | Cumulative severity score, early single-sport specialization, and performance level

We tested differences in cumulative severity scores for overuse injuries, acute injuries, and illnesses associated with early or single-sport specialization, and performance level. Univariable (*P* = 0.06-0.85) and multiple (*P* = 0.09-0.96) linear regression analyses showed that the cumulative severity score did not differ significantly between the binary categories of early or single-sport specialization or performance level (data not shown).

TABLE 2 Relationship between the number of health problems (mean and 95% CI) and self- and coach-evaluated performance, being a single-sport athlete at entry and early specialization. Data are based on unadjusted univariable and multiple linear regression analyses adjusted for sport category, sex, and baseline training load

	Number of health problems (n)[a]		Unadjusted		Adjusted	
	Yes[b]	No[b]	P	B (95% CI)	P	B (95% CI)
Self-evaluated top 10% performance level (n = 259)[a]	n = 171	n = 88				
All health problems	3.5 (3.2, 3.8)	3.6 (3.2, 4.0)	0.86	−0.05 (−0.56, 0.46)	0.91	0.03 (−0.49, 0.55)
Acute injuries	0.8 (0.7, 1.0)	1.1 (0.8, 1.3)	0.08	−0.24 (−0.52, 0.03)	0.09	−0.24 (−0.51, 0.04)
Overuse injuries	1.0 (0.9, 1.2)	0.8 (0.6, 1.0)	0.08	0.24 (−0.03, 0.51)	0.026	0.31 (0.04, 0.59)
Illness	1.7 (1.5, 1.9)	1.8 (1.5, 2.0)	0.72	−0.07 (−0.42, 0.29)	0.71	−0.06 (−0.41, 0.28)
Substantial health problems	2.1 (1.9, 2.4)	2.2 (1.9, 2.5)	0.83	−0.04 (−0.43, 0.35)	1.00	0.0 (−0.40, 0.40)
Substantial acute injuries	0.5 (0.4, 0.6)	0.6 (0.5, 0.8)	0.25	−0.12 (−0.33, 0.09)	0.23	−0.13 (−0.33, 0.08)
Substantial overuse injuries	0.5 (0.4, 0.7)	0.4 (0.3, 0.6)	0.23	0.12 (−0.08, 0.32)	0.13	0.16 (0.05, 0.37)
Substantial illness	1.1 (0.9, 1.3)	1.1 (0.9, 1.4)	0.76	−0.04 (−0.32, 0.23)	0.80	−0.03 (−0.29, 0.23)
Coach-evaluated top 50% performance level (n = 210)[a]	n = 96	n = 114				
All health problems	3.5 (3.1, 3.9)	3.2 (2.9, 3.6)	0.29	0.27 (−0.23, 0.78)	0.22	0.31 (−0.19, 0.82)
Acute injuries	0.9 (0.7, 1.1)	0.8 (0.6, 1.0)	0.46	0.11 (−0.18, 0.39)	0.70	0.03 (−0.22, 0.33)
Overuse injuries	1.0 (0.7, 1.2)	0.8 (0.7, 1.0)	0.37	0.13 (−0.15, 0.40)	0.28	0.15 (−0.12, 0.42)
Illness	1.6 (1.4, 1.9)	1.6 (1.3, 1.9)	0.92	0.02 (−0.35, 0.39)	0.57	0.10 (−0.25, 0.46)
Substantial health problems	1.8 (1.6, 2.1)	2.0 (1.8, 2.3)	0.31	−0.20 (−0.59, 0.19)	0.26	−0.22 (−0.62, 0.17)
Substantial acute injuries	0.5 (0.4, 0.7)	0.5 (0.4, 0.6)	0.77	0.03 (−0.18, 0.25)	0.78	−0.03 (−0.24, 0.18)
Substantial overuse injuries	0.4 (0.3, 0.6)	0.5 (0.3, 0.6)	0.73	−0.04 (−0.24, 0.17)	0.73	−0.04 (−0.24, 0.17)
Substantial illness	0.9 (0.7, 1.0)	1.1 (0.9, 1.3)	0.16	−0.20 (−0.47, 0.08)	0.24	−0.16 (−0.42, 0.11)
Single-sport athlete previous 2 y (n = 251)[a]	n = 121	n = 130				
All health problems	3.5 (3.1, 3.8)	3.7 (3.3, 4.0)	0.41	−0.21 (−0.70, 0.29)	0.66	−0.11 (−0.63, 0.40)
Acute injuries	0.9 (0.8, 1.1)	0.8 (0.6, 1.0)	0.44	0.10 (−0.16, 0.37)	0.40	−0.12 (−0.39, 0.16)
Overuse injuries	0.9 (0.8, 1.1)	1.0 (0.8, 1.2)	0.79	−0.04 (−0.30, 0.23)	0.68	−0.06 (−0.34, 0.22)
Illness	1.6 (1.4, 1.8)	1.9 (1.6, 2.2)	0.08	−0.31 (−0.65, 0.04)	0.85	0.03 (−0.31, 0.37)
Substantial health problems	2.2 (1.9, 2.5)	2.2 (1.9, 2.4)	0.75	0.06 (−0.32, 0.44)	0.56	0.12 (−0.28, 0.52)
Substantial acute injuries	0.6 (0.5, 0.8)	0.5 (0.3, 0.6)	0.08	0.18 (−0.02, 0.37)	0.92	−0.01 (−0.21, 0.19)
Substantial overuse injuries	0.6 (0.4, 0.7)	0.5 (0.3, 0.7)	0.27	0.11 (−0.09, 0.30)	0.41	0.09 (−0.12, 0.29)
Substantial illness	1.0 (0.8, 1.2)	1.2 (1.0, 1.4)	0.10	−0.22 (−0.49, 0.04)	0.75	0.04 (−0.22, 0.30)
Early specialization (≤12 y) (n = 259)[a]	n = 102	n = 157				
All health problems	3.5 (3.1, 3.9)	3.6 (3.3, 3.9)	0.79	−0.07 (−0.56, 0.43)	0.92	0.03 (−0.50, 0.55)
Acute injuries	1.1 (0.8, 1.3)	0.8 (0.6, 0.9)	0.045	0.27 (0.01, 0.54)	0.48	0.09 (−0.18, 0.38)
Overuse injuries	0.8 (0.6, 1.0)	1.0 (0.9, 1.2)	0.11	−0.21 (−0.47, 0.05)	0.10	−0.23 (−0.51, 0.05)
Illness	1.6 (1.4, 1.9)	1.8 (1.6, 2.0)	0.35	−0.17 (−0.51, 0.18)	0.45	0.13 (−0.21, 0.48)
Substantial health problems	2.2 (1.8, 2.5)	2.2 (1.9, 2.4)	0.98	0.00 (−0.37, 0.38)	0.84	0.03 (−0.36, 0.45)
Substantial acute injuries	0.7 (0.6, 0.9)	0.4 (0.3, 0.6)	0.004	0.30 (0.10, 0.49)	0.18	0.14 (−0.07, 0.35)
Substantial overuse injuries	0.4 (0.3, 0.6)	0.6 (0.4, 0.7)	0.13	−0.15 (−0.34, 0.04)	0.06	−0.20 (−0.41, 0.01)
Substantial illness	1.0 (0.8, 1.2)	1.2 (1.0, 1.3)	0.29	−0.14 (−0.41, 0.12)	0.47	0.10 (−0.17, 0.36)

[a]Numbers may vary due to missing values.

[b]Values are the number of athletes in each category (yes/no) for each exposure variable.

4 | DISCUSSION

Even though early sport specialization was associated with an increased risk of acute injuries, our data suggest that early or single-sport specialization cannot be considered risk factors for health problems among youth elite athletes after enrollment into an intensive sport academy program. Also, an increased risk of overuse injuries in the self-evaluated top 10% performance group was evident, but as an overall finding the best performing athletes in the program were not at greater risk of becoming injured or ill.

4.1 | No increased risk of injury in early specialized athletes

Some of the specific results from our study need to be addressed. First, crude data indicated that early sport specialization was associated with an increased risk of acute (substantial) injuries. However, in a previous study we reported a significantly higher prevalence of acute injuries among team and technical athletes compared to endurance athletes.[17] Both team and technical athletes tended to specialize earlier and were more likely to practice a single sport than endurance athletes. So after we adjusted for sport category, this association was no longer significant.

Second, we did not detect an increased risk of overuse injuries between early and late-specializing athletes and no association between the more severe injuries (ie, cumulative severity score) and early specialization. This is in contrast to the findings of Jayanthi et al, who found the highly specialized athletes to be at a higher risk of incurring more serious overuse injuries. Methodological differences may explain this discrepancy, as discussed below. Additionally, in the same study by Jayanthi et al,[2] the initiation age of specialization (early versus late) was not associated with an increased risk of injuries. This is similar to our findings, that early specialization was not associated with an increased injury risk.

4.2 | Lack of consensus regarding early sport specialization

There is only a handful previous reports on early single-sport specialization and injury risk, and a lack of consensus of what should be considered a highly specialized youth athlete makes direct comparisons across studies difficult.

Some studies have reported an increased injury risk.[2,7,26] Jayanthi et al reported that during a 4 week summer tournament, junior tennis players specializing in tennis only were about six times more likely to suffer a time-loss injury compared to multi-sport athletes.[7] Hall and co-workers observed a 1.5-4 fold greater risk of developing anterior knee pain (patellofemoral pain, Osgood-Schlatter disease, and patellar tendinopathy) among 13-14-year-old female single sport-specialized athletes in basketball, volleyball and soccer in a retrospective study.[26] And finally, an independent risk of injury and serious injury in young athletes who specialize in a single sport was demonstrated in a clinical case-control study comparing injured athletes aged 7-18 years from a sports medicine clinic to non-injured peers.[2]

Compared to our study, these studies differ in both definitions used, design and methods.[2,7,9,26] The term specialization was defined either by single-sport participation[7,26] or by degree of specialization (low, moderate, high).[2] The studies were either of a very short duration (only 4 weeks during a summer tournament season),[7] retrospective[26] or case-control based.[2] Additionally, recall bias is a limitation in the retrospective study, as well as a possible selection bias in the case-control study, where the more specialized youth athletes may have been more likely to seek help from sports medicine specialists when injured, possibly overestimating the risk of injury in this group.

4.3 | Challenges regarding how to define early sport specialization

Age is a common injury risk factor among youth athletes.[27,28] Therefore, it seems important to identify at which age sport specialization may be detrimental for the youth athlete, and at which point it might become beneficial.[14] Recent studies regarding sports specialization have focused mostly on the degree of specialization, rather than the age of specialization.[2,8,26,29-32] Based on the literature,[5,18-20] we considered "early specialization" as specialization at 12 years or younger, and defined sport specialization as the time when the athletes considered one sport as being more important to them than other sports, and wanting to excel in this sport.[11,12,20-22] This did not include quitting other sports, practicing one sport solely, whether or not they had ever only participated in one single sport, or the timeframe within which the sport was practiced.

Another definition suggested is “year round intensive training in a single sport at the exclusion of other sports”.[2,6] In accordance with this definition, a 3-point scale has been suggested to categorize the degree of specialization as low, moderate or high, depending on the fulfillment of one or more of these three criteria: (a) Year-round training (more than 8 months per year), (b) Choosing a single sport, and (c) Quitting all sports to focus on a single sport.[2,8] However, there are some challenges that need to be recognized even if using this more graded definition of what constitutes being a “highly specialized” youth athlete. First, it does not define what is considered an early age for specialization, as previously discussed. Second, it does not consider performance level. Third, at least in Scandinavia, even recreational youth athletes participate for more than 8 months per year in one main sport.

In our study, we used both the age of sport specialization, as well as participation in other than their main sport during the past two years as measures of the degree of specialization. As illustrated in Table 2, 48% were single-sport athletes and 39% had specialized early. Interestingly, only 23% reported both early sport specialization and practicing a single sport (Table 1). However, all athletes fulfilled at least two of three criteria on the 3-point scale (year-round training and choosing a main sport) and would be considered moderately specialized. Additionally, all single-sport athletes would be considered "highly specialized" (fulfilling all three criteria). Therefore, in our opinion this classification method is not either complete and of limited value, at least in our cohort.

4.4 | High performance level and risk of overuse injuries

To detect the best performing athletes in this cohort, we asked both athletes and coaches to assess current performance level. Coaches were asked to compare with athletes in their own training group, athletes ranked themselves compared to same-age athletes in their sport in Norway. In our experience, most youth elite athletes have a good knowledge about their own performance level based on previous competitions, matches, talent camps, etc In our experience, it comes as no surprise that 66% of these youths rank themselves in the top level, as admittance to the sport academy high schools is based on previous rankings, tests, results, and information from their club coaches. We also know through personal correspondence with the schools that approximately two-thirds of their student-athletes are successful in taking a medal in their sport while enrolled at the Sport Academy High School.

Among the athletes who evaluated themselves as being among the top 10% in the country, we detected a 30% increased risk of overuse injuries. When the coaches selected the top 50% in the cohort, we did not detect any association between performance level and injury risk. An obvious limitation was that the coaches failed to evaluate nearly 20% of the athletes. However, as the distribution between sport categories ($P = 0.10$) and gender ($P = 0.13$) in this group was similar to the rest of the study population, a selection bias seems unlikely. Also, if we compared the subgroup of athletes who were rated in the top-performing categories by both themselves and their coaches (36% of the cohort), we detected no significant increase in overuse injury risk compared to the rest of the cohort.

We analyzed the combination of the highest performance level evaluated by both athlete and coach, but not all four risk factors together. As there were no consistent associations in univariate analyses with any of these factors, we would argue that it would be imprudent to go further with and report on more complex modeling of the data.

Most previous studies suggest an increased injury risk in higher performing youth athletes.[33-38] Johnson[35] showed that high-performing youth athletes, who are often early maturers, were more prone to injuries because of a higher training load, playing more matches and holding the more exposed positions. Studies from team sports such as football,[37,38] ice hockey,[39] and volleyball[36] have all provided data documenting a greater injury risk among youth elite players with high levels of tactical and technical skills. Few studies have reported a lack of association between injuries and high skills in youth athletes.[33,40]

One potential explanation for our observations, and a limitation of our study, was that only 82% of all first-year students participated. The missing 18% were abroad training or competing when the baseline questionnaire was distributed during school hours, and thus they could not be included in the study. This might have introduced a selection bias; the best performing athletes practicing summer sports were more likely to have been absent.

Another possible explanation was that athletes and coaches compared performance level between different groups; athletes to other same-age Norwegian athletes in their sport, coaches only between athletes in their training group. Also, in order to be selected for a Sport Academy High School, athletes must have attained a high skill level in their sport, resulting in a relatively homogenous cohort. Detecting an effect of performance level on injury risk, might therefore be difficult, as they all belonged to a highly skilled group.

4.5 | Methodological considerations

Prospective data collection depends on comprehensive athlete responses,[23,24] and missing data represent a challenge. The app-based questionnaires were meant to be easy to use and readily accessible at all times, but poor Wi-Fi coverage at times generated low participation rates, as did holiday periods (Christmas, Easter) and multiple software upgrades. Therefore, we chose to use supplemental interview data to fill in the gaps. This obviously could lead to recall bias.[17] We therefore compared between prospectively collected data and interview data and found minimal differences. In this way, each data set served as a control for the other and no systematic bias in either direction could be seen, as documented previously.[17]

Prospective data collection was carried out from October until the end of the school year (May), when the athletes started their exam period. In total, 28 weeks were registered. In line with the methodology of Clarsen et al,[23,24] data from the first 2 weeks of the study period were excluded. We do not know what the injury/illness risk was during the period from late August until data collection started in October. An increased training load and subsequent increased injury and illness risk after entering a specialized sport academy high school is possible. However, as our study covers most of the school year, we would argue that the observation period of 26 weeks is sufficient to be representative to quantify the injury/illness risk for the athletes enrolled in the study.

Another factor which might be considered a limitation of the study is that athletes and coaches were asked to evaluate sport performance level by different cut-offs and by comparing to different groups. The coaches were asked to rank the athletes in their training group in quartiles. This was successful, resulting in an even distribution between the quartiles, and 46% assessed as being above average and 54% below. For the athletes, we chose more detailed categories, because we did not know what the distribution would be. But as the results showed, this ranking method allowed us to dichotomize the group into above or below the top 10% performers in their sport in Norway (66% above, 33% below).

Finally, youth athletes not enrolled in high performance sport academies were not included in the risk factor study. However, in a previous paper we showed that the prevalence of health problems was surprisingly similar between the best performing elite team sport athletes attending sport academy high schools, versus their subelite teammates from the same clubs not attending sport academy high schools.[17]

5 | PERSPECTIVES

This study shows that, even though youth elite athletes seem to be at a high risk of becoming injured or ill, early single-sport specialization and high performance level cannot be considered solitary risk factors. Thus, advocating participation in several sports or promoting specialization at an older age in order to reduce the risk of injury and illness is not possible based on our findings. However, our concerns regarding youth elite athletes and overscheduling still seem relevant as almost half of the athletes in our cohort reported a health problem at any given time.[17]

Finally, there is still a methodological challenge related to what is considered a highly specialized youth athlete. Future studies regarding the health of youth elite athletes and early sport specialization need to consider not only if they practice year-round training in a single sport. Performance level, sport category and age of single-sport specialization also need to be taken into account for these aspiring young athletes. There is an urgent need to care for young athletes by improving injury and illness prevention strategies.

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The association between physical fitness level and number and severity of injury and illness in youth elite athletes

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Youth elite athletes often double their training and competition load after enrollment into specialized sport academy high school programs. The least fit athletes may be exposed to an excessive and too rapid increase in training load, with negative adaptations such as injury and illness as a consequence. In this study, our aim was to determine whether these least fit athletes were at greater risk of injury or illness during their first school year. Participants were 166 youth elite athletes (72% boys) from a variety of team, technical, and endurance sports newly enrolled into specialized sport academy high schools. The Oslo Sports Trauma Research Center Questionnaire on Health Problems was used to self-report injuries and illnesses weekly for 26 weeks. Athletes completed the Ironman Jr physical fitness test battery at baseline, evaluating endurance, strength, agility, and speed properties. We ranked the athletes based on their combined test scores and identified the least fit quartile. The main outcome was the number and severity of health problems, comparing the least fit quartile of athletes to the rest of the cohort. Overall, the least fit quartile of athletes did not report more health problems (mean 3.7, 95% CI 3.0-4.4) compared with the rest of the cohort (3.6, 3.2-3.9). In conclusion, we demonstrated no association between low physical fitness level and number and severity of injury and illness in youth elite athletes after enrollment into a specialized sport academy high school program.

KEYWORDS
adolescent, growth, high school athlete, injury prevention, overuse injury, physical fitness, risk factors, sport academy

1 | INTRODUCTION

Increasingly, youth athletes engage in organized sports and elite sports. Because of their natural learning skills and physiological development, they are well suited to the training and competitive demands of sports. Improving muscular fitness, endurance, and agility are essential components of youth athletic development programs.[1] Nevertheless, the divide between what is required to maintain and improve athletic skills and physical fitness vs minimizing injury and illness risk is not well understood. Recent studies on adult elite athletes agree that rapid increases in training load might result in more soft-tissue injuries. Those accustomed to high training loads have less risk of incurring injuries than athletes training at lower workloads and of lower physical fitness.[2] Whether this is applicable also for youth elite athletes, is yet unknown.

Numerous studies related to various elements of physical fitness have attempted to identify factors that contribute to injury and illness risk in young athletes,[3-9] although not at the elite level. Typically, physical fitness tests encompass components such as cardiorespiratory endurance, muscular strength, flexibility tests, and functional movement tests.[10-18] Prior research studies on the adult population have demonstrated an association between higher levels of aerobic fitness and decreased injury risk,[11,17,19] whereas research on the relationship between physical fitness level and illness risk is limited and mostly focus on increasing training loads.[20-23] For youth elite athletes, there are even less data addressing the relationship between physical fitness and injury and illness risk and the results are conflicting.[12-16,24,25] While some studies claim that well-developed aerobic fitness might protect youth athletes from future injury or illness,[8,10,17,18] no association has been shown with functional movement screening tests,[13,16] nor with a relatively lower fitness level.[12]

In a previous study, we reported a high prevalence of injury and illness among youth elite athletes newly enrolled into specialized sport academy environments.[26] These youth athletes often double their training and competition load after enrollment.[6,27] The least fit athletes may be exposed to an excessive and too rapid increase in training load, with negative adaptions such as injury and illness, as a consequence.[2,5,28-30]

We therefore wanted to address the association between lower physical fitness level and number and severity of injury and illness among youth elite athletes. We used physical fitness tests related to endurance, strength, agility, and speed to identify the least fit quartile of athletes newly enrolled into a specialized sport academy high school and investigated whether, among these, the least fit athletes were at greater risk of getting injured or ill during their first school year.

2 | METHODS

2.1 | Study design

This study is a prospective cohort study involving youth elite athletes enrolled in three specialized Sport Academy High Schools in Norway. These three schools represent a convenience sample, but also truly elite programs, having developed numerous Olympic and World champions in many different sports over the past decade. Details on the prevalence and severity of health problems in this cohort during their first school year have been presented in a separate paper.[26] Baseline data were collected in August 2014, and the athletes reported their weekly injury and illness status prospectively for 26 weeks from October until May 2015, when supplemental interviews were done to complete the injury/illness recording. The study was approved by the Norwegian Data Inspectorate (No. 38888) and reviewed by the South-Eastern Norwegian Regional Committee for Research Ethics (2014/902/REK Sør-Øst).

2.2 | Participants

Inclusion criteria for the study were as follows: first-year students enrolled in three selected specialized Sport Academy High Schools in Norway 2014/2015 completing a set of standardized fitness tests (Ironman Test-batteries; "Attacking Vikings," version 4.2, August 15, 2013, att. 7) modified for our use.

To attend these Sport Academy High Schools, athletes must demonstrate excellent skills in their sport, compete at a high level, and pass multiple admission tests. Verbal and written information was given to the 316 first-year students (11th grade, age 15 or 16 years) and their parents at the beginning of the school year outlining the purposes and procedures of the study. Of these, 259 consented to participate. A large proportion of the athletes were the members of regional (76%) or national (37%) representative teams and competed at the national or international level.[26] Thirty different sport disciplines (both summer and winter sports from both individual and team sports) were represented and grouped into three major categories (endurance [n = 69], technical [n = 62], and team sports [n = 128]).[26]

At baseline, 166 participants completed the Ironman Jr test-battery prior to the start of the 26-week prospective recording period, whereas 93 athletes were absent on the test day or did not perform all tests required. Written consent was obtained from participants and parents.

