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PhD Thesis

Analgesic use in youth elite athletes: a longitudinal mixed-methods study

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'The expert at anything was once a beginner'

- Helen Heyes

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Preface

This PhD project was conducted at the Research Unit for Musculoskeletal Function and Physiotherapy, Department of Sports Science and Clinical Biomechanics, Faculty of Health Sciences, University of Southern Denmark from August 2021 to November 2024.

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Publications included in the PhD thesis

This thesis is based on the following papers:

I. Pedersen JR, Andreucci A, Thorlund JB, Koes B, Møller M, Storm LK, Bricca A. Prevalence, frequency, adverse events, and reasons for analgesic use in youth athletes: A systematic review and meta-analysis of 44,381 athletes. *J Sci Med Sport.* 2022:25(10);810-819.

II. Pedersen JR, Møller M, Storm LK, Koes B, Mohammednejad A, Thorlund JB. Popping pills in youth elite sports – fact or fiction? A 36-week prospective cohort study of analgesic use 1195 youth elite athletes and student controls. J Orthop Sports Phys Ther. 2024;54(8):551-559.

III. Pedersen JR, Storm LK, Larsen AC, Møller M, Koes B, Thorlund JB. '*It may not be the smartest thing to do, but sometimes it's the only option'*: A mixed-methods study of analgesic use in youth elite athletes (in review).

IV. Pedersen JR, Møller M, Storm LK, Koes B, Mohammednejad A, Thorlund JB. Large variations in trajectories of analgesic use in youth elite athletes: A 28-week prospective cohort study (in review).

Thesis at a glance

Paper	Objective	Methods	Conclusion
I. Systematic review and meta-analysis	To identify prevalence, frequency, adverse events, and reasons for analgesic use in youth athletes	*Design:* Systematic review and meta-analysis *Population:* Athletes aged 15-24 years *No. of included studies:* 49 *Outcomes:* Prevalence and frequency of analgesic use, reasons for analgesic use, and adverse events	Youth athletes commonly use analgesics, but estimates vary depending on the type of analgesic and prevalence measure. NSAIDs appeared to be the most used analgesic. Across studies, 7-50% of athletes reported weekly use. Adverse events were reported by 3-19% of athletes. Reasons for using analgesics included treatment of sports-related pain or injury and associated symptoms, to treat illness, and to enhance performance.
II. Prospective cohort study	To investigate analgesic use in a cohort of Danish youth elite athletes and compare weekly prevalence and frequency of analgesic use over 36 weeks to student controls To investigate and compare reasons for use and types of analgesics used.	*Design:* 36-week prospective cohort study with weekly monitoring of analgesic use *Population:* 690 youth elite athletes (44% female) and 505 student controls (59% female) aged 15-20 years *Outcomes:* Prevalence and frequency of analgesic use, reasons for use, and types of analgesics used	Analgesic use was common in both youth elite athletes and student controls, with a mean weekly prevalence of ~20% in both cohorts. Participating in youth elite sports was associated with lower odds of analgesic use compared to student controls, but usage rates were similar between the groups. There were no differences in odds of analgesic use between the groups when stratified by sex. Reasons for use and types of analgesics used differed between youth elite athletes and student controls.
III. Mixed-methods study	To compare analgesic use over 36 weeks between team athletes, endurance athletes, and technical athletes, and explore experiences and sociocultural factors impacting analgesic use	*Design:* Longitudinal explanatory mixed-methods study with weekly monitoring of analgesic use for 36 weeks and focus group interviews. *Population:* 689 youth elite athletes (44% females) aged 15-20 years were included in the cohort study, and 32 participants (75% female) were included across nine focus group interviews. *Outcomes:* Prevalence and frequency of analgesic use, reasons for use, and types of analgesics used (cohort study). Experiences with analgesic use and sociocultural factors influencing the use (focus group interviews)	There were no differences in odds or rate of analgesic use or types of analgesics used between team athletes, endurance athletes, and technical athletes. More endurance athletes used analgesics to treat menstrual pain and pain not related to sports compared to team athletes and technical athletes. Athletes described diverse experiences with analgesic use ranging from rare, non-systematic use of over-the-counter analgesics to long-term, daily use of opioids. Norms, values, and structures in sports environments, such as pressure to participate in sports despite health problems, feeling responsible for team performance, and challenges in balancing academic and sports commitments influenced analgesic use.
IV. Trajectory analysis	To identify trajectories of analgesic use among youth elite athletes and a reference group of students To examine differences in risk of analgesic use, sex distribution, consumption frequency, and types of analgesics used between trajectory groups.	*Design:* 28-week prospective cohort study with weekly monitoring of analgesic use *Population:* 690 youth elite athletes (44% female) and 505 students (59% female) aged 15-20 years Outcomes: Trajectories of analgesic use based on prevalence estimates. Sex distribution, frequency of use and types of analgesics used in each trajectory group.	Approximately half of both youth elite athletes and students had minimal or no use of analgesics, while 21% of athletes and 14% of students exhibited concerning analgesic consumption patterns with biweekly or weekly analgesic use and 11-28 times higher risk of analgesic use at any given time. Persistent users had a higher proportion of females, higher weekly consumption frequency, and a higher use of opioids.

English summary

This PhD thesis aimed to investigate the epidemiology of analgesic use in youth elite athletes and explore experiences and sociocultural influences on the use. To answer this aim, four studies were conducted:

Paper I was a systematic review and meta-analysis with the objective of synthesising the evidence on prevalence, usage frequency, adverse events, and reasons for analgesic use in youth athletes. The review, based on forty-nine studies of 44,381 athletes from various competition levels, found common use of NSAIDs, with a point prevalence of 48% and period prevalence estimates ranging from 7 to 95%. Other analgesics, including paracetamol, acetylsalicylic acid, topical analgesics, opioids, injectable analgesics, mixed analgesics, and unspecified analgesics generally yielded lower prevalence estimates. Seven to 50% of athletes reported weekly analgesic use. The proportion of adverse events ranged from 3.3% to 19.2%. Reasons for using analgesics included treatment of sports-related pain or injury, to treat illness, and to enhance performance. Overall quality of evidence was very low to low.

Paper II was a 36-week prospective cohort study including 690 youth elite athletes and 505 students 15-20 years of age. Participants provided weekly reports on number of days with analgesic use, reasons for use, and types of analgesics used via SMS. Analgesic use was common in both athletes and students, with weekly prevalence estimates ranging from 15-32% in athletes and 15-52% in students. Overall, athletes had lower odds of analgesic use (OR=0.78, 95% CI 0.64-0.95) compared to students, but the usage rate was similar between the groups (IRR=1.04, 95% CI 0.99-1.11). Subgroup analyses stratified by sex suggested no statistically significant differences in the odds of analgesic use. More athletes reported using analgesics to prevent or treat pain or injury in relation to sports participation and to use topical gels compared to students.

Paper III was a mixed-methods study combining prospective data on analgesic use in youth elite athletes from paper II with focus group interviews to examine differences in analgesic consumption between athletes from different sports categories, explore their experiences with analgesics, and identify sociocultural influences on the use. There were no differences in odds of analgesic use between endurance athletes (reference group), technical athletes (OR 0.94, 95% CI 0.65-1.37), and team athletes (OR 0.88, 95% CI 0.62-1.25), nor in the rate of analgesic use (endurance athletes

(reference), technical athletes (IRR 0.97, 95% CI 0.87,1.07), or team athletes (IRR= 1.03, 95% CI 0.94-1.14). Reasons for use varied significantly between groups, but the types of analgesics used were similar. Athletes described diverse experiences with analgesics, from rare, non-systematic use of over-the-counter analgesics to daily, long-term use of opioids. Sociocultural factors influencing analgesic use were, for example, considering the potential consequences of using analgesics for pain and injury, and feeling responsible for team performance.

Paper IV was a 28-week prospective cohort study based on prospective data from paper II with the objectives of identifying distinct trajectories of analgesic use in youth elite athletes and students, and to compare risk of analgesic use, sex distribution, consumption frequency, and types of analgesics used between trajectory groups. Four trajectories of analgesic use were identified for both athletes and students: minimal/non-users (48% of athletes/53% of students), occasional users (31%/33%), frequent users (19%/11%), and persistent users (2.5%/3.2%). Compared to athlete minimal/non-users, the relative risk of analgesic use was significantly higher for occasional users (RR=6.2 [95% CI 5.5-7.2]), frequent users (RR= 15.1 [95% CI 13.3-17.2]), and persistent users (RR=28.3 [95% CI 24.6-32.5]), with a similar pattern observed among students. The mean weekly prevalence of analgesic use varied across trajectory groups, ranging from 3% to 88% in athletes and 5% to 94%. Frequent and persistent users had a higher proportion of females, higher weekly consumption frequency, and used analgesics with a higher risk of serious adverse events.

The findings of this thesis suggest that analgesic use is common in youth elite athletes, but the prevalence and frequency of use is comparable to that of a student population of the same age. However, distinct groups of users with large variations in analgesic consumption patterns exist, including small subgroups with concerning usage patterns. While overall usage is similar between athletes and students, a larger proportion of athletes' analgesic use is related to sports participation, which may stem from perceived pressure to participate in sports despite experiencing health problems, a strong sense of personal responsibility for team performance, and a culture embedded within elite sports environments fostering the normalisation of analgesic use.

Dansk resumé

Det overordnede formål med denne ph.d.-afhandling var at undersøge epidemiologien for brug af smertestillende medicin blandt unge eliteatleter, udforske deres erfaringer og identificere de sociokulturelle faktorer, der påvirkninger forbruget. For at besvare dette formål blev der gennemført fire studier:

Artikel I var et systematisk litteraturstudie og meta-analyse, der havde til formål at gennemgå og syntetisere evidensen om prævalens, frekvens, bivirkninger og årsager til brug af smertestillende medicin blandt unge atleter. Litteraturstudiet, som omfattede 49 studier med 44.381 atleter fra forskellige konkurrenceniveauer, fandt udbredt brug af NSAID med en punktprævalens på 48% og periodeprævalensestimater fra 7 til 95%. Andre typer smertestillende medicin, herunder paracetamol, acetylsalicylsyre, smertestillende gel, opioider, injektioner med smertestillende medicin, blandede smertestillende præparater og uspecificerede præparater viste generelt lavere prævalensestimater. Syv til 50 % af atleterne rapporterede at bruge smertestillende medicin ugentligt. Forekomsten af bivirkninger varierede fra 3,3 % til 19,2 % på tværs af fire studier. Årsagerne til brug af smertestillende medicin omfattede behandling af sportsrelaterede smerter eller skader, behandling af sygdomme, og til at forbedre præstation. Kvaliteten af evidensen var meget lav til lav.

Artikel II var et 36-ugers prospektivt kohortestudie med 690 unge eliteatleter og 505 studerende, som ugentligt rapporterede via SMS om deres brug af smertestillende medicin, herunder antal dage, årsager til brug og typer af smertestillende medicin. Resultaterne viste, at brugen af smertestillende medicin er almindelig blandt både atleter og studerende, med ugentlige prævalensestimater fra 15-32 % blandt atleter og 15-52 % blandt studerende. Atleterne havde lavere odds for brug af smertestillende medicin sammenlignet med studerende (OR=0.78, 95% CI 0.64-0.95), men brugsraten var ens mellem grupperne (IRR=1.04, 95% CI 0.99-1.11). Subgruppeanalyser opdelt efter køn viste ingen statistisk signifikante forskelle i oddsene for brug af smertestillende medicin. I forhold til studerende, var der flere atleter der brugte smertestillende medicin til at forebygge eller behandle smerter eller skader i forbindelse med sportsdeltagelse, ligesom flere anvendte smertestillende gels, såsom Voltaren gel.

Artikel III var et mixed-methods-studie, der kombinerede prospektive data om brug af smertestillende medicin blandt unge eliteatleter fra studie II med fokusgruppeinterviews. Formålet var at udforske forskelle i brug af smertestillende medicin mellem atleter fra forskellige sportskategorier, samt undersøge deres erfaringer med brug af smertestillende medicin og identificere de sociokulturelle faktorer, der påvirker brugen. Der var ingen forskelle i odds for brug af smertestillende medicin mellem udholdenhedsatleter (referencegruppe), tekniske atleter (OR 0.94, 95% CI 0.65-1.37) og holdatleter (OR 0.88, 95% CI 0.62-1.25), og heller ikke i forbrugsraten (udholdenhedsatleter (reference), tekniske atleter (IRR 0.97, 95% CI 0.87-1.07) eller holdatleter (IRR= 1.03, 95% CI 0.94-1.14)). Årsagerne til brug af smertestillende medicin varierede mellem grupperne, men typerne af smertestillende medicin var de samme. Atleterne beskrev forskellige erfaringer med brug af smertestillende midler, fra sjælden, sporadisk brug af håndkøbsmedicin til daglig, langvarig brug af opioider. Sociokulturelle faktorer, der påvirkede brugen, omfattede blandt andet overvejelser om de potentielle konsekvenser af brug af smertestillende for smerter og skader samt følelsen af ansvar for holdets præstation.

Artikel IV var et 28-ugers prospektivt kohortestudie baseret på prospektive data fra artikel II, med det formål at identificere of sammenligne forskellige forløb af brug af smertestillende medicin blandt unge eliteatleter og studerende. Fire forbrugsmønstre blev identificeret for begge grupper: minimal/ikke-brugere (48% af atleterne/53% af studerende), lejlighedsvise brugere (31%/33%), hyppige brugere (19%/11%) og vedvarende brugere (2.5%/3.2%). Sammenlignet med atleter med minimalt/intet brug af smertestillende medicin var den relative risiko for brug af smertestillende medicin signifikant højere for lejlighedsvise brugere (RR = 6,2 [95% CI 5,5-7,2]), hyppige brugere (RR = 15,1 [95% CI 13,3-17,2]) og vedvarende brugere (RR = 28,3 [95% CI 24,6-32,5]), med et lignende mønster observeret blandt studerende. Den gennemsnitlige ugentlige prævalens af brug af smertestillende medicin varierede på tværs af de fire forbrugsmønstre, fra 3% til 88% blandt atleter og fra 5% til 94% blandt studerende. Hyppige og vedvarende brugere havde en højere andel af kvinder, højere ugentlig forbrugshyppighed og brugte smertestillende midler med højere risiko for alvorlige bivirkninger.

Resultaterne af dette projekt tyder på, at brug af smertestillende medicin er udbredt blandt unge eliteatleter, men prævalensen og frekvensen er sammenlignelig med jævnaldrende studerende. Der blev dog identificeret forskellige grupper af brugere med store variationer i forbrugsmønstre.

Selvom det overordnede forbrugsmønster er ens for unge atleter og studerende, er en større del af atleternes brug relateret til sportsdeltagelse, hvilket kan skyldes oplevet pres for at deltage i sport trods helbredsproblemer, en stærk følelse af personligt ansvar for holdets præstation og en kultur indlejret i eliteidræt, der normaliserer brug af smertestillende midler.

List of abbreviations

APPA	Average Posterior Probability Assignment
CI	Confidence interval
COREQ	Consolidated criteria for reporting qualitative research
IOC	International Olympic Committee
IRR	Incidence rate ratio
MeSH	Medical Subject Heading
N	Number
NSAIDs	Non-steroidal anti-inflammatory drugs
NOS	Newcastle-Ottawa Scale
OCC	Odds of Correct Classification
OR	Odds ratio
PAMUS	PAin Medication Use in youth elite athleteS questionnaire
PERSiST	Implementing Prisma in Exercise, Rehabilitation, Sports medicine and SporTs science
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-analyses
RCT	Randomized controlled trial
STROBE	Strengthening the Reporting of Observational studies in Epidemiology

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Introduction

In sports medicine, the use of analgesics in elite athletes has been a long-standing topic of debate and concern (1-3). A 2018 systematic review by the International Olympic Committee (IOC) highlighted the widespread use of analgesics in elite sports, but also emphasised an urgent need for high-quality longitudinal research, as the evidence at the time relied on cross-sectional data from retrospective surveys, doping control forms, and studies conducted during tournaments (4, 5). Moreover, research had predominantly focused on rugby, athletics, or football, with a primary emphasis on the use of non-steroid anti-inflammatory drugs (NSAIDs). The available evidence was even more sparse regarding youth elite athletes, with only a few studies exploring analgesic use in this population (4, 5). The authors of the IOC review also recognised the need for qualitative research to explore and understand the complexities of analgesic use in elite sports environments and provide a nuanced contextual understanding of athletes' experiences with analgesics and the factors influencing the use (4, 5).

Epidemiology of analgesic use in elite sports

The evidence on the epidemiology of analgesic use in elite athletes was most recently synthesised in the systematic review conducted by the IOC in 2018 (4). They identified 45 studies reporting data on the prevalence of analgesic use in elite athletes, including professional, collegiate, Olympic, Paralympic, and other elite athletes (4).

Analysis of data from 25 of these studies showed large variations in prevalence estimates of NSAID use, attributable to differences in study methodologies, reporting periods, and data sources. Some studies reported a low prevalence of NSAID use with estimates ranging from 2.4% of urine samples testing positive for NSAIDs at the 1988 Winter Olympics to 11.1% of Olympic athletes declaring NSAIDs use on doping control forms during the 2004 Athens games (4). Conversely, other studies reported high prevalence estimates, including 50% of collegiate American football players reporting use within a season and 93% of Italian professional football players reporting use within the past 12 months (4). Data on non-NSAID oral analgesics was limited and often reported simply as *analgesics* rather than specifying the specific drug. Reported prevalence estimates of these analgesics ranged from 0.4% of football players at the 2007 U20 World Cup to 20% of Italian elite

cyclists reporting use within the previous three months. Three studies of collegiate athletes found that between 58% and 73% reported using non-prescription over-the-counter analgesics (4). Only two studies examining the use of lidocaine were identified, and both reported prevalence estimates below 2% (4). Estimates of corticosteroid use also varied widely across studies, partly due to differences in measurement methods. Doping control forms from the mid-2000s indicated that the prevalence of corticosteroid use within the past three days ranged from 1% to 9.2%. Throughout two seasons, the prevalence of corticosteroid use among elite cyclists was estimated at 15.8%, and surveys of physicians revealed that 32% to 83.9% prescribed oral corticosteroids to their athletes (4). Compared to oral NSAIDs, fewer studies were identified on the use of injectable NSAIDs. In the 2000 NFL season, 93% of team physicians reported administration of injectable ketorolac as often as once per week. Additionally, 79% of U.S. sports medicine physicians reported using injectable ketorolac with collegiate athletes and 43% with professional athletes. During the 1996 African National Cup, 31% of football players were estimated to have received NSAID injections before matches (4). Some studies documented the use of injectable anaesthetics and/or corticosteroids, though the methods for measuring and reporting these data varied. For example, in NFL players, an estimated 13.5% of hamstring injuries were treated with injectable corticosteroids, and between 2.2% and 5.7% of male athletes used either injectable anaesthetics or corticosteroids during the 2002-2012 FIFA Futsal World Cup tournaments (4). Studies on opioid use generally indicated rare usage, with the majority reporting prevalence estimates of less than 1%. For example, a review of pharmacy records from team South Africa during the 2004 Athens Olympics showed that, on average, 1.5 opioid-containing analgesic tablets were dispensed per athlete. However, a smaller study revealed that 3.3% of elite cyclists had used tramadol in the previous 3 months, while 5.6% of Nigerian professional athletes reported having used codeine at some point in the past (4).