2.3 | Baseline data collection

Within 2 weeks after inclusion, participants completed a web-based questionnaire with information on their anthropometrics (height, weight, and date of birth), medical history, and sport category. The questionnaire was completed during school hours. They also reported how many hours on average they had participated in training and competition during each of the past 12 months. Body mass index (BMI; kg/m^2) of the athletes was calculated based on the self-reported data. Characteristics of the participants have been reported elsewhere.[26]

2.4 | Physical fitness testing

Since 2002, the Norwegian World Cup alpine team has used a set of standardized fitness tests (Ironman Test-batteries; "Attacking Vikings," version 4.2, August 15, 2013, att. 7) to evaluate and promote the general physical fitness level needed for competing at the elite level. Although initially developed for alpine skiing, it has since been used in multiple sports to assess aerobic and anaerobic endurance, strength, agility/coordination, and speed. A total performance score is calculated based on separate scores from all tests. The Ironman Test-battery has been adapted for younger athletes

(12-16 years) as the Ironman Jr test-battery. The main differences between the two test batteries are the replacement of submaximal and maximal squats (1 RM) with squat technique (Jr) and standing long jumps (Jr), and push-ups (Jr) instead of bench-press. For the Ironman Jr test-battery, there is no scoring system available, neither for single tests nor for total performance.

To evaluate the level of physical fitness between participants, we therefore calculated a composite score based on performance on each separate test. For each test, we ranked the athletes from 1 to 166 and, by summing these ranks, we identified the quartile of athletes with the greatest total score (composite score; ie, the least fit quartile of athletes). Our candidate risk factor was the quartile of athletes with the highest total composite score. We stratified the cohort by sex and sport category, and identified the quartile with the greatest composite score in each stratum as the least fit.

2.4.1 | The Ironman Jr Test-battery

We performed the tests at the Norwegian School of Sports Science and at the Sport Academy High School at Lillehammer. We invited all participants to perform this test battery at baseline. We used seven of the eight tests of the Ironman Jr Test-battery; practicing the technique for testing submaximal leg strength test (squat technique) was not included. For the running test, two of the schools used a 1500 m distance and one school 3000 m (Table 1). The specific tests were performed in a standardized order with 30-minute warm-up and 15-minute active breaks after standing long jumps and crunches (Table 1). Prior to testing, all test procedures were standardized and monitored by the research team.

2.4.2 | 1500-m and 3000-m running

The athletes performed the 1500-m and 3000-m runs on an outdoor 400-m running track, after a general warm-up and 10-15 minutes of running at increasing intensities. Time was measured with a stopwatch. Time in minutes and seconds was retained for analysis.

2.4.3 | Hexagonal obstacle

The athlete jumped as fast as possible with a two-foot landing in an hexagonal pattern across all obstacles (Figure 1). All athletes performed a warm-up of 2-4 rounds. The athletes were given a maximum of 3 and minimum of 2 attempts in both directions. Athletes performed all clockwise attempts first and then the counterclockwise attempts. Time was measured with a stopwatch. The sum of the best time in minutes and seconds in both directions was retained for analysis.

TABLE 1 Ironman Jr Test-battery, fitness properties[a]

Test	Properties
1500 m[b]	Endurance
3000 m[b]	Endurance
Hexagon obstacle (s)	Speed and agility/ coordination
Long jumps (cm)	Leaping power and max leg strength
Push-ups (no)	Strength upper body, core, chest, triceps
Chin-ups (no)	Strength upper body/ back, latissimus dorsi
Crunches on a vaulting box (no)	Abdominal strength
90 s bench jumps	Anaerobic capacity and leg strength

[a]Squat technique was excluded from the test battery.
[b]Two of the schools included performed the 1500 m running test rather than 3000 m running test.

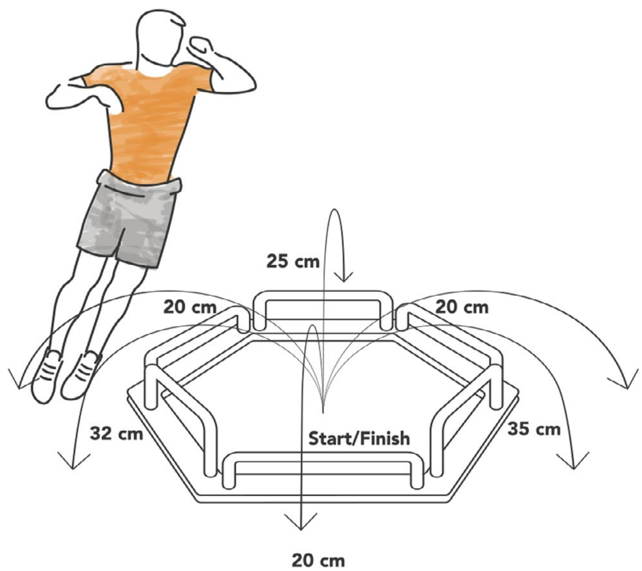

FIGURE 1 Hexagonal obstacle. One attempt consisted of two rounds in the same direction, jumping in and out of the hexagonal obstacle. Start and finish were inside the hurdles, next to the 20-cm fence. One run consisted of two complete rounds through the hexagon, either clockwise or counterclockwise

2.4.4 | Standing long jumps

All athletes were allowed a warm-up of 4-5 trials while feedback on technique and performance was given. The tests were performed starting with both feet behind the starting line, landing in a sand pit. The athletes had a minimum of 3 trials and were allowed additional jumps as long as the length increased for every jump. We measured the jumping distance in centimeters from the starting line to the rear point of the landing body. The longest legal jump was registered.

2.4.5 | Push-ups

Warm-up was 5-10 repetitions with feedback on correct technique and performance. No time limit was given, but the athletes were warned if stopping for more than 1-2 seconds between repetitions. The athletes started in a prone position with their hands lifted off the floor. When extending their arms, the whole body had to be lifted rigidly off the floor with the chin, chest, hips, and thighs moved simultaneously from the floor until the arms were fully extended. The same position was required as the elbows flexed and body was lowered. The hands had to be lifted off the floor between every repetition. We noted the number of correctly performed push-ups.

2.4.6 | Chin-ups

Warm-up was 2-5 repetitions with feedback on correct technique and performance. There was no time limit, but the athlete was warned if pausing for more than a couple of seconds between repetitions. The athletes started hanging with the hands 10 cm wider than shoulder width (Figure 2A). We noted the number of correctly performed chin-ups.

2.4.7 | Crunches on a vaulting box

A warm-up of 2-5 repetitions with feedback on correct technique and performance was given. The athlete started hanging upside down with knees flexed in a 90° position with hands held behind the head, holding a 5-cm rope ring (Figure 2B). There was no time limit, but the athlete received a warning if pausing more than 1 second during the exercise. We noted the number of correctly performed crunches.

2.4.8 | 90-second bench jump test

Warm-up was 15-20 seconds of high-intensity jumping. Athletes were requested to perform the maximum number of jumps possible within 90 seconds. All athletes started on the top of the bench (Figure 2C). The test started when the athlete hit the ground on the first jump. We noted the number of side-to-side jumps within 90 seconds.

2.5 | Injury and illness recording

2.5.1 | Definition of injury and illness

Health problems were defined as all self-reported injuries and illnesses, regardless of severity and consequences.

Health problems were classified as an injury if affecting the musculoskeletal system, as well as concussions,[31] and as an illness if affecting other organ systems such as respiratory, gastrointestinal, cardiac, dermatological, and psychological systems, as well as unspecified or generalized symptoms such as fever, dizziness, or fatigue.[32] Injuries were further categorized into acute and overuse as reported by the athlete. A definition of acute (linked to a specific injury event, such as falling or being tackled) vs overuse (those that could not be linked to a single clearly identifiable event) was shown each time the athlete opened the app for their weekly health report.[33] The instructions also emphasized that sadness, depression, anxiety, and feeling troubled should be registered as an illness. If an illness were reported, athletes were asked to select the main symptoms they had experienced during the past week. Illnesses were coded according to organ system affected.[32]

Substantial health problems were defined as problems leading to moderate or severe reductions in training volume or performance, or complete time loss from sport.[31]

2.5.2 | Prospective recording of injury and illness

Details about the injury and illness registration and the data collection procedures have been reported previously.[26] The Oslo Sports Trauma Research Centre (OSTRC) questionnaire on health problems was used to self-report injuries, illnesses, and training load weekly through a smartphone application (Spartanova NV, Gent, Belgium).[32] The OSTRC questionnaire records the consequences of any health problems the athlete may have experienced during the past week. It consists of four-graded questions about sport participation, training volume, performance, and health problems experienced, with specific text prompts given (Appendix S1).[31,32] Each question is allocated a numerical value from 0 to 25, where 0 represent no problems and 25 the maximum level for each question. The values for intermediate responses are chosen in order to maintain as even a distribution from 0 to 25 as possible while using whole numbers. Therefore, questions 1 and 4 (with 4 response options) are scored 0-8-17-25, and questions 2 and 3 (with 5 response options) are scored 0-6-13-19-25.[31] The four response values are summed, resulting in a severity score from 0 to 100 for each health problem reported. If the lowest score on each of the four key questions is recorded (no health problems or symptoms reported), the questionnaire is complete for that week. However, if any health problem is reported, the athletes are asked to define the problem as an injury or an illness. In case there are multiple health problems during the same week, the questionnaire repeats itself up to four times. Participants were instructed to report all health problems every week, regardless of whether or not the problem has been registered the previous week. The OSTRC questionnaire on health problems modified for our use is provided in an Appendix S1.

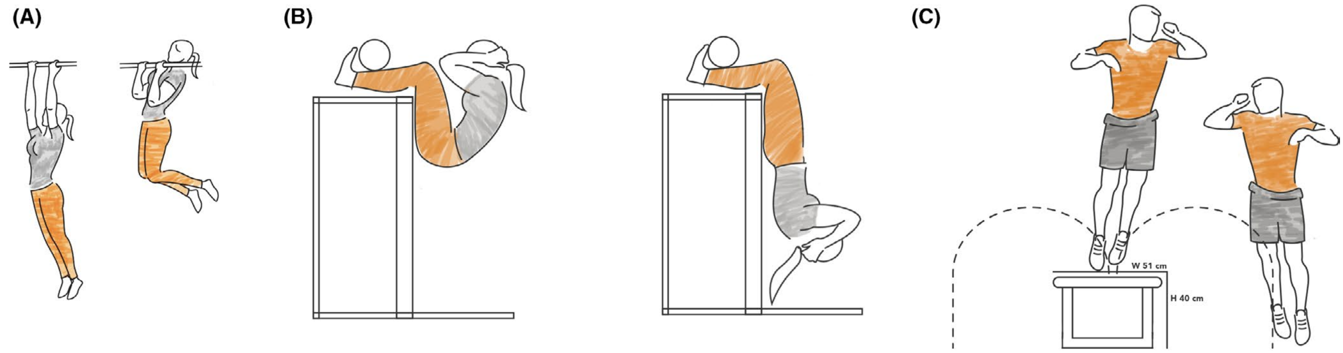

FIGURE 2 A, Chins. Pronated grip with the chin elevated above the rod in every repetition, and the arms fully extended between repetitions. B, Crunches on a vaulting box. Valid repetitions required the seat touching the box throughout the whole movement, elbows touching the outside of the knees, and full extension of the hips between repetitions. C, 90-s bench jump test. The athlete jumped sideways landing on the top of the bench. Jumps were counted every time the athlete hit the top of the bench

2.5.3 | Supplemental interviews

At the end of the study period, we conducted supplemental interviews with all available participants.[26] The athletes brought their training diaries to the interview. We used all available prospective OSTRC questionnaire data recorded, and we registered all major competitions in the interview form beforehand. Interviews were conducted in person at school or during a training session. During the athlete interviews, the data recorded prospectively using the smartphone app were reviewed and quality controlled, and missing data were supplemented using interview data.[26] One OSTRC questionnaire was completed for every health problem registered during the 26-week period.

2.5.4 | Outcomes

For every athlete, we calculated the number of all and substantial health problems during the 26-week period. The cumulative severity score of injuries and illnesses was calculated by summing the score for every week the health problem was reported, as previously described in detail.[26]

2.6 | Statistical methods

Data were analyzed using SPSS for Windows (version 24). Comparisons of means were based on independent samples *t* tests and one-way ANOVA as appropriate. The rate of the health problems (the number of all and substantial health problems, illnesses, acute, and overuse injuries) was estimated with means and 95% confidence intervals, based on the *t*-distribution. Pairwise comparisons between sport categories after initial ANOVA tests were done with Bonferroni-adjusted *t* tests. Due to data skewness, we used median and interquartile range to present cumulative severity scores for all health problems, illnesses, acute injuries, and overuse injuries. For each outcome, we used linear or median regression models, respectively (both crude and adjusted), to explore the differences in outcome measures between the least fit quartile and the rest of the cohort based on the composite score ranking. The adjusted models used the following potentially confounding factors as covariates: birthdate, baseline training load, and BMI. The selection of covariates was based on experience from clinical practice and literature review. The cohort was stratified by sex and sport category. Results are reported as the mean with 95% confidence intervals. Statistical significance was defined as *P*-value <0.05.

3 | RESULTS

3.1 | Ironman Jr test results

The results from the physical fitness tests are displayed in Table 2. Test results differed significantly between boys and girls on all tests ($P < 0.006$), except for abdominal strength ($P = 0.55$). Sport category did also influence test results. Endurance athletes performed significantly better in endurance tests compared with technical and team sport athletes ($P < 0.001$), and also significantly better in push-ups ($P = 0.002$) and bench jumps ($P = 0.034$) compared with the other sport categories. The composite score differed significantly between sport categories ($P = 0.017$), mainly between endurance and technical sport athletes ($P = 0.014$). The composite score showed linear correlations with the aerobic running tests, as well as with the separate neuromuscular tests for speed, agility, and leg power.

3.2 | Injury and illness events

During the 26-week period, the athletes reported 156 overuse injuries, 146 acute injuries, and 294 illnesses. Each athlete reported an average of 3.6 (95% CI: 3.3-3.9) health problems (range 0-12; Table 3). An average of 2.0 substantial health problems (95% CI: 1.8-2.2) were reported during the same period (range 0-6; Table 3). Overall, girls reported more health

TABLE 2 Ironman Jr test results according to gender and sport category

	All athletes (n = 166)	Boys (n = 119)	Girls (n = 47)	Team sports (n = 84[a])	Technical (n = 37[b])	Endurance (n = 45[c])
1500 m (n = 110; min)	5.4 (5.3-5.6)	5.2 (5.0-5.3)	6.0 (5.7-6.3)	5.4 (5.2-5.5)	6.1 (5.7-6.6)	5.0 (4.6-5.4)
3000 m (n = 56; min)	11.9 (11.4-12.4)	11.5 (11.0-12.0)	13.0 (12.2-13.8)	13.0 (12.1-13.9)	12.7 (12.0-13.5)	10.7 (10.2-11.1)
Hexagon obstacle (s)	22.4 (22.1-22.7)	22.2 (21.9-22.5)	23.1 (22.4-23.7)	22.2 (21.9-22.6)	22.7 (21.9-23.6)	22.6 (22.1-23.1)
Standing long jumps (cm)	232 (229-235)	238 (235-241)	215 (211-220)	234 (230-238)	230 (223-236)	229 (223-236)
Push-ups (no)	28 (26-30)	31 (29-32)	21 (18-24)	28 (26-30)	23 (20-27)	32 (28-36)
Chin-ups (no)	5 (5-6)	7 (6-8)	1 (0-2)	5 (4-6)	5 (4-7)	6 (5-8)
Crunches (no)	14 (13-15)	14 (13-15)	14 (12-15)	14 (13-15)	14 (12-15)	15 (13-16)
Bench jumps 90 s (no)	73 (70-75)	79 (76-81)	58 (54-62)	74 (70-77)	67 (59-74)	76 (73-80)
Composite score[d]	565 (530-601)	480 (445-515)	782 (736-827)	560 (512-607)	650 (574-725)	507 (436-578)

Note: Data are shown as means with 95% CI.
[a]Boys n = 57, Girls n = 27.
[b]Boys n = 28, Girls n = 9.
[c]Boys n = 34, Girls n = 11
[d]Sum of individual range on every test.

problems and more overuse injuries than boys ($P = 0.004$ and $P = 0.045$, respectively). Endurance athletes reported more illnesses but less acute injuries compared with team and technical sport athletes ($P < 0.001$). However, the number of overuse injuries did not differ significantly across sport categories ($P = 0.28$; Table 3). The total burden of injuries and illness during the 26-week period is displayed in Table 4. Endurance athletes reported a higher cumulative severity score for illnesses compared with the other sport category athletes ($P < 0.001$; Table 4). Finally, excluded athletes reported significantly more substantial health problems and a greater cumulative severity score for all health problems compared with participants ($P = 0.03$ and $P = 0.004$, respectively, Tables 3 and 4).

Knees and ankles were the most common acute injury sites (each 14%). For overuse injuries, the lower back (18%), knee, and calf (each 16%) injuries were most commonly reported. Most illnesses reported were infections in the respiratory tract (80%).

3.3 | Association between physical fitness level and health problems

Table 5 displays the number, and Table 6 displays the severity of health problems comparing the least fit athletes at school start with the rest of the cohort. As an overall finding, there was no difference in the number or severity of health problems reported between the least fit athletes and the rest of the cohort (Tables 5 and 6). For groups stratified by sex and sport category, we demonstrated no statistically significant differences between the least fit athletes and the rest of the cohort, except for the least fit girls who reported more substantial overuse injuries and the least fit endurance athletes who reported more illnesses.

4 | DISCUSSION

In this study, we used physical fitness tests related to endurance, strength, agility, and speed to identify the least fit quartile among youth elite athletes newly enrolled into a specialized sport academy high school. Our main finding was that the least fit athletes were not at greater risk of becoming injured or ill during their first school year. Due to the test performance differences between sexes, shown in Table 2, and the greater prevalence of health problems among girls, shown in Table 3, we also found it necessary to examine the a priori hypothesis separately among boys and girls. Again, we found no association.

We also explored the same relationship for subcategories of outcomes (illness/acute injury/overuse injury and substantial health problems in each of these categories) and subgroups (team/technical/endurance sports). The least fit girls reported more substantial overuse injuries during the school year, whereas the least fit endurance athletes tended to report more illnesses. These finding must be interpreted with caution. First, as this is not a confirmatory study, we did not adjust for multiple comparisons. Interpretations of statistical results are made with full knowledge of the

TABLE 3 Number of all and substantial health problems (illness, acute, and overuse injuries)

	All athletes (n = 166)	Excluded athletes (n = 93)[a]	*P*-value[b]	Girls (n = 47)	Boys (n = 119)	Team (n = 84)	Technical (n = 37)	Endurance (n = 45)
All health problems	3.6 (3.3-3.9)	3.5 (3.1-3.9)	0.50	4.3 (3.8-4.8)	3.3 (3.0-3.7)	3.6 (3.2-4.0)	3.7 (2.9-4.4)	3.6 (3.1-4.1)
Illness	1.8 (1.6-2.0)	1.6 (1.3-1.9)	0.28	2.0 (1.6-2.5)	1.7 (1.4-1.9)	1.5 (1.3-1.8)	1.4 (0.9-1.9)	2.5 (2.2-2.9)
Acute injury	0.9 (0.7-1.1)	0.9 (0.7-1.1)	0.98	1.1 (0.7-1.4)	0.8 (0.6-1.0)	1.0 (0.8-1.3)	1.2 (0.7-1.7)	0.4 (0.2-0.6)
Overuse injury	0.9 (0.8-1.1)	1.0 (0.7-1.2)	0.90	1.2 (0.9-1.5)	0.8 (0.7-1.9)	1.0 (0.8-1.2)	1.1 (0.7-1.5)	0.7 (0.4-1.0)
Substantial health problems	2.0 (1.8-2.2)	2.5 (2.1-2.8)	0.03	2.2 (1.8-2.6)	1.9 (1.7-2.2)	2.0 (1.7-2.3)	1.8 (1.4-2.3)	2.1 (1.7-2.5)
Illness	1.1 (0.9-1.2)	1.2 (0.9-1.4)	0.72	1.2 (0.8-1.5)	1.0 (0.9-1.2)	0.9 (0.7-1.1)	0.6 (0.3-0.9)	1.8 (1.4-2.1)
Acute injury	0.5 (0.4-0.6)	0.7 (0.5-0.9)	0.05	0.5 (0.3-0.7)	0.5 (0.3-0.6)	0.6 (0.4--0.7)	0.7 (0.4-1.0)	0.2 (0-0.3)
Overuse injury	0.4 (0.3-0.6)	0.6 (0.4-0.8)	0.11	0.5 (0.2-0.7)	0.4 (0.3-0.6)	0.5 (0.4-0.7)	0.5 (0.3-0.8)	0.2 (0.1-0.3)

Note: Data are shown as means with 95% CI.

[a]Absent at test day or participating in less than 7 tests.

[b]Excluded athletes vs all athletes, data are based on linear regression analyses adjusted for sex.

TABLE 4 Median cumulative severity score of health problems (illness, acute, and overuse injuries)

	All athletes (n = 166)	Excluded athletes (n = 93)[a]	*P*-value[b]	Girls (n = 47)	Boys (n = 119)	Team (n = 84)	Technical (n = 37)	Endurance (n = 45)
All health problems	304 (156-651)	592 (201-1252)	0.004	372 (210-811)	267 (106-632)	337 (146-753)	280 (130-644)	303 (172-530)
Illness	100 (31-218)	84 (0-249)	0.57	132 (22-237)	94 (36-198)	82 (37-191)	31 (0-152)	189 (84-383)
Acute injury	13 (0-136)	29 (0-438)	0.56	32 (0-169)	6 (0-120)	40 (0-174)	20 (0-192)	0 (0-7)
Overuse injury	31 (0-184)	20 (0-376)	1.00	42 (0-188)	8 (0-183)	55 (0-298)	36 (0-276)	0 (0-64)

Note: Data are shown as median with interquartile ranges (Q1 to Q3).

[a]Absent at test day or participating in less than 7 tests.

[b]Excluded athletes vs all athletes, data are based on median regression analyses adjusted for sex.