Evidently, the evidence on the epidemiology of analgesic use in elite athletes has several serious limitations. These include (I) limited data on the use of non-NSAID analgesics, (II) a limited number of studies involving youth elite athletes, (III) lack of longitudinal data, and (IV) limited data on athletes from sports other than football, rugby, and athletics (4, 5). The lack of longitudinal data is critical, as it precludes identification of groups with distinct consumption patterns and detailed interpretation of consumption patterns over time. The limitations of quantifying analgesic use based on cross-sectional estimates have been demonstrated in other populations. In a study of 16,000 people with hip and knee osteoarthritis, 62% self-reported to have used analgesics within the three

months preceding their enrolment in a standardised exercise therapy and patient education program (6). However, analysis of registry data showed that 10% of analgesic users accounted for 45%, 50%, and 70% of the total paracetamol, NSAID, and opioid consumption, respectively (7).
In addition to the identified need for more comprehensive data on analgesic use in a broader range of sports, another limitation is the lack of sufficient data directly comparing analgesic consumption patterns across different sports disciplines. A study on Finnish elite athletes showed that the 7-day prevalence of analgesic use was lower among team sport athletes (n=152, 28.3%) compared to speed and power athletes (n=113, 41.6%) (8). Prior research also suggest that athletes' willingness to take risks in relation to their sport, such as competing with underlying health problems, varies across sports disciplines (9, 10), and an association between this practice, also known as *willingness to compete hurt*, and analgesic use, has been documented (11). Furthermore, differences in injury and illness prevalence and severity have been observed between youth athletes from team sports, technical sports, and endurance sports (12), and as analgesics are often used to manage these symptoms (13-19), patterns of analgesic use may also vary between overarching sports categories. Finally, the IOC systematic review identified only one study comparing analgesic use between elite athletes and an age-matched reference population, and this study focused exclusively on male retired athletes, limiting its relevance to those currently active in their careers. Considering that several studies have concluded that analgesics are frequently used in non-athlete populations, including young people, adults, and clinical populations (6, 20-22), there is a need for meaningful comparisons of analgesic use between elite athletes and non-athlete reference populations. Such comparisons are essential for gaining contextualised insights into the influence of elite sports participation on analgesic use.

Analgesic use in a sports-specific cultural context

Embedded in elite sports is a *culture of risk*, encompassing a set of beliefs, cultural values, and processes of athletic socialisation normalising the risks, injuries, and pain associated with elite-level sports (23, 24). Consequently, competing despite underlying health problems, or playing through pain, is common in athletes (25-27), and several studies have shown that elite athletes use analgesics to prevent or block pain to enable sports participation, to manage sports-related pain and injury, to enhance performance, and to treat symptoms of illness (13-19). While these findings offer insights into the reasons for analgesic use among elite athletes, data remains limited and is drawn from studies with varying objectives and methodologies. This hampers a comprehensive

understanding of why elite athletes use analgesics and precludes meaningful comparisons of results across studies. Further, although more quantitative data is needed on the reasons for analgesic use, there is a significant gap in the literature addressing the specific social and cultural context of the use and the complex interactions and interdependencies that may influence analgesic use in elite athletes (5). The only peer-reviewed qualitative study on this subject identified four key factors influencing analgesic use in elite athletes, including (I) athletes legitimising the use of analgesics to compete while injured by attributing importance to specific competitions, (II) coaches persuading athletes to use analgesics, even when they were hesitant, (III) the normalisation of analgesic use as part of the broader mindset of making sacrifices for the sports, and (IV) using analgesics to reduce the impact of pain and injury on performance (19). These findings illustrate that athletes' use of analgesics is not an isolated behaviour, but is influenced and shaped by norms, values, and structures inherent in their sports environments. These qualitative insights offer a nuanced understanding of the contextual factors shaping athletes' use of analgesics, insights that cannot fully be captured through quantitative surveys alone.

Despite being understudied regarding their analgesic use, youth elite athletes may represent an athlete subgroup of particular interest. Health problems, such as injuries and illness, are common in youth sports (12, 28, 29), and their impact on athlete health and development has been an area of interest in recent years (30). International consensus on youth athletic development emphasises sustainable, inclusive, and enjoyable participation at all levels of athletic achievement (30). Yet, studies have described how competitive youth sport is increasingly characterised by a culture of risk, including risk glorification, increasing professionalism, pain normalisation, and psychological stressors from internal and external performance expectations (30, 31). These factors may partly account for the high prevalence of analgesic use highlighted in the IOC systematic review (4). In addition, research indicates that youth elite athletes often lack awareness of potential adverse effects (32), frequently misuse analgesics, and are significantly influenced by external stakeholders regarding their use of analgesics (16, 17, 32). Finally, although estimates vary across settings and countries, a recent systematic review revealed that only a small percentage of youth elite athletes advance to an equivalent competition level in adulthood (33), further emphasising the importance of athlete health protection at the youth level, including safe and ethical use of analgesics.

Analgesic efficacy and adverse events

Despite the common use of analgesics in elite athletes, evidence regarding their efficacy and associated risks remains limited and inconsistent across studies. To address this, the following section presents research findings from studies involving elite and non-elite athletes. A recent systematic review including 13 randomized controlled trials (RCT) compared pain reduction in athletes treating musculoskeletal injuries with topical or oral over-the-counter medications versus placebo medications and found a statistically significant, medium-to-large pooled effect size reflecting a reduction in pain outcomes for the topical treatment versus placebo, but a non-significant reduction in pain outcomes for the oral treatment versus placebo (34).

A review of eight RCTs, primarily published before 1990, examined the effects of different analgesic treatments used in elite athletes (4). The sample sizes ranged from 13 to 60 athletes, and most studies compared the efficacy of various oral NSAIDs in treating acute pain from sports-related injuries. In each study, self-reported pain was the primary outcome, while secondary outcomes included swelling, return to sport, and physical function. Results showed that flurbiprofen was more effective than aspirin for pain reduction and return to play in athletes with acute lower-limb soft tissue injuries, while piroxicam had a larger effect compared to tenoxicam, naproxen, and ibuprofen in reducing pain and improving physical function in athletes with sprains, strains, and other soft tissue injuries. Another study found diflunisal as effective as paracetamol with codeine in managing acute pain, soreness, and swelling in collegiate athletes (4). Another study, conducted in 2006, found that polidocanol injections were more effective in improving pain and physical function than lidocaine with epinephrine injections for the treatment of chronic patellar tendinopathy. Additionally, one study suggested that naloxone may reduce affective components of pain in non-injured athletes, though it did not affect overall pain intensity (4).

The systematic review by Harle et al. (4) also identified 14 observational studies evaluating the effect of various analgesic treatments. Twelve studies examined the effects of non-NSAID injectables, such as corticosteroids, local anaesthetics, regenerative dextrose injections, and sclerosing injections, in treating various sports-related injuries and pain conditions. These studies primarily focused on groin pain, lumbar disk herniation, patellar tendinopathy, and hamstring injuries, with a mix of acute, subacute, and chronic cases. Most studies reported positive outcomes, such as pain reduction and improved function, though some studies with negative or null results

recommended assessing the risks and benefits on a case-by-case basis. However, the absence of control groups in these studies raises concerns about potential biased conclusions. The mean sample size was 55, with seven studies involving fewer than 30 participants. The two largest studies retrospectively evaluated the complications associated with injectable therapies, reporting that while the majority of athletes perceived the treatments as helpful, some experienced delayed recovery or worsening of their injuries. Additionally, intranasal sumatriptan alleviated 86% of acute headaches among 28 Australian football players, while a qualitative study with interviews of 36 breaststroke swimmers suggested that NSAIDs might be useful in relieving chronic knee pain symptoms (4).

A limited number of studies have examined the occurrence of adverse events associated with analgesic use in athletes. Two studies investigated the prevalence of adverse events from intramuscular ketorolac use in collegiate and professional athletes. Both studies collected data through surveys sent to team physicians, with 12% and 21% of respondents reporting adverse events. Reported adverse events included muscle injuries, gastrointestinal disturbances, post-injection soreness, bleeding, and kidney complications (35, 36). In another study, the incidence of adverse events was compared between marathon runners who ingested NSAIDs before the race and those who did not. The results showed that runners in the NSAID group had a five-fold higher incidence of adverse events, including gastrointestinal cramps and bleeding, cardiovascular events, haematuria, and muscle cramps. The incidence of adverse events increased significantly with increasing analgesic doses (37). Additionally, a primary concern with using analgesics to facilitate continued athletic activity is the potential for injury or pain progression (38). A descriptive case series including three professional football teams showed that progression of injury, secondary to injection and continued athletic activity, occurred in 7% of cases of administration of local anaesthetics (39).

In youth athletes, the proportion of NSAIDs users experiencing adverse events, including, amongst others, gastrointestinal symptoms, decrease in perceived muscle power, nausea, headache, fatigue, and allergic reactions, have been reported to range between 3.3 and 19.2% (8, 40, 41). Additionally, a study found that 6.3% of users of non-NSAID analgesics reported adverse events, including non-immunomodulated adverse reactions, oral allergy syndrome, bronchospasms, and anaphylaxis (42).

Summary and rationale for this thesis

The use of analgesics in elite sports, particularly among youth athletes, is a critical yet understudied area in sports medicine. Despite their central role in pain management, the ethical, safe, and effective use of analgesics in these populations remains a topic of concern. Existing research indicates widespread use of analgesics, yet the evidence is exclusively based on cross-sectional estimates, primarily involving senior elite athletes, and without comparing consumption patterns to non-athlete reference populations. The lack of qualitative insights also limits a deeper understanding of athletes' experiences with analgesics, the context of the use, and identification of sociocultural factors impacting their use.

This thesis aims to address the significant gaps in the current literature by conducting mixed-methods research to better understand analgesic use in youth elite athletes. Investigating sociocultural factors impacting analgesic use will provide valuable insights into how pain management practices can be improved. By focusing on both the epidemiology and the complex social context surrounding analgesic use, this research may contribute to the development of evidence-based, ethical, and athlete-centered pain management strategies. The findings may inform guidelines and policies to protect the health of elite athletes, particularly during their formative years, ensuring that pharmacological pain management is administered safely and responsibly.

Aim

The overall aim of this thesis was to provide foundational data to improve the understanding of analgesic use in youth elite sports.

Objectives

The overall aim of this thesis was operationalised into five study-specific objectives:

I. To review and synthesise the evidence on prevalence, usage frequency, adverse events, and reasons for analgesic use in youth athletes (paper I).

II. To compare weekly prevalence and frequency of analgesic use over 36 weeks between youth elite athletes and a reference group of students (paper II) and youth elite athletes from different sports categories (paper III).

III. To identify and compare reasons for analgesic use and types of analgesics used between youth elite athletes and a reference group of students (paper II) and youth elite athletes from different sports categories (paper III).

IV. To explore youth athletes' experiences with analgesics and identify sociocultural influences on analgesic use (paper III).

V. To identify distinct trajectories of analgesic use in youth elite athletes and a reference group of students, and compare risk of analgesic use, sex distribution, consumption frequency, and types of analgesics used between trajectory groups (paper IV).

Methods

Paper I

Study design

This study was a systematic review and meta-analysis performed in accordance with the Cochrane Handbook (43) and reported using the PERSiST (implementing Prisma in Exercise, Rehabilitation, Sport medicine and SporTs science) guidance (44) and the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA 2020) statement (45). A study protocol was pre-registered on Open Science Framework (https://osf.io/4ktsr/).

Eligibility criteria

Studies were included if they met the eligibility criteria presented in Table 1.

Table 1 Study I eligibility criteria

Inclusion criteria	**Exclusion criteria**
Retrospective or prospective cohort, cross-sectional, case-control studies, case-series	Mixed populations (e.g., athletes and non-athletes) not reporting data separately for athletes
Athletes aged 15-24 years (46) participating in any sports discipline at any competition level	Assessed analgesic use in athletes with underlying diseases or conditions not related to sport (e.g., cancer pain)
Reported the prevalence of analgesic use	Reported only on non-medical use of analgesics
Full-text paper published in English, Spanish, Italian, Dutch, or any Scandinavian language in a peer-reviewed journal	

Outcomes

Main outcome was prevalence of analgesic use. Analgesics were defined as pharmacological agents reducing pain sensation without inducing loss of consciousness (47). These agents were categorised as paracetamol, NSAIDs, acetylsalicylic acid, anaesthetic injections, opioids, mixed analgesics (when analgesics were, for example, reported as *paracetamol and/or NSAIDs* without further subclassification), and unspecified analgesics (when reported simply as *analgesics* without further

classification or specification) with no restrictions on route of administration. Both period prevalence and point prevalence measures were included (48). There were no restrictions on reporting methods (e.g., athlete self-report, coach reports, pharmacy records, doping control forms). Secondary outcomes included consumption frequency, adverse events, and reasons for use. All approaches to estimating and reporting secondary outcomes were included.

Search strategy

Systematic literature searches were conducted in Medline (PubMed), Embase (Ovid), and SPORT-Discus on September 17th, 2021, without publication date or language restrictions. The search strategy included Medical Subject Headings (MeSH) terms and text words in title and abstract covering two domains (i.e., 'analgesics' and 'sport/athletes'). Hand searches were conducted by screening the references cited in a previous systematic review on analgesic use in elite athletes (4). Finally, the reference lists of included studies were screened to identify additional relevant studies, and forward citation tracking was conducted in Web of Science.

Study selection

Following duplicate removal, two authors independently conducted a two-phase article selection process. First, articles were screened for eligibility by title and abstract screening using Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia). Second, full-text articles were retrieved and screened for inclusion. Disagreements were resolved through discussion or, if needed, by review of a third author.

Data extraction

Two authors independently extracted data using a standardised data extraction form. Disagreements were resolved through discussion or, if needed, by review of a third author. If a study reported multiple types of analgesics or prevalence measures, all data were extracted for analysis. If relevant data was not reported in text, the data was extracted from graphs and figures. If relevant data could not be extracted from the published studies, e-mails were sent to the corresponding and/or senior author including a list specifying the data of interest.

Study quality assessment

Study quality was independently assessed by two authors using the Newcastle-Ottawa scale (NOS) for cohort studies and the modified NOS for cross-sectional studies as recommended in the

Cochrane Handbook for Systematic Reviews of Interventions (49, 50). These scales encompass three overarching domains concerning the selection of study groups, comparability of groups, and ascertainment of exposure/outcome. For cohort studies, eight items were scored with one or two stars, resulting in a maximum score of nine stars and an overall judgement of study quality as low, moderate, or high. For cross-sectional studies, seven items were scored with one or two stars, resulting in a maximum score of 10 stars and leading to an overall judgement of study quality as unsatisfactory, satisfactory, good, or very good. Disagreements were resolved through discussion or, if needed, by review of a third author. The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) tool for systematic reviews of prognostic studies was used to assess the overall quality of evidence for point prevalence estimates (51, 52).

Data synthesis

Random-effects meta-analyses with continuity corrections were used to calculate pooled prevalences with 95% confidence intervals (95% CI). Pooled prevalence estimates were calculated for paracetamol, NSAIDs, mixed analgesics, unspecified analgesics, acetylsalicylic acid, anaesthetic injections, and opioids and stratified by prevalence time-point. If a study reported more than one subtype of the same analgesic (e.g., non-prescription and prescription NSAIDs) at the same prevalence time-point, the subtype with the highest prevalence was included in the primary analysis to prevent underestimation of proportion estimates. Univariate meta-regression analyses investigated the effect of the proportion of females, age, and year or publication on the pooled proportion estimates when ≥10 studies were available (49). Subgroup analyses investigated the impact of performance level (elite (i.e., elite or professional as defined by the individual studies) vs. non-elite (i.e., all other performance levels)) on the pooled proportion estimates of NSAIDs and unspecified analgesics. Statistical heterogeneity was assessed using tau-squared (τ^2) and I-squared (I^2) and reported in analyses containing ≥ 4 studies (53-55). The presence of small-study bias was evaluated through visual inspection of funnel plots. Given the low number of studies available per outcome, the presence of small-study bias was only evaluated for point prevalence of NSAIDs and unspecified analgesics (49). Due to heterogeneity in measures used to estimate usage frequency, prevalence of adverse events, and reasons for analgesic use in individual studies, these outcomes were summarised narratively. The statistical analysis was performed in Stata version 17 (StataCorp 2021, College Station, TX, USA).

Sensitivity analyses

Several sensitivity analyses were conducted to examine whether the overall findings were robust towards the potentially influential decisions made in the design of this review. First, in studies reporting multiple subtypes of the same analgesic at the same prevalence time-point (e.g., 3-month prevalence of prescription and non-prescription NSAIDs use), the meta-analyses, initially conducted with the analgesic subtype displaying higher prevalence, were repeated using the alternate subtype (i.e., the analgesic subtype displaying lower prevalence). Second, due to unclear reporting and inconsistencies in the definitions of point prevalence across studies, two sensitivity analyses were conducted. The first excluded studies that explicitly assessed current analgesic use, and the second excluded those with unclear definitions of point prevalence. Finally, as most of the included studies did not clearly describe route of administration, a sensitivity analysis was conducted categorising injectable anaesthetics according to their active pharmacological agent (i.e., paracetamol, NSAID, acetylsalicylic acid, opioids, mixed analgesics, or unspecified analgesics), rather than by route of administration. These analyses were not included in the pre-registration.