TABLE 5 The association between injury or illness (mean number of health problems with 95% CI) comparing the least fit athletes (lowest quartile according to composite score) to the rest of the cohort. Data are based on univariate and multiple linear regression analyses adjusted for BMI, baseline training load and birthdate[a]

	Number of health problems (mean)		Unadjusted		Adjusted	
	Least fit	Rest of cohort	*P*-value	*B* (95% CI)	*P*-value	*B* (95% CI)
All athletes (n = 166)	n = 42	n = 124				
All health problems	3.7 (3.0-4.4)	3.6 (3.2-3.9)	0.77	0.10 (−0.59 to 0.79)	0.62	0.18 (−0.52 to 0.87)
Illnesses	1.9 (1.3-2.4)	1.7 (1.5-2.0)	0.63	0.12 (−0.36 to 0.59)	0.49	0.17 (−0.31 to 0.65)
Acute injuries	1.0 (0.6-1.4)	0.9 (0.7-1.0)	0.51	0.13 (−0.26 to 0.52)	0.38	0.18 (−0.22 to 0.57)
Overuse injuries	0.8 (0.5-1.2)	1.0 (0.8-1.2)	0.44	−0.14 (−0.50 to 0.22)	0.37	−0.17 (−0.54 to 0.20)
Substantial health problems	2.2 (1.8-2.7)	1.9 (1.7-2.2)	0.18	0.34 (−0.16 to 0.83)	0.18	0.34 (−0.16 to 0.84)
Illnesses	1.1 (0.7-1.5)	1.1 (0.9-1.2)	0.84	0.04 (−0.33 to 0.41)	0.83	0.04 (−0.33 to 0.42)
Acute injuries	0.6 (0.3-0.9)	0.4 (0.3-0.6)	0.26	0.15 (−0.11 to 0.41)	0.24	0.16 (−0.11 to 0.42)
Overuse injuries	0.6 (0.3-0.8)	0.4 (0.3-0.5)	0.27	0.14 (−0.11 to 0.40)	0.28	0.14 (−0.12 to 0.40)
Girls (n = 47)	n = 12	n = 35				
All health problems	4.0 (3.1-4.9)	4.4 (3.8-4.9)	0.50	−0.37 (−1.46 to 0.72)	0.29	−0.54 (−1.55 to 0.47)
Illnesses	2.0 (0.9-3.1)	2.0 (1.6-2.5)	0.95	−0.03 (−1.02 to 0.96)	0.72	−0.18 (−1.15 to 0.80)
Acute injuries	0.8 (0.1-1.4)	1.2 (0.8-1.6)	0.27	−0.42 (−1.18 to 0.34)	0.28	−0.43 (−1.21 to 0.36)
Overuse injuries	1.3 (0.4-2.2)	1.2 (0.8-1.5)	0.83	0.08 (−0.65 to 0.81)	0.87	0.06 (−0.70 to 0.83)
Substantial health problems	2.7 (1.8-3.5)	2.0 (1.5-2.5)	0.15	0.67 (−0.25 to 1.58)	0.13	0.71 (−0.21 to 1.62)
Illnesses	1.3 (0.4-2.1)	1.1 (0.7-1.5)	0.79	0.11 (−0.71 to 0.93)	0.91	0.04 (−0.76 to 0.84)
Acute injuries	0.5 (0.0-1.1)	0.5 (0.3-0.8)	0.86	−0.04 (−0.53 to 0.45)	0.95	0.02 (−0.49 to 0.52)
Overuse injuries	0.9 (0.1-1.7)	0.3 (0.1-0.6)	0.04	0.60 (0.03-1.17)	0.03	0.65 (0.05-1.24)
Boys (n = 119)	n = 30	n = 89				
All health problems	3.5 (2.6-4.5)	3.3 (2.9-3.6)	0.50	0.29 (−0.55 to 1.13)	0.35	0.41 (−0.45 to 1.27)
Illnesses	1.8 (1.2-2.5)	1.6 (1.4-1.9)	0.53	0.17 (−0.36 to 0.71)	0.42	0.22 (−0.33 to 0.77)
Acute injuries	1.1 (0.6-1.6)	0.7 (0.5-0.9)	0.13	0.35 (−0.10 to 0.80)	0.06	0.44 (−0.01 to 0.90)
Overuse injuries	0.7 (0.3-1.0)	0.9 (0.7-1.1)	0.26	−0.23 (−0.64 to 0.18)	0.23	−0.26 (−0.68 to 0.17)
Substantial health problems	2.1 (1.5-2.6)	1.9 (1.6-2.2)	0.50	0.20 (−0.39 to 0.79)	0.58	0.17 (−0.44 to 0.77)
Illnesses	1.0 (0.6-1.5)	1.0 (0.8-1.2)	0.96	0.01 (−0.40 to 0.42)	0.92	−0.02 (−0.44 to 0.40)
Acute injuries	0.6 (0.3-1.0)	0.4 (0.3-0.6)	0.15	0.23 (−0.09 to 0.54)	0.18	0.22 (−0.1 to 0.55)
Overuse injuries	0.4 (0.2-0.6)	0.4 (0.3-0.6)	0.78	−0.04 (−0.31 to 0.24)	0.82	−0.03 (−0.32 to 0.25)
Team athletes (n = 84)	n = 21	n = 63				
All health problems	3.0 (2.1-3.9)	3.8 (3.3-4.2)	0.11	−0.76 (−1.71 to 0.19)	0.09	−0.83 (−1.79 to 0.13)
Illnesses	1.3 (0.7-2.0)	1.6 (1.4-1.9)	0.33	−0.27 (−0.81 to 0.27)	0.36	−0.26 (−0.82 to 0.30)
Acute injuries	1.0 (0.5-1.4)	1.1 (0.8-1.3)	0.66	−0.11 (−0.61 to 0.39)	0.63	−0.12 (−0.63 to 0.38)
Overuse injuries	0.7 (0.3-1.2)	1.1 (0.9-1.3)	0.13	−0.38 (−0.88 to 0.11)	0.08	−0.45 (−0.95 to 0.05)
Substantial health problems	2.1 (1.4-2.8)	2.0 (1.6-2.4)	0.74	0.13 (−0.62 to 0.88)	0.81	0.09 (−0.67 to 0.85)
Illnesses	0.9 (0.5-1.3)	0.9 (0.7-1.1)	0.83	−0.05 (−0.48 to 0.39)	0.87	−0.04 (−0.49 to 0.41)
Acute injuries	0.7 (0.2-1.1)	0.5 (0.4-0.7)	0.51	0.13 (−0.26 to 0.51)	0.55	0.11 (−0.26 to 0.48)
Overuse injuries	0.6 (0.2-0.9)	0.5 (0.3-0.7)	0.81	0.05 (−0.34 to 0.44)	0.93	0.02 (−0.38 to 0.41)

(Continues)

TABLE 5 (Continued)

	Number of health problems (mean)		Unadjusted		Adjusted	
	Least fit	Rest of cohort	*P*-value	*B* (95% CI)	*P*-value	*B* (95% CI)
Technical athletes (n = 37)	n = 8	n = 29				
All health problems	5.0 (2.3-7.7)	3.3 (2.5-4.0)	0.07	1.7 (−0.13 to 3.58)	0.24	1.02 (−0.71 to 2.75)
Illnesses	2.3 (0.6-3.9)	1.1 (0.6-1.7)	0.08	1.11 (−0.14 to 2.36)	0.27	0.62 (−0.50 to 1.76)
Acute injuries	2.0 (0.5-3.6)	0.9 (0.4-1.4)	0.07	1.07 (−0.11 to 2.25)	0.22	0.73 (−0.45 to 1.91)
Overuse injuries	0.8 (0.0-1.6)	1.2 (0.8-1.6)	0.32	−0.46 (−1.37 to 0.46)	0.47	−0.34 (−1.29 to 0.61)
Substantial health problems	2.4 (1.0-3.7)	1.7 (1.3-2.1)	0.17	0.69 (−0.30 to 1.67)	0.35	0.48 (−0.54 to 1.50)
Illnesses	0.9 (0.0-2.0)	0.6 (0.3-0.8)	0.35	0.32 (−0.38 to 1.02)	0.48	0.25 (−0.46 to 0.95)
Acute injuries	0.9 (0.2-1.6)	0.6 (0.3-0.9)	0.44	0.25 (−0.41 to 0.92)	0.84	0.07 (−0.61 to 0.75)
Overuse injuries	0.6 (0.0-1.5)	0.5 (0.2-0.8)	0.75	0.11 (−0.58 to 0.80)	0.65	0.17 (−0.56 to 0.90)
Endurance athletes (n = 45)	n = 11	n = 34				
All health problems	3.8 (2.7-4.9)	3.5 (2.9-4.1)	0.58	0.32 (−0.84 to 1.48)	0.47	0.42 (−0.75 to 1.59)
Illnesses	3.2 (2.2-4.2)	2.3 (1.9-2.7)	0.05	0.86 (0.01 to 1.71)	0.06	0.86 (−0.03 to 1.74)
Acute injuries	0.4 (0.0-0.7)	0.4 (0.1-0.6)	0.96	0.01 (−0.47 to 0.49)	0.88	0.04 (−0.46 to 0.53)
Overuse injuries	0.3 (0.0-0.7)	0.8 (0.5-1.2)	0.10	−0.55 (−1.20 to 0.10)	0.15	−0.47 (−1.12 to 0.17)
Substantial health problems	2.3 (1.3-3.3)	2.0 (1.6-2.5)	0.61	0.24 (−0.72 to 1.20)	0.59	0.27 (−0.73 to 1.27)
Illnesses	2.1 (1.1-3.1)	1.7 (1.3-2.0)	0.27	0.44 (−0.36 to 1.25)	0.31	0.43 (−0.41 to 1.26)
Acute injuries	0.1 (0.0-0.3)	0.2 (0.0-0.4)	0.64	−0.09 (−0.45 to 0.28)	0.63	−0.09 (−0.47 to 0.28)
Overuse injuries	0.1 (0.0-0.3)	0.2 (0.0-0.4)	0.46	−0.12 (−0.43 to 0.20)	0.65	−0.07 (−0.37 to 0.24)

[a]Born before or after July 1st.

increased risk of spurious significant findings. Second, due to reduced sample size in the stratified subgroup analyses, statistical power is limited in the subgroup analyses, which means that true relationships may be overlooked. To aid the reader when interpreting the data, we have provided adjusted and/or unadjusted B-values all for these analyses (Tables 5 and 6).

There is a wide array of different physical performance tests, but limited and conflicting evidence regarding their measurement properties.[34-36] No test batteries for youth elite athletes are available and validated for use across a variety of sports. We therefore used the Ironman JR Test-battery, preferred by the Sport Academy High Schools and adapted specifically for youth athletes. The purpose of the test battery is to evaluate general physical fitness level, to promote versatile training and to provide motivation for further training goals.

Prior to testing, all test procedures were standardized and monitored by the research team; however, test-retest reliability is not known. An overall scoring system for Ironman Jr has not been developed. Instead, because we wanted to evaluate general physical fitness level across different sports and not sport-specific performance or fitness, we used a composite score based on each athlete's ranking on each separate test summed. A limitation of this approach is that all test components are weighted equally, and their relevance may differ between different sports—both related to performance and injury risk. Confounding factors such as differences in sport-specific skills between participants from different sport categories or disciplines, as well as different familiarity with the testing procedures, may also have affected the internal validity of the tests. Likewise, categorization of continuous variables results in loss of information, potentially masking other associations.

Maturational vs chronological age are risk factors specifically related to adolescent athletes.[6,37] In this study, the less mature athletes may have performed at a lower level compared with their more mature peers, and a bias toward the less mature athletes being in the less fit quartile is possible.

Another concern is previous injury, consistently representing as a risk factor in previous research.[8,29,30,38] We did not adjust for previous injuries in our analyses, but the same proportion of athletes (85%) reported one or more previous injuries both among participating and excluded athletes. Thus, a selection bias in either direction is less likely.

Finally, we have previously reported that differences between prospectively collected injury and illness data and retrospective collected data are minimal, with an average weekly prevalence for health problems reported prospectively of 44% (95% CI: 37%-52%) vs problems reported retrospectively of 40% (95% CI: 31%-51%).[26] Consequently, a recall bias related to outcomes is unlikely.

4.1 | The association between level of physical fitness and all health problems

Previous research regarding the association between physical fitness level and injury and illness risk in youth athletes is limited. Only a few studies have provided data in line with our results. First, in an epidemiological study on 21 division 1-4 male and female football teams (age 12-18 years) no association was demonstrated between pre-season physical fitness tests and in-season injury.[12] Second, pre-season physical fitness tests were of limited value in predicting new injuries in two prospective studies on male elite youth football players (n = 84 and n = 67).[13,14] Finally, in a prospective study on 382 male elite junior Australian rules football players, an association between physical fitness compounds (lower aerobic endurance, greater sprint, and agility performances) with increased injury risk was first demonstrated,[15] but not reproduced.[16]

Two studies on youth elite alpine skiers are in conflict with our results. A 2-year prospective study on 81 youth alpine ski racers attending a ski boarding school demonstrated an association between poor core and reactive leg strength with injury and injury severity.[24] Likewise, core strength was associated with a greater risk of ACL injuries in a retrospective study on 370 youth elite ski racers.[25] Some factors might explain the apparent discrepancy. We evaluated a mixed cohort representing 30 different sports, not only alpine skiers. Injuries might be more sport-specific in the youth elite population. Stratification by endurance, technical and team sport groups only, may have masked true associations between physical fitness tests within the same sports, as well as between the different physical fitness tests. We also examined physical fitness level in general, and although there were substantial differences in test results, youth elite athletes still represent a relatively homogeneous group of youth athletes. A ceiling effect is therefore possible.[8]

4.2 | The association between sex, level of physical fitness, and health problems

In our study, the least fit girls reported more substantial overuse injuries during the school year. This has not been demonstrated previously at the elite youth level, only in a case-control study among 54 adolescent female youth soccer players at a lower performance level, demonstrating that in-season injury and illness risk were associated with pre-season aerobic fitness level. In our cohort, the steep increase in training and competition load when entering the sport academy high school environment can possibly explain more overuse injuries among the least fit girls.[27]

4.3 | The association between sport category, level of physical fitness, and health problems

Sport category influenced the association between fitness level and injury and illness risk differently in youth elite athletes. For youth elite endurance athletes, there was a tendency that the least fit athletes were at greater risk of incurring an illness. This has not been demonstrated in previous research. Rather, previous authors have discussed long-term intensive training periods as a risk factor for illness, mainly in the adult endurance athletic population,[20,21,23] but also in a previous study on 18 youth elite swimmers.[39] Nevertheless, some previous reports suggest that youth athletes may need longer recovery than adult athletes.[5,28] This is in line with our results.

In contrast, there was a tendency of less health problems among the least fit team sport athletes. Two prospective cohort studies on elite youth football and volleyball players are in support of this finding, describing youth elite players with a high level of football skills or greater jumping ability as being at a higher risk of sustaining injuries.[40,41] Greater athleticism might expose the more fit team sport athletes to higher match exposure, as well as attending multiple practices with several different teams.[26] Consequently, inadequate rest and recovery may result in negative outcomes such as injury and illness for the most fit team sport athletes.[27]

5 | PERSPECTIVES

Youth elite athletes are at a high risk of becoming injured or ill after enrollment into a specialized sport academy high school environment. Internal risk factors specifically relevant to this population need further exploration. We used physical fitness tests to identify the least fit quartile among youth elite athletes of both sexes and across endurance, technical, and team sports. Overall, we demonstrated no significant association between low physical fitness level and number and severity of injury and illness. However, the least fit girls reported more overuse injuries and the least fit endurance athletes tended to report more illnesses. In order to protect the youth elite athletes from negative adaptations such as injury and illness, and allow them to withstand the

TABLE 6 The association between median cumulative severity score of health problems with interquartile ranges (Q1, Q3) comparing the least fit athletes (lowest quartile according to composite score) to the rest of the cohort. Data are based on multiple median regression analyses adjusted for date of birth[a], baseline training load, and BMI

	Median cumulative severity score		Adjusted	
	Least fit	Rest of cohort	*P*-value	*B* (95% CI)
All athletes (n = 166)	n = 42	n = 124		
All health problems	304 (153, 741)	304 (157, 643)	0.82	−20 (−195 to 155)
Illnesses	86 (0, 224)	100 (45, 204)	0.37	−28 (−90 to 34)
Acute injuries	14 (0, 122)	13 (0, 152)	1.00	−5 (−33 to 33)
Overuse injuries	0 (0, 169)	37 (0, 187)	0.35	−29 (−91 to 33)
Girls (n = 47)	n = 12	n = 35		
All health problems	473 (246, 798)	362 (206, 845)	0.94	17 (−402 to 436)
Illnesses	55 (2, 305)	138 (38, 228)	0.21	−89 (−231 to 53)
Acute injuries	0 (0, 59)	50 (0, 179)	0.76	−22 (−166 to 122)
Overuse injuries	10 (0, 699)	46 (0, 170)	0.70	−39 (−244 to 165)
Boys (n = 119)	n = 30	n = 89		
All health problems	271 (103, 716)	267 (109, 631)	0.96	5 (−189 to 198)
Illnesses	98 (0, 219)	92 (46, 194)	0.84	−7 (−80 to 65)
Acute injuries	24 (0, 129)	0 (0, 99)	0.57	13 (−32 to 58)
Overuse injuries	0 (0, 127)	14 (0, 203)	0.77	−11 (−84 to 62)
Team (n = 84)	n = 21(1)	n = 63(0)		
All health problems	506 (134, 939)	319 (142, 661)	0.34	134 (−143 to 410)
Illnesses	72 (0, 163)	92 (46, 192)	0.22	−46 (−119 to 27)
Acute injuries	42 (0, 143)	37 (0, 185)	0.71	−17 (−106 to 72)
Overuse injuries	0 (0, 876)	60 (0, 273)	0.67	−40 (−231 to 150)
Technical athletes (n = 37)	n = 8	n = 29		
All health problems	428 (168, 786)	274 (108, 535)	0.61	110 (−324 to 545)
Illnesses	113 (9, 216)	8 (0, 144)	0.09	74 (−13 to 162)
Acute injuries	82 (11, 303)	14 (0, 192)	0.47	−58 (−220 to 104)
Overuse injuries	14 (0, 585)	43 (0, 276)	0.91	−22 (−414 to 370)
Endurance athletes (n = 45)	n = 11 (1)	n = 34 (0)		
All health problems	304 (106, 459)	285 (172, 536)	0.63	58 (−184 to 299)
Illnesses	304 (60, 399)	184 (85, 352)	0.21	155 (−92 to 403)
Acute injuries	0 (0, 35)	0 (0, 0)	1.00	−5 (−11 to 11)
Overuse injuries	0 (0, 0)	0 (0, 76)	1.00	3 (−63 to 63)

[a]Born before or after July 1st.

high training- and competition load applied, future studies need to further evaluate potential risk factors such as physical fitness level, sex, and sport category as well as growth and maturation.

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SUPPORTING INFORMATION

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

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Oslo Sports Trauma
RESEARCH CENTER

The OSTRC Questionnaire on Health Problems

Please answer all questions regardless of whether or not you have experienced health problems in the past week. Select the alternative that is most appropriate for you, and in the case that you are unsure, try to give an answer as best you can anyway.
If you have several illness or injury problems, please refer to the one that has been your worst problem this week. You will have a chance to register other problems at the end of the questionnaire.

Question 1
Have you had any difficulties participating in normal training and competition due to injury, illness or other health problems during the past week?

- ☐ Full participation without health problems
- ☐ Full participation, but with injury/illness
- ☐ Reduced participation due to injury/illness
- ☐ Cannot participate due to injury/illness

Question 2
To what extent have you reduced you training volume due to injury, illness or other health problems during the past week?

- ☐ No reduction
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Question 3
To what extent has injury, illness or other health problems affected your performance during the past week?

- ☐ No effect
- ☐ To a minor extent
- ☐ To a moderate extent
- ☐ To a major extent
- ☐ Cannot participate at all

Question 4
To what extent have you experienced symptoms/health complaints during the past week?

- ☐ No symptoms/health complaints
- ☐ To a mild extent
- ☐ To a moderate extent
- ☐ To a severe extent

Oslo Sports Trauma
RESEARCH CENTER

Question 5

Is the health problem referred to in the four questions above an injury or an illness?

- ☐ Acute injury (linked to a specific injury event, such as falling or being tackled)
- ☐ Overuse injury (not linked to a single clearly identifiable event)
- ☐ Illness

Question 6 - Injury Area

Please select box that best describes the location of your injury. If the injury involves several locations please select the main area. If you have multiple injuries please complete a separate registration of each one.

- ☐ Head/face
- ☐ Neck
- ☐ Shoulder (including clavicle)
- ☐ Upper arm
- ☐ Elbow
- ☐ Forearm
- ☐ Wrist
- ☐ Hand/fingers
- ☐ Chest/ribs
- ☐ Abdomen
- ☐ Thoracic spine
- ☐ Lumbar spine
- ☐ Pelvis and buttock
- ☐ Hip and groin
- ☐ Thigh
- ☐ Knee
- ☐ Lower leg
- ☐ Ankle
- ☐ Foot/toes
- ☐ Other

Oslo Sports Trauma
RESEARCH CENTER

Question 7 - Illness Symptoms

Please check the boxes corresponding to the major illness symptoms you have experienced during the past 7 days. You may select several alternatives.

- ☐ Fever
- ☐ Fatigue/malaise
- ☐ Swollen glands
- ☐ Sore throat
- ☐ Blocked nose/running nose/sneezing
- ☐ Cough
- ☐ Breathing difficulty/tightness
- ☐ Headache
- ☐ Nausea
- ☐ Vomiting
- ☐ Diarrhoea
- ☐ Constipation
- ☐ Fainting
- ☐ Rash/itchiness
- ☐ Irregular pulse/arrhythmia
- ☐ Chest pain/angina
- ☐ Abdominal pain
- ☐ Other pain
- ☐ Numbness/pins and needles
- ☐ Anxiety
- ☐ Depression/sadness
- ☐ Irritability
- ☐ Eye symptoms
- ☐ Ear symptoms
- ☐ Symptoms from urinary tract/genitalia
- ☐ Other. *Please specify* ____________________

Question 8 - Time loss

Please state the number of days over the past 7-day period that you have had to completely miss training or competition due to this problem?

☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7

Question 9

Have you experienced any other illnesses, injuries or other health problems during the past 7 days?

☐ Yes, I want to report another problem

☐ No, I am finished

Question 10

How many hours have you trained/competed during the past 7 days? ____________hours

SENTER FOR Idrettsskadeforskning KLOKE AV SKADE

Skadeskjema nummer: ☐

«Helsesjekk»
Den unge eliteutøverens helse
2014/2015

Utøvers navn: ____________________ Fødselsdato: ____________________

Skole: ____________________ Idrett: ____________________

Treningsdagbok: ☐Nei ☐ Ja Type dagbok: ____________________

Tilgang: ☐Nei ☐ Ja

APP-data tilgjengelig: ☐Nei ☐Ja

Uke	Dato 2014-2015	Samling/konkurranse	Skade: (sett kryss OG merk som 1,2..)	Sykdom: (sett kryss OG merk som 1,2...)
45	03-09.11			
46	10-16.11			
47	17-23.11			
48	24-30.11			
49	01-07.12			
50	08-14.12			
51	15-21.12			
52	22-28.12	Juleferie		
1	29.12-04.01			
2	05-11.01			
3	12-18.01			
4	19-25.01			
5	26.01-01.02			
6	02-08.02			
7	09-15.02			
8	16-22.02	Vinterferie		
9	23.02-01.03			
10	02-08.03			
11	09-15.03			
12	16-22.03			
13	23-29.03	Påskeferie		
14	30.03-05.04			
15	06-12.04			
16	13-19.04			
17	20-26.04			
18	27.04-03.05			

Antall skader/sykdom: ____________ Antall skade-/sykdomsskjema: __________

SENTER FOR
Idrettsskadeforskning
KLOKE AV SKADE

Skadeskjema nummer: ☐

App-data:

Har utøveren registrert regelmessig via Helsesjekken?