Papers II-IV

Design

Papers II and IV are based on the same prospective cohort study and are reported according to the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guideline (56). Paper III is a longitudinal explanatory mixed-methods study reported in accordance with the STROBE guideline (56) and the Consolidated criteria for reporting qualitative research (COREQ) checklist (57). A study protocol was publicly available on Open Science Framework before data collection was finalised (https://osf.io/k5spz/). The Regional Scientific Ethics Committee of the region of Southern Denmark determined the project exempt from the requirement for ethical approval since only self-reported data was collected (case number 20202000-176). The project was approved by The Danish Data Protection Agency (case number 11.642).

Participants and recruitment

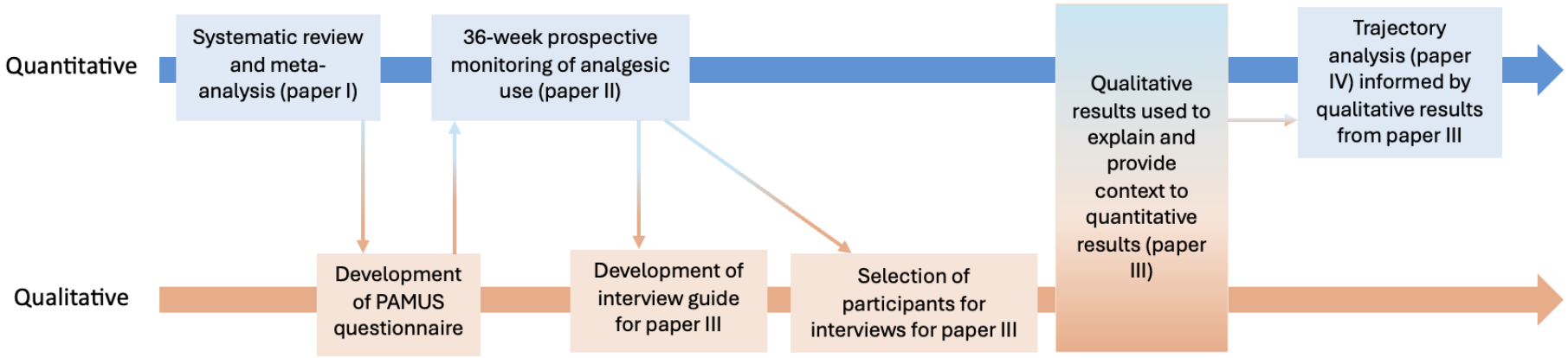
In March 2022, e-mail invitations to participate in the study were extended to thirty upper secondary education institutions in Denmark offering elite sports programs (i.e., dual career support) and regular academic programs. These schools were identified by representatives from Team Denmark and Danske Eliteidrætsgymnasier. Elite sports coordinators from interested schools (n=24) were subsequently invited to attend individual online meetings to receive further information and to plan the local recruitment strategy.

For the prospective cohort study utilised in papers II, III, and IV, participants were included and provided baseline data during on-site visits by the principal investigator at each school during the enrolment period from August 2022 to October 2022. At each school, youth elite athletes and students between 15 and 20 years of age (i.e., the usual age range of students enrolled in Danish high schools) were included. Athletes were considered *elite* if they were enrolled in an elite sports program. These programs support young athletes in pursuing full-time careers as professional athletes by allowing them to combine an upper-secondary education with participation in elite sports. This is achieved through extended educational programs, support and guidance from dual career counsellors, and flexible schedules to accommodate training and travelling commitments. Athletes were categorized into three overarching categories (i.e., endurance (e.g., triathlon, orienteering), technical (e.g., dance, taekwondo), and team (e.g., basketball, handball) sports) in accordance with a previous study including a heterogeneous group of athletes (12).

We aimed to include athletes and students of comparable age and representative of the national gender distribution at Danish high schools (i.e., approximately 54% girls and 46% boys). This was accomplished by recruiting athletes and student controls from corresponding academic years (i.e., first, second, and third school years) and diverse academic specialisations (e.g., social science, natural science, language science, and musical science classes). Both athletes and students had to possess proficiency in Danish reading and writing and be able to receive and respond to Short Message Services (SMS) on their phones. Participants were recruited by convenience sampling.

For the focus group interviews in paper III, athletes were selected through purposeful sampling by recruiting from eight participating high schools representative of diverse geographical locations, sizes, and educational programs. To be eligible for inclusion, athletes had to I) participate in the cohort study, and II) have a high weekly response rate in the cohort study, defined as <20% missing data. We aimed at maximising variation in athlete age, sex, type of sport, and analgesic consumption patterns by selecting participants based on their demographic information and responses to the weekly questionnaires. In February 2024, a list of athletes eligible for inclusion was provided to the respective elite sports coordinators, who then contacted the athletes identified by the principal investigator to inquire about potential participation in a focus group interview. Selection of participants for focus group interviews represented the fourth point of the quantitative and qualitative methods of the study (integration points 1, 2, and 3 are described in the *outcomes* and *experiences with analgesic use and sociocultural factors influencing the use* sections, respectively) (Figure 1)

Figure 1 Integration points of the quantitative and qualitative methods throughout the project



Data collection

For the prospective cohort study utilised in papers II, III, and IV, athletes and students completed an electronic baseline questionnaire concerning contact information, demographics, and sports history distributed via a QR code during on-site meetings with the principal investigator. From this questionnaire, mobile phone numbers were obtained to prospectively collect data using an SMS-track system (www.sms-track.com). Each Sunday evening, beginning from the week of inclusion (i.e., participants were continuously enrolled between August and October 2022 and received the first questionnaire on the Sunday of the same week as they were included) to April 23rd 2023, participants completed a standardised weekly questionnaire via SMS on their use of analgesics in the preceding seven days. Participants who did not respond received reminder text messages 24 and 72 hours after the initial text message. Participants who had not responded for three consecutive weeks were contacted by phone by the principal investigator to encourage continued participation. Since we used a continuous enrolment strategy, the number of participants increased weekly during the first eight weeks of the study (i.e., the enrolment period). For studies II and III, we used the full 36-week study period, as the statistical models could handle the different sample sizes during the enrollment period. For paper IV, we used data from weeks 9 to 36 (i.e., 28 weeks) to ensure that participants contributed with the same number of weeks.

For the focus group interviews utilised in paper III, nine semi-structured focus group interviews with 32 athletes (2-5 athletes per interview) were conducted collaboratively by the principal investigator and a student assistant in February and March 2023. To ensure familiarity and accessibility, the interviews were conducted face-to-face in classrooms during teaching hours (58). Research on the impact of grouping interviewees by age, sex, and familiarity is equivocal. Some studies suggest that demographic-based grouping is essential for fostering discussion, while others emphasise that participants may feel safer and more open to expressing their opinions when placed in groups with familiar peers (58). Consequently, we did not apply strict criteria for age or sex distribution nor familiarity among participants within individual focus group interviews. Since paper III aimed to explore differences in analgesic use between overarching sports categories, variety in sports disciplines in individual focus group interviews was considered. Constructing focus groups with athletes from various sports disciplines enabled a nuanced exploration of how sociocultural factors uniquely influence analgesic use and allowed for exploration of whether certain attitudes or practices of analgesic use were sports-specific or reflected broader, cross-

disciplinary norms. Furthermore, bringing together athletes from different sports facilitated natural comparisons and contrasting viewpoints, prompting athletes to critically reflect on their own sports practices in light of others' experiences. This approach enabled an exploration of norms, structures, and attitudes that might otherwise remain implicit to athletes from the same discipline (58, 59). All interviews were audio recorded and facilitated using an interview guide. The interviews started with several open-ended questions to allow spontaneous reporting, and prompts were used throughout the interviews to facilitate nuanced discussions and direct the conversation towards the topics of interest. The interviews lasted between 45 and 60 minutes.

Outcomes

Analgesic use

As no validated questionnaire intended for weekly use in youth elite athletes was identified in the literature search in paper I, the PAin Medication Use in youth elite Sport (PAMUS) questionnaire was developed and content validated following the guidelines by Patrick et al. (60, 61) and the COSMIN methodology on the content validity of patient-reported outcome measures (62). As the questionnaire was based on a formative model, content validation and data saturation are especially important (63). Therefore, the development followed the seven steps outlined in Figure 2.

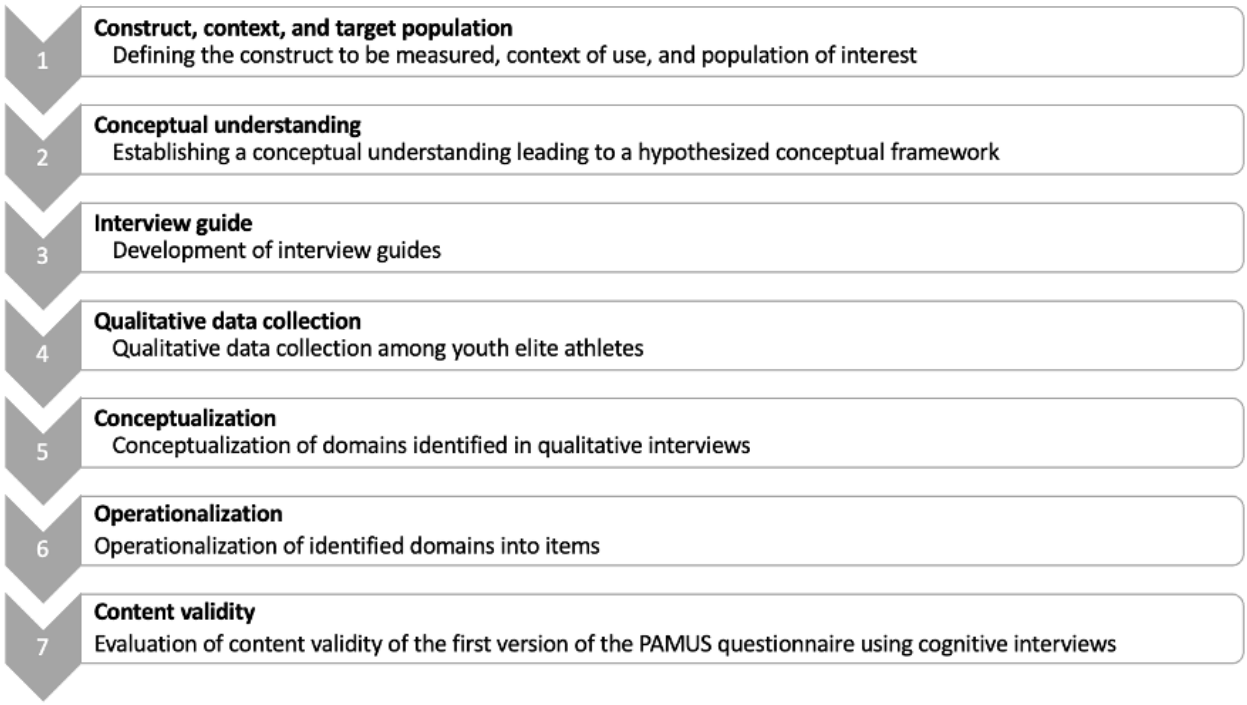


Figure 2 Steps included in the development and content validation of the PAMUS questionnaire

Step 1: Construct, context of use and target population

The construct to be measured was analgesic use. Analgesics were defined as pharmacological agents reducing pain sensation without inducing loss of consciousness, irrespective of the route of administration (47). The questionnaire was developed as a digital (i.e., SMS-track or app-based data collection) monitoring tool intended for weekly use in young (15-20 years of age) elite-level athletes with no restrictions on the type of sport.

Step 2: Conceptual understanding

The conceptual understanding was established through a literature review (paper I) and interviews with researchers. The conceptual understanding was inspired by The International Olympic Committee's (IOC) position statement on pain management in elite athletes, which served as a theoretical model (38). The IOC position statement is particularly relevant as it acknowledges the multidimensional aspects of pain and the unique requirements of pharmacological pain management in high-performance athletic environments and provides clear guidelines on the use of analgesics in elite athletes, considering the duration of use, implications for use, type of analgesic agent used, and complementary pain management strategies. Paper I and an additional systematic review on analgesic use in athletes served as additional literature (4, 64). Using the results from paper I in the development of the PAMUS questionnaire represented the first integration point of the quantitative and qualitative methods of the study (Figure 1). Finally, three online one-to-one semi-structured interviews were performed with international researchers representing medicine, pharmacy, and questionnaire technique in sports medicine to identify additional concepts related to analgesic use in youth elite athletes not identified by the literature review. The interviews also covered the order of importance of identified constructs and the strengths and limitations of the proposed data collection method. The interviews started with several open-ended questions to allow spontaneous reporting, and prompts were used throughout the interviews to facilitate nuanced discussions and direct the conversation towards the topics of interest. The interview guide is available in Appendix 1. All interviews were recorded using the audio recorder function in Zoom (Zoom Video Communications Inc.). Data saturation was evaluated to determine data sufficiency using a saturation matrix. The theoretical model, supportive literature, and expert interviews were used to inform the development of a hypothesised conceptual framework (Figure 3).

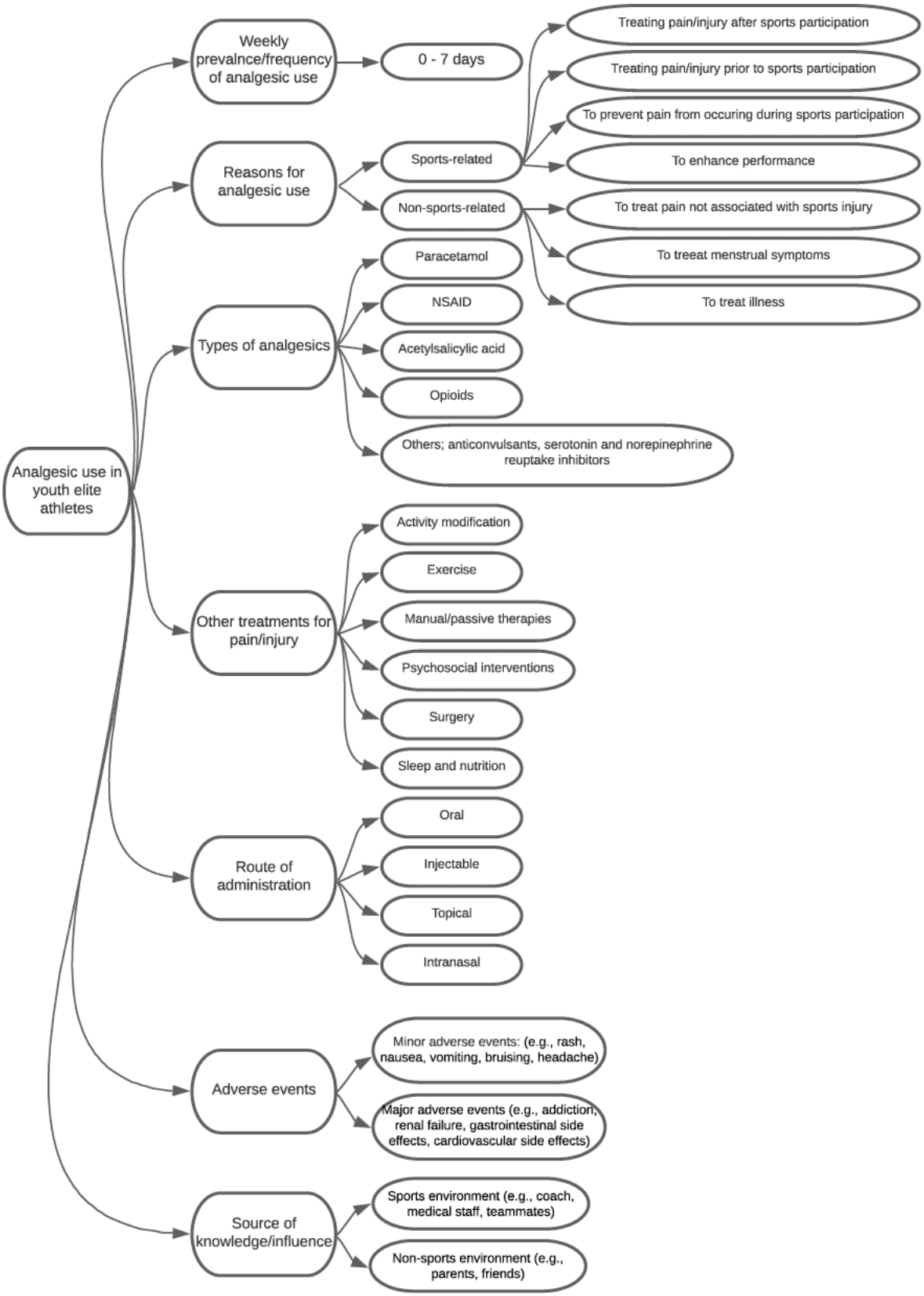


Figure 3 Hypothesised conceptual framework

Step 3: Development of interview guide

The interview guide for focus group interviews with youth elite athletes was constructed based on the above-described hypothesised conceptual framework. Broad, open-ended questions about analgesic use in sports were listed at the beginning of the interview guide to allow for open reflection. These reflections were followed up with questions on knowledge and understanding of analgesic effects, potential adverse events, experiences, attitudes, and interventions used to treat sports-related pain and injury. Questions on sociocultural influences and structures (e.g., parents, sports culture, coach) were also included to explore how these constructs were perceived to affect analgesic use. Finally, the feasibility of the data collection method (i.e., SMS-track or mobile phone application) was explored, and the participants were asked to quantify the maximum number of questions they would be willing to respond to every week. Prompts were included in the interview guide to facilitate nuanced discussions and direct the conversation towards the topics of interest. The interview guide is available in Appendix 2.

Step 4: Qualitative data collection

Data was collected using semi-structured focus group interviews with youth elite athletes representing various sports. Diversity in sporting background stimulated discussions of similarities and differences that may be implicit to athletes from the same type of sport. Inclusion criteria for focus group interviews were I) athletes enrolled in an elite sports program in upper secondary education offering dual-career programs, II) age between 15 and 20 years at the time of the interview, and III) that they could participate in an interview conducted in Danish. The recruitment of participants was carried out in two steps. First, local elite sports coordinators from two Danish high schools were contacted via e-mail, including a short description of the project, of which both responded positively regarding participation. Second, the elite sports coordinators identified participants by purposive sampling. The participants were sampled to represent as many different sports as possible while ensuring variation in age and gender. Nine youth elite athletes were invited to participate in the focus group interviews, of which seven agreed and were included. We conducted two focus group interviews with three and four participants, respectively. Within each focus group, participants were of the same sex, but differed in sports disciplines and age. The principal investigator conducted both interviews. Interviews were recorded using a smartphone audio recorder, and data saturation was evaluated to determine data sufficiency using a saturation matrix.