☐ Ja ☐ Nei, hvorfor ikke:

- ☐ Brukernavn og passord fungerte ikke
- ☐ Har registrert regelmessig (data ikke importert i SpartaNova)
- ☐ Problemer med innlogging
- ☐ Det stod på Appen at jeg hadde levert ukens helsesjekk
- ☐ Vært frisk
- ☐ Operert
- ☐ Annen langvarig skade eller sykdom
- ☐ Glemte det
- ☐ Har ikke trent
- ☐ Ble lei, ønsket ikke å delta lenger
- ☐ Manglet nettverk
- ☐ Annet, hva:

Har utøveren hatt noen kjente feilregistreringer på Helsesjekken?

☐ Nei ☐ Ja, beskriv:

Andre kommentarer:

SENTER FOR
Idrettsskadeforskning
KLOKE AV SKADE

Skadeskjema nummer: ☐

Skade- og sykdomsskjema for
den unge eliteutøveren

Navn   Kjønn: K☐ M☐

Skaderegion: ☐ Høyre ☐ Venstre ☐ Ingen

- ☐ Hodet/ ansikt
- ☐ Nakke/hals
- ☐ Skulder inkl. kragebein
- ☐ Overarm
- ☐ Albue
- ☐ Underarm
- ☐ Håndledd
- ☐ Fingre
- ☐ Brystkasse inkl. indre organer
- ☐ Mageregion inkl. indre organer
- ☐ Øvre del av rygg (brystrygg)
- ☐ Nedre del av rygg (korsrygg)
- ☐ Bekken
- ☐ Hofte/lyske
- ☐ Lår
- ☐ Kne
- ☐ Legg
- ☐ Ankel
- ☐ Fot/tær

Skadetype:

- ☐ Akutt
- ☐ Belastning
- ☐ Sykdom

Fravær fra trening eller konkurranse:

- ☐ Nei
- ☐ Ja ☐ Antall dager

Diagnose ved sykdom/skade:

Mer utfyllende om alvorlighetsgraden av den aktuelle skaden/sykdommen
i GJENNOMSNITT FOR HELE PERIODEN:

Hadde du problemer med å **delta** i din idrett på grunn av dette helseproblemet?

- ☐ Deltok for fullt uten problemer
- ☐ Deltok for fullt, men med skade-/sykdomsproblem
- ☐ Redusert deltagelse, på grunn av skade/sykdom
- ☐ Kunne ikke delta på grunn av skade/sykdom

I hvilken grad reduserte du **treningsmengden** din på grunn av dette helseproblemet?

- ☐ Ingen reduksjon
- ☐ I liten grad
- ☐ I moderat grad
- ☐ I stor grad
- ☐ Kunne ikke delta

I hvilken grad opplevde du at dette helseproblemet påvirket din **prestasjonsevne** i din idrett?

- ☐ Ingen påvirkning
- ☐ I liten grad
- ☐ I moderat grad
- ☐ I stor grad
- ☐ Kunne ikke delta

I hvilken grad opplevde du **symptomer/helseplager** ila denne perioden?

- ☐ Ingen symptomer/helseplager
- ☐ I liten grad
- ☐ I moderat grad
- ☐ I stor grad

Trenerevaluert ferdighetsnivå av utøvere

Vurdér utøveren og sett kryss i det tilhørende rubrikkfeltet der du mener utøveren befinner seg i forhold til gjennomsnittet for din utøvergruppe, blant de 25% svakeste, blant de 25% under middels, blant de 25% over middels eller blant de 25% beste. For hver utøver settes kun ett kryss per spørsmål .

To spørsmål skal besvares for hver utøver 3 ganger i løpet av skoleåret; i dag, etter 5 måneder og etter 10 måneder:

1. På hvilket nivå mener du at spilleren/utøveren **presterer idag** i forhold til gjennomsnittet for din utøvergruppe?
2. På hvilket nivå forventer du at spilleren/utøveren **vil prestere på sikt** i forhold til gjennomsnittet for din utøvergruppe?

Idrett	*Navn*	*Spørsmål*	*Svakest 25%*	*Middels 25%*	*25%*	*Best 25%*
1.		1. Prestasjon idag?				
		2. Prestasjon på sikt?				
2.		1. Prestasjon idag?				
		2. Prestasjon på sikt?				
3.		1. Prestasjon idag?				
		2. Prestasjon på sikt?				
4.		1. Prestasjon idag?				
		2. Prestasjon på sikt?				
5.		1. Prestasjon idag?				
		2. Prestasjon på sikt?				
6.		1. Prestasjon idag?				
		2. Prestasjon på sikt?				
7.		1. Prestasjon idag?				
		2. Prestasjon på sikt?				

Skjemaet er fylt ut av trener: .... Dato: ....

Ironman Testbatteriene

Versjon 4.2, 15. aug 2013

Norges Skiforbund
Olympiatoppen

Innholdsfortegnelse

INTRODUKSJON

Hensikten med dette heftet er å dokumentere test protokoller, scoring systemer, og standarder for Ironman Testbatteriene, versjon 4. Håpet er at hele alpin Norge, fra klubb til World Cup nivå, kan få nytte av en felles test system i en rekke år fremover.

BAKGRUNN

Ironman test batteriet ble opprinelige utviklet i våren 2002 for herrer landslagene (World Cup, Europa Cup, og Junior lagene). Hensikten var å evaluere det generelle fysisk grunnlag som er nødvendig for å konkurrere på topp nivå i alpint samt å sette en mer offensiv, nesten konkurranse likt preg på testing. Siden det tiden har Ironman begynte å bli brukte av flere miljøer i Alpin-Norge. Samtidig har hensikten for Ironman vokste til å innebære det følgende:

- Test den generelle fysisk grunnlag som er nødvendig for å bli en topp alpinist.
- Sett fokus på generelle, allsidig, grunnlags trening for yngre løpere.
- Skap motivasjon for trening ved å gi et system for målsetting og feedback i forhold til langsiktig og kortsiktig mål.
- Sett prestisje i å være i god fysisk form. Ironman skal være et ledd i et system som skaper en offensiv, grense sprengende trenings kultur.
- Skap en "historikk" i resultater gjennom å føre opp rekorder på enkelte tester og sammenlagt score.
- Skap en balansert og allsidig perspektiv på trening. Vi trener ikke bare for idrettens skyld, men også for å øke livskvalitet.
- Test dagen i seg selv skal være en bra trenings økt.
- Testene skal være enkle, lett gjennomførbare, og tilgjengelige for testing over hele landet.

Når Ironman begynte å bli brukte av aldersgrupper yngre enn det som var det opprinelige målgruppen, noen tilpasninger var nødvendig. Dette førte til utvikling av Ironman Jr. for yngre alpinister. Samtidig som Ironman Jr. skulle være tilpasset yngre utøvere så skulle den definere en fornuftig progresjon mot standard testen Ironman.

NY TIL VERSJON 4.2

Følgende endringer er tatt med til versjon 4.2:

- Start kommando for HEX er "KLAR ….. GO!" Både utøver og klokka starter på "GO!"
- Begge bein må treffe bakken innenfor HEX'en for en godkjent målgang, ellers så teller man forsøket som disk.
- På KASSEHOPP starter utøveren på toppen av kassen. Utøveren begynner av eget initiativ og klokka starter på første bakketreff.
- Det er ikke lov med pauser på BRUTAL BENKEN, enten de er i bunn eller på toppen av bevegelsen. På første pause over 1 sekund varsles utøveren. På neste pause stopper testen.
- Diverse presiseringer i protokollen og oppdateringer i registreringsskjemaer.

TESTBATTERIENE

Det er nå definert to testbatterier. Ironman er batteriet for både damer og herrer, 17 år og eldre. Ironman Jr. er for både jenter og gutter i alder 12 til 16 år. **Formelt sett så skal utøvere skifte til Ironman sesongen de fyller 17 år.** Men denne overgangen må vurderes for hver enkelt utøver basert på deres modenhet og treningsbakgrunn. Sikkerhet og kvalitet i gjennomføring av testene skal alltid prioriteres og utøvere skal kun ta steget fra Ironman Jr til Ironman når de er fysisk klar for det.

Testbatteriene består av 8 øvelser. Gitt at hensikten for Ironman er å teste den generelle fysisk grunnlag, så dekker testene en bred spekter av fysiske egenskaper som er viktig med tanke på den grunnlag som man må ha for å trene de belastningene nødvendig for å bli en topp alpinist.

	IRONMAN JR (12 til 16 år)	IRONMAN (17 år og eldre)
AEROB UTHOLDENHET	3000 m (s. 6)	3000 m (s. 6)
HURTIGHET KOORDINASJON	HEXAGONAL OBSTACLE (s. 7)	HEXAGONAL OBSTACLE (s. 7)
MAKS STYRKE BEIN	LENGDE UTEN TILLØP (s. 10)	1 RM KNEBØY (s. 9)
SUBMAKS STYRKE BEIN	KNEBØY TEKNIKK (s. 12)	SUBMAKS KNEBØY (s. 11)
STYRKE OVERKROPP	PUSH-UPS (s. 14)	1 RM BENKPRESS (s. 13)
STYRKE OVERKROPP	CHINS (s. 15)	CHINS (s. 15)
STYRKE BUK	BRUTAL BENK (s. 16)	BRUTAL BENK (s. 16)
ANAEROB UTHOLDENHET	90 SEK KASSEHOPP (s. 17)	90 SEK KASSEHOPP (s. 17)
ARBEIDS KAPASITET	--	SAMMENLAGT POENG (s. 18)

TEST REKKEFØLGE

<u>For at man skal kunne sammenligne resultater fra test til test er det veldig viktig at man følger nøye test rekkefølgen</u>. Testen skal utføres som en type ”10 kamp” og tar ca. 4 timer. Løperne skal ha minimum 30 minutters tid til oppvarming. De kan varme opp etter eget protokoll, men det burde innholde en del løping på relativt høy intensitet før 3000 m. Det er viktig at man følger retningslinjene for pausene men tidene kan justeres noe i forhold til logistikk.

IRONMAN JR (12 til 16 år)	IRONMAN (17 år og eldre)
OPPVARMING	OPPVARMING
1. 3000 M	1. 3000 M
2. HEXAGONAL OBSTACLE	2. HEXAGONAL OBSTACLE
3. LENGDE UTEN TILLØP	Ca. 30 min pause med aktiv restitusjon
Ca. 15 min pause med aktiv restitusjon	3. 1 RM KNEBØY
4. KNEBØY TEKNIKK	4. SUBMAKS KNEBØY
5. PUSH-UPS	5. 1 RM BENKPRESS
6. CHINS	6. CHINS
7. BRUTAL BENK	7. BRUTAL BENK
Ca. 15 min pause med aktiv restitusjon	Ca. 15 min pause med aktiv restitusjon
8. 90 SEK KASSEHOPP	8. 90 SEK KASSEHOPP

3000 M

(Ironman og Ironman Jr)

EGENSKAPER :

Aerob kapasitet, fysisk og psykisk kapasitet å presse seg selv.

UTSTYR :

Standard friidrettsbane (400m bane, helst tartan dekke), stoppeklokka (ha gjerne 1 ekstra klokka som back up).

OPPVARMING :

Siden dette er første test er en veldig grundig generelle og spesifikk oppvarming viktig. Oppvarmingen burde bestå av minimalt 30 minutter generelle oppvarming og 10 til 15 minutter løping med progressivt økt intensitet.

PROSEDYRE :

Målet er å løpe 3000 m så fort som mulig. Løpere skal gjennomføre 7,5 runder rundt en 400m bane. Start kommandoen er ”KLAR ... FERDIG … GO!” Løpere og tidtagning starter på ”GO”. Det er lov å gi sekundering (Se skjema i vedlegg A). Tid i minutter og sekunder er registrert som resultatet.

HEXAGONAL OBSTACLE

(Ironman og Ironman Jr)

EGENSKAPER :

Koordinasjon og hurtighet i en skispesifikk øvelse.

UTSTYR :

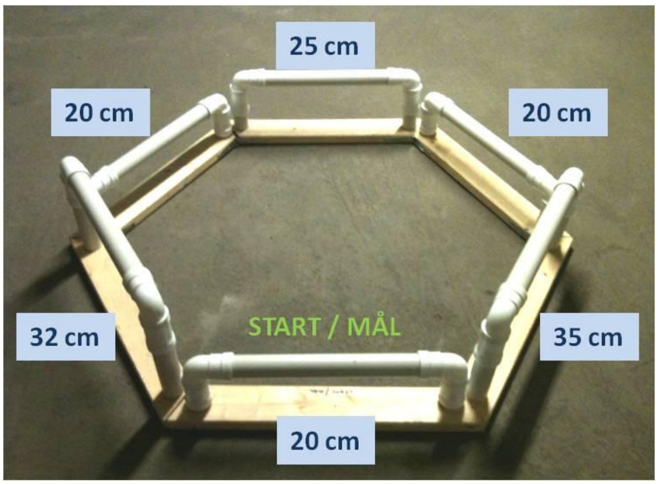
Standard Hexagonal Obstacle (se vedlegg for spesifikasjoner), stoppeklokka, hardt underlag med god friksjon (tørr tartan dekk på friidrettsbane, tørr asfalt).

OPPVARMING :

Siden testen kommer i etterkant av 3000 m, så burde utøverne være grundig oppvarmet generelt sett. Utøverne kan ha en spesifikk oppvarming av 2 til 4 oppvarmings forsøk.

PROSEDYRE :

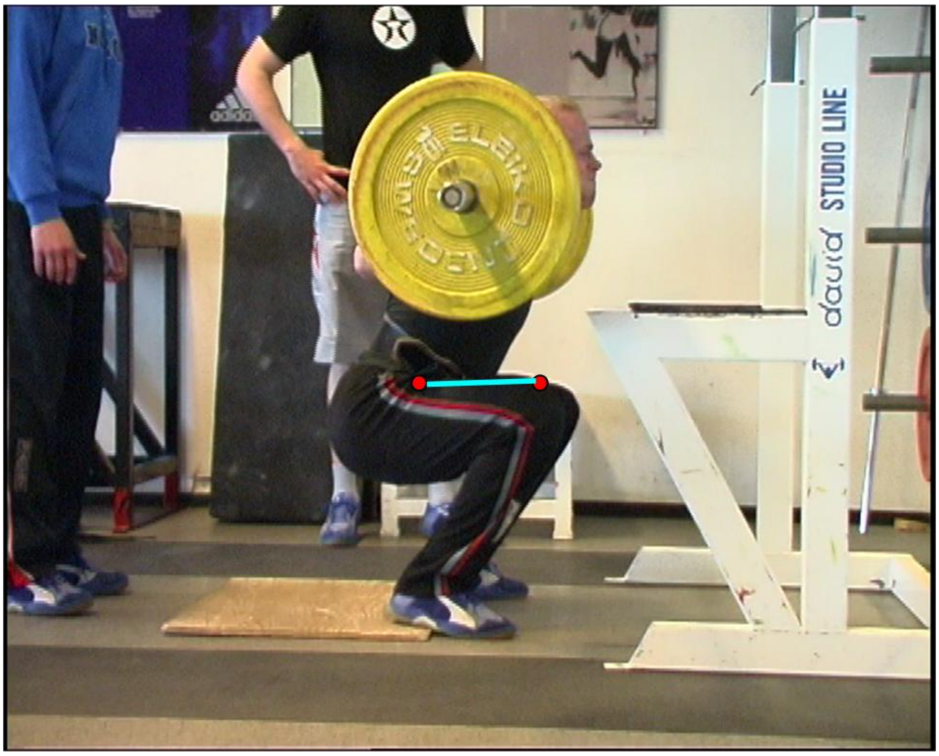
Målet er å hoppe gjennom hinderet så fort som mulig. Start posisjonen er på innsiden av hinderet ved siden av den 20 cm hekken som er mellom 32 og 35 cm hekkene (se diagram). Start kommandoen er ”KLAR …GO!” Utøver og tidtagning starter på ”GO!”. På start signalet begynner utøveren å hoppe med to bein rundt hinderet. Utøveren vender seg i fartsretningen. Et forsøk består av 2 runder og klokka er stoppet når utøveren lander <u>med begge bein</u> tilbake i midten av hinderet etter siste hopp over enten den 32 eller 35 cm hekken, avhengig av kjøreretningen.



Testen består av maksimalt 3 forsøk—og minimum 2 forsøk—i hver kjøreretning (med og mot klokka). Beste tid i hver retning er summert og summen er registrert som resultatet. Alle forsøk i retningen med klokka er gjennomført først, så alle forsøk i retningen mot klokka. Det er ikke lov å berøre hekkene. Hvis en hekk er slått nok til at vibrasjon i hekken er synlig for testlederen, så telles forsøket som en disk ***(NB: Unntaket er når hekken er slått under de to første hopp på et forsøk. I så fall registreres ikke disk og utøveren får starte på nytt. Dette er for å unngå passiv starter.)*** Hvis en utøver disker på alle 3 tillat forsøk i en kjøreretning, så er disk registrert som resultatet og utøveren scorer 0 poeng på Hex.

1 RM KNEBØY

(Ironman)



EGENSKAPER :

Maksimal bein styrke.

UTSTYR :

Knebøy stativ, standard 20 kg stang, vekter, vekt belt. Minimum 4 personer (3 spotting og 1 som passer teknikken).

OPPVARMING :

Utøverne skal justere den spesifikk oppvarmingen selv basert på personlig rutiner under treningen. Oppvarmingen skal gjerne bestå av øvelser med egen kroppsvekt fulgt av 5 til 6 serier med progressivt økt belastning. Overgangen til test serier burde følge naturlig fra oppvarmings seriene. Feedback i forhold til teknikk og gjennomføring burde gis under oppvarming. Et forslag til oppvarmingsrutine er gitt i Vedlegg C.

PROSEDYRE :

Målet er å løftet mest mulig vekt i en repetisjon med godkjent teknikk. Oppvarming består av 4 til 5 serier med gradvis økende belastning. Det er tillat å bruke vekt belt – knee wraps, osv er ikke tillat. Hver repetisjon skal ned til det punkt hvor forsiden av låret - ved omdreiningspunktet i hofteledet - er lavere enn høyeste punkt på kneet. God teknikk SKAL alltid prioriteres. Det vil si at maks vekt er nådd når utøveren ikke klarer å gjennomføre løftet med god teknikk lenger – dette er ikke nødvendigvis det punktet hvor de svikter.

LENGDE UTEN TILLØP

(Ironman Jr)

EGENSKAPER :

Spenst, bein styrke.

UTSTYR :

Måleband centimeter, sand trap for lengde på friidrettsbane

OPPVARMING :

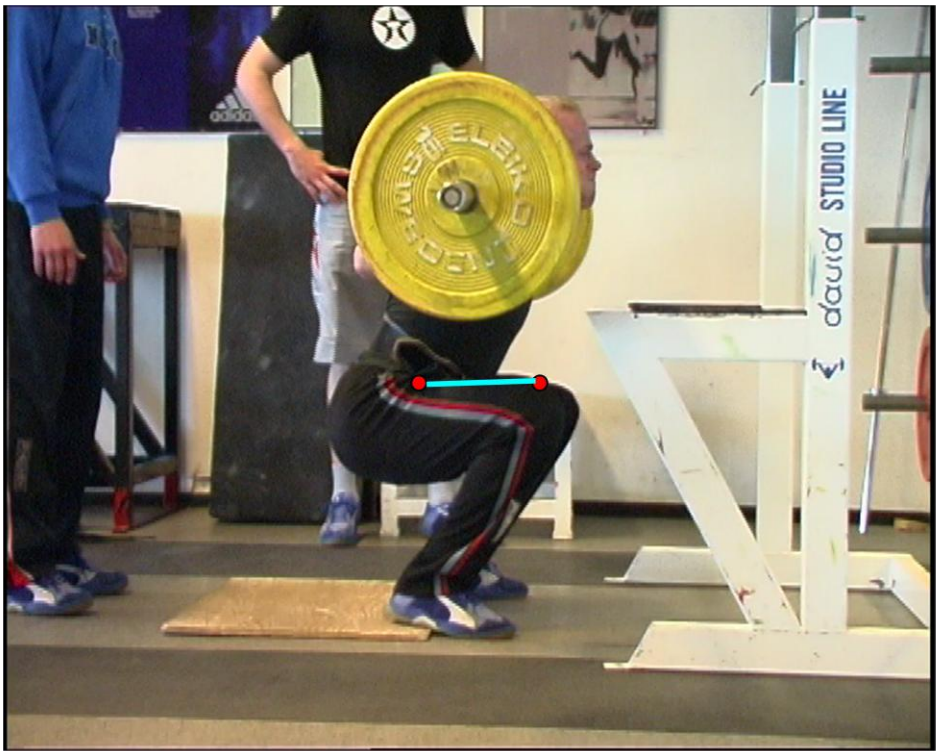
Utøverne får 4 til 5 oppvarmingsforsøk. Feedback i forhold til teknikk og gjennomføring burde gis under oppvarming.

PROSEDYRE :

Målet er å hoppe lengst mulig med godkjent teknikk. Testen skal bestå av minimum 3 forsøk. Flere forsøk enn 3 er tillat hvis man fortsetter å øke for hver forsøk. Testen skal helst foregå i en vanlig lengdehopp anlegg (det vil si at man lander i sand). Merker en start strek hvor måling skal begynne. Man stiller seg med tærne på strekken. Føttene skal ikke forflytte seg under bevegelsen. Man forsøker å hoppe lengste mulig fra en stille posisjon. Avstand er målt fra start linjen til den bakerst kontakt punkt med bakken / sand -uansett hvilken kroppsdel lander bakerst (hæl, rumpa, hånd, osv). Den lengste hopp er registrert som utøvers resultat.

SUBMAKS KNEBØY

(Ironman)



EGENSKAPER :

Submaksimal bein styrke.

UTSTYR :

Knebøy stativ, standard 20 kg stang, vekter, vekt belt. Minimum 2 personer, helst 4 (3 spotting, og 1 som passer teknikken).

OPPVARMING :

En spesifikk oppvarming for testen er normalt ikke gjennomført siden testen kommer i etterkant av 1RM Knebøy. I tilfeller der 1RM Knebøy ikke er gjennomført så burde det være en spesifikk oppvarming til knebøy over flere serier med progressivt økt belastning.

PROSEDYRE :

Målet er å løftet flest mulig repetisjoner med test belastning med godkjent teknikk. ***Det skal brukes 1,5 ganger egen kroppsvekt for herrer, og 1,2 ganger egen kroppsvekt for damer for test belastningen*** – mindre vekter kan tillates ved spesiel behov, men da teller ikke resultatet i Ironman sammendraget. Det er tillat å bruke vekt belt – knee wraps, osv er ikke tillat. God teknikk skal alltid prioriteres. Hver repetisjon skal ned til det punkt hvor forsiden av låret ved omdreiningspunktet i hofteledet er lavere enn høyeste punkt på kneet.

KNEBØY TEKNIKK

(Ironman Jr)

EGENSKAPER :

Knebøy løfteteknikk og submaks styrke.

UTSTYR :

Knebøy stativ, standard 20 kg stang, vekter, vekt belt. Minimum 2 personer (en til spotting, en til å passe teknikk)

OPPVARMING :

Oppvarming inngår som en del av test prosedyren. Et forslag til oppvarmingsrutine er gitt i Vedlegg C.

PROSEDYRE :

Målet er å gi utøverne feedback i forhold til knebøy løfteteknikk over 4 til 5 serier, eventuelt med progresjon i belastning. Test belastningen øker gradvis med alder for å skape en naturlig progresjon til full Submaks Knebøy test som 17-åring:

12 - 14 år – kun evaluering av teknikk med stangen
15 år – kroppsvekt x 20 rep
16 år – kroppsvekt + 10 kg x 20 rep

Det er derfor viktig at man justerer de overnevnt forslag for hver enkelt individ basert på treningsbakgrunn og styrke. God løfteteknikk skal alltid prioriteres. Det er tillat å bruke vekt belt, men ikke anbefalt. Knee wraps, osv er ikke tillat. Hver repetisjon skal ned til det punkt hvor forsiden av låret ved omdreiningspunktet i hofteledet er lavere enn høyeste punkt på kneet.

1RM BENKPRESS

(Ironman)

EGENSKAPER :

Maks styrke overkropp, bryst, triceps.

UTSTYR :

Standard benkpress apparat, standard 20 kg stang, vekter

OPPVARMING :

Utøverne skal justere den spesifikk oppvarmingen selv basert på personlig rutiner under treningen. Oppvarmingen skal gjerne bestå av 3 til 4 serier med progressivt økt belastning. Overgangen til test serier burde følge naturlig fra oppvarmings seriene.

PROSEDYRE :

Målet er å løfte mest mulig vekt for en repetisjon med godkjent teknikk. Bredde mellom pekefingrene skal være maksimalt 81 cm; rillene på styrkeløftstang (NB: ikke alle stanger er likt på dette mål). Vekten skal løftes rolig ned til midt på brystet og løftes opp igjen i en bevegelse uten å kippe stanga på brystet. ***Rumpa skal holdes i kontakt med benken under hele løftet. Føttene skal holdes flatt på bakken, alternativt opp i luftet med bøyd knær i tilfelle rygg smerter.***

PUSH-UPS

(Ironman Jr)

EGENSKAPER :

Stabiliserings styrke buk. Styrke overkropp, bryst, triceps.

UTSTYR :

Flatt jevn underlag. En portrør eller liggende kan benyttes av testleder, men det er ikke nødvendig.

OPPVARMING :

1-2 serier, 5 til 10 repetisjoner. Feedback i forhold til teknikk og gjennomføring burde gis under oppvarming.

PROSEDYRE :

Målet er å gjennomføre flest mulig godkjent repetisjoner. Det er ingen tidsbegrensning, men pauser lengre enn 1-2 sekunder er ikke tillatt. Ved første stopp over 1-2 sekunder får utøveren en varsel og testen stoppes ved neste stopp. Start posisjon for hver repetisjon er liggende på magen med hendene løftet opp fra gulvet. Når utøveren presser oppover skal hele kroppen løftes rigid, som en enhet. Det vil si at hakken, bryst, hofte, og lår løftes samtidig opp fra gulvet opp til armene når full ekstensjon. Alt beveger seg som en enhet ned igjen til hakken, bryst, hoftet, og lår treffer bakken samtidig. Hendene skal løftes fra gulvet mellom hver repetisjon.

Testleder må posisjonere seg lavt og langs siden for å kunne kontrollere dette. Når formen bryttes skal utøveren varsles en gang. Hvis problemet gjentar seg så teller ikke repetisjonene. Og hvis problemet fortsetter for et par repetisjoner så stopper testen. Som testleder er det spesielt viktig å følge med når utøveren starter en ny repetisjon og begynner å løfte fra bakken. Følg med på at alt løftes som en enhet mens de holder en nøytral og stabil buk/rygg posisjon. En typisk feil er at hoftet og lår blir liggende i bakken mens overkroppen løftes. Dette fører til svei i ryggen.

CHINS

(Ironman og Ironman Jr)

EGENSKAPER :

Overkropp styrke – Latissimus dorsi og rygg.

UTSTYR :

Hang ups stang.

OPPVARMING :

2 til 5 repetisjoner. Feedback i forhold til teknikk og gjennomføring burde gis under oppvarming.

PROSEDYRE :

Målet er å gjennomføre flest mulig repetisjoner med godkjent teknikk. Det er ingen tids begrensning, men man får ikke lov til mer enn et par sekunder hvile mellom repetisjoner. For å starte testen henger løperen med hendene ca 10 cm bredere enn skulder brede på begge sider (overtak). Haka skal over stangen for hver repetisjon. Man skal ned til armene er helt strake på hver repetisjon. Bevegelser skal være rolig og kontrollerte. ***Ingen form for kipping tillates. Rolig føring av beina fremover under en repetisjon tillates. Sparking og andre brå bevegelser med beina er strengt ikke tillatt.***

BRUTAL BENK

(Ironman og Ironman Jr)

EGENSKAPER :

Buk styrke.

UTSTYR :

Standard turn kasse, standard grønn matte, tau ring med ca 5 cm diameter.

OPPVARMING :

2 til 5 repetisjoner. Feedback i forhold til teknikk og gjennomføring burde gis under oppvarming.

PROSEDYRE :

Målet er å gjennomføre flest mulig repetisjoner med godkjent teknikk. Det er ingen tids begrensning, men man får ikke lov til å hvile taktisk mellom repetisjoner (< 1 sek mellom repetisjoner), verken på toppen eller på bunnen av bevegelsen. Hvis pausen er lengre enn 1 sek, så får utøveren en varsling. Neste gang pausen er lengre enn 1 sek brytter testen. Man skal holde to fingre fra hver hånd gjennom en tau ring ca 5 cm i diameter. Dette skal holdes bak hodet. Hver repetisjon skal helt ned og så helt opp til albuene tar på forsiden av knærne. Hoftet skal være i kontakt med kassen til enhver tid. Dette innebærer to ting: (a.) bevegelser må være rolig og kontrollerte, og (b.) løperen må bevisst slappe av i quadriceps muskulaturen. Hver gang de tar på knærne teller det som 1 repetisjon. Repetisjoner med ikke godkjent teknikk telles ikke

90 SEK KASSEHOPP

(Ironman og Ironman Jr)

EGENSKAPER :

Anaerob utholdent, bein styrke.

UTSTYR :

Stoppeklokka, standard kasse (Vedlegg D, 40 cm høy, 51 cm bredt, 60 cm lang). Det er tillat å bygge kassen lengre, men bredden og høyden må være henholdsvis 40 og 51 cm. At kassen er av standard størrelse er veldig viktig. Det er behov for minimum to personer å gjennomføre testen (en for å telle høyt, en for å passe tiden og skriv ned intervaller).

OPPVARMING :

En god oppvarming er viktig for denne testen. Det anbefales en drag med høy tempo på 15 til 20 sekunder med en pause i etterkant.

PROSEDYRE :

Målet er å gjennomføre flest mulig godkjent hopp i løpet av 90 sekunder. Man begynner testen på toppen av kassen. Tid starter på utøverens først bakketreff. Utøveren hopper ned til en side, tilbake til toppen, og så ned til den andre side og tilbake til toppen. Man hopper langs den 51 cm lengde. Hver gang man hopper til toppen av kassen telles det som en hopp. Det er ikke lov å gå opp, man må hoppe med begge bein. Hoppen skal hovedsakelig være sideveis, men rotasjon av kroppen er tillat. Sekundering er tillat. Antall hopp klart i 90 sekunder er registrert som scoret. Under testen, en person skal telle hopp høyt og en person skal passe tiden og skrive ned intervaller hver 15 sekunder.

IRONMAN SAMMENLAGT SCORE

(Ironman)

EGENSKAPER :

”Arbeidskapacitet” – fysisk grunnlag. Også en verktøy for å skape prestisje i å prestere bra på testen.

PROSEDYRE :

For hver Ironman test er det utviklet scoring tabeller som er brukt i utregning av Sammenlagt Score (Vedlegg E). I tillegg er noen av testene ”vektet” mer enn andre. Poengsummen for de testene som er mest ski spesifikk er ganget med en faktor av 1,4 (det vil si submaks knebøy, og kassehopp). Poengsummen for de testene som representerer grunnleggende fysisk kvaliteter for alpint er ganget med en faktor av 1,0 (3000m, hexagonal obstacle, 1rm knebøy, buk test). Poengsummen for de minst ski spesifikk tester er ganget med en faktor av 0,6 (chins, benkpress). Denne vektingen er allerede beregnet inn i poeng tabellene.

Punkttabellene stopper på null. Alle resultater dårligere enn null punktet skal gis null punkter.

Poeng summen fra alle 8 tester teller som sammenlagt score. Løperen må gjennomføre minst 6 av de 8 testene for at scoren skal telle og at rekorder skal registreres.

Legg merk til at det er kun Ironman som scores. Det er ikke utviklet scoring tabeller for Ironman Jr.

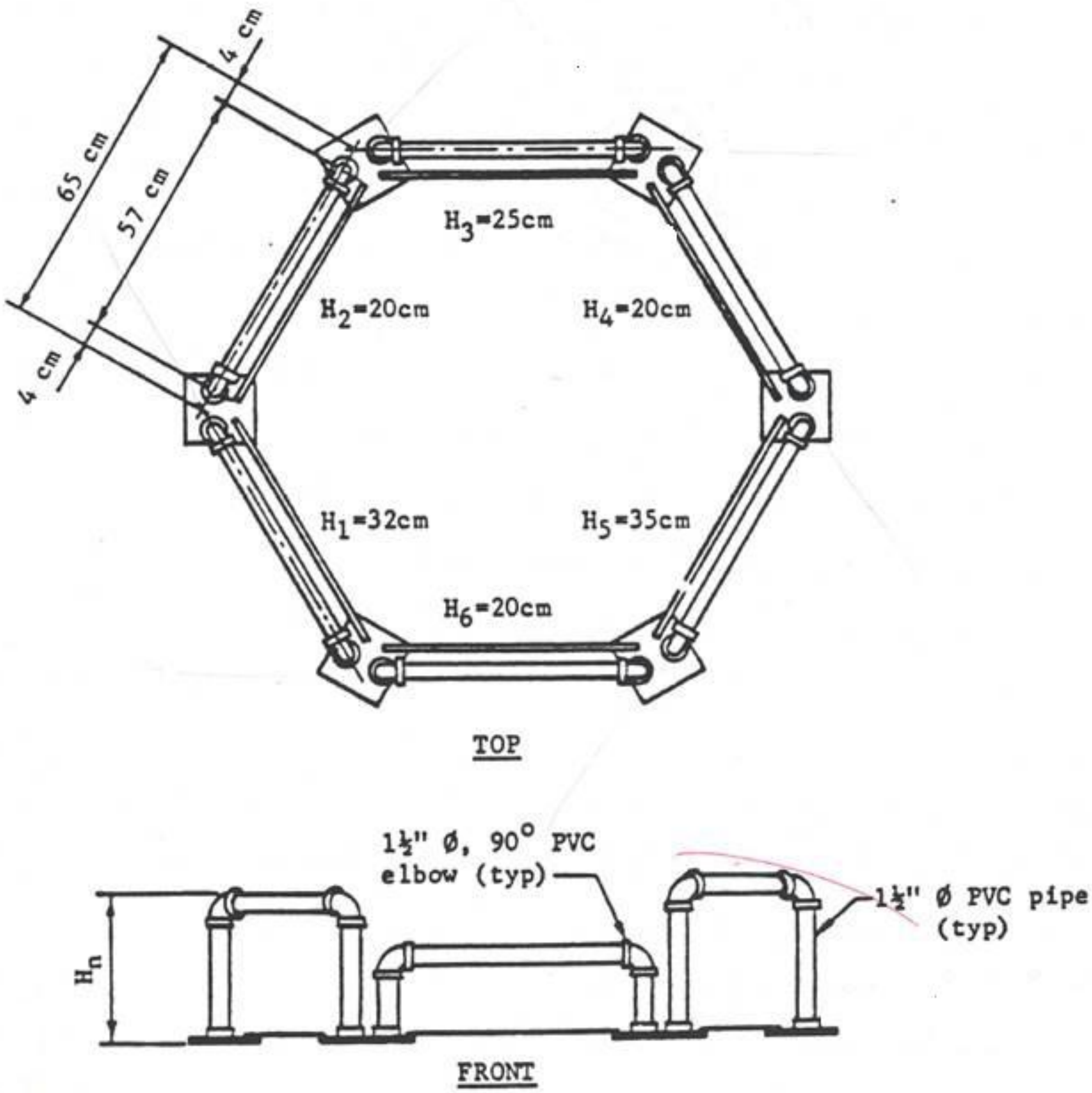
VEDLEGG A.

SEKUNDERINGSSKJEMA 3000 M

RUNDE TID	0,5	1,5	2,5	3,5	4,5	5,5	6,5	MÅL
01:12	00:36	01:48	03:00	04:12	05:24	06:36	07:48	09:00
01:13	00:36	01:49	03:02	04:15	05:28	06:41	07:54	09:07
01:14	00:37	01:51	03:05	04:19	05:33	06:47	08:01	09:15
01:15	00:37	01:52	03:07	04:22	05:37	06:52	08:07	09:22
01:16	00:38	01:54	03:10	04:26	05:42	06:58	08:14	09:30
01:17	00:38	01:55	03:12	04:29	05:46	07:03	08:20	09:37
01:18	00:39	01:57	03:15	04:33	05:51	07:09	08:27	09:45
01:19	00:39	01:58	03:17	04:36	05:55	07:14	08:33	09:52
01:20	00:40	02:00	03:20	04:40	06:00	07:20	08:40	10:00
01:21	00:40	02:01	03:22	04:43	06:04	07:25	08:46	10:07
01:22	00:41	02:03	03:25	04:47	06:09	07:31	08:53	10:15
01:23	00:41	02:04	03:27	04:50	06:13	07:36	08:59	10:22
01:24	00:42	02:06	03:30	04:54	06:18	07:42	09:06	10:30
01:25	00:42	02:07	03:32	04:57	06:22	07:47	09:12	10:37
01:26	00:43	02:09	03:35	05:01	06:27	07:53	09:19	10:45
01:27	00:43	02:10	03:37	05:04	06:31	07:58	09:25	10:52
01:28	00:44	02:12	03:40	05:08	06:36	08:04	09:32	11:00
01:29	00:44	02:13	03:42	05:11	06:40	08:09	09:38	11:07
01:30	00:45	02:15	03:45	05:15	06:45	08:15	09:45	11:15
01:31	00:45	02:16	03:47	05:18	06:49	08:20	09:51	11:22
01:32	00:46	02:18	03:50	05:22	06:54	08:26	09:58	11:30
01:33	00:46	02:19	03:52	05:25	06:58	08:31	10:04	11:37
01:34	00:47	02:21	03:55	05:29	07:03	08:37	10:11	11:45
01:35	00:47	02:22	03:57	05:32	07:07	08:42	10:17	11:52
01:36	00:48	02:24	04:00	05:36	07:12	08:48	10:24	12:00
01:37	00:48	02:25	04:02	05:39	07:16	08:53	10:30	12:07
01:38	00:49	02:27	04:05	05:43	07:21	08:59	10:37	12:15
01:39	00:49	02:28	04:07	05:46	07:25	09:04	10:43	12:22
01:40	00:50	02:30	04:10	05:50	07:30	09:10	10:50	12:30
01:41	00:50	02:31	04:12	05:53	07:34	09:15	10:56	12:37
01:42	00:51	02:33	04:15	05:57	07:39	09:21	11:03	12:45
01:43	00:51	02:34	04:17	06:00	07:43	09:26	11:09	12:52
01:44	00:52	02:36	04:20	06:04	07:48	09:32	11:16	13:00
01:45	00:52	02:37	04:22	06:07	07:52	09:37	11:22	13:07
01:46	00:53	02:39	04:25	06:11	07:57	09:43	11:29	13:15
01:47	00:53	02:40	04:27	06:14	08:01	09:48	11:35	13:22
01:48	00:54	02:42	04:30	06:18	08:06	09:54	11:42	13:30
01:49	00:54	02:43	04:32	06:21	08:10	09:59	11:48	13:37
01:50	00:55	02:45	04:35	06:25	08:15	10:05	11:55	13:45
01:51	00:55	02:46	04:37	06:28	08:19	10:10	12:01	13:52
01:52	00:56	02:48	04:40	06:32	08:24	10:16	12:08	14:00
01:53	00:56	02:49	04:42	06:35	08:28	10:21	12:14	14:07
01:54	00:57	02:51	04:45	06:39	08:33	10:27	12:21	14:15
01:55	00:57	02:52	04:47	06:42	08:37	10:32	12:27	14:22
01:56	00:58	02:54	04:50	06:46	08:42	10:38	12:34	14:30

VEDLEGG B.

TEKNISK SPESIFIKASJONER HEXAGONAL OBSTACLE


4 cm
65 cm
57 cm
4 cm
H3=25cm
H2=20cm
H4=20cm
H1=32cm
H5=35cm
H6=20cm
TOP
1½" Ø, 90° PVC
elbow (typ)
1½" Ø PVC pipe
(typ)
Hn
FRONT

VEDLEGG C.

OPPVARMINGSRUTINER FOR KNEBØY

OPPVARMINGSRUTINER FOR KNEBØY

PHASE 1: Oppvarming med lett belastning

Smal hockey + smal knebøy	1 x 10 + 10, uten vekt
Litt bredere hockey + knebøy	1 x 10 + 10, uten vekt
Bred hockey + bred knebøy	1 x 10 + 10, uten vekt
Ned på høyre – skift til venstre – opp	1 x 10 pr fot, uten vekt
Bred klovneknebøy	1 x 10 med stang
Overheadsquat	2 x 5 med stang
Utøying	

PHASE 2: Oppvarming med stang og vekt

Estimert 70 – 110 kg i maks

2 x 4-6	med 40 kg
1 x 2-4	med 60 kg
1 x 2-3	med 80 kg
1 x 1-2	med 90 kg
1 x 1	med 100 kg

Estimert 120 – 160 kg i maks

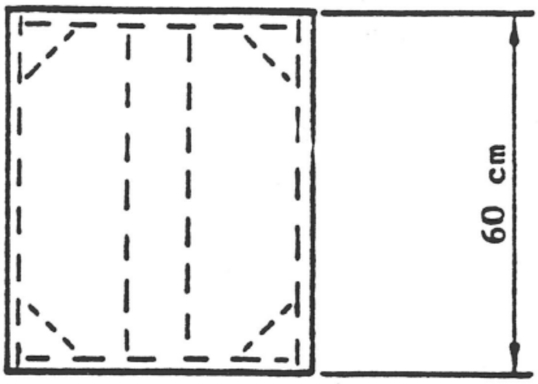
2 x 6	med 60 kg
2 x 4	med 90 kg
1 x 2-3	med 110 kg
1 x 1-2	med 120 kg
1 x 1	med 140 kg
1 x 1	med 150 kg

Estimert 170 – 200 kg i maks

2 x 6	med 60 kg
2 x 5	med 100 kg
1 x 3	med 130 kg
1 x 1-2	med 130 kg
1 x 1-3	med 150 kg
1 x 1-2	med 160-170 kg
1 x 1	med 180 kg

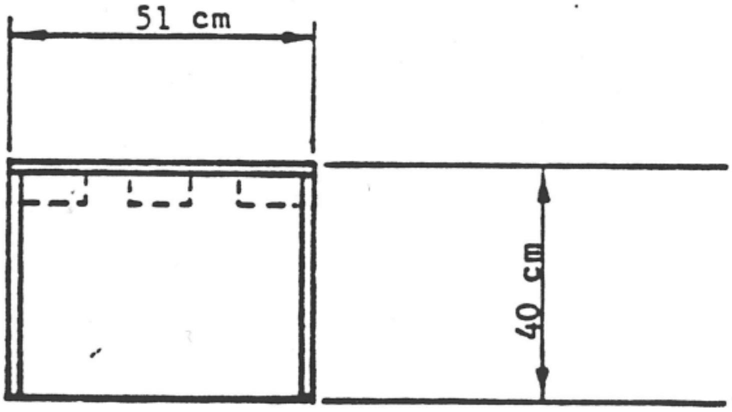
VEDLEGG D.

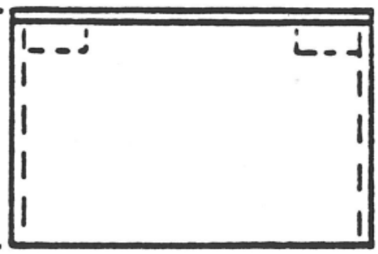
TEKNISKE SPESIFIKASJONER KASSEHOPP



Note: Top and sides are 3/4" plywood. Interior braces are 2"x4".

TOP





FRONT

SIDE

VEDLEGG E.