Step 5: Conceptualisation

The conceptualisation of turning information obtained during the focus group interviews into domains of the PAMUS questionnaire was done stepwise. This conceptualisation started with the principal investigator coding the interviews by repeatedly reviewing the audio records for information on analgesic consumption patterns, experiences, attitudes, knowledge, and sociocultural aspects of analgesic use. The initial organising of data was based on content analysis, which was used to condense and organise codes by counting and reporting the frequency of concepts, words, attitudes, and opinions held within the data (65). Second, the codes from each interview were organised into themes, each covering at least one code. Following conceptual discussions in the author team, the themes developed from the focus group interviews were compiled in domains to be included in the PAMUS questionnaire.

Step 6: Operationalisation

The operationalisation aimed to transform the content from the identified domains into items. The principal investigator formulated the initial items and response options based on the codes and themes identified in the qualitative data. Each item reflected a specific aspect of a theme. Similarly, response options were constructed to reflect all identified codes within the particular theme. Whenever possible, precise phrases or words used by the participants in the interviews were applied in the phrasing of the items. The item formulations were then discussed in detail in the author team. Subsequently, items were adjusted until the author team reached consensus that the items reproduced the identified domains and appeared understandable and relevant to the target population.

Step 7: Content validity

The content validity of PAMUS was primarily secured in steps 1-6. In addition, content validity was explored using cognitive interviews with participants from the target population. Seven one-to-one online cognitive interviews were conducted to explore how elite youth athletes understood, interpreted, and answered the candidate items of the questionnaire. Interviews were performed with a sample of seven other youth elite athletes (i.e., they did not participate in the focus group interviews). These athletes were recruited using the same procedure as described in step four. A combination of *think-aloud* and probing techniques was used in these interviews (19). While

responding to the questionnaire, participants were asked to think aloud, followed by structured questions on relevance, comprehensiveness, comprehensibility, acceptability, and feasibility. The interview guide is available in Appendix 3.

Results of questionnaire development and content validation

Step 1-3: Context of use, conceptual understanding, and development of interview guide

The conceptual understanding provided the basis for developing a hypothesised conceptual framework (Figure 3) and an interview guide (Appendix 2), including seven broad concepts relating to analgesic use. The saturation matrix revealed no new knowledge was added from the third expert interview (Table 2).

Table 2 Expert saturation matrix outlining identified content and codes and number of new codes identified in each interview

Concepts	Expert 1	Expert 2	Expert 3
Overall concepts			
Type of pain medication	X	X	X
Prevalence/frequency	X	X	X
Duration of use	X		
Reasons for use	X	X	
Doses	X		
Sources and knowledge of side effects	X		
Prevalence of side effects	X		X
Route of administration		X	
Effect on self-reported pain	X		X
Number of new concepts	8	1	0
High-priority concepts to measure			
Prevalence/frequency of use	X	X	X
Type of pain medication	X	X	X
Reasons for use	X	X	X
Duration of use			
Doses			
Knowledge of side effects			
Prevalence of side effects			
Route of administration			
Effect on self-reported pain			

Step 4: Qualitative data collection, recruitment, and study population

The seven participants, representing handball, football, badminton, sailing, rugby, athletics, and bobsleigh at national or international levels, participated in the focus groups. The participants were between 16 and 19 years old, 42% were girls, and two were first-year high school students, two were second-year students, and three were third-year students, respectively. Except for one construct (adverse events), no new knowledge was added from the second focus group interview with athletes (Table 3). As adverse events were not included in the final questionnaire, further interviews were deemed unnecessary.

Table 3 Athlete saturation matrix outlining identified content and codes, number of new codes identified in individual interviews, and frequency of codes mentioned

Concepts	Focus group 1	Focus group 2	Frequency
Types of analgesics			
Paracetamol	X	X	6
Ipren	X	X	5
Voltaren gel	X	X	6
Number of new codes	3	0	
Sources of knowledge on analgesics			
Own experiences	X		1
Parents	X	X	5
Sports environment	X	X	3
Doctor	X	X	1
Number of new codes	4	0	
Adverse events			
Worsening of injury	X	X	1
Addiction	X	X	1
Fatigue	X	X	1
Gastrointestinal symptoms		X	1
Increased tolerance		X	2
Number of new codes	3	2	
Frequency of analgesic use			
Varies widely	X	X	6
Almost never	X		1
Number of new codes	2	0	
Reasons for sports-related use of pain medication			
To treat pain/injury after participating in sport	X	X	3
To treat pain/injury prior to participating in sport	X	X	5
To prevent pain during sports participation	X		1
Number of new codes	3	0	
Reasons for non-sports related use of pain medication			
Menstrual pain	X		3
Illness/fever	X	X	4
To treat pain not related to sport	X	X	1
Number of new codes	3	0	
Sociocultural influences on pain medication use			
Coach	X	X	2
Physiotherapist	X	X	2
Teammates	X	X	1
Parents	X	X	6
Number of new codes	4	0	
Other interventions used for sports-related pain and injury			
Laser	X		2
Kinesiotape	X		2
Exercise	X	X	4
Acupuncture	X		1

Massage	X		1
RICE (Rest, ice, compression and elevation)	X	X	3
Time away from sport	X	X	2
Number of new codes	7	0	

Step 5: Conceptualisation

All codes and the related themes are outlined in Tables 2 and 3. Examples of codes were '*using analgesics to cover pain to be able to participate in sport', 'potential worsening of injury secondary to masking of pain and injury'* and *'coach and physiotherapist encouraging analgesic use'.* The structure of codes in the saturation matrix guided the generation of themes by examining differences and similarities between the codes. A draft list of eight themes was developed, including types of analgesics, sources of knowledge on analgesics, adverse events, frequency of analgesic use, reasons for sports-related use of analgesics, non-sports related use of analgesics, sociocultural influences on analgesic use, and types of interventions used to treat sports-related pain and injury. Following discussions in the author team, three domains were constructed based on the eight themes, including frequency of analgesic use, reasons for analgesic use, and types of analgesics used. Sports-related and non-sports related use of analgesics was grouped into one domain. Four themes were not included in the three domains. Based on expert opinion, monitoring adverse events every week was deemed unnecessary due to high chances of symptom misclassification. Similarly, while numerous external influences and sources of knowledge on analgesic use were identified in the focus group interviews, consistent patterns or experiences were not found within the data, thus hindering further conceptualisation. As a result, it was decided that aspects related to sociocultural influences and the impact of the athlete environment on analgesic use should be explored through qualitative research methods. Finally, it was deemed inappropriate to ask about other interventions used for sports-related pain and injury, as analgesics may be used for different purposes than the treatment of sports-related pain and injury.

Step 6: Operationalisation

A total of three items were created across the three domains. The first item determined the weekly frequency of analgesic use, the second determined the reasons for analgesic use, and the third determined the types of analgesics used. Before drafting the full questionnaire, two pharmacists were consulted to ensure proper representation of analgesic categories and brand names available in Denmark. Injectable analgesics were classified as a separate category due to the assumption that

athletes frequently lack awareness of the specific drug administered to them via injection. The final instrument is outlined in Table 4. A gate-keeper logic was applied to avoid inconsistent replies, so if a participant replied ‘0 days’ to the first question on consumption frequency, the questionnaire was finalised for the week. If a participant replied 1-7 days of use, two further questions were presented on reasons for use and type(s) of drugs used. For these questions, participants were asked to select all relevant answer options.

Table 4 Final PAMUS questionnaire

Questions	Answer options
How many days have you used pain medication during the past 7 days?	▪ 0 ▪ 1 ▪ 2 ▪ 3 ▪ 4 ▪ 5 ▪ 6 ▪ 7
Why did you use pain medication? (choose all relevant response options)	▪ To treat pain or injury after participating in sport ▪ To treat pain or injury prior to participating in sport ▪ To prevent pain that might occur during sports participation ▪ To treat pain not related to sport (e.g., headache, back pain) ▪ To treat menstrual pain ▪ To treat illness ▪ Other reasons
What type(s) of pain medication did you use? (choose all relevant response options)	▪ Paracetamol (e.g., panodil, pamol, paracetamol, pinex) ▪ Non-steroidal antiinflammatory drugs (e.g., ipren, ibuprofen, ibumetin, diclofenac, naproxen) ▪ Gels (e.g., voltaren gel, ipren gel, ibutop) ▪ Acetylsalicylic acid (e.g., treo, triplo, kodimagnyl) ▪ Opioids (e.g., tramadol, codein, fentanyl, oxycodone) ▪ Injections ▪ Other (e.g., antiepileptic medicine [gabapentin, pregabalin], anti-depressive medicine [amitryptilin, duloxetine])

Step 7: Content validity

Seven members of the target population answered the draft questionnaire and shared their assessments of the PAMUS questionnaire. The seven participants represented handball, football, badminton, and basketball on national or international level, were between 16 and 19 years old, 57% were girls, and two were first-year high school students, one was second-year students, and four were third-year students, respectively. Overall, the participants were positive towards the questionnaire and found the items and related response options clear and unambiguous. All participants were satisfied with the total number of questions and felt that all were relevant to them.

The interviews revealed that no adjustment was necessary to finalise the questionnaire. Utilising the PAMUS questionnaire in the cohort study represented the second integration point of the quantitative and qualitative methods of the study (Figure 1).

Experiences with analgesic use and sociocultural factors influencing the use

The qualitative data in paper III provided a deeper and more nuanced contextual understanding of the quantitative findings (66). As such, an interview guide was developed based on preliminary results from the cohort study and findings from paper I, thereby using empirical insights to explore coherent and plausible explanations (67, 68). The development of the interview guide represented the third integration point of the quantitative and qualitative methods of the study (Figure 1). The interview guide consisted of four sections: I) information about the interview, ethics, and participant rights, II) introduction of interviewees and icebreaker questions unrelated to the topic of interest to foster an open conversation and create a comfortable atmosphere for the participants, III) main interview topics covering knowledge of and experiences with different types of analgesics, sports and non-sports related reasons for analgesic use, and sociocultural influences on the use, and IV) closing of the interview allowing the participants to bring up any topic, story, or question not addressed during the interview. The interview guide consisted of several open-ended questions to allow the interview to take the form of a free-flowing conversation between the interviewees (e.g., *Why did/do you use analgesics in that/those particular situation(s)?*).

Sample size

Since no prior studies have compared analgesic use between youth elite athletes and a reference group, and no consensus exists on meaningful differences in analgesic usage, a pragmatic approach was applied to estimating the sample size required for this study. A total of 388 participants per group (i.e., youth elite athletes and students) were needed to detect a 10% difference in proportions of analgesic users (defined as non-users (0 days use) vs users (≥1 day use)) between the groups per week with 80% power and a two-sided significance level of 0.05. Anticipating dropouts, we aimed to recruit ≥500 in each group, allowing for at least a 22% dropout rate during the study period. We had no pre-specified hypotheses. For the focus group interviews utilised in paper III, data saturation was evaluated continuously and used as a criterion for discontinuing the data collection, meaning no new significant findings emerged.

Statistical analyses

In papers II-IV, continuous baseline demographics were presented as means ± standard deviation (SD) or medians and interquartile range (IQR) as appropriate and categorical demographics as frequency and percentage distribution. In papers II and III, data on prevalence and frequency of analgesic use was analyzed in two ways. Firstly, by summarising weekly prevalence of analgesic users (i.e., 0 days use vs. ≥1 days use) and weekly mean consumption frequency (calculated based on participants who reported between 1 and 7 days of use) with 95% confidence intervals (95% CI) during the full 36-weeks study period stratified by athletic status and sex (paper II) and sports category and sex (paper III). Secondly, to examine potential between-group differences in prevalence and frequency of analgesic use between youth elite athletes and students (paper II) and endurance athletes, team athletes, and technical athletes (paper III) during the full 36-weeks study period, mixed effects logistic regression models were applied to estimate odds ratios (OR) with 95% CI, and mixed effects Poisson regression models were applied to estimate incidence rate ratios (IRR) with 95% CI, respectively. Endurance athletes were considered the reference group for these analyses. Individual ID was included as a random effect. Subgroup analyses were conducted stratifying by sex. Due to the high weekly response rate (mean of 87%) and limited missing data, no imputation was conducted. Additionally, mixed effects models are robust towards missing data and only require the data missing at random assumption (69). In paper II, two sensitivity analyses were conducted. First, the enrolment period was omitted. This sensitivity analysis was performed as similar weekly data collection tools have shown that first-time responses should be cautiously interpreted (70), and due to the smaller sample size during these weeks, potentially impacting the robustness of the estimates. Second, students reporting to compete in a sport at the national or international level, but were not enrolled in an elite sports program (n=74), were excluded. Before collecting baseline data, a Directed Acyclic Graph was prepared to identify potential confounding factors in the association between athletic status and analgesic use (paper II), but no common causes of the exposure and the outcome were identified. Similarly, no confounding factors were identified in the association between sports category and analgesic use tested in paper III. Reasons for use and types of analgesics used were also analyzed in two ways. Firstly, by calculating the proportion of participants (with 95% CIs) reporting each reason/type ≥ 1 during the 36-week study period, with Chi-square tests applied for statistical comparisons. Secondly, descriptively as frequency and percentage distribution based on the total number of responses obtained during the full study period.

Both were stratified by athletic status and sex (paper II) and sports category and sex (paper III). Due to the exploratory nature of these studies, no multiplicity adjustment was performed (71).

For paper IV, group-based trajectory modelling (GBTM) was used to identify distinct trajectory groups based on the prevalence of analgesic users among I) youth elite athletes and II) students. Two logistic models were developed in four steps. First, the optimal number of groups for each model was identified using pre-defined hypotheses and statistical tests, including group sizes of K=1-7 groups. Based on discussions within the author group, it was hypothesised that four groups was optimal for both elite youth athletes and students. Bayesian Information Criteria (BIC) values and the number of included participants in each subgroup were evaluated for each model. Second, optimal shapes for each trajectory were identified by testing various polynomial functions, including intercept, quadratic, linear, and cubic functions. Based on the assumption that analgesic use might change over time, the initial models included four cubic trajectories. Functions were varied if trajectories were non-significant according to their polynomial function. Third, absolute model fit was evaluated using Average Posterior Probability Assignment (APPA) and Odds of Correct Classification (OCC) statistics, with criteria set at APPA >70% and OCC >5.0 for each class. Lastly, graphic presentations were assessed for interpretation.

Mixed effects Poisson regression models with robust standard errors estimated risk ratios (RR) of analgesic use between trajectory groups, using minimal/non-users as reference groups (72). Sex distribution within each trajectory group was presented as frequency and percentage distribution. Data on analgesic consumption frequency was presented as weekly median (interquartile range, IQR) number of days with analgesic use for each trajectory group over the 28-week study period. Data on types of analgesics were reported as the proportions of participants with 95% CIs within each trajectory group reporting use of each type of analgesic ≥ 1 during the 28-week study period. To address the potential impact of short-term analgesic use related to illness, injury, or surgery, a sensitivity analysis was conducted. This analysis defined participants as users if they reported using the same analgesic at least three times during the 28-week study period (i.e., recurrent users of the same type of analgesic). The statistical analyses were conducted in Stata version 18 (StataCorp 2023, College Station, TX, USA).

Qualitative analysis

The qualitative data in paper III was analysed using a thematic analysis approach within a critical realism framework (73-75). Thematic analysis was considered the most appropriate analysis

strategy for addressing the research question, as it is particularly suitable for analysing people's experiences in relation to an issue or the factors or processes underlying and influencing particular phenomena (i.e., analgesic use) and can be used to identify patterns in people's reported behaviours, practices, views and perspectives on a specific topic (74). Thematic analysis has also been described as an approach largely independent of theory and epistemology and can, therefore, be applied across a broad range of theoretical and epistemological approaches (76). In this project, critical realism was applied as a philosophical framework. Situated within a realist ontology and a constructivist epistemology, critical realism uses retroduction to combine observation and interpretation in searching for causation and allows for an understanding of the mechanisms that influence and generate outcomes (75, 77). Combining observation and interpretation is grounded in the assumption of stratified ontology, consisting of three levels, including empirical, actual, and real. The *empirical* layer captures experiences and events that are observable (e.g., youth elite athletes report using analgesics to prevent pain during sports participation). The *actual* level refers to events or phenomena that happen but may or may not be observed by humans (e.g., while athletes may report to successfully use analgesics to prevent pain during sports participation, underlying physiological effects occur whether the athlete realises it or not, such as delay in healing of injuries, the risk of aggravating underlying injuries, or building tolerance to the drugs over time). The final layer, *real*, refers to real but typically unseen mechanisms that precede and generate events (e.g., social pressures and institutional structures influence athletes' use of analgesics) (75, 78). This philosophical framework was chosen because it offers a unique opportunity to answer complex research questions requiring quantitative and qualitative evidence (78).

The analysis proceeded in six steps. First, the audio records were transcribed verbatim, and the principal investigator and a student assistant familiarised themselves with the data. Second, initial codes were generated across the dataset (e.g., *analgesics are not discussed on the team/club, access to analgesics in the club, self-medication practices, intrinsic motivation*). Third, these codes were categorised and organised into potential themes (e.g., the codes *analgesics are not discussed on the team/club* and *access to analgesics in the club* were organised into one theme *Normalisation of analgesic use within team and club culture,* and the codes *self-medication practices* and *intrinsic motivation* were organised into one theme *High degree of autonomy in addition to a strong personal drive to participate in sport*) which were subsequently reviewed by an experienced qualitative researcher to challenge the initial data interpretation. This stage represented the fifth integration point of the quantitative and qualitative methods to uncover different levels of reality,

including empirical, actual, and real (75). Fourth, themes were reviewed for applicability to the coded extracts and the entire dataset. Fifth, themes were further refined and defined. Finally, the themes underwent a final revision to ensure they presented a coherent narrative across and within and across themes. Retroduction was used in the later stages of the analysis by moving from the level of observations and detailed qualitative data to postulate about the underlying structures and mechanisms that account for analgesic use among youth elite athletes.

Gender/sex terminology

In the baseline questionnaire, participants were asked to select their gender and all identified as either girl/woman or boy/man. Given that the participants' ages spanned across 18 years old (i.e., an age typically considered the transition point for using the terms *girls/boys* versus *women/men*), it was decided to refer to participants as *female* and *male*, even though participants reported information on gender identity, rather than biological attributes associated with physical or physiological features.

Results

Paper I

Study selection process

After conducting the literature searches and removing duplicates, 10,595 records were screened by title/abstract and 287 full-text articles were assessed for inclusion. Following full-text screening, 39 studies met the inclusion criteria. Additionally, three studies were identified through citation tracking, and seven studies were identified from reference list screening. Consequently, the total number of included studies was 49 (8, 13-18, 32, 40-42, 79-116).

Study characteristics

Of the 49 included studies, 43 were cross-sectional studies and six were cohort studies, providing data on 44,381 athletes (range n=21-11.577, average percentage of female=37%). Data on analgesic use reported in the cohort studies were cross-sectional baseline data. Competition levels of athletes included in the individual studies varied from recreational to elite.

Risk of bias and GRADE

For cohort studies, one study was judged as low quality, two as moderate quality, and three as high quality. For cross-sectional studies, eight studies were judged as unsatisfactory quality, 19 as satisfactory quality, 14 as good quality, and two as very good quality. Overall quality of evidence was very low to low across outcomes, mainly due to inconsistency and indirectness.

Prevalence of analgesic use

NSAIDs

The pooled point prevalence of NSAID users was 48% (95% CI 23%-73%; 13 studies). Pooled period prevalence estimates of NSAID users varied from 7% in the previous seven days (95% CI 6% to 8%; two studies) to 95% lifetime prevalence (95% CI 92% to 97%; two studies) (Figure 4). Meta-regression analyses showed no impact of the proportion of females, age, or year of publication on pooled point prevalence estimates of NSAID users. Subgroup analysis of performance level showed a higher point prevalence of NSAID users in elite athletes (64% [95% CI 20% to 97%]; five studies) compared to non-elite athletes (31% [95% CI 6% to 64%]; seven studies), but did not reduce heterogeneity. The sensitivity analyses excluding the four studies assessing current NSAID

use and including alternate NSAIDs subtypes did not alter the results. Excluding the nine studies with unclear point prevalence definitions resulted in a lower point prevalence (12% [95% CI 0.01 to 0.33]; four studies), but did not reduce heterogeneity.

Unspecified analgesics

The pooled point prevalence of users of unspecified analgesics was 50% (95% CI 0.36 to 0.64; nine studies). Pooled period prevalence estimates varied from 7% in the previous three days (95% CI 0.06 to 0.8; two studies) to 73% in the previous season (95% CI 0.66 to 0.80; one study) (Figure 4). Subgroup analysis of performance level showed a lower point prevalence of users of unspecified analgesics in elite athletes (40% [95% CI 15% to 67%]; three studies) compared to non-elite athletes (61% [57% to 65%]; five studies), and also reduced heterogeneity in the pooled estimate for non-elite athletes. Contrarily, the 12-month period prevalence was higher in elite athletes (71% [95% CI 61% to 80%]; three studies) compared to non-elite athletes (36% [95% CI 33% to 39%]; two studies). The sensitivity analyses did not alter the results of the primary analyses nor reduce heterogeneity.

Mixed analgesics

The pooled point prevalence of users of mixed analgesics was 54% (95% CI 0.29 to 0.79; five studies). Pooled period prevalence estimates varied from 11% in the previous seven days (95% CI 0.08 to 0.14; two studies) to 29% in the previous 12 months (95% CI 0.28 to 0.30; two studies) (Figure 4).

Local anaesthetic injections

The pooled 3-day period prevalence estimate for users of injectable local anaesthetic was 2% (95% CI 0.01 to 0.03, two studies). The sensitivity analysis categorising anaesthetic injections according to their active pharmacological agent did not alter the results of the primary analyses.

Paracetamol, acetylsalicylic acid, and opioids

The pooled point prevalence of paracetamol users was 21% (95% CI 0.17 to 0.25, two studies). One study each reported estimates of paracetamol users in the previous month, three months, and 12 months (Figure 4). One study reported estimates of point prevalence of acetylsalicylic acid (25% [95% CI 0.19 to 0.31]). Period prevalence estimates of acetylsalicylic acid users ranged from 3% in

the previous month (95% CI 0.02 to 0.04; one study) to 16% in the previous 12 months (95% CI 0.15 to 0.17; one study). The pooled 12-month period prevalence of opioid users was 13% (95% CI 0.13 to 0.14, two studies). One study each reported estimates of point prevalence and 3-month period prevalence of opioid users (Figure 4).

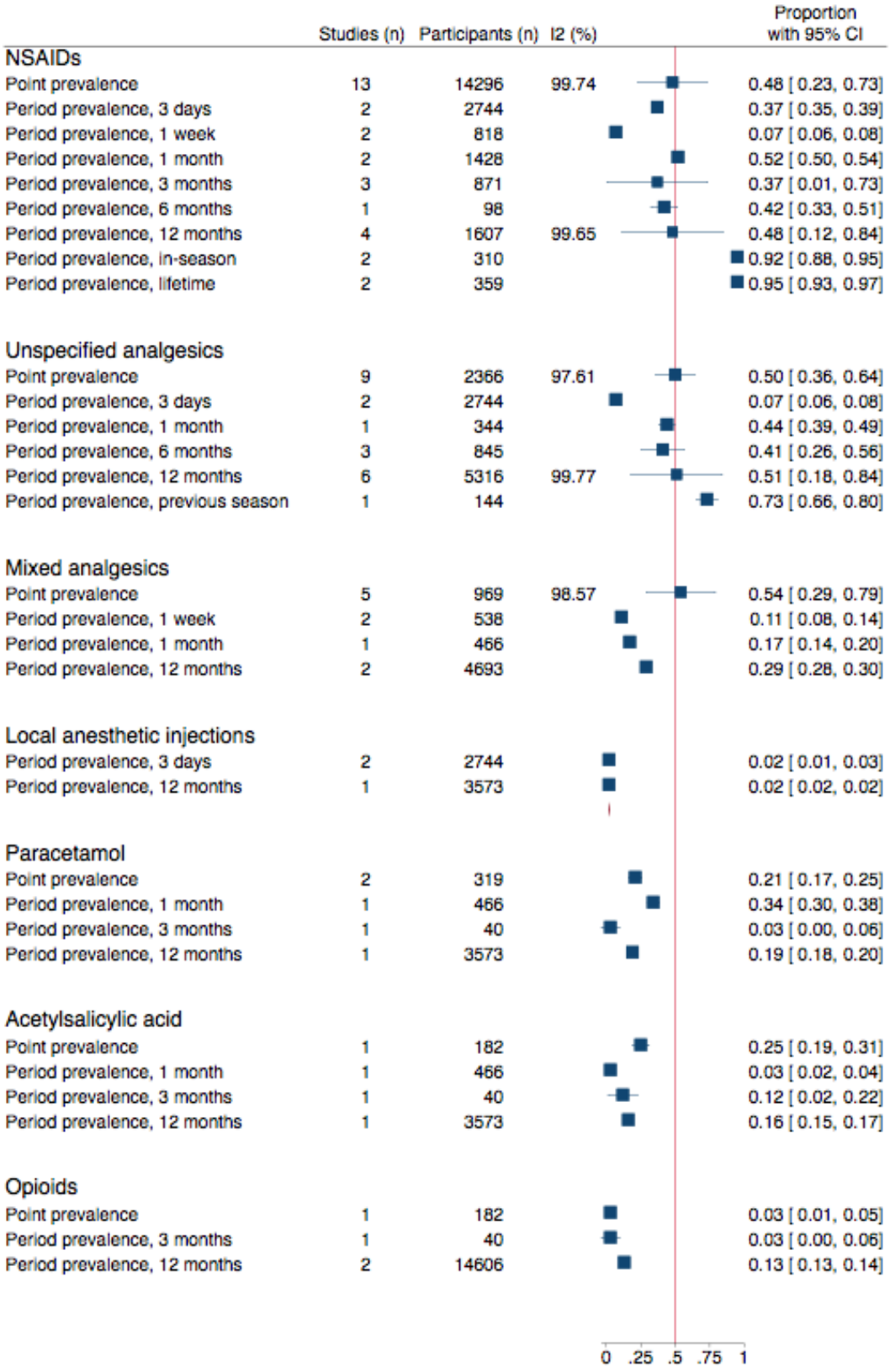


Figure 4 stratified prevalence meta-analysis. Rows indicate pooled estimates. The red line represents a 50% prevalence. The boxes indicate study weight, and whiskers indicate 95% CI. Figure from paper I

Sex-specific differences in prevalence of analgesic use

Five studies reported higher prevalence of analgesic use in female athletes compared to male male athletes, and two studies reported higher prevalence in male athletes compared to female athletes (Table 5).

Table 5 Sex-specific differences in analgesic use

Study	Prevalence measure	No. included females	Proportion of females reporting analgesic use	No. included males	Proportion of males reporting analgesic use
Andersson et al. 1991[a]	12 months period prevalence	348	28%	1116	26%
Andersson et al. 1991[b]	12 months period prevalence	460	34.3%	1292	33.3%
Brewer et al. 2014	Point prevalence	136	41.9%	127	29.9%
Christopher et al. 2020	Point prevalence	230	28%	83	20%
Gauvin et al. 1996	Point prevalence	282	17%	472	19%
Qasrawi et al. 2021	Point prevalence	94	42.8%	133	57.2%
Rossi et al. 2016	1 month period prevalence	508	75%	454	59.6%
Sari et al. 2021	4 week period prevalence	220	53.2%	246	29.6%

Andersson et al. reported data separately for 1985 (a) and 1989 (b) in the same publication

Frequency of analgesic use

Across the fourteen studies reporting data on frequency of analgesic use, 6-35% of athletes reported monthly use, and 7-50% reported weekly use.

Adverse events

The proportion of users experiencing adverse events from NSAID use ranged from 3.3% to 19.2% across three studies. One study examined the prevalence of adverse events associated with non-NSAID analgesics (unspecified), which was reported by 6.3% of users.

Reasons for analgesic use

Twenty studies examined reasons for analgesic use. Athletes used analgesics to treat sports-related injury and pain in 16 studies, to block or prevent pain in seven studies, to manage cramps or general muscle soreness in two studies, to treat illnesses including colds, fever, and headaches, and to enhance performance in one study each, respectively. One study provided estimates for analgesic

use categorised by sports-related reasons and non-sports-related reasons, with 35% of users reporting sports-related reasons.

Paper II-IV

Sample characteristics

A total of 735 youth elite athletes and 545 students completed the baseline questionnaire and were enrolled in the analgESic uSE iN youTh elIte AthLetes (ESSENTIAL) cohort. Out of the 1280 participants, 690 athletes (94%) and 505 students (93%) completed the 36-week prospective monitoring of analgesic use and were included in the analyses in studies II and IV (Figure 5). Due to missing data on sports discipline from one athlete, 689 athletes were included in the analysis in paper III. The mean weekly response rate was 88% (range 80-99%) among athletes and 85% (range 77-97%) among students over the full 36-week observation period. The athletes had a mean age of 17.1 years, and 44% were female. Forty-six sports were represented, with 137 athletes (20%) from endurance sports, 229 (33%) from technical sports, and 323 (47%) from team sports (Table 6). The students had a mean age of 17.4 years, 59% were female, and 62% participated in sports, with 24% (n=74) competing at the national or international level (Table 6). Baseline characteristics of the included participants were similar to those of participants who were lost to follow-up.

Thirty-two athletes (75% female, 16-19 years of age) included in the cohort study participated in focus group interviews. The athletes represented BMX, gymnastics, dance, karate, football, swimming, golf, sailing, figure skating, handball, cycling, badminton, and basketball.

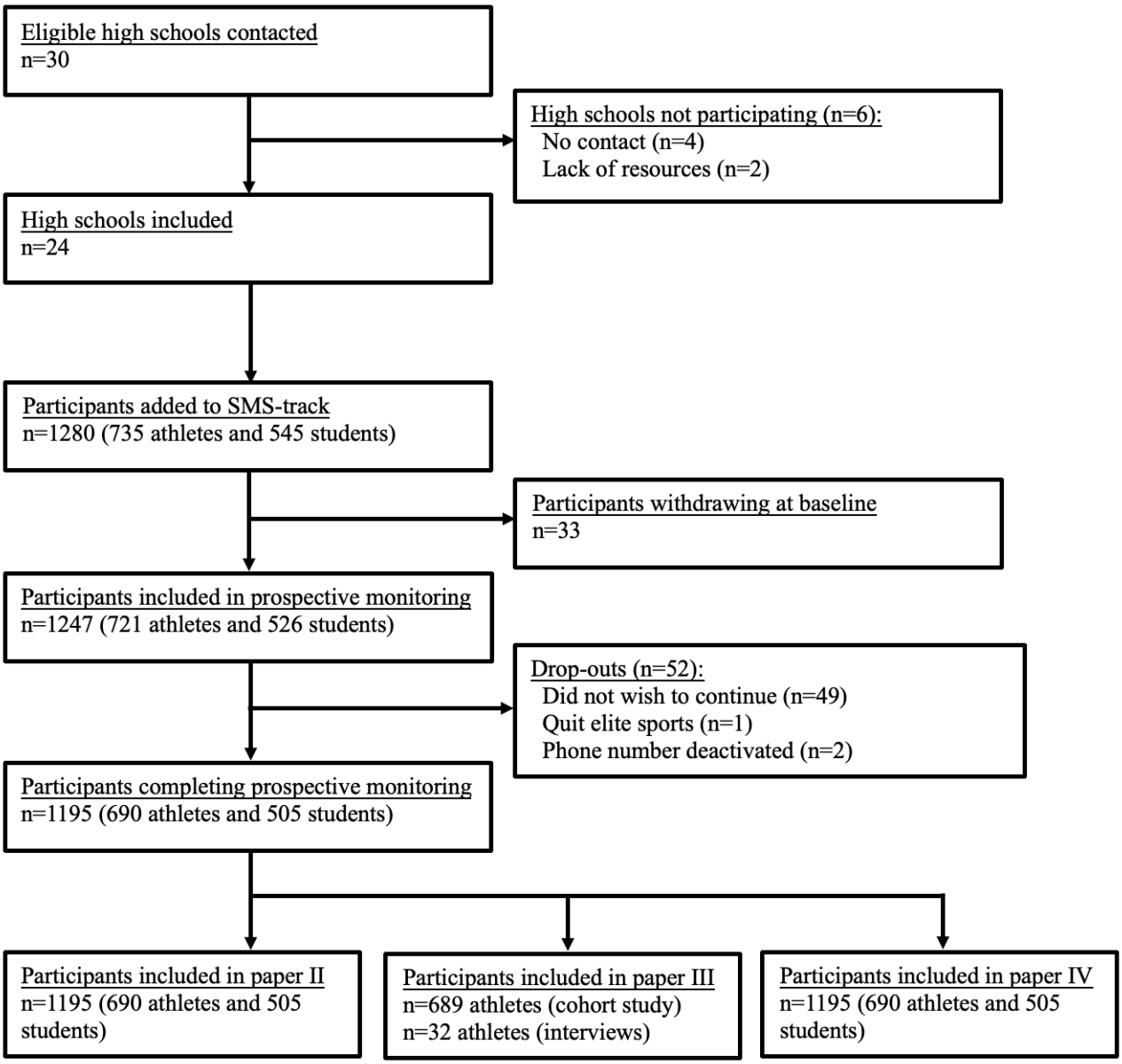


Figure 5 Flow chart of participants included in the ESSENTIAL cohort and in papers II-IV. Adapted from papers II-IV.

Table 6 Baseline characteristics of participants included in the ESSENTIAL cohort

	All athletes (n=690)	All students (n=505)	Female athletes (n=305)	Female students (n=299)	Male athletes (n=385)	Male students (n=206)
Age, mean (SD): years	17.1 (0.4)	17.4 (0.4)	17.1 (1.1)	17.3 (0.9)	17.1 (1.1)	17.6 (0.9)
Female, n (%)	305 (44.2)	299 (59.2)	305 (100)	299 (100)	0 (0)	0 (0)
BMI, mean (SD)	21.9 (0.1)	21.9 (0.2)	21.7 (3.4)	21.6 (3.8)	22.2 (2.3)	22.4 (3.4)
Weekly sports exposure, mean (SD): hours[b]	16.2 (6.3)	6.7 (4.6)	16.1 (6.6)	5.8 (4.5)	16.2 (6.2)	7.8 (4.6)
Students' participation in a specific sport, n (%)	N/A		N/A		N/A	
Yes		313 (62%)		153 (51%)		160 (78%)
No		192 (38%)		146 (49%)		46 (22%)
Type of sport, n (%)	[a]	[b]		[b]	[a]	
Team sport	323 (47%)	143 (46%)	122 (40%)	61 (41%)	201 (52%)	82 (51%)
Endurance sport	137 (20%)	18 (6%)	73 (24%)	11 (7%)	64 (17%)	7 (4%)
Technical sport	229 (33%)	150 (48%)	110 (36%)	79 (52%)	119 (31%)	71 (45%)
Athlete competition level, n (%)		N/A		N/A		N/A
Regional	47 (7%)		17 (6%)		30 (8%)	
National	327 (47%)		141 (46%)		186 (48%)	
International	316 (46%)		147 (48%)		169 (44%)	
Student competition level, n (%)*	N/A		N/A		N/A	
Recreational		188 (60%)		85 (55%)		103 (64%)
Regional		51 (16%)		24 (15%)		27 (17%)
National		65 (21%)		38 (25%)		27 (17%)
International		9 (3%)		6 (5%)		3 (2%)
Age at sports debut, mean (SD): years	7.5 (3.2)	N/A	7.2 (.9)	N/A	7.6 (3.4)	N/A
Age at sports specialisation, mean (SD): years	13.0 (2.3) [c]	N/A	12.9 (2.3)[a]	N/A	13.1 (2.2)[b]	N/A
Baseline sports-related injury, n (%)**						
No	318 (46%)	337 (67%)	130 (43%)	201 (67%)	188 (49%)	136 (66%)

Yes, but the injury did not affect sports participation	179 (26%)	80 (16%)	83 (27%)	44 (15%)	96 (25%)	36 (18%)
Yes, the injury affected sports participation for less than 4 weeks	81 (12%)	39 (8%)	32 (11%)	23 (8%)	49 (13%)	16 (8%)
Yes, the injury affected sports participation for more than 4 weeks	81 (12%)	37 (7%)	41 (13%)	26 (9%)	40 (10%)	11 (5%)
Yes, time-loss injury	31 (4%)	12 (2%)	19 (6%)	5 (1%)	12 (3%)	7 (3%)
Previous frequent use of analgesics (i.e., use on a weekly basis), n (%)						
No	464 (67%)	347 (69%)	187 (61%)	190 (63%)	277 (72%)	157 (76%)
Yes	226 (33%)	158 (31%)	118 (39%)	109 (37%)	108 (28%)	49 (24%)

[a] missing n=1, [b] missing n=2, [c] missing n=3, *This proportion is calculated based on the 313 student controls reporting to participate in a specific sport, **answer options relating to affected sports participation was defined as being able to participate in sport but with altered intensity/frequency and time-loss was defined as complete absence from sport. Adapted from papers II-IV

Prevalence of analgesic use (papers II and III)

Summary estimates of weekly prevalence of analgesic use across cohort subgroups are available in Table 7 and Figure 6. Overall, athletes had lower odds of analgesic use compared to students (OR 0.78, 95% CI 0.64-0.95; p=0.01). However, when stratified by sex, no statistically significant differences were found between female athletes and female students, or male athletes and male students (Table 8). The sensitivity analyses excluding the enrollment period and students competing at the national or international level did not change the interpretation of the results (Table 8). Similarly, there were no differences in the odds of analgesic use between endurance athletes (reference group), technical athletes (OR 0.94 [95% CI 0.65-1.37; p=0.77), and team athletes (OR 0.88 [95% CI 0.62-1.25]; p=0.49). Stratifying by sex did not change the interpretation of these results (Table 8).