IRONMAN SCORING TABELLER

3000 M HERRER

TID	POENG
12:20	0
12:19	1
12:18	3
12:17	4
12:16	5
12:15	6
12:14	8
12:13	9
12:12	10
12:11	11
12:10	13
12:09	14
12:08	15
12:07	16
12:06	18
12:05	19
12:04	20
12:03	21
12:02	23
12:01	24
12:00	25
11:59	26
11:58	28
11:57	29
11:56	30
11:55	31
11:54	33
11:53	34
11:52	35
11:51	36
11:50	38
11:49	39
11:48	40
11:47	41
11:46	43
11:45	44
11:44	45
11:43	46
11:42	48
11:41	49
11:40	50
11:39	51
11:38	53
11:37	54
11:36	55
11:35	56
11:34	58
11:33	59
11:32	60
11:31	61
11:30	63
11:29	64
11:28	65
11:27	66
11:26	68
11:25	69
11:24	70
11:23	71
11:22	73
11:21	74

TID	POENG
11:20	75
11:19	76
11:18	78
11:17	79
11:16	80
11:15	81
11:14	83
11:13	84
11:12	85
11:11	86
11:10	88
11:09	89
11:08	90
11:07	91
11:06	93
11:05	94
11:04	95
11:03	96
11:02	98
11:01	99
11:00	100
10:59	101
10:58	103
10:57	104
10:56	105
10:55	106
10:54	108
10:53	109
10:52	110
10:51	111
10:50	113
10:49	114
10:48	115
10:47	116
10:46	118
10:45	119
10:44	120
10:43	120
10:42	121
10:41	122
10:40	123
10:39	123
10:38	124
10:37	125
10:36	126
10:35	126
10:34	127
10:33	128
10:32	129
10:31	129
10:30	130
10:29	131
10:28	132
10:27	132
10:26	133
10:25	134
10:24	135
10:23	135
10:22	136
10:21	137

TID	POENG
10:20	138
10:19	138
10:18	139
10:17	140
10:16	141
10:15	141
10:14	142
10:13	143
10:12	144
10:11	144
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09:53	158
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09:46	163
09:45	164
09:44	165
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09:42	166
09:41	167
09:40	168
09:39	168
09:38	169
09:37	170
09:36	171
09:35	171
09:34	172
09:33	173
09:32	174
09:31	174
09:30	175

HEXAGONAL OBSTACLE HERRER

TID	POENG
20,67	0
20,66	1
20,65	1
20,64	2
20,63	2
20,62	3
20,61	3
20,60	4
20,59	4
20,58	5
20,57	5
20,56	6
20,55	6
20,54	7
20,53	7
20,52	8
20,51	9
20,50	9
20,49	10
20,48	10
20,47	11
20,46	11
20,45	12
20,44	12
20,43	13
20,42	13
20,41	14
20,40	14
20,39	15
20,38	16
20,37	16
20,36	17
20,35	17
20,34	18
20,33	18
20,32	19
20,31	19
20,30	20
20,29	20
20,28	21
20,27	21
20,26	22
20,25	22
20,24	23
20,23	24
20,22	24
20,21	25
20,20	25
20,19	26
20,18	26
20,17	27
20,16	27
20,15	28
20,14	28
20,13	29
20,12	29
20,11	30
20,10	30
20,09	31
20,08	32

TID	POENG
20,07	32
20,06	33
20,05	33
20,04	34
20,03	34
20,02	35
20,01	35
20,00	36
19,99	36
19,98	37
19,97	37
19,96	38
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19,94	39
19,93	40
19,92	40
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19,81	46
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19,59	58
19,58	58
19,57	59
19,56	59
19,55	60
19,54	60
19,53	61
19,52	61
19,51	62
19,50	63
19,49	63
19,48	64

TID	POENG
19,47	64
19,46	65
19,45	65
19,44	66
19,43	66
19,42	67
19,41	67
19,40	68
19,39	68
19,38	69
19,37	70
19,36	70
19,35	71
19,34	71
19,33	72
19,32	72
19,31	73
19,30	73
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19,28	74
19,27	75
19,26	75
19,25	76
19,24	76
19,23	77
19,22	78
19,21	78
19,20	79
19,19	79
19,18	80
19,17	80
19,16	81
19,15	81
19,14	82
19,13	82
19,12	83
19,11	83
19,10	84
19,09	84
19,08	85
19,07	86
19,06	86
19,05	87
19,04	87
19,03	88
19,02	88
19,01	89
19,00	89
18,99	90
18,98	90
18,97	91
18,96	91
18,95	92
18,94	93
18,93	93
18,92	94
18,91	94
18,90	95
18,89	95
18,88	96

TID	POENG
18,87	96
18,86	97
18,85	97
18,84	98
18,83	98
18,82	99
18,81	99
18,80	100
18,79	101
18,78	101
18,77	102
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18,51	116
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18,49	117
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18,45	119
18,44	119
18,43	120
18,42	120
18,41	121
18,40	121
18,39	122
18,38	122
18,37	123
18,36	124
18,35	124
18,34	125
18,33	125
18,32	126
18,31	126
18,30	127
18,29	127
18,28	128

TID	POENG
18,27	128
18,26	129
18,25	129
18,24	130
18,23	130
18,22	131
18,21	132
18,20	132
18,19	133
18,18	133
18,17	134
18,16	134
18,15	135
18,14	135
18,13	136
18,12	136
18,11	137
18,10	137
18,09	138
18,08	139
18,07	139
18,06	140
18,05	140
18,04	141
18,03	141
18,02	142
18,01	142
18,00	143
17,99	143
17,98	144
17,97	144
17,96	145
17,95	145
17,94	146
17,93	147
17,92	147
17,91	148
17,90	148
17,89	149
17,88	149
17,87	150
17,86	150
17,85	151
17,84	151
17,83	152
17,82	152
17,81	153
17,80	153
17,79	154
17,78	155
17,77	155
17,76	156
17,75	156
17,74	157
17,73	157
17,72	158
17,71	158
17,70	159
17,69	159
17,68	160

1RM KNEBØY HERRER

KG	POENG	KG	POENG
139	0	198	134
140	2	199	136
141	5	200	139
142	7	201	141
143	9	202	143
144	11	203	145
145	14	204	148
146	16	205	150
147	18	206	152
148	20	207	155
149	23	208	157
150	25	209	159
151	27	210	161
152	30	211	164
153	32	212	166
154	34	213	168
155	36	214	170
156	39		
157	41		
158	43		
159	45		
160	48		
161	50		
162	52		
163	55		
164	57		
165	59		
166	61		
167	64		
168	66		
169	68		
170	70		
171	73		
172	75		
173	77		
174	80		
175	82		
176	84		
177	86		
178	89		
179	91		
180	93		
181	95		
182	98		
183	100		
184	102		
185	105		
186	107		
187	109		
188	111		
189	114		
190	116		
191	118		
192	120		
193	123		
194	125		
195	127		
196	130		
197	132		

SUBMAKS KNEBØY HERRER

ANTALL	POENG
3	0
4	6
5	13
6	19
7	25
8	32
9	38
10	45
11	51
12	57
13	64
14	70
15	76
16	83
17	89
18	95
19	102
20	108
21	115
22	121
23	127
24	134
25	140
26	149
27	158
28	167
29	176
30	185
31	193
32	202
33	211
34	220
35	229
36	238
37	247
38	256
39	265
40	274
41	283
42	291
43	300
44	309
45	318
46	327
47	336
48	345
49	354
50	363

1RM BENKPRESS HERRER

KG	POENG
90	0
91	3
92	5
93	8
94	11
95	14
96	16
97	19
98	22
99	25
100	27
101	30
102	33
103	35
104	38
105	41
106	44
107	46
108	49
109	52
110	55
111	57
112	60
113	63
114	65
115	68
116	71
117	74
118	76
119	79
120	82
121	83
122	85
123	87
124	88
125	90
126	92
127	93
128	95
129	97
130	98
131	100
132	101
133	103
134	105
135	106
136	108
137	110
138	111
139	113
140	115
141	116
142	118
143	119
144	121
145	123
146	124
147	126
148	128
149	129

CHINS HERRER

ANTALL	POENG
8	0
9	8
10	15
11	23
12	30
13	38
14	45
15	53
16	60
17	68
18	75
19	80
20	84
21	89
22	93
23	98
24	102
25	107
26	111
27	116
28	120
29	125
30	129

BRUTAL BENK HERRER

ANTALL	POENG
8	0
9	8
10	15
11	23
12	31
13	38
14	46
15	54
16	62
17	69
18	77
19	85
20	89
21	94
22	98
23	103
24	108
25	112
26	117
27	122
28	126
29	131
30	135
31	140
32	145
33	149
34	154
35	158

KASSEHOPP HERRER

ANTALL	POENG
79	0
80	7
81	13
82	20
83	27
84	33
85	40
86	47
87	53
88	60
89	67
90	73
91	80
92	87
93	93
94	100
95	107
96	113
97	120
98	127
99	133
100	140
101	147
102	153
103	160
104	167
105	173
106	183
107	192
108	201
109	211
110	220
111	229
112	239
113	248
114	257
115	267
116	276
117	285
118	295
119	304
120	313
121	323
122	332
123	341
124	351
125	360

3000 M DAMER

TID	POENG
13:20	0
13:19	1
13:18	3
13:17	4
13:16	5
13:15	6
13:14	8
13:13	9
13:12	10
13:11	11
13:10	13
13:09	14
13:08	15
13:07	16
13:06	18
13:05	19
13:04	20
13:03	21
13:02	23
13:01	24
13:00	25
12:59	26
12:58	28
12:57	29
12:56	30
12:55	31
12:54	33
12:53	34
12:52	35
12:51	36
12:50	38
12:49	39
12:48	40
12:47	41
12:46	43
12:45	44
12:44	45
12:43	46
12:42	48
12:41	49
12:40	50
12:39	51
12:38	53
12:37	54
12:36	55
12:35	56
12:34	58
12:33	59
12:32	60
12:31	61
12:30	63
12:29	64
12:28	65
12:27	66
12:26	68
12:25	69
12:24	70
12:23	71
12:22	73
12:21	74

TID	POENG
12:20	75
12:19	76
12:18	78
12:17	79
12:16	80
12:15	81
12:14	83
12:13	84
12:12	85
12:11	86
12:10	88
12:09	89
12:08	90
12:07	91
12:06	93
12:05	94
12:04	95
12:03	96
12:02	98
12:01	99
12:00	100
11:59	101
11:58	103
11:57	104
11:56	105
11:55	106
11:54	108
11:53	109
11:52	110
11:51	111
11:50	113
11:49	114
11:48	115
11:47	116
11:46	118
11:45	119
11:44	120
11:43	120
11:42	121
11:41	122
11:40	123
11:39	123
11:38	124
11:37	125
11:36	126
11:35	126
11:34	127
11:33	128
11:32	129
11:31	129
11:30	130
11:29	131
11:28	132
11:27	132
11:26	133
11:25	134
11:24	135
11:23	135
11:22	136
11:21	137

TID	POENG
11:20	138
11:19	138
11:18	139
11:17	140
11:16	141
11:15	141
11:14	142
11:13	143
11:12	144
11:11	144
11:10	145
11:09	146
11:08	147
11:07	147
11:06	148
11:05	149
11:04	150
11:03	150
11:02	151
11:01	152
11:00	153
10:59	153
10:58	154
10:57	155
10:56	156
10:55	156
10:54	157
10:53	158
10:52	159
10:51	159
10:50	160
10:49	161
10:48	162
10:47	162
10:46	163
10:45	164
10:44	165
10:43	165
10:42	166
10:41	167
10:40	168
10:39	168
10:38	169
10:37	170
10:36	171
10:35	171
10:34	172
10:33	173
10:32	174
10:31	174
10:30	175

HEXAGONAL OBSTACLE DAMER

TID	POENG
21,33	0
21,32	1
21,31	1
21,30	2
21,29	2
21,28	3
21,27	3
21,26	4
21,25	4
21,24	5
21,23	5
21,22	6
21,21	6
21,20	7
21,19	8
21,18	8
21,17	9
21,16	9
21,15	10
21,14	10
21,13	11
21,12	11
21,11	12
21,10	12
21,09	13
21,08	13
21,07	14
21,06	15
21,05	15
21,04	16
21,03	16
21,02	17
21,01	17
21,00	18
20,99	18
20,98	19
20,97	19
20,96	20
20,95	20
20,94	21
20,93	22
20,92	22
20,91	23
20,90	23
20,89	24
20,88	24
20,87	25
20,86	25
20,85	26
20,84	26
20,83	27
20,82	27
20,81	28
20,80	28
20,79	29
20,78	30
20,77	30
20,76	31
20,75	31
20,74	32

TID	POENG
20,73	32
20,72	33
20,71	33
20,70	34
20,69	34
20,68	35
20,67	35
20,66	36
20,65	37
20,64	37
20,63	38
20,62	38
20,61	39
20,60	39
20,59	40
20,58	40
20,57	41
20,56	41
20,55	42
20,54	42
20,53	43
20,52	44
20,51	44
20,50	45
20,49	45
20,48	46
20,47	46
20,46	47
20,45	47
20,44	48
20,43	48
20,42	49
20,41	49
20,40	50
20,39	51
20,38	51
20,37	52
20,36	52
20,35	53
20,34	53
20,33	54
20,32	54
20,31	55
20,30	55
20,29	56
20,28	56
20,27	57
20,26	58
20,25	58
20,24	59
20,23	59
20,22	60
20,21	60
20,20	61
20,19	61
20,18	62
20,17	62
20,16	63
20,15	63
20,14	64

TID	POENG
20,13	65
20,12	65
20,11	66
20,10	66
20,09	67
20,08	67
20,07	68
20,06	68
20,05	69
20,04	69
20,03	70
20,02	70
20,01	71
20,00	72
19,99	72
19,98	73
19,97	73
19,96	74
19,95	74
19,94	75
19,93	75
19,92	76
19,91	76
19,90	77
19,89	77
19,88	78
19,87	78
19,86	79
19,85	80
19,84	80
19,83	81
19,82	81
19,81	82
19,80	82
19,79	83
19,78	83
19,77	84
19,76	84
19,75	85
19,74	85
19,73	86
19,72	87
19,71	87
19,70	88
19,69	88
19,68	89
19,67	89
19,66	90
19,65	90
19,64	91
19,63	91
19,62	92
19,61	92
19,60	93
19,59	94
19,58	94
19,57	95
19,56	95
19,55	96
19,54	96

TID	POENG
19,53	97
19,52	97
19,51	98
19,50	98
19,49	99
19,48	99
19,47	100
19,46	101
19,45	101
19,44	102
19,43	102
19,42	103
19,41	103
19,40	104
19,39	104
19,38	105
19,37	105
19,36	106
19,35	106
19,34	107
19,33	108
19,32	108
19,31	109
19,30	109
19,29	110
19,28	110
19,27	111
19,26	111
19,25	112
19,24	112
19,23	113
19,22	113
19,21	114
19,20	115
19,19	115
19,18	116
19,17	116
19,16	117
19,15	117
19,14	118
19,13	118
19,12	119
19,11	119
19,10	120
19,09	120
19,08	121
19,07	122
19,06	122
19,05	123
19,04	123
19,03	124
19,02	124
19,01	125
19,00	125
18,99	126
18,98	126
18,97	127
18,96	127
18,95	128
18,94	128

TID	POENG
18,93	129
18,92	130
18,91	130
18,90	131
18,89	131
18,88	132
18,87	132
18,86	133
18,85	133
18,84	134
18,83	134
18,82	135
18,81	135
18,80	136
18,79	137
18,78	137
18,77	138
18,76	138
18,75	139
18,74	139
18,73	140
18,72	140
18,71	141
18,70	141
18,69	142
18,68	142
18,67	143
18,66	144
18,65	144
18,64	145
18,63	145
18,62	146
18,61	146
18,60	147
18,59	147
18,58	148
18,57	148
18,56	149
18,55	149
18,54	150
18,53	151
18,52	151
18,51	152
18,50	152
18,49	153
18,48	153
18,47	154
18,46	154
18,45	155
18,44	155
18,43	156
18,42	156
18,41	157
18,40	158
18,39	158
18,38	159
18,37	159
18,36	160
18,35	160
18,34	161

1 RM KNEBØY DAMER

KG	POENG
85	0
86	3
87	5
88	8
89	10
90	13
91	15
92	18
93	20
94	23
95	25
96	28
97	30
98	33
99	35
100	38
101	40
102	43
103	45
104	48
105	50
106	53
107	55
108	58
109	60
110	63
111	65
112	68
113	70
114	73
115	75
116	78
117	80
118	83
119	85
120	88
121	90
122	93
123	95
124	98
125	100
126	103
127	105
128	108
129	110
130	113
131	115
132	118
133	120
134	123
135	125
136	128
137	130
138	133
139	135
140	138
141	140
142	143
143	145

KG	POENG
144	148
145	150
146	153
147	155
148	158
149	160
150	163
151	165
152	168
153	170
154	173
155	175
156	178
157	180
158	183
159	185
160	188

SUBMAKS KNEBØY DAMER

ANTALL	POENG
3	0
4	6
5	13
6	19
7	25
8	32
9	38
10	45
11	51
12	57
13	64
14	70
15	76
16	83
17	89
18	95
19	102
20	108
21	115
22	121
23	127
24	134
25	140
26	149
27	158
28	167
29	176
30	185
31	193
32	202
33	211
34	220
35	229
36	238
37	247
38	256
39	265
40	274
41	283
42	291
43	300
44	309
45	318
46	327
47	336
48	345
49	354
50	363

1RM BENKPRESS DAMER

KG	POENG
43	0
44	3
45	5
46	8
47	11
48	14
49	16
50	19
51	22
52	25
53	27
54	30
55	33
56	35
57	38
58	41
59	44
60	46
61	49
62	52
63	55
64	57
65	60
66	63
67	65
68	68
69	71
70	74
71	76
72	79
73	82
74	85
75	87
76	89
77	91
78	92
79	94
80	95
81	97
82	99
83	100
84	102
85	104
86	105
87	107
88	109
89	110
90	112
91	113
92	115
93	117
94	118
95	120
96	122
97	123
98	125
99	127
100	128
101	130
102	131

CHINS DAMER

ANTALL	POENG
2	0
3	8
4	15
5	23
6	30
7	38
8	45
9	53
10	60
11	68
12	75
13	83
14	87
15	92
16	96
17	101
18	105
19	110

BRUTAL BENK DAMER

ANTALL	POENG
8	0
9	8
10	15
11	23
12	31
13	38
14	46
15	54
16	62
17	69
18	77
19	85
20	89
21	94
22	98
23	103
24	108
25	112
26	117
27	122
28	126
29	131
30	135
31	140
32	145
33	149
34	154
35	158

KASSEHOPP DAMER

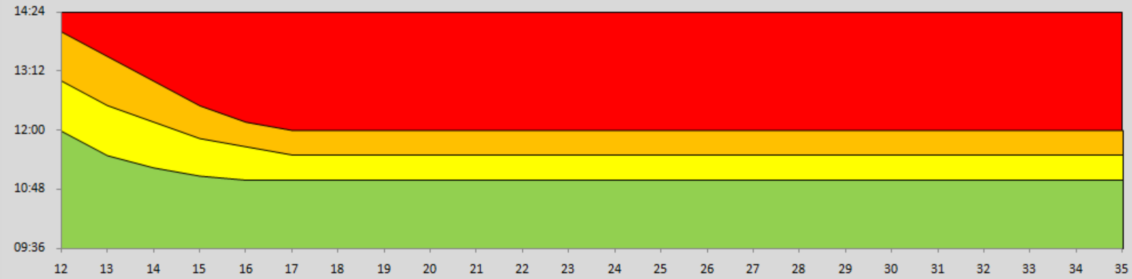
ANTALL	POENG
69	0
70	7
71	13
72	20
73	27
74	33
75	40
76	47
77	53
78	60
79	67
80	73
81	80
82	87
83	93
84	100
85	107
86	113
87	120
88	127
89	133
90	140
91	147
92	153
93	160
94	167
95	173
96	183
97	192
98	201
99	211
100	220
101	229
102	239
103	248
104	257
105	267
106	276
107	285
108	295
109	304
110	313
111	323
112	332
113	341
114	351
115	360

VEDLEGG F.

TEST STANDARDER HERRER

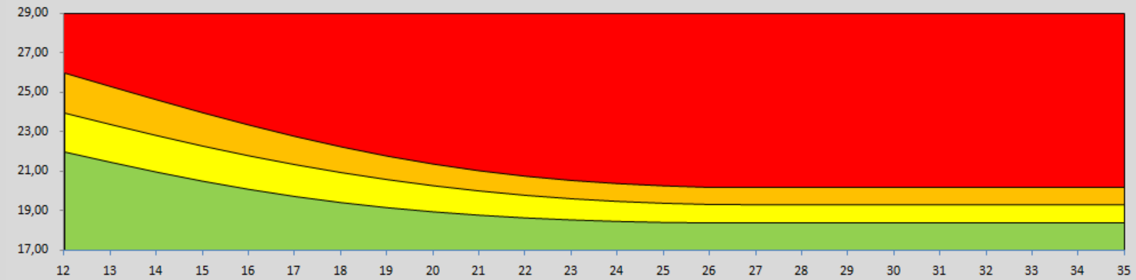
3000 M

AGE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MÅL	12:00	11:30	11:15	11:05	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00	11:00
KAN FORBEDRES	13:00	12:30	12:10	11:50	11:40	11:30	11:30	11:30	11:30	11:30	11:30	11:30	11:30	11:30	11:30	11:30	11:30	11:30	11:30	11:30	11:30	11:30	11:30	11:30
TRENGER JOBB	14:00	13:30	13:00	12:30	12:10	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00
RØD FLAGG	14:00	13:30	13:00	12:30	12:10	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00	12:00



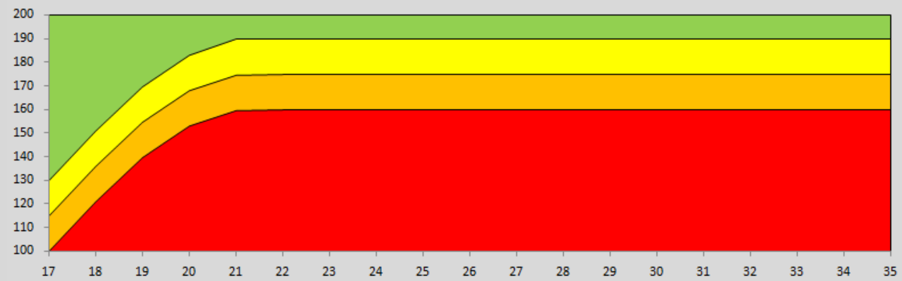
HEXAGONAL OBSTACLE

AGE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MÅL	22,00	21,48	20,98	20,51	20,10	19,74	19,43	19,17	18,96	18,79	18,65	18,55	18,47	18,42	18,40	18,40	18,40	18,40	18,40	18,40	18,40	18,40	18,40	18,40
KAN FORBEDRES	24,00	23,42	22,85	22,32	21,82	21,37	20,97	20,61	20,30	20,03	19,81	19,63	19,50	19,41	19,34	19,33	19,33	19,33	19,33	19,33	19,33	19,33	19,33	19,33
TRENGER JOBB	26,00	25,31	24,64	23,99	23,36	22,78	22,25	21,79	21,38	21,04	20,77	20,55	20,39	20,28	20,20	20,20	20,20	20,20	20,20	20,20	20,20	20,20	20,20	20,20
RØD FLAGG	26,00	25,31	24,64	23,99	23,36	22,78	22,25	21,79	21,38	21,04	20,77	20,55	20,39	20,28	20,20	20,20	20,20	20,20	20,20	20,20	20,20	20,20	20,20	20,20



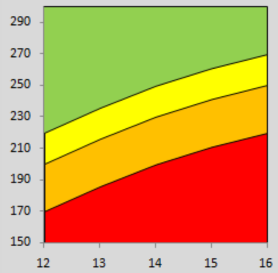
1RM KNEBØY

AGE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MÅL						130	151	170	183	190	190	190	190	190	190	190	190	190	190	190	190	190	190	190
KAN FORBEDRES						115	136	155	168	175	175	175	175	175	175	175	175	175	175	175	175	175	175	175
TRENGER JOBB						100	121	140	153	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160
RØD FLAGG						100	121	140	153	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160