Frequency of analgesic use (papers II and III)

Summary estimates of weekly analgesic consumption frequency across cohort subgroups are available in Table 7. Overall, there was no difference in the rate of analgesic use between athletes and students (IRR 1.04, 95% CI 0.99-1.11; p=0.09) (Table 7). There were also no differences when stratified by sex. The sensitivity analysis excluding students competing in sports at the national or international level demonstrated a statistically significant higher rate of analgesic use in athletes compared to students. The sensitivity analysis omitting the enrolment period did not change the interpretation of the results (Table 8). Similarly, there were no differences in the rate of analgesic use between endurance athletes (reference), technical athletes (IRR 0.97, 95% CI 0.87,1.07; p=0.59), or team athletes (IRR= 1.03, 95% CI 0.94-1.14; p=0.45). There were also differences when stratified by sex (Table 8).

Table 7 Summary estimates of prevalence and frequency of analgesic use

Group	Mean weekly prevalence of analgesic use (95% CI)[a]	Range of prevalences[b]
Athletes (n=690)	20% (17-23%)	15-32%
Students (n=505)	23% (19-27%)	15-52%
Female athletes (n=305)	29% (24-34%)	23-40%
Male athletes (n=385)	14% (10-18%)	7-28%
Female students (n=299)	29% (24-34%)	18-59%
Male students (n=206)	14% (9-19%)	7-42%
Endurance athletes (n=137)	20% (13-27%)	12-31%
Team athletes (n=323)	20% (15-25%)	13-43%
Technical athletes (229)	21% (15-27%)	15-33%
	Mean weekly consumption frequency, days (95% CI)[c,d]	**Range of means**
Athletes (n=690)	2.5 (2.4-2.5)	2.1-2.9
Students (n=505)	2.4 (2.3-2.4)	2.1-3.0
Female athletes (n=305)	2.6 (2.5-2.6)	2.3-3.0
Male athletes (n=385)	2.4 (2.3-2.4)	1.9-3.0
Female students (n=299)	2.4 (2.3-2.4)	2.1-2.8
Male students (n=206)	2.4 (2.3-2.5)	1.0-3.4
Endurance athletes (n=137)	2.4 (2.2-2.6)	1.8-3.6
Team athletes (n=323)	2.6 (2.5-2.7)	2.0-3.3
Technical athletes (229)	2.5 (2.4-2.6)	1.9-3.8

[a] Prevalence estimates were averaged across the 36-week observation period; [b] Range of observed weekly prevalence estimates across the 36-week observation period; [c] These analyses were based on participants reporting analgesic use (i.e., reporting 1-7 days of use); [d] Calculated as the mean of means

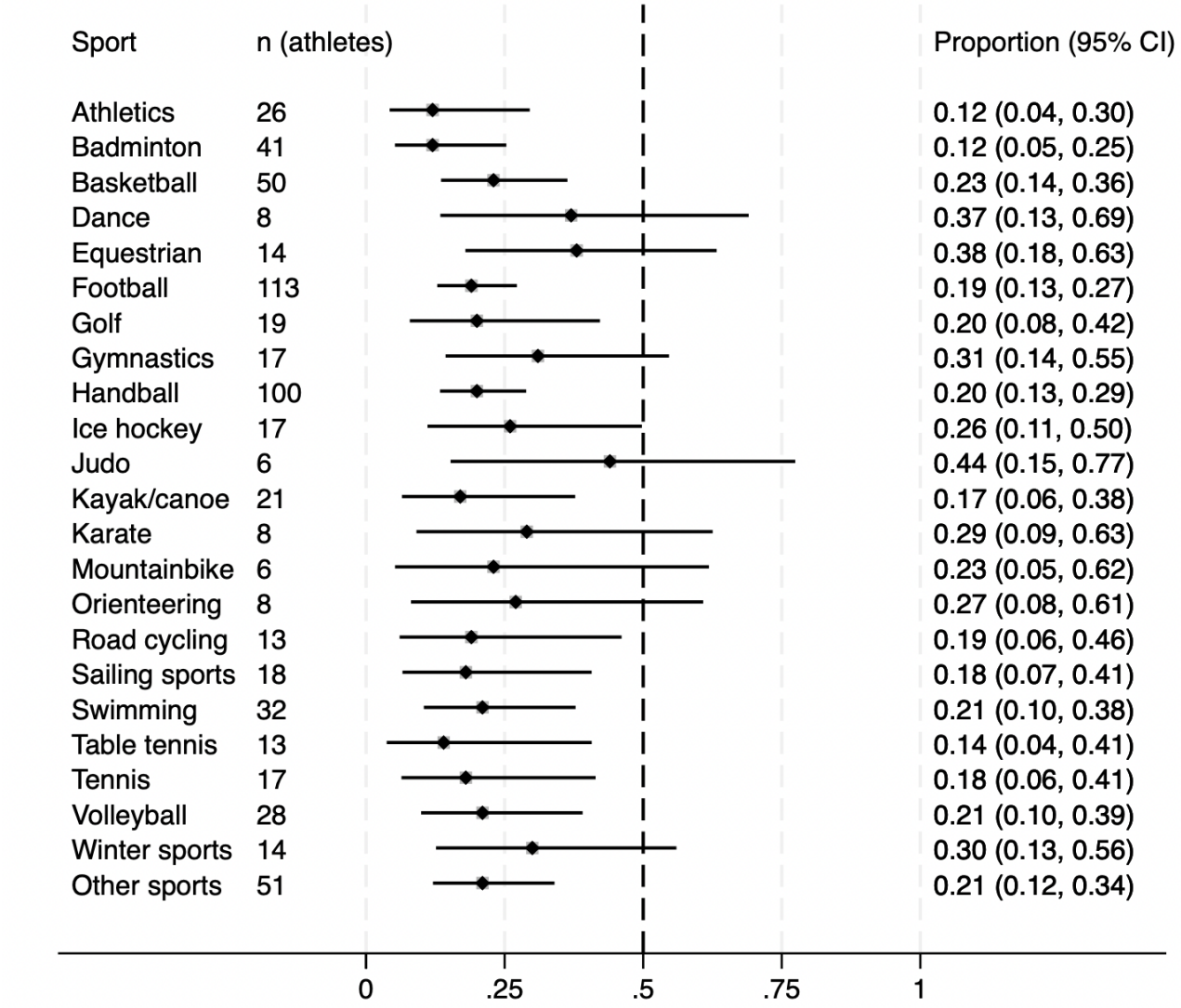


Figure 6 Mean weekly proportion of analgesic users across included sports disciplines. Sports disciplines with ≤5 athletes were categorised under 'other sports' and included weightlifting (n=5), American football (n=4), climbing (n=4), wrestling (n=4), floorball (n=4), motorsports (n=4), rowing (n=4), BMX (n=3), archery (n=3), fencing (n=3), taekwondo (n=3), cheerleading (n=2), dart (n=2), triathlon (n=2), track cycling (n=1), beach volleyball (n=1), boxing (n=1), rugby (n=1), trampoline (n=1), ice hockey (n=1), Thai boxing (n=1), windsurfing (n=1).

Table 8 Statistical comparisons of prevalence and frequency of analgesic use

Prevalence of analgesic use			
	OR	**95% CI**	**P-value**
Athletes vs. students	0.78	0.64 to 0.95	0.01
Female athletes vs. female students	0.95	0.74 to 1.21	0.70
Male athletes vs. male students	0.98	0.74 to 1.31	0.93
Endurance athletes vs. technical athletes	0.94	0.65 to 1.37	0.77
Endurance athletes vs. team athletes	0.88	0.62 to 1.25	0.49
Female endurance athletes vs. female technical athletes	0.89	0.56 to 1.40	0.63
Female endurance athletes vs. female team athletes	0.88	0.56 to 1.37	0.58
Male endurance athletes vs. male technical athletes	1.27	0.76 to 2.13	0.35
Male endurance athletes vs. male team athletes	1.43	0.88 to 2.31	0.14
Sensitivity analysis, exposure[a]			
Athletes vs. student controls	0.80	0.65 to 0.98	0.039
Sensitivity analysis, enrollment period omitted			
Athletes vs. student controls	0.82	0.66 to 1.01	0.068
Frequency of analgesic use			
	IRR	**95% CI**	**P-value**
Athletes vs. students	1.04	0.99 to 1.11	0.09
Female athletes vs. female student	1.04	0.97 to 1.11	0.23
Male athletes vs. male students	1.08	0.98 to 1.20	0.11
Endurance athletes vs. technical athletes	0.97	0.87 to 1.07	0.59
Endurance athletes vs. team athletes	1.03	0.94 to 1.14	0.45
Female endurance athletes vs. female technical athletes	0.99	0.88 to 1.12	0.94
Female endurance athletes vs. female team athletes	1.12	1.00 to 1.27	0.05
Male endurance athletes vs. male technical athletes	0.92	0.77 to 1.09	0.36
Male endurance athletes vs. male team athletes	0.92	0.78 to 1.09	0.37
Sensitivity analysis, exposure[a]			
Athletes vs. student controls	1.06	1.00 to 1.13	0.02
Sensitivity analysis, enrollment period omitted			
Athletes vs. student controls	1.04	0.98 to 1.11	0.15

[a] The sensitivity analysis of exposure status excluded student controls reporting to compete in a sport at the national or international level. Adapted from papers II and III

Reasons for analgesic use (papers II and III)

In paper II, significantly more athletes than students used analgesics to treat pain or injury prior to (39% vs. 13%) or after sports participation (42% vs. 21%), and to prevent pain during sports participation (22% vs. 7%). However, significantly fewer athletes used analgesics to treat pain not related to sport (53 vs. 65%), illness (44% vs. 52%), and menstrual pain (21% vs. 33%) (Table 9). Similar differences were observed when stratified by sex. In both athletes and students, the most frequently reported reason for using analgesics was to treat pain not related to sports, accounting for 27% of all reported reasons among athletes and 40% among students. Paper III showed significant differences in the proportions of endurance athletes, technical athletes, and team athletes reporting use of analgesics to treat pain not related to sport (61% vs. 55% vs. 48%), and to treat menstrual pain (26% vs. 24% vs. 17%), respectively (Table 9). When stratified by sex, statistically significant differences were observed in the proportions of female athletes across sports categories reporting to use analgesics to treat illness. For all sports categories, the most frequently reported reason for using analgesic was to treat pain not related to sport, accounting for 24-30% of all reported reasons.

Types of analgesics (papers II and III)

In paper II, significantly more athletes than students used topical gels (28% vs. 13%), but significantly fewer used paracetamol (74% vs. 80%) and acetylsalicylic acid (11% vs. 17%) (Table 9). Similar differences were observed when stratified by sex. In both athletes and students, the most frequently used analgesic type was paracetamol, accounting for 59% of all reported analgesic types among athletes and 64% among students. In paper III, no differences were observed in the types of analgesics used between sports categories or sexes (Table 9). In all sports categories, paracetamol was the most frequently used analgesic, accounting for 58-60% of the total number of reported types of analgesics.

Table 9 Reasons for use and types of analgesics used (proportions of participants reporting each reason and type at least once during the 36-week study period). Adapted from papers II and III.

Reasons for use, n (% [95% CI])	**All athletes (n=690)**	**All students (n=505)**	**p-value**	**Endurance athletes (n=137)**	**Technical athletes (n=229)**	**Team athletes (n=323)**	**p-value**
To treat pain or injury after participating in sport	289 (42% [38-46])	107 (21% [18-25])	<0.001	52 (38% [29-47])	101 (44% [38-50])	135 (42% [36-47])	0.514
To treat pain or injury prior to participating in sport	271 (39% [35-43])	67 (13% [10-16])	<0.001	46 (34% [26-42])	89 (39% [33-45])	135 (42 % [36-47])	0.254
To prevent pain that might occur during sports participation	154 (22% [19-25])	38 (7% [5-10])	<0.001	24 (18% [12-24])	56 (24% [19-30])	74 (23% [18-28])	0.289
To treat pain not related to sport (e.g., headache, back pain)	368 (53% [49-57])	332 (65% [61-69])	<0.001	84 (61% [53-69])	127 (55% [48-62])	156 (48% [43-53])	0.027
To treat menstrual pain	147 (21% [18-24])	169 (33% [29-37])	<0.001	36 (26% [19-34])	55 (24% [18-30])	56 (17% [13-21])	0.049
To treat illness	304 (44% [40-48])	265 (52% [48-56])	0.004	71 (52% [43-60])	102 (45% [38-51])	131 (41% [35-46])	0.083
Other reasons	87 (12% [10-15])	113 (22% [18-26])	<0.001	12 (9% [4-14])	39 (17% [12-22])	36 (11% [8-15])	0.038
Types of analgesics, n (% [95% CI])							
Paracetamol	509 (74% [70-77])	403 (80% [76-83])	0.015	100 (73% [65-80])	168 (73% [67-79])	240 (74% [69-79])	0.947
Nonsteroidal anti-inflammatory drugs	288 (42% [38-46])	192 (38% [34-42])	0.195	53 (39% [30-47])	104 (45% [39-52])	131 (41% [35-46])	0.371
Topical gels	193 (28% [25-31])	64 (13% [10-16])	<0.001	36 (26% [19-34])	69 (30% [24-36])	88 (27% [22-32])	0.667
Acetylsalicylic acid	77 (11% [9-14])	86 (17% [14-20])	0.003	20 (15% [9-21])	29 (13% [8-17])	28 (9% [6-12])	0.124
Opioids	33 (5% [3-6])	35 (7% [5-9])	0.113	8 (6% [2-11])	9 (4% [1-7])	16 (5% [3-7])	0.697
Injections	30 (4% [2-6])	26 (5% [3-7])	0.518	8 (6% [2-11])	9 (4% [1-7])	13 (4% [2-6])	0.635
Other	33 (5% [3-6])	35 (7% [5-9])	0.113	4 (3% [0-7])	12 (5% [2-8])	17 (5% [3-8])	0.519

Youth elite athletes' experiences with analgesic use (paper III)

The thematic analysis identified a wide range of experiences with analgesic use, from rare, non-systematic use of over-the-counter analgesics to daily, long-term opioid use. All athletes shared experiences with using analgesics to manage illness, pain unrelated to sport, or to treat or prevent pain and injury related to sports participation. The majority described using only over-the-counter analgesics, often favouring topical analgesics for superficial and localised pain, and with few accounts of opioid use or administration of injectable analgesics. While most athletes experienced a high degree of autonomy about their use of analgesics, several also described seeking advice from parents, coaches, doctors, or physiotherapists regarding the appropriate analgesic type and dosage.

Sociocultural influences on youth elite athletes' analgesic use (paper III)

Twelve themes of how analgesic use was shaped by and embedded in various sociocultural factors were developed. These include (I) performance pressures, encompassing team responsibilities, competition demands, and balancing academic and athletic commitments, (II) cultural and environmental influences, such as the normalisation of analgesic use within teams and coaches' attitudes and values, and (III) individual decision-making, driven by autonomy, a strong internal motivation to compete, and considerations of long-term health and injury management, all of which shape athletes' behaviours and attitudes towards pharmacological pain management. Some factors were explicitly related to increased or decreased analgesic use, while others revealed more complex interactions between the athletes and their environments.