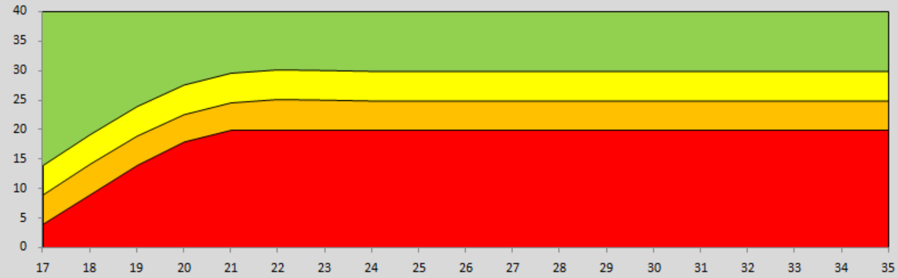
LENGDE UTEN TILLØP

AGE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MÅL	220	236	250	261	270																			
KAN FORBEDRES	200	216	230	241	250																			
TRENGER JOBB	170	186	200	211	220																			
RØD FLAGG	170	186	200	211	220																			



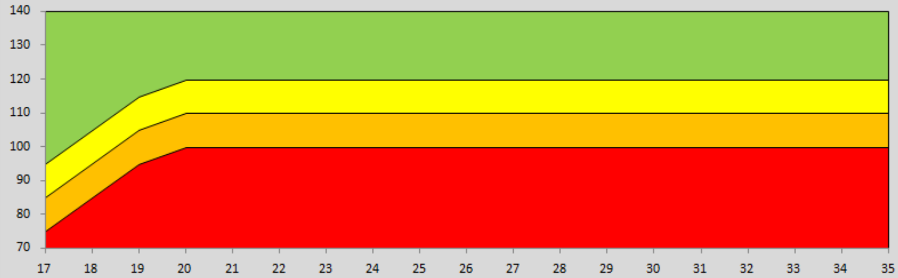
SUBMAKS KNEBØY 1.5 X KROPPSVEKT

AGE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MÅL						14	19	24	28	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
KAN FORBEDRES						9	14	19	23	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
TRENGER JOBB						4	9	14	18	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
RØD FLAGG						4	9	14	18	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20



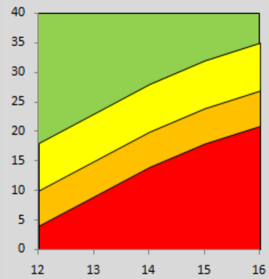
1RM BENK PRESS

AGE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MÅL						95	105	115	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120	120
KAN FORBEDRES						85	95	105	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110	110
TRENGER JOBB						75	85	95	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
RØD FLAGG						75	85	95	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100



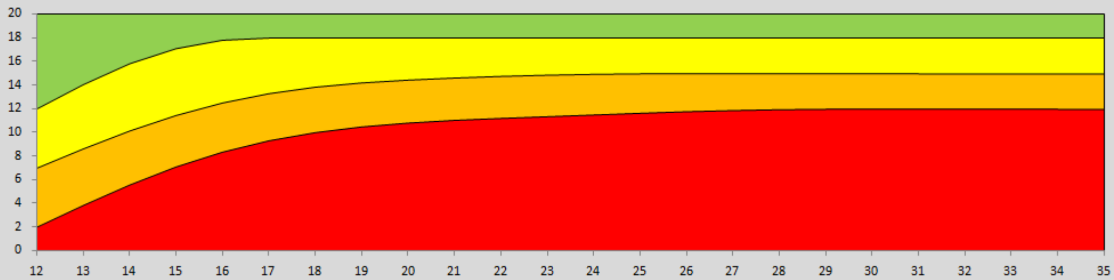
DIPS

AGE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MÅL	18	23	28	32	35																			
KAN FORBEDRES	10	15	20	24	27																			
TRENGER JOBB	4	9	14	18	21																			
RØD FLAGG	4	9	14	18	21																			



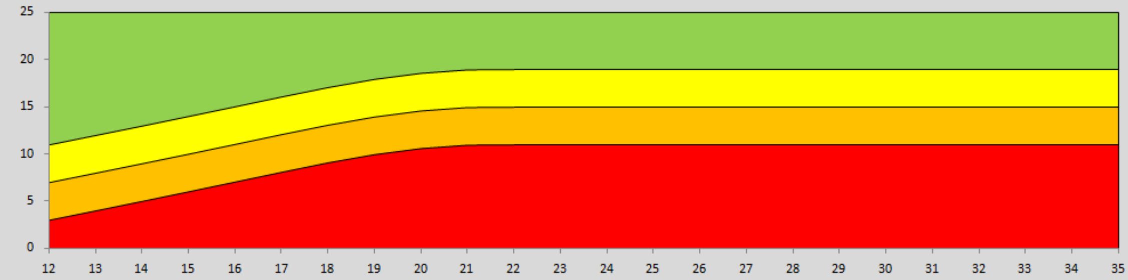
CHINS

AGE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MÅL	12	14	16	17	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
KAN FORBEDRES	7	9	10	11	13	13	14	14	14	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
TRENGER JOBB	2	4	6	7	8	9	10	11	11	11	11	11	12	12	12	12	12	12	12	12	12	12	12	12
RØD FLAGG	2	4	6	7	8	9	10	11	11	11	11	11	12	12	12	12	12	12	12	12	12	12	12	12



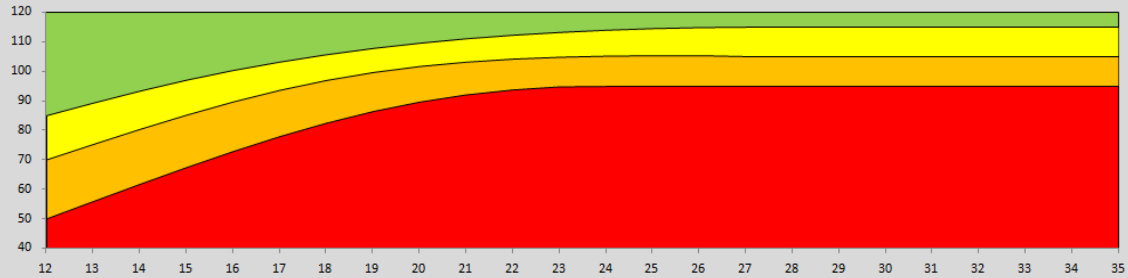
BUK

AGE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MÅL	11	12	13	14	15	16	17	18	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
KAN FORBEDRES	7	8	9	10	11	12	13	14	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
TRENGER JOBB	3	4	5	6	7	8	9	10	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
RØD FLAGG	3	4	5	6	7	8	9	10	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11



KASSEHOPP

AGE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MÅL	85	89	93	97	100	103	106	108	110	111	112	113	114	115	115	115	115	115	115	115	115	115	115	115
KAN FORBEDRES	70	75	80	85	90	94	97	100	102	103	104	105	105	105	105	105	105	105	105	105	105	105	105	105
TRENGER JOBB	50	56	62	67	73	78	83	86	90	92	94	95	95	95	95	95	95	95	95	95	95	95	95	95
RØD FLAGG	50	56	62	67	73	78	83	86	90	92	94	95	95	95	95	95	95	95	95	95	95	95	95	95

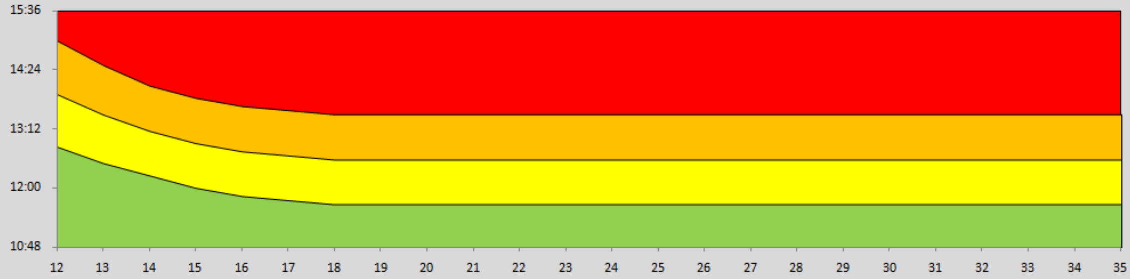


VEDLEGG G.

TEST STANDARDER DAMER

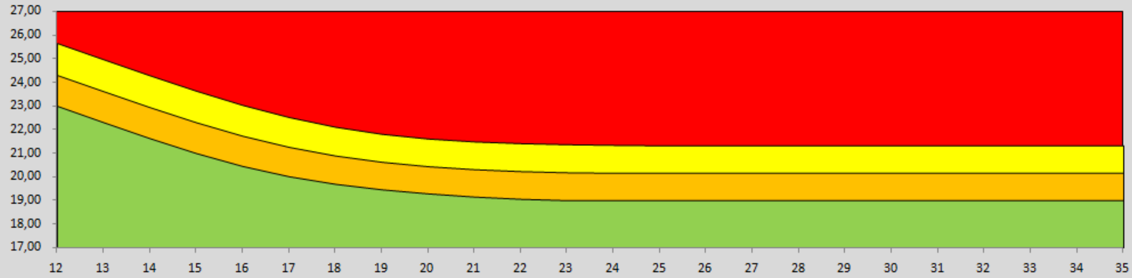
3000 M

AGE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MÅL	12:50	12:30	12:15	12:00	11:50	11:45	11:40	11:40	11:40	11:40	11:40	11:40	11:40	11:40	11:40	11:40	11:40	11:40	11:40	11:40	11:40	11:40	11:40	11:40
KAN FORBEDRES	13:55	13:30	13:10	12:55	12:45	12:40	12:35	12:35	12:35	12:35	12:35	12:35	12:35	12:35	12:35	12:35	12:35	12:35	12:35	12:35	12:35	12:35	12:35	12:35
TRENGER JOBB	15:00	14:30	14:05	13:50	13:40	13:35	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30
RØD FLAGG	15:00	14:30	14:05	13:50	13:40	13:35	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30	13:30



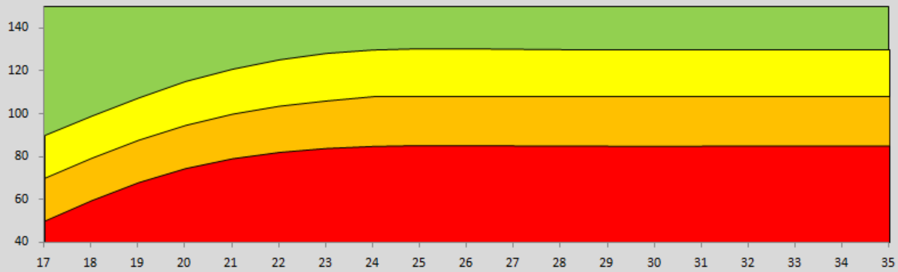
HEXAGONAL OBSTACLE

AGE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MÅL	23,00	22,31	21,63	21,00	20,45	20,02	19,69	19,46	19,29	19,15	19,06	19,00	19,00	19,00	19,00	19,00	19,00	19,00	19,00	19,00	19,00	19,00	19,00	19,00
KAN FORBEDRES	24,33	23,64	22,96	22,32	21,75	21,27	20,91	20,64	20,45	20,32	20,24	20,19	20,17	20,17	20,17	20,17	20,17	20,17	20,17	20,17	20,17	20,17	20,17	20,17
TRENGER JOBB	25,67	24,98	24,30	23,65	23,04	22,53	22,12	21,82	21,62	21,49	21,42	21,38	21,35	21,33	21,33	21,33	21,33	21,33	21,33	21,33	21,33	21,33	21,33	21,33
RØD FLAGG	25,67	24,98	24,30	23,65	23,04	22,53	22,12	21,82	21,62	21,49	21,42	21,38	21,35	21,33	21,33	21,33	21,33	21,33	21,33	21,33	21,33	21,33	21,33	21,33



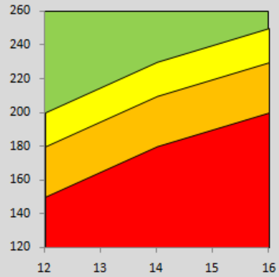
1RM KNEBØY

AGE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MÅL						90	99	108	115	121	125	128	130	130	130	130	130	130	130	130	130	130	130	130
KAN FORBEDRES						70	79	88	95	100	104	106	108	108	108	108	108	108	108	108	108	108	108	108
TRENGER JOBB						50	60	68	75	79	82	84	85	85	85	85	85	85	85	85	85	85	85	85
RØD FLAGG						50	60	70	75	80	80	85	85	85	85	85	85	85	85	85	85	85	85	85



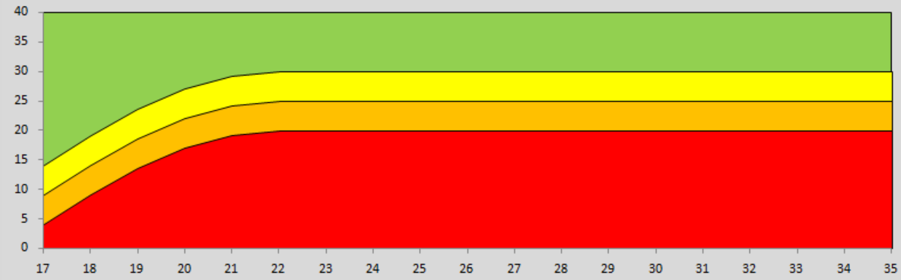
LENGDE UTEN TILLØP

AGE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MÅL	200	215	230	240	250																			
KAN FORBEDRES	180	195	210	220	230																			
TRENGER JOBB	150	165	180	190	200																			
RØD FLAGG	150	165	180	190	200																			



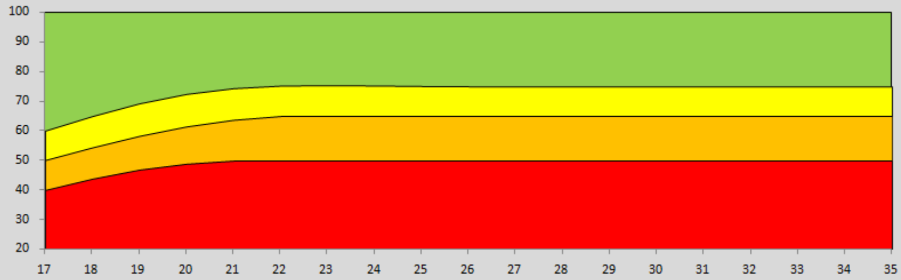
SUBMAKS KNEBØY 1.2 X KROPPSVEKT

AGE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MÅL						14	19	24	27	29	30	30	30	30	30	30	30	30	30	30	30	30	30	30
KAN FORBEDRES						9	14	19	22	24	25	25	25	25	25	25	25	25	25	25	25	25	25	25
TRENGER JOBB						4	9	14	17	19	20	20	20	20	20	20	20	20	20	20	20	20	20	20
RØD FLAGG						4	9	14	17	19	20	20	20	20	20	20	20	20	20	20	20	20	20	20



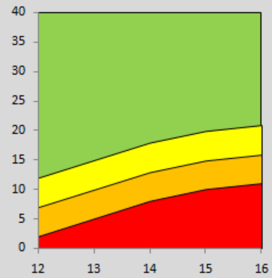
1RM BENK PRESS

AGE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MÅL						60	65	69	72	74	75	75	75	75	75	75	75	75	75	75	75	75	75	75
KAN FORBEDRES						50	54	58	61	64	65	65	65	65	65	65	65	65	65	65	65	65	65	65
TRENGER JOBB						40	44	47	49	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
RØD FLAGG						40	44	47	49	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50



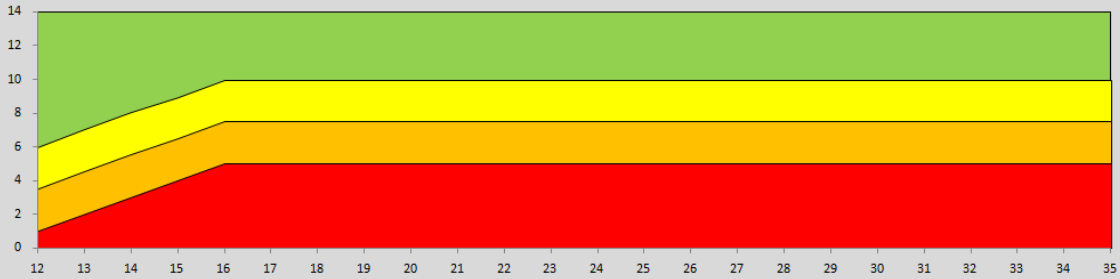
DIPS

AGE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MÅL	12	15	18	20	21																			
KAN FORBEDRES	7	10	13	15	16																			
TRENGER JOBB	2	5	8	10	11																			
RØD FLAGG	2	5	8	10	11																			



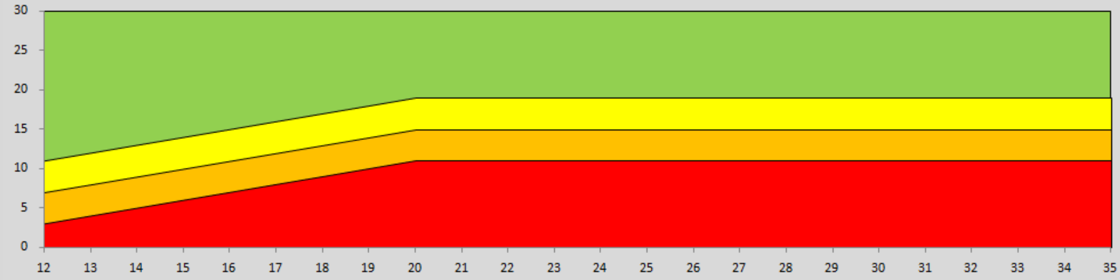
CHINS

AGE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MÅL	6	7	8	9	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
KAN FORBEDRES	3	5	6	6	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
TRENGER JOBB	1	2	3	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
RØD FLAGG	1	2	3	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5



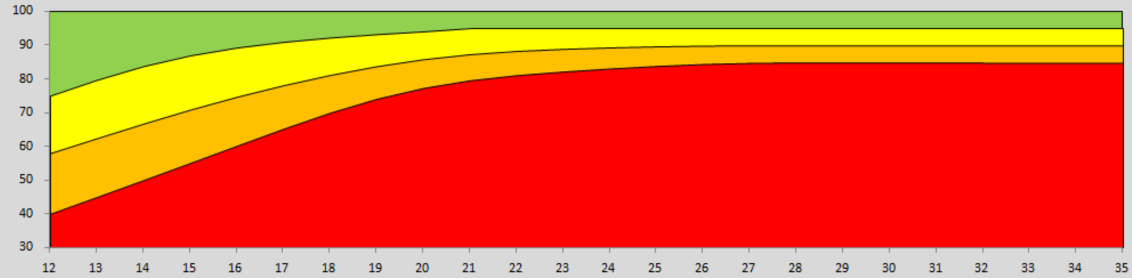
BUK

AGE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MÅL	11	12	13	14	15	16	17	18	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19	19
KAN FORBEDRES	7	8	9	10	11	12	13	14	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
TRENGER JOBB	3	4	5	6	7	8	9	10	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
RØD FLAGG	3	4	5	6	7	8	9	10	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11



KASSEHOPP

AGE	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35
MÅL	75	80	84	87	89	91	92	93	94	95	95	95	95	95	95	95	95	95	95	95	95	95	95	95
KAN FORBEDRES	58	62	67	71	75	78	81	84	86	87	88	89	89	90	90	90	90	90	90	90	90	90	90	90
TRENGER JOBB	40	45	50	55	60	65	70	74	77	80	81	82	83	84	85	85	85	85	85	85	85	85	85	85
RØD FLAGG	40	45	50	55	60	65	70	74	77	80	81	82	83	84	85	85	85	85	85	85	85	85	85	85



VEDLEGG F.

REGISTRERINGS SKJEMAER

IRONMAN RESULTAT LIST

LAG:

DATO:

STED:

TESTLEDER:

NAVN	VEKT	AEROB	SPESIFIKK HURTIGHET	MAKS STYRKE	SUBMAKS STYRKE		OV. KR. STYRKE	OV. KR. STYRKE	BUK STYRKE	SPESIFIKK ANAEROB	SAMMENLAGT SCORE
		3000m	Hexagonal Obstacle	1 RM Knebøy	Submaks bøy		1 RM Benk	Chins	Buk test	Kassehopp	
	(kg)	min:sek	(sek)	(kg)	vekt (kg)	rep (#)	(kg)	rep (#)	rep (#)	hopp (#)	poeng
POENG											
POENG											
POENG											
POENG											
POENG											
POENG											
POENG											
POENG											
POENG											
POENG											
POENG											
POENG											

IRONMAN JR RESULTAT LIST

LAG:

DATO:

STED:

TESTLEDER:

NAVN	VEKT	AEROB	SPESIFIKK HURTIGHET	MAKS STYRKE	KNEBØY TEKNIKK		OV. KR. STYRKE	OV. KR. STYRKE	BUK STYRKE	SPESIFIKK ANAEROB	SAMMENLAGT SCORE
		3000m	Hexagonal Obstacle	Lengde Uten Tilløp	Submaks bøy		Push-Ups	Chins	Buk test	Kassehopp	
	(kg)	min:sek	(sek)	(cm)	vekt (kg)	rep (#)	rep (#)	rep (#)	rep (#)	hopp (#)	poeng
POENG											
POENG											
POENG											
POENG											
POENG											
POENG											
POENG											
POENG											
POENG											
POENG											
POENG											
POENG											

NOKKELPUNKTER KASSE PROTOKOLLEN:

- Utøveren starter på toppen av kassa.
- Når alt er klart begynner utøveren testen på eget initiativ.
- Klokka starter på utøverens første bakketreff.
- En testleder teller hopp høyt.
- En til testleder følger på klokka og noterer antall hopp hver 15. sekund.
- Utøveren kan sekunderes etter eget ønske, evt hvert 15. sekund.

IRONMAN RESULTAT LIST - KASSEHOPP SKJEMA

LAG: **STED:**

DATO: **TESTLEDER:**

NAVN:

TID	HOPP	SPLITT
15		
30		
45		
60		
75		
90		

NAVN:

TID	HOPP	SPLITT
15		
30		
45		
60		
75		
90		

NAVN:

TID	HOPP	SPLITT
15		
30		
45		
60		
75		
90		

NAVN:

TID	HOPP	SPLITT
15		
30		
45		
60		
75		
90		

NAVN:

TID	HOPP	SPLITT
15		
30		
45		
60		
75		
90		

NAVN:

TID	HOPP	SPLITT
15		
30		
45		
60		
75		
90		

NAVN:

TID	HOPP	SPLITT
15		
30		
45		
60		
75		
90		

NAVN:

TID	HOPP	SPLITT
15		
30		
45		
60		
75		
90		

NAVN:

TID	HOPP	SPLITT
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NAVN:

TID	HOPP	SPLITT
15		
30		
45		
60		
75		
90		

NAVN:

TID	HOPP	SPLITT
15		
30		
45		
60		
75		
90		

NAVN:

TID	HOPP	SPLITT
15		
30		
45		
60		
75		
90		

NOKKELPUNKTER HEX PROTOKOLLEN:

- Det gjennomføres opp til 3 forsøk i hver retning (med og mot klokka).
- I utgangspunktet har man 2 forsøk i en gitt retning, men hvis man disker på en av de 2 får man den 3. forsøk. Hvis man kommer i mål på begge av de to første forsøk så får man <u>ikke</u> den 3. forsøk.
- Alle forsøk med klokka er kjørt før man starter mot klokka.
- Test lederen gir start kommandoen "KLAR …. GO!" Utøveren og klokka starter på GO.
- Hvis man treffer en hekk slik at test lederen ser rørelsen i hekken så stoppes forsøket og det teller som disk.
- Hvis rørelsen skjer i forbindelse med en av de to første hopp på starten, så telles det ikke som disk og utøveren får starte forsøket på nytt.
- Begge bein skal treffe bakken omtrent samtidig. I noen tilfeller er det en liten skift der ytre bein lander litt tidligere. Dette er tillat så lenge skiftet mellom bein ikke blir så stor at du ser et tydelig uavhengig bein arbeid. I så fall er det ikke disk. Utøveren stoppes, korrigeres, og får prøve på nytt.
- Begge bein må treffe bakken innenfor HEX'en for en godkjent målgang, ellers så teller forsøket som disk.

IRONMAN RESULTAT LIST - HEXAGONAL OBSTACLE SKJEMA

LAG: **STED:**

DATO: **TESTLEDER:**

NAVN:

CW1:		CCW1:	
CW2:		CCW2:	
CW3:		CCW3:	

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NAVN:

CW1:		CCW1:	
CW2:		CCW2:	
CW3:		CCW3:	

Norsk samfunnsvitenskapelig datatjeneste AS
NORWEGIAN SOCIAL SCIENCE DATA SERVICES

NSD

Harald Hårfagres gate 29
N-5007 Bergen
Norway
Tel +47-55 58 21 17
Fax +47-55 58 96 50
nsd@nsd.uib.no
www.nsd.uib.no
Org.nr. 985 321 884

Christine Holm Moseid
Senter for idrettsskadeforskning Norges Idrettshøgskole
Postboks 4014 Ullevål Stadion
0806 OSLO

Vår dato: 14.07.2014 Vår ref: 38888 / 3 / LT Deres dato: Deres ref:

TILBAKEMELDING PÅ MELDING OM BEHANDLING AV PERSONOPPLYSNINGER

Vi viser til melding om behandling av personopplysninger, mottatt 26.05.2014. All nødvendig informasjon om prosjektet forelå i sin helhet 26.06.2014. Meldingen gjelder prosjektet:

38888	*Den unge eliteutøverens helse*
Behandlingsansvarlig	*Norges idrettshøgskole, ved institusjonens øverste leder*
Daglig ansvarlig	*Christine Holm Moseid*

Personvernombudet har vurdert prosjektet, og finner at behandlingen av personopplysninger vil være regulert av § 7-27 i personopplysningsforskriften. Personvernombudet tilrår at prosjektet gjennomføres.

Personvernombudets tilråding forutsetter at prosjektet gjennomføres i tråd med opplysningene gitt i meldeskjemaet, korrespondanse med ombudet, ombudets kommentarer samt personopplysningsloven og helseregisterloven med forskrifter. Behandlingen av personopplysninger kan settes i gang.

Det gjøres oppmerksom på at det skal gis ny melding dersom behandlingen endres i forhold til de opplysninger som ligger til grunn for personvernombudets vurdering. Endringsmeldinger gis via et eget skjema, http://www.nsd.uib.no/personvern/meldeplikt/skjema.html. Det skal også gis melding etter tre år dersom prosjektet fortsatt pågår. Meldinger skal skje skriftlig til ombudet.

Personvernombudet har lagt ut opplysninger om prosjektet i en offentlig database, http://pvo.nsd.no/prosjekt.

Personvernombudet vil ved prosjektets avslutning, 30.06.2027, rette en henvendelse angående status for behandlingen av personopplysninger.

Vennlig hilsen

Vigdis Namtvedt Kvalheim

Lis Tenold

Kontaktperson: Lis Tenold tlf: 55 58 33 77
Vedlegg: Prosjektvurdering

Dokumentet er elektronisk produsert og godkjent ved NSDs rutiner for elektronisk godkjenning.

Personvernombudet for forskning

Prosjektvurdering - Kommentar

Prosjektnr: 38888

Det gis skriftlig informasjon og innhentes skriftlig samtykke både fra ungdommen og dennes foreldre. Personvernombudet finner informasjonsskrivet mottatt 26.06.2014 tilfredsstillende utformet i henhold til personopplysningslovens vilkår.

Det behandles sensitive personopplysninger om helseforhold.

Det behandles enkelte opplysninger om tredjeperson. Det skal kun registreres opplysninger som er nødvendig for formålet med prosjektet. Opplysningene skal være av mindre omfang og ikke sensitive, og skal anonymiseres i publikasjon. Så fremt personvernulempen for tredjeperson reduseres på denne måten, kan prosjektleder unntas fra informasjonsplikten overfor tredjeperson, fordi det anses uforholdsmessig vanskelig å informere.

Personvernombudet legger til grunn at forsker etterfølger Norges idrettshøgskole sine interne rutiner for datasikkerhet. Dersom personopplysninger skal sendes elektronisk eller lagres på mobile enheter, bør opplysningene krypteres tilstrekkelig.

Questback er databehandler for prosjektet og det er inngått databehandleravtale mellom NIH og Questback.

Innsamlede opplysninger anonymiseres ved prosjektslutt, senest 30.06.2027. Med anonymisering innebærer at navnelister slettes/makuleres, og ev. kategorisere eller slette indirekte personidentifiserbare opplysninger. NIN må også sikre at det ikke heller vil foreligge personopplysninger hos Questback ved prosjektslutt.

Personvernombudet gjør oppmerksom på at godkjenningen kun gjelder for spørreskjemaundersøkelsen, de fysiske tester som skal gjennomføres det første året samt innsamling av opplysninger gjennom den elektroniske treningsdagboken. Oppfølgningsundersøkelser utover dette må meldes gjennom utfylling av endringsskjema, http://www.nsd.uib.no/personvern/meldeplikt/skjema.html

Region:	Saksbehandler:	Telefon:	Vår dato:	Vår referanse:
REK sør-øst	Anne S. Kavli	22845512	24.06.2014	2014/902/REK sør-øst A
			Deres dato:	**Deres referanse:**
			13.05.2014	

Vår referanse må oppgis ved alle henvendelser

Christine Holm Moseid
Norges idrettshøgskole

2014/902 Den unge eliteutøverens helse

Vi viser til søknad om forhåndsgodkjenning av ovennevnte forskningsprosjekt. Søknaden ble behandlet av Regional komité for medisinsk og helsefaglig forskningsetikk (REK sør-øst) i møtet 12.06.2014. Vurderingen er gjort med hjemmel i helseforskningsloven § 10, jf. forskningsetikklovens § 4.

Forskningsansvarlig: Norges idrettshøgskole
Prosjektleder: Christine Holm Moseid

Prosjektbeskrivelse

Formålet med prosjektet er å kartlegge unge eliteidrettsutøveres skade og sykdomsomfang for å kunne utvikle skadeforebyggingstiltak.

Studien er en prospektiv kohortstudie som skal kartlegge helseplager hos unge eliteidrettsutøvere som begynner på toppidrettsgymnas. En hypotese er at denne gruppen har økt risiko for helseplager grunnet stor økning i treningsbelastning over kort tid eller grunnet stort treningsvolum generelt.

I studien skal tre grupper ungdom sammenliknes; En gruppe eliteutøvere som er elever ved et toppidrettsgymnas, en gruppe unge eliteutøvere som ikke går på toppidrettsgymnas og en gruppe ungdom som ikke driver toppidrett og som går på vanlig videregående skole. Det skal inkluderes 500 ungdommer som skal besvare et standardisert spørreskjema via en app på smarttelefonen. I starten av prosjektet skal deltakerne fylle ut et spørreskjema om egen helse.

Det skal samles inn informasjon fra eliteidrettsutøvernes treningsdagbok og fra de standardiserte fysiske testene de gjennomgår som en del av skolegangen. For idrettsutøvere vil man også se på fysisk form ved oppstart samt økning i treningsmengde. Man vil undersøke sammenhengen mellom fysisk form ved oppstart og risiko for skade og sykdom gjennom skoleåret.

Det er kun spørreskjemaene og registrering av høyde og vekt som kommer i tillegg til elevenes ordinære opplegg. Det skal ikke innhentes noe biologisk materiale og foretas ingen intervensjon. Spørreskjemaet inneholder en del opplysninger om deltakernes helse, men det er sykdoms- og skadefrekvensen som er det essensielle.

Komiteens vurdering

Studien er en ren kartleggingsstudie uten intervensjon. Den har et helseforebyggende perspektiv, men er ikke direkte forskning på helse og sykdom, snarere på effekten av treningsvolumet som unge eliteidrettsutøvere utsettes for. Studien kan bringe ny kunnskap om effekt av stor treningsmengde av ungdom og dermed bidra til forebygging av skade og tilpasning av treningsopplegg.

Deltakerne får god informasjon om hvorfor opplysningene hentes inn, hva de skal brukes til og at det er frivillig å delta.

Målet er ikke å oppnå ny kunnskap om diagnose eller behandling av sykdom, og deltakerne utsettes ikke for risiko eller belastning ved å delta i prosjektet.

Etter REKs vurdering faller dermed prosjektet, slik det er beskrevet, utenfor virkeområdet til helseforskningsloven. Helseforskningsloven gjelder for *medisinsk og helsefaglig forskning* på norsk territorium eller når forskningen skjer i regi av en forsknings-ansvarlig som er etablert i Norge.

Hva som er medisinsk og helsefaglig forskning fremgår av helseforskningsloven § 4 bokstav a hvor medisinsk og helsefaglig forskning er definert slik: ”virksomhet som utføres med vitenskapelig metodikk for å skaffe til veie ny kunnskap om helse og sykdom”, jf. helseforskningsloven §§ 2 og 4a. Formålet er avgjørende, ikke om forskningen utføres av helsepersonell, på pasienter eller benytter helseopplysninger.

Vedtak

Prosjektet faller utenfor helseforskningslovens virkeområde, jf. § 2, og kan derfor gjennomføres uten godkjenning av REK. Det er institusjonens ansvar på å sørge for at prosjektet gjennomføres på en forsvarlig måte med hensyn til for eksempel regler for taushetsplikt og personvern.

Komiteens vedtak kan påklages til Den nasjonale forskningsetiske komité for medisin og helsefag, jf. helseforskningsloven § 10, 3 ledd og forvaltningsloven § 28. En eventuell klage sendes til REK Sørøst A. Klagefristen er tre uker fra mottak av dette brevet, jf. forvaltningsloven § 29.

Med vennlig hilsen

Knut Engedal
Professor dr. med.
Leder

Anne S. Kavli
Førstekonsulent

Kopi til:roald@nih.no; Norges idrettshøgskole ved øverste administrative ledelse: postmottak@nih.no

NORGES IDRETTSHØGSKOLE

SENTER FOR
Idrettsskadeforskning
KLOKE AV SKADE

Til deg som er toppidrettsutøver

Kan du tenke deg å delta i et prosjekt om toppidrett og helse?

Du og mange andre førsteklassinger på toppidrettsgymnasene Wang og NTG inviteres til å bli med i en undersøkelse om idrett og helse.

Vi ønsker å kartlegge helseplager som rammer unge idrettsutøvere på toppidrettsgymnas, og å sammenligne dette med helseplager hos ungdom som ikke går på toppidrettsgymnas.

Undersøkelsen vil forløpe gjennom tre år.

Gjennom denne undersøkelsen vil vi kartlegge forhold som trenings- og konkurransebelastning, symptomer på skade eller sykdom, treningsfravær pga skade eller sykdom, treningsbakgrunn, motivasjon og medisinbruk.

For deg vil deltakelse i studien bestå av å fylle ut et elektronisk spørreskjema ved starten av skoleåret. De neste spørreskjemaene består av kun fire spørsmål som du besvarer en gang i uken ved hjelp av en ny «app» for smarttelefoner.

Det vil også bli testing av fysisk form ved skolestart.

NTG og Wang ønsker å bidra til at flest mulig elever kan være med i denne undersøkelsen. De vil legge til rette for gjennomføringen. Vi vil være tilstede når du fyller ut det første skjemaet, og for å hjelpe til med å laste ned applikasjonen til telefonen din.

Rett etter skolestart vil det bli gitt et første foredrag om hva studien innebærer, og en mer utfyllende bakgrunn for studien. Påmelding til studien skjer i etterkant av dette møtet.

Vi gjør oppmerksom på at det er helt frivillig å delta i undersøkelsen, og du kan trekke deg når som helst. Du er sikret full anonymitet. Som forskere er vi underlagt taushetsplikt.

Prosjektet er meldt og godkjent av Personvernombudet for forskning, Norsk samfunnsvitenskapelig datatjeneste (NSD) og det er godkjent av Regional komité for medisinsk og helsefaglig forskningsetikk (REK).

Siden du er under 18 år, må dine foresatte også gi tilbakemelding til oss om du kan delta eller ikke. Vi ber derfor om at du viser dette brevet til dine foresatte. Formell påmelding vil bli gjort ved skolestart, og ytterligere informasjon kommer i forkant av dette.

På forhånd tusen takk.

Vennlig hilsen

Christine Holm Moseid
Stipendiat
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Roald Bahr
Professor
roald.bahr@nih.no

NORGES IDRETTSHØGSKOLE

SENTER FOR
Idrettsskadeforskning
KLOKE AV SKADE

«Den unge eliteutøverens helse»

Hvordan påvirkes unge eliteutøvere av skader og sykdom?

Hvem har størst risiko for sykdom og skade?

Er det en sammenheng mellom risiko for sykdom og skade, fysisk form

eller trenings- og konkurranseprogram?

Vi ønsker at færre unge eliteidrettsutøvere skal pådra seg skader og sykdom.

Derfor er årets førsteklassinger på toppidrettsgymnasene Wang Oslo, NTG Lillehammer og NTG Bærum, og noen av deres lagkamerater, invitert til å bli med i en undersøkelse om idrett og helse, der vi vil kartlegge helseproblemer hos unge idrettsutøvere på høyt nivå.

Undersøkelsen varer i ett år i første omgang.

For deres utøvere innebærer undersøkelsen å svare på et generelt spørreskjema som dreier seg om helse (sykdom og skader) og treningsbakgrunn.

Deretter består selve undersøkelsen av fire spørsmål i en «helse-app». Disse besvares ukentlig via utøvernes egen smarttelefon gjennom hele skoleåret. Spørsmålene dreier seg om forhold rundt deltagelse på trening og konkurranse, treningsmengde, prestasjon og symptomer på skade eller sykdom.

Det er helt frivillig å delta i undersøkelsen, og utøveren kan trekke seg når som helst. De er sikret full anonymitet og som forskere er vi underlagt taushetsplikt.

Prosjektet er meldt og godkjent av Norsk samfunnsvitenskapelig datatjeneste (NSD) og det er meldt til Regional komité for medisinsk og helsefaglig forskningsetikk (REK).

Toppidrettsskolene NTG og Wang er svært positive til prosjektet. De bidrar til at flest mulig elever kan være med i prosjektet og legger godt til rette for gjennomføringen av hele undersøkelsen.

Vi håper at også dere kan være med oss, og ivareta de unge eliteutøvernes helse.

På forhånd tusen takk.

Vennlig hilsen prosjektgruppa for

«Den unge eliteutøverens helse»

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Forespørsel om deltakelse i forskningsprosjektet

«Den unge eliteutøverens helse»

Bakgrunn og hensikt
Dette er et spørsmål til deg om å delta i et forskningsprosjekt der vi ønsker å kartlegge helseplager hos unge toppidrettsutøvere som går på toppidrettsgymnas. Du forespørres om å bli med i studien, siden du begynner i 1. klasse på toppidrettsgymnas høsten 2014. Undersøkelsen er planlagt og gjennomføres av Senter for idrettsskadeforskning, Norges idrettshøgskole, i samarbeid med skolene Wang og NTG.

Hva innebærer studien?
Studien innebærer at du ved skolestart vil svare på et generelt spørreskjema om helse, sykdom, skader, idrettsdeltakelse, trenings- og konkurransebakgrunn, restitusjon og motivasjon. Dette spørreskjemaet besvares i en skoletime. I begynnelsen av skoleåret vil vi også gjennomføre fysiske tester for å måle styrke, hurtighet, spenst og utholdenhet hos alle elever. Gjennom skoleåret vil vi følge den elektroniske treningsdagboken som du selv fører som en del av skolens opplegg, for å se hvor mange timer du trener, treningstype, antall kamper/renn etc.

Du vil så få installert en ny app på din smarttelefon. Deretter vil du én gang hver uke gjennom skoleåret bli bedt om å svare på fire spørsmål; om du er frisk og skadefri, eller om du har helseproblemer som begrenser trenings- eller prestasjonsevne. Når det har gått om lag 5 og 10 måneder, vil du få et par ekstra spørsmål om motivasjon, utvilthet, antall trenere og nivå du spiller på, høyde og vekt. Du vil ikke motta noen spørreskjema i skolens sommerferie.

Mulige fordeler og ulemper
Ulempen med å delta i studien er den tiden det tar å fylle ut spørreskjemaene. Det første kartleggingsskjemaet tar noe tid, om lag en halvtime, men de ukentlige skjemaene, som kan fylles ut på telefonen din, tar kun 2-3 minutter å svare på. Det er ingen tilleggs risiko forbundet med studien. Vi vil måle høyde og vekt. De fysiske testene som registreres, tester generell fysisk form. De tar noen timer å gjennomføre, og kan sees på som en egen treningsøkt.

Hva skjer med informasjonen om deg?
Informasjonen som registreres om deg skal kun brukes slik som beskrevet i hensikten med studien. Alle opplysningene vil bli behandlet uten navn og fødselsnummer eller andre direkte gjenkjennende opplysninger. En kode knytter deg til dine opplysninger gjennom en navneliste. Det er kun autorisert personell knyttet til prosjektet som har adgang til navnelisten og som kan finne tilbake til deg. Opplysningene om deg vil oppbevares i 10 år. Det vil ikke være mulig å identifisere deg i resultatene av studien når disse publiseres.

Senere oppfølgingsstudier
Når denne studien er avsluttet, er det mulig at prosjektgruppen vil ta ny kontakt for eventuelle oppfølgingsstudier. Ved å samtykke i å delta i denne studien, gir du også ditt samtykke i å kunne bli kontaktet på ny for mulige oppfølgingsstudier. Opplysningene om deg vil derfor oppbevares i 10 år. Dersom du ikke har blitt kontaktet ila denne perioden, vil personopplysningene om deg anonymiseres.

Frivillig deltakelse
Det er frivillig å delta i studien. Du kan når som helst og uten å oppgi noen grunn trekke ditt samtykke til å delta i studien. Dette vil ikke få negative konsekvenser for deg. Dersom du ønsker å delta, undertegner du samtykkeerklæringen på siste side. Om du nå sier ja til å delta, kan du senere trekke tilbake ditt samtykke uten at det påvirker ditt forhold til skolen eller trenere.

Dersom du senere ønsker å trekke deg eller har spørsmål til studien, kan du kontakte prosjektleder:

Christine Holm Moseid, mail: c.h.moseid@ nih.no

Samtykke til deltakelse i studien

Jeg er villig til å delta i studien «Den unge eliteutøverens helse»

Navn:

(Signert av prosjektdeltaker, dato)

Godkjenning til deltakelse fra foresatte:

(Signert av foresatte, dato)

NORGES IDRETTSHØGSKOLE

SENTER FOR
Idrettsskadeforskning

Forespørsel om deltakelse i forskningsprosjektet

«Den unge eliteutøverens helse»

Bakgrunn og hensikt
Dette er et spørsmål til deg om å delta i et forskningsprosjekt der vi ønsker å kartlegge helseplager hos unge toppidrettsutøvere som går på toppidrettsgymnas. Vi ønsker å sammenligne helseplager i denne gruppen med to kontrollgrupper, én gruppe som trener på høyt nivå og går på vanlig videregående skole og én gruppe som ikke driver med konkurranseidrett og går på vanlig videregående skole. Dersom du sier ja til å være med, er du en del av en av disse kontrollgruppene. Undersøkelsen er planlagt og gjennomføres av Senter for idrettsskadeforskning, Norges idrettshøgskole, i samarbeid med skolene Wang og NTG.

Hva innebærer studien?
Studien innebærer at du ved skolestart vil svare på et generelt spørreskjema om helse, sykdom, skader, idrettsdeltakelse, trenings- og konkurransebakgrunn, restitusjon og motivasjon. Dette spørreskjemaet besvares hjemme på egen PC, telefon eller nettbrett.

Du må deretter installere en ny «app» på din smarttelefon. Via denne vil du én gang hver uke gjennom hele skoleåret bli bedt om å besvare fire spørsmål som dreier seg om du er frisk og skadefri, eller om du har helseproblemer som begrenser din trenings- eller prestasjonsevne. Når det har gått om lag 5 og 10 måneder, vil du få et par ekstra spørsmål om motivasjon og utvilthet, antall trenere og nivå du spiller på, høyde og vekt. Du vil ikke motta noen spørreskjema i skolens sommerferie.

Mulige fordeler og ulemper
Ulempen med å delta i studien er den tiden det tar å fylle ut spørreskjemaene. Det første kartleggingsskjemaet tar noe tid, om lag en halvtime, mens de ukentlige skjemaene, som skal fylles ut via telefonen din, tar kun 2 minutter å svare på. Det er ingen tilleggs risiko forbundet med studien.

Hva skjer med informasjonen om deg?
Informasjonen som registreres om deg skal kun brukes slik som beskrevet i hensikten med studien. Alle opplysningene vil bli behandlet uten navn og fødselsnummer eller andre direkte gjenkjennende opplysninger. En kode knytter deg til dine opplysninger gjennom en navneliste. Det er kun autorisert personell knyttet til prosjektet som har adgang til navnelisten og som kan finne tilbake til deg. Opplysningene om deg vil oppbevares i 10 år. Det vil ikke være mulig å identifisere deg i resultatene av studien når disse publiseres.

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Det er helt frivillig å delta i studien. Du kan når som helst og uten å oppgi noen grunn trekke ditt samtykke til å delta i studien. Dette vil ikke få negative konsekvenser for deg. Dersom du ønsker å delta, undertegner du samtykkeerklæringen på neste side. Om du nå sier ja til å delta, kan du senere trekke tilbake ditt samtykke uten at det påvirker ditt forhold til skolen eller trenere.

Prosjektet er meldt og godkjent av Norsk samfunnsvitenskapelig datatjeneste (NSD) og det er meldt til Regional komité for medisinsk og helsefaglig forskningsetikk (REK).

Dersom du senere ønsker å trekke deg eller har spørsmål til studien, kan du kontakte prosjektleder:

Christine Holm Moseid, mail: c.h.moseid@ nih.no

Samtykke til deltakelse i studien

Jeg er villig til å delta i studien «Den unge eliteutøverens helse»

Navn:

(Signert av prosjektdeltaker, dato)

Godkjenning til deltakelse fra foresatte:

(Signert av foresatte, dato)