Analgesic use driven by team performance responsibility

Athletes often felt a strong sense of responsibility towards their team, which influenced their decision to use analgesics. The pressure to perform and contribute to team success led athletes to prioritise their participation in sports, even when experiencing health problems such as pain, injury, or illness. Athletes felt accountable for maintaining team tactics, avoiding disruption, and not letting down their teammates, which was explicitly used as a reason for using analgesics to suppress symptoms and ensure continued participation. This sense of responsibility extended beyond individual performance, as athletes perceived that their absence could negatively impact the team's dynamics, training, or competitive outcomes **(theme 1)**:

'I feel like I have a responsibility towards the team and if I have to withdraw from playing, then we are missing a part of the tactic. So that's why I have also done it [used analgesics] to prevent pain' (P12)

'You collect points for the club, so you are not just playing for yourself, but for the team and it's kind of your fault if something goes wrong and that is why you want to be able to perform for the team. And then you use a bit [analgesics] beforehand' (P15)

Normalisation of analgesic use within team and club culture

Several athletes also discussed how the use of analgesics was a normalised and openly accepted practice among teammates. Athletes exchanged analgesics in locker rooms, creating a culture where using analgesics was seen as routine. This collective behaviour fostered a sense of shared understanding, where teammates shared analgesics with each other to ensure participation, further reinforcing the normalisation of this practice. The use of analgesics was an integral part of the team's approach to dealing with pain and injuries, with older or more experienced teammates offering guidance and sharing medication. This cultural acceptance within a team reinforced the use of analgesics as a quick fix for pain, enabling athletes to meet the demands of both training and competition without interruption **(theme 2)**:

'If someone is not feeling well, then the others (i.e., teammates) are like 'then take some analgesics so you can participate'. It's not like you're trying to hide it' (P7)

'We're getting it [analgesics] from each other in the locker room. It has become this thing' (P25)

'My teammates are a bit older than me, and one of them gave me analgesics and said "here, take these and you'll be ready in a minute" (P18)

Competition and performance considerations as drivers of analgesic use

Moreover, athletes spoke of competition and performance considerations as factors influencing their use of analgesics. The intense focus on performance, both self-imposed and from external expectations, created a climate where managing pain and other health problems through analgesics became a necessity. Many athletes felt the weight of scrutiny from spectators and peers, which amplified their motivation to perform optimally. As one athlete noted, the need to excel was not just

about individual success, but also about contributing to the team, prompting many to utilise analgesics to ensure they could perform despite minor injuries. The competitive landscape in various sports further reinforced this reliance on analgesics. Athletes recognised that their rankings and potential selections for prestigious competitions depended on consistent high-level performance, which often meant pushing through pain and other health problems. For instance, participants expressed that the perceived pressure to maintain peak performance levels led them to take analgesics regularly, especially before matches and practices deemed critical for their competitive standing. The sentiment was that performance could not be compromised; hence, analgesics became a tool to mitigate pain and enhance their ability to compete. One athlete recognised this practice as less than ideal, but saw analgesics as the only viable solution to ensure optimal performance despite health problems **(theme 3)**:

'For the past two years, I have had to do it [take analgesics] more or less before every match, as I feel like when you're playing a match, then you have to perform' (P32)

'You just perform better (i.e., if using analgesics) than you would if you were in pain, so using analgesics so that the pain won't be what sets the limit as to what you can and cannot do' (P14)

Analgesic use under pressure to participate in sports despite pain, injury, and illness

This perceived pressure to continue participating in sports despite health problems or physical limitations was also related to their everyday environment. The use of analgesics among athletes frequently emerged as a response to intense pressures to participate in sports, even in the face of pain, injury, or illness. Many participants reported feeling compelled to push through health problems due to the expectations set by coaches, teammates, and even family members. For instance, one athlete recounted the experience of a head injury while attending a demanding dance camp, expressing that, despite medical advice to rest, they chose to resume dancing earlier than recommended due to feelings of inadequacy and pressure from their coach, resulting in an increased use of analgesics. Another athlete described being told that absence from practice due to pain could lead to being removed from the team, prompting them to take high dosages of paracetamol to ensure participation. Athletes described an environment where pushing through pain was normalised, with coaches implicitly encouraging the use of analgesics to maintain attendance and performance. One athlete articulated this dynamic, noting how their coach's strict approach created

a culture where using pain relief became a common strategy to enable participation, even if it meant disregarding the need for recovery. This pressure to consistently show up, particularly during critical training periods or competitions, fostered a mindset where using analgesics was a necessary means to achieve performance goals. Furthermore, familial influences also played a role, as parents sometimes advocated for the use of analgesics to ensure their children could compete, reinforcing the idea that participation was paramount. This was evident in anecdotes where athletes felt they had to follow their parents' encouragement to use analgesics in order to perform. However, some athletes did not feel this pressure to participate in sports when facing health problems and felt comfortable skipping practice or competition if they were unwell. One athlete noted that they felt no pressure from others and could easily skip practice without anyone reacting. This lack of external pressure allowed them to prioritise their health without fear of repercussions, highlighting a contrasting perspective to those who felt compelled to participate in sport **(Theme 4)**:

'With our previous coach, being injured wasn't really legitimate, he didn't really have any sympathy for that. He'd prefer us being in the game.. and if you were in pain, you'd use analgesics, and most of us did' (P21)

'I was playing the next day, and my dad was like 'No, you can do it. Take some analgesics' and I was like 'no, I can't' and then I went to practice the day after what happened to my knee and I couldn't even kick a ball' (P19)

Coaches' influence on athletes' use of analgesics

The influence of coaches on athletes' decisions to use analgesics was identified as a prominent theme, reflecting a complex interplay of pressure, expectation, and perceived necessity in the pursuit of performance. Many athletes noted that their coaches actively encouraged or implicitly endorsed the use of analgesics to enable continued participation in training and competition. For instance, one athlete described their coach's attitude towards missed practices, stating that the coach preferred athletes to take analgesics and attend practice rather than skip it altogether, illustrating a prioritisation of attendance over health. This encouragement extended to pre-competition scenarios as well. Coaches were reported to suggest taking analgesics as a solution for athletes feeling unwell before games, reinforcing the idea that participation was paramount, even at the cost of personal well-being. One participant recounted how their coach would casually offer options like "blue and

yellow pills" to ensure they were ready for matches. In some instances, athletes expressed that their coaches had minimal regard for health concerns, focusing instead on the competitive outcomes. This sentiment was captured in a participant's reflection on their coach's lack of understanding of the potential adverse effects of analgesics, stating that the coach seemed primarily focused on winning rather than the athletes' health.

Some athletes described how their coaches allowed for personal discretion regarding analgesic use. For instance, one participant remarked that their coaches were open about analgesic use, suggesting that it was ultimately up to the athletes to determine their need for medication. Another athlete emphasised that their coach had never pressured them to use analgesics, indicating that the decision remained entirely in their hands. Finally, one athlete shared that their club had implemented a ban on analgesics during practice, stating that players who required analgesics during practice would not be permitted to continue participating in that session. This divergence illustrated a spectrum of coaching attitudes towards analgesic use, with some fostering an environment of pressure, others promoting athlete autonomy, and some enforcing strict bans on analgesics altogether (**Theme 5)**:

'My coach would rather that we use analgesics and come to practice than not show up, because if you don't show up to practice then it will be hard to keep up' (P11)

'I don't really think about the fact that my coach is like "just take some pills and go play" because everyone on the team just wants to play, so of course they take it (P17)

'When something is wrong my coach usually says 'talk to your mom about it' or something because he is not a specialist in that area (i.e., analgesics)' (D1)

'It's not something you discuss with your teammates or coach [using analgesics], at least I don't discuss it with my coach, because then he would just tell me that I shouldn't play as much' (P6)

High degree of autonomy in addition to a strong personal drive to participate in sport

Contrary to the themes relating to the influence of people within the athletes' immediate environments on their analgesic use, a notable theme that was identified was the high degree of autonomy athletes exercised in their decision to use analgesics, fueled by a strong personal drive to participate in sport. Many athletes illustrated how their intrinsic motivation often outweighed

concerns about potential health risks. One athlete described their determination to practice just days after breaking an arm, opting to take analgesics to alleviate the pain. This sentiment was echoed by another athlete who, despite the worsening pain in their foot during the Danish Championships, chose to take analgesics to ensure they could compete, fully aware of the potential consequences. The motivation and willingness driving athletes to push through pain was highlighted. One athlete acknowledged feeling conflicted about using analgesics but ultimately justified it by their intense desire to compete, expressing that analgesics allowed them to participate without completely overwhelming their body. Another athlete stated that their choice to use analgesics was not influenced by external pressures, such as parental advice, but stemmed purely from their desire to attend practice. Overall, this theme underscores how athletes navigated their health decisions with a strong sense of autonomy, prioritising their passion for sport and competition above all else **(Theme 6)**:

'It was the Danish championships a year ago, and I had just returned to sport after my ankle injury and during the first three matches, the pain in my foot just got worse, but as I really wanted to play, I took analgesics knowing that it might get worse afterwards' (P10)

'It has mostly been in relation to competition (i.e., use of analgesics). But in my club, it's not like if you are too sick to participate, it's mostly because I really want to participate' (P2)

The role of perceived importance of training and competition on analgesic use

How important the athletes perceived specific training sessions or competitions further influenced their analgesic use. Athletes often felt a heightened sense of urgency to perform, especially leading up to major competitions such as the Danish Championships. One participant highlighted the difficulty of sitting out during crucial times, stating that it was "easier to use a lot of analgesics and then go out and do the best you can". This sense of urgency was echoed by other athletes who noted that they rarely used analgesics except when facing critical competitions, suggesting that the stakes of these events pushed them to manage their pain through analgesics. Several athletes described specific instances where they turned to analgesics due to injuries occurring right before important matches. For example, one athlete shared that they took analgesics after twisting their ankle just before a match that held significant personal importance. Another athlete recounted using injectable analgesics in the lead-up to the World Championships, reflecting the extreme lengths they would go

to in order to participate despite physical limitations. This trend was consistent among athletes, many of whom acknowledged that their commitment to performing at their best drove them to use analgesics, particularly during competitions where the stakes were highest, demonstrating a clear distinction between their approach to training and competition. Moreover, the influence of competitive environments extended beyond individual choices; athletes often sought permission from coaches or physiotherapists to use analgesics in these high-pressure contexts, highlighting the shared understanding of the importance of performance in competitive sports. Athletes repeatedly underscored that their desire to be fully ready for significant events drove their decision to use analgesics, with one athlete summarising that they would not consider using pain relief unless they were preparing for something they truly wanted to participate in **(Theme 7)**:

'It's mainly if it's something important, I will usually not use analgesics if it's just regular practice' (P28)

'I played internationally for the first time this year and I felt an old injury flare up, so I called her (i.e., physiotherapist) and asked if it was alright to take some paracetamol and then play and she told me that it was alright just this one time because it was in Portugal' (P15)

Balancing academic and athletic pressures by using analgesics

In addition to factors primarily situated within the sports environment, athletes described how difficulties in balancing academic and athletic commitments influenced their use of analgesics. Some athletes described the challenges of fitting in late-night homework after rigorous training sessions, which sometimes resulted in headaches that prompted them to take analgesics to push through their academic responsibilities. The early morning practices and long days at school left some athletes with aching legs, leading them to use analgesics to alleviate pain and maintain their performance throughout the day. The need to perform well both academically and athletically often meant that these athletes prioritised their commitments, sometimes at the expense of their health, as highlighted by one athlete who described using analgesics to manage severe menstrual pain during a school day, driven by the fear of falling behind in both sports and studies. Additionally, the intense schedule of matches often left little room for rest and recovery, leading athletes to perceive analgesics as a necessary tool to cope with overwhelming demands **(Theme 8)**:

'With late training sessions, then you get home and do your school homework until late and often get a headache, and then it is easier to use analgesics and try to push through rather than making it worse' (P10)

'To be able to sleep afterwards (i.e., practice/match), that definitely influences my use (i.e., of analgesics), because if I'm in a lot of pain, then I won't be able to sleep and that negatively affects me in school and my everyday life' (P13)

Training adaptations over analgesic pain management

Some athletes emphasised their commitment to modifying training routines based on their current physical state rather than relying on analgesics to mask pain. One athlete highlighted the importance of open communication with their coach, explaining that they regularly assessed their physical condition before training sessions, allowing for adjustments in intensity or duration to align with how their body felt. For athletes aware of the potential consequences of pushing through pain, such as exacerbating an injury, the focus remained on listening to their bodies and making necessary training modifications **(Theme 9)**:

'I actually never use analgesics if I'm training. Then I will modify my training according to how my body is feeling' (P15)

'If my physiotherapist has told me that it (i.e., pain or injury) can become worse if I keep training, then I don't want to use analgesics. In general, if I'm feeling any pain, then I try to modify my training accordingly' (P28)

Considering the potential risks of using analgesics for pain and injury

In conjunction with modifying training activities in accordance with physical complaints, some athletes spoke of refraining from using analgesics when dealing with pain or injury that had the potential to worsen or cause long-term issues. Athletes highlighted the importance of consulting with healthcare professionals, such as physiotherapists, to assess the risks associated with continued training while injured. One athlete emphasised that they would refrain from using analgesics if advised that doing so could worsen an injury, opting instead to wait for recovery. Another athlete noted that their primary concern was the potential for pain to escalate into a more severe injury,

indicating a proactive mindset in evaluating the implications of masking symptoms with analgesics. The input from physiotherapists also played a significant role in shaping athletes' perspectives, with warnings about the long-term consequences of using analgesics during youth sports resonating strongly with some athletes **(Theme 10)**:

'You take it very seriously (i.e., considering using analgesics to treat pain or injury) if someone tells you that it can cause problems in the future if you don't take a break' (P13)

'If I'm sick, then I don't think it can get worse, it's more so if I'm in pain, then I'm afraid that it can turn into a severe injury, otherwise I don't think about it' (P25)

'You think about it (i.e., potentially worsening an injury by using analgesics to cover symptoms) if you're told that it can affect you for the rest of your career, or even just for longer than right now' (P14)

Athletes' acceptance of pain and management without analgesics

Some athletes also spoke of pain and injury as an inherent part of elite sports and did not view it as necessarily requiring analgesic treatment. These athletes often expressed the belief that they could tolerate pain without relying on analgesics, emphasising mental toughness and perseverance as their primary strategies for pain management. For example, one athlete noted that in their group, pain was rarely discussed, and complaining about it could result in being sent home. Others shared that, while they experienced pain or injuries, they chose to push through, believing the discomfort would eventually subside without medical intervention. Additionally, several athletes mentioned that they reserved the use of analgesics for more serious, long-term injuries, rather than for the everyday aches and pains associated with training and competition **(Theme 11)**:

'I don't know if others use it (i.e., analgesics), but we are some tough guys who usually shut up about it (i.e., pain), and then you don't need them (i.e., analgesics). If you're whining, then you're going home' (P1)

'I don't really use it (i.e., analgesics) in relation to injuries. Because, like, if you can play, then it's just because it hurts. I just think that I'm not afraid of pain like that' (P29)

Physiotherapists' long-term perspective and focus on rehabilitation

Finally, when discussing how other people may influence the athletes' analgesic use, some described that their physiotherapists actively discouraged the use of analgesics and instead emphasised the importance of proper rehabilitation and long-term health and well-being. Some athletes shared that their physiotherapists directly discouraged the use of analgesics. Physiotherapists were portrayed as advocating for alternative solutions, such as rehabilitation exercises, to ensure athletes' recovery and longevity in their sport. One athlete explained that their physiotherapist repeatedly encouraged them to avoid analgesics and prioritise consistent rehabilitation through exercise. This cautious approach was particularly valued by some athletes, who recognised that while they were eager to return to play, their physiotherapists maintained a focus on their long-term health and career prospects. Physiotherapists often advised against the use of analgesics, and in some cases, athletes were required to consult with them before using pain relief, indicating a proactive approach to injury management in certain sports cultures. Overall, physiotherapists' recommendations reflected a broader concern with preventing the escalation of injuries and fostering sustainable athletic careers, reinforcing the importance of rehabilitation over temporary fixes **(Theme 12)**:

'I want to get back to on the court as soon as possible if I'm injured.. But I think it's nice that these physiotherapists are more concerned with the future than right now' (P10)

'If you ask football physios, I don't think any of them will tell you that it's a good idea (i.e., to use analgesics), they will probably recommend against it' (P5)

'I think they (i.e., physiotherapists) would rather avoid it (i.e., using analgesics) and do rehab instead' (P13)

Trajectories (paper IV)

In paper IV, four trajectories of analgesic use were identified in both youth elite athletes and students based on prevalence data: minimal/non-users (48.1% of athletes/52.5% of students), occasional users (30.9% of athletes/33.2% of students), frequent users (18.5% of athletes/11.1% of students), and persistent users (2.5% of athletes/3.2% of students) (Figures 7 and 8). In both athletes and students, the risk of analgesic use increased statistically significantly with higher trajectory groups, up to 20-28 times higher risk in persistent use groups compared to minimal/non-use groups (Table 9). Data on mean weekly prevalence and median consumption frequency in trajectory groups are presented in Table 10.

The proportion of females increased with higher trajectory groups, up to 88% among athlete persistent users and 87% among student persistent users (Table 10). Paracetamol was the most used analgesic across all trajectory groups for athletes and students (Table 11). In athletes, the proportion of users of acetylsalicylic acid, opioids, topical gels, and *other* analgesics increased with higher trajectory groups. This was also observed among students, with increased use of opioids, topical gels, and injectable analgesics in higher trajectory groups (Table 11). The sensitivity analysis examining the proportion of recurrent users of the same analgesic showed similar patterns, though the proportions of users were lower across all analgesic types.

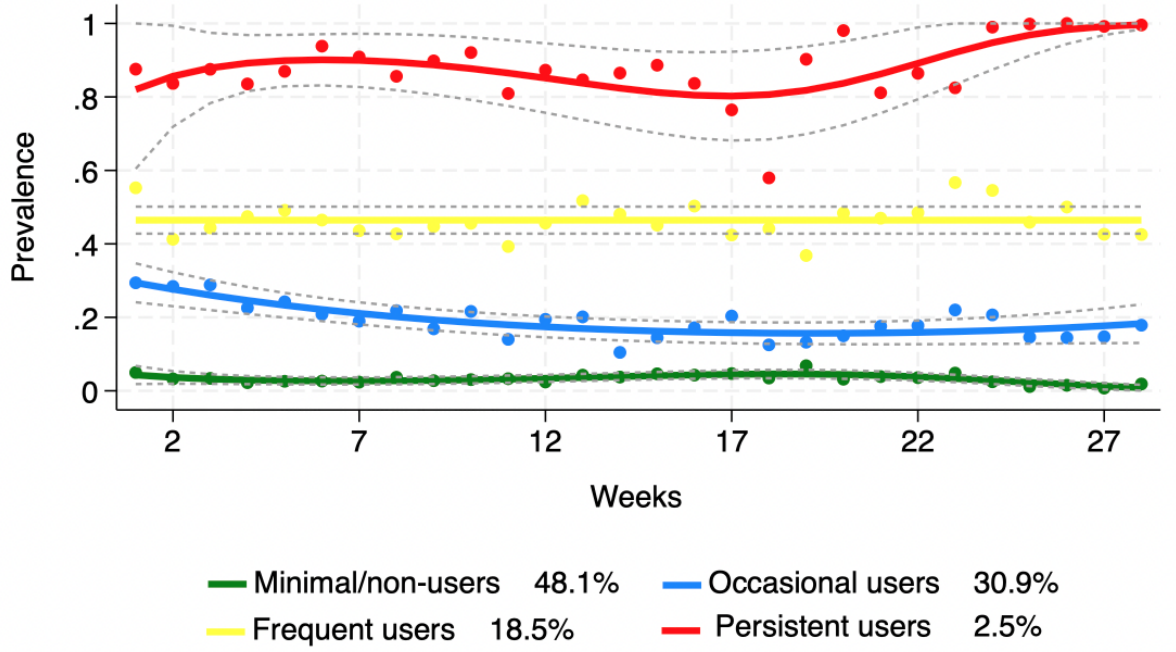


Figure 7 Athlete trajectory groups: Minimal/non-users (n=332), occasional users (n=213), frequent users (n=128), persistent users (n=17). The dotted lines represent 95% CI. Figure from paper IV.

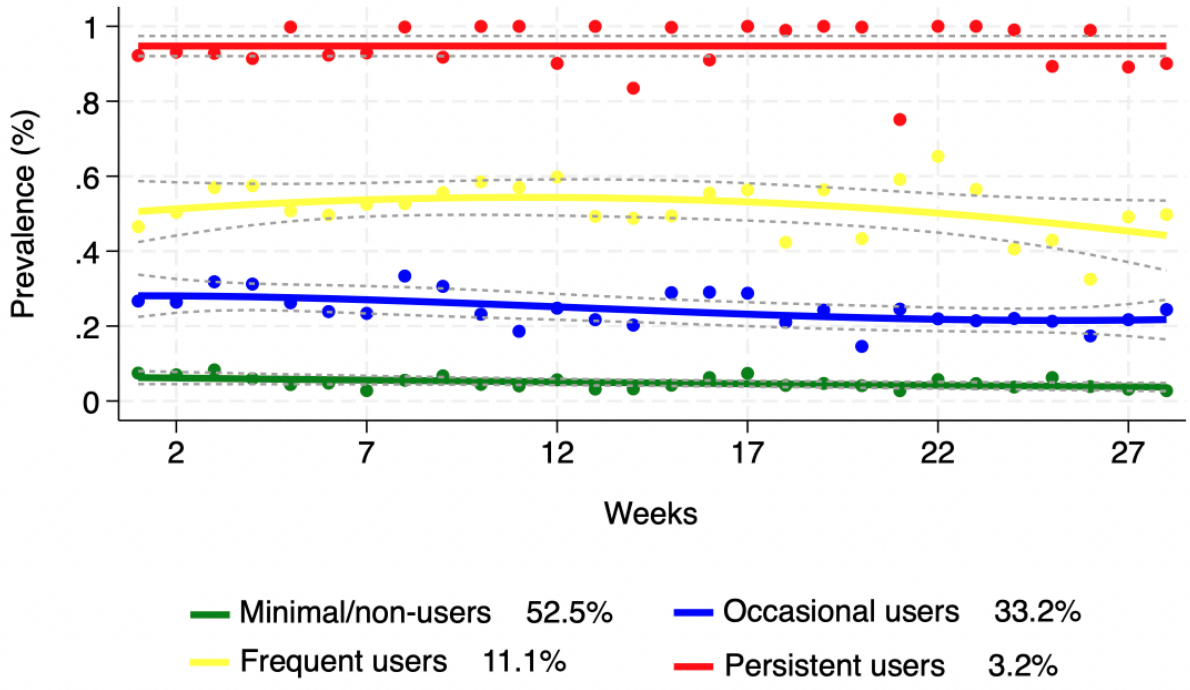


Figure 8 Student trajectory groups: Minimal/non-users (n=265), occasional users (n=168), frequent users (n=56), persistent users (n=17). The dotted lines represent 95% CI. Figure from paper IV.

Table 10 Relative risks, mean weekly prevalence and median consumption frequency, and sex distribution across trajectory groups. Adapted from paper IV.

Groups	Relative risk (95% CI)	Mean weekly prevalence (95% CI)	Median weekly consumption frequency (no. of days, IQR)	Proportion of females, n(%)
Athletes				
Minimal/non-users (n=332)	Reference	3% (1-5%)	0 (0-0)	87 (26%)
Occasional users (n=213)	6.2 (5.5-7.2)	19% (14-25%)	0 (0-0)	113 (53%)
Frequent users (n=128)	15.1 (13.3-17.2)	47% (38-56%)	1 (0-2)	90 (70%)
Persistent users (n=17)	28.3 (24.6-32.5)	88% (63-99%)	3 (2-6)	15 (88%)
Students				
Minimal/non-users (n=265)	Reference	5% (2-8%)	0 (0-0)	115 (43%)
Occasional users (n=168)	5.4 (4.7-6.1)	25% (18-32%)	0 (0-1)	122 (73%)
Frequent users (n=56)	11.3 (10.1-12.8)	53% (39-67%)	1 (0-2)	48 (86%)
Persistent users (n=16)	20.2 (17.9-22.8)	94% (70-100%)	4 (2-7)	15 (87%)

Table 11 Proportion of participants in each trajectory group reporting use of each analgesic at least once during the 28-week observation period. Adapted from paper IV.

	Paracetamol	NSAIDs	Topical gels	ACA	Opioids	Injections	Other
Athletes							
Minimal/non-users (n=332)	164 (49%)	66 (20%)	39 (12%)	14 (4%)	3 (1%)	5 (2%)	4 (1%)
Occasional users (n=213)	204 (96%)	111 (52%)	77 (36%)	24 (11%)	10 (5%)	12 (6%)	14 (7%)
Frequent users (n=128)	125 (98%)	98 (77%)	64 (50%)	32 (25%)	15 (12%)	12 (9%)	13 (10%)
Persistent users (n=17)	16 (94%)	13 (76%)	13 (76%)	7 (41%)	5 (29%)	1 (6%)	2 (12%)
Students							
Minimal/non-users (n=265)	169 (64%)	45 (17%)	19 (7%)	21 (8%)	6 (2%)	8 (3%)	11 (4%)
Occasional users (n=168)	165 (98%)	92 (55%)	28 (17%)	38 (23%)	20 (12%)	7 (4%)	10 (6%)
Frequent users (n=56)	54 (96%)	44 (79%)	13 (23%)	22 (39%)	6 (11%)	7 (13%)	9 (16%)
Persistent users (n=17)	15 (93%)	11 (69%)	4 (25%)	5 (31%)	3 (19%)	4 (25%)	5 (31%)

Discussion

This thesis is based on the results of four papers (papers I, II, III, and IV) uncovering the epidemiology, experiences, and sociocultural influences on analgesic use among Danish youth elite athletes. Below, the findings and methodological concerns of each paper are discussed and clinical implications and directions for future research are presented.

Summary of main findings

Paper I

Based on cross-sectional data from 49 studies, including 44,381 athletes from various competition levels, we provided a range of prevalence estimates for the use of seven categories of analgesics. NSAIDs appeared to be the most commonly used analgesic, with 7-95% of athletes reporting use across prevalence time points. Overall, prevalence estimates were lower for the remaining types of analgesics, but varied across prevalence time-points. Across 14 studies, 6% to 35% of athletes reported monthly analgesic use, and 7% to 50% reported weekly use. Athletes used analgesics to treat sports-related pain or injury, prevent or block pain, treat illness, and enhance performance. Four studies reported data on adverse events, with prevalence estimates ranging from 3% to 19% of athletes. Overall quality of evidence was very low to low.

Papers II, III, and IV

In a 36-week prospective cohort study of 690 youth elite athletes and 505 students, athletes had lower odds of analgesic use compared to students, but the usage rate was similar between the groups. However, subgroup analyses stratified by sex showed no differences in the odds of analgesic use. More athletes reported using analgesics to prevent or treat pain or injury in relation to sports participation and to use topical gels compared to students (paper II). Analysis of analgesic use across sports categories revealed no differences in prevalence, frequency, or types of analgesics used between endurance athletes, technical athletes, and team athletes, but fewer team athletes used analgesics to treat menstrual pain and other non-sports related pain (paper III). Athletes described diverse experiences with analgesics, from rare, non-systematic use of over-the-counter analgesics to daily, long-term use of opioids. Twelve sociocultural factors influencing analgesic use were identified. While factors such as pressure to participate in sports despite experiencing health problems and feeling responsible for team performance increased analgesic use, considering the

potential consequences of using analgesics for pain and injury decreased the usage. Other factors, such as coaches' influence, revealed more complex interactions between the athletes and their environments. In papers II and III, approximately one in five young people used analgesics in any given week regardless of athletic status (i.e., athlete or student) and sports category. However, a more detailed analysis, using group-based trajectory modelling in paper IV, confirmed the qualitative results from paper III by uncovering large variations in trajectories of analgesic use. Four trajectories of analgesic use were identified for both athletes and students, including minimal/non-users, occasional users, frequent users, and persistent users. In both athletes and students, the risk of analgesic use increased statistically significantly with higher trajectory groups, up to 20-28 times higher risk in persistent use groups compared to minimal/non-use groups (paper IV).

Explanation of results and comparison with previous findings

Patterns of analgesic use in youth athletes: Insights from systematic reviews

In line with the findings of the IOC systematic review (4), paper I identified widespread use of NSAIDs, with a pooled point-prevalence of 48% and period-prevalence estimates ranging from 7% in the past seven days to 92% reporting in-season use. Due to the health risks associated with NSAIDs, international expert consensus recommend paracetamol, either alone or in combination with NSAIDs, for managing acute pain in athletes and emphasise that there, in most cases, is no sound rationale for prolonged use of NSAIDs (38). Despite these recommendations, prevalence estimates of paracetamol use were generally lower than estimates of NSAID use in studies reporting these data separately. Prevalence estimates of opioid use were reported in only four studies and ranged from 3% to 13% across prevalence time points. These findings align with a previous systematic review on opioid use in sports, highlighting that while available estimates vary across studies, they tend to be lower than estimates for over-the-counter analgesics (117). While the IOC consensus statement suggests that opioids may be circumstantially appropriate to manage acute, severe pain in athletes, the studies included in paper I did not report data on reasons, frequency, or duration of opioid use, which limits a comprehensive understanding of opioid consumption patterns in youth athletes. The importance of closely monitoring and cautiously prescribing opioids to youth athletes was emphasised by Dunne et al., who reported that opioid use during an athlete's active career predicted use and misuse later in life (118). To achieve contextualised insights into the influence of elite sports participation on analgesic use, comparing estimates of analgesic use in

athletes to those of a reference population is of particular interest. However, none of the studies included in paper I compared analgesic use between athletes and non-athletes. Consistent with the findings of paper I, a systematic review from 2022 also reported considerable variation in prevalence estimates of analgesic use for musculoskeletal pain in non-athlete adolescents (≤19 years of age), with reported proportions of users ranging from 8% to 75% across 20 studies (20). Another systematic review, including 163 studies, found that the proportion of adolescents reporting engaging in self-medication practices ranged from 5% to 93% across 14 different prevalence time points (119). These systematic reviews confirm the findings of paper I regarding the considerable variation in available estimates, variability influenced by factors such as assessment methods and prevalence time-points, but they do not provide a framework for meaningful comparisons or interpretation of the impact of sports participation on analgesic usage patterns, mainly due to large differences in research methodologies and population characteristics. The findings from paper I also revealed that as many as 50% of youth athletes report using analgesics on a weekly basis. These findings raise significant concerns, given the increased risk of adverse events associated with high or long-term analgesic use (120, 121). Self-medication and lack of awareness about the potential adverse events and consequences of prolonged use are likely contributing factors (32, 106, 115).

Unpacking analgesic use in youth elite athletes: A longitudinal perspective

Building on the findings of paper I, papers II and III aimed to address significant gaps in the literature by examining the prevalence and frequency of analgesic use in a longitudinal, repeated measures design. The results revealed that, on average, one in five young people, regardless of their athletic status or sports category, used analgesics in any given week, with an average consumption frequency of 2.4 to 2.6 days per week. In all cohort subgroups, prevalence estimates were higher in females than males. While this finding aligns with previous research in Scandinavian non-athlete adolescents (122, 123), the results of paper I were inconsistent regarding gender/sex-specific differences in analgesic use among youth athletes. A comparison of prevalence estimates from the cohort study (used in papers II-IV) with those from the systematic review (paper I) also highlighted discrepancies. For example, the systematic review generally reported higher prevalence estimates for NSAIDs use compared to the cohort study. Conversely, the cohort study showed higher prevalence estimates for mixed analgesics and paracetamol use. Estimates for opioid and acetylsalicylic acid use were similar across both studies (Figure 9).

When analysing prevalence and frequency data using mixed effects regression models, the results of paper II showed lower odds of analgesic use in youth athletes compared to students, but that was not replicated in the sex-stratified subgroup analyses. These contrasting results are likely attributed to several factors. First, sample sizes were smaller in subgroup analyses, reducing statistical power. Second, the prevalence of analgesic use was higher among females than males, regardless of athletic status. However, the differing sex distributions within the athlete and student cohorts led to a statistically significant difference in the odds of analgesic use between the two groups, primarily influenced by the contrast between male athletes and female students. Finally, the non-collapsibility of the odds ratio suggests that the marginal measure of association does not equate to a weighted average of the subgroup-specific measures of association (124). In paper III, there were no differences in either odds or rate of analgesic use between endurance athletes, technical athletes, and team athletes. This lack of association between sports category and analgesic use suggests that the sociocultural factors affecting analgesic use among youth elite athletes are consistent across different sports, or if variations exist, that the resulting impact on analgesic use is negligible. Only one study has previously reported data on differences in the prevalence of analgesic use in elite athletes from different sports, showing a lower 7-day period prevalence of analgesic use among team sport athletes (n=152, 28.3%) compared to speed and power athletes (n=113, 41.6%) (8), but this finding was not replicated in paper III. Similarly, research on other health-related sociocultural practices in youth sports has yielded contrasting results. For example, a study by Meyer et al. found that athletes from technical sports showed a higher willingness to compete in sports despite experiencing health issues compared to their counterparts from other sports (9), though this finding was not replicated in a similar study on our cohort (11). Interview data further supported the lack of association between sports category and analgesic use, revealing no consistent sports-specific patterns of analgesic use. This finding contrasts with earlier studies suggesting that the extent of athletes' risk-taking behaviours is influenced by sports-specific norms and constraints, which differently mediate the characteristics of a culture defined by pain normalisation, risk acceptance, and performance expectations (9, 23, 24, 31).

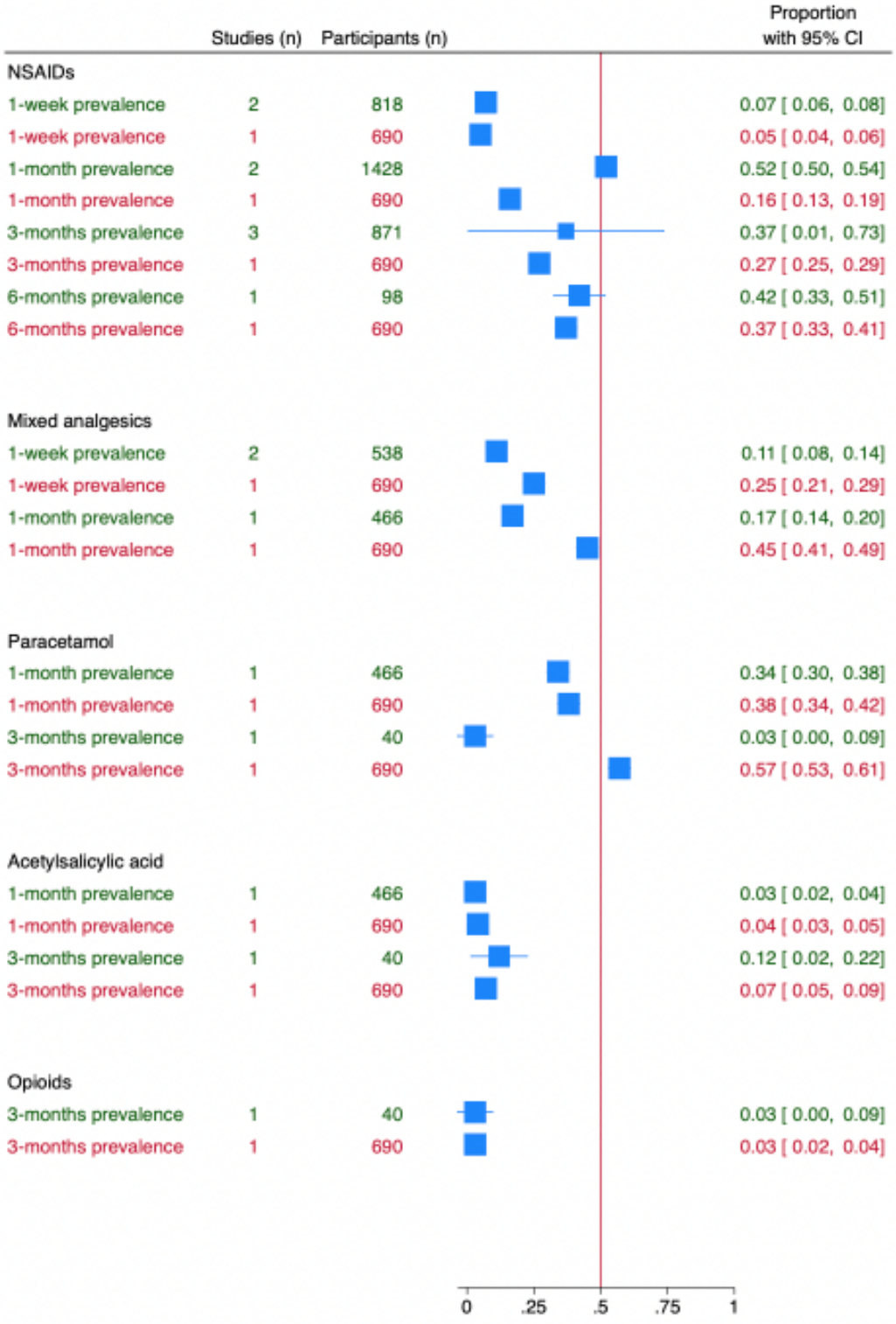


Figure 9 Overlay of results from systematic review (paper I, green rows) and prospective cohort study (papers II-IV, red rows).

Embedded practices: The complex role of sociocultural factors in analgesic use

Consistent with the findings of paper I, papers II and III showed that youth elite athletes often use analgesics to treat pain or injury in relation to sports participation and to prevent pain from occurring during sports participation. International expert consensus recommends against using analgesics for pain prevention and emphasises that the health of athletes prevails over competitive considerations (38). Yet, integrating quantitative data with in-depth qualitative data in paper III revealed that numerous underlying, complex sociocultural structures influence analgesic use among youth elite athletes in relation to sports participation, particularly when facing injuries, pain, and illness. These included, amongst others, performance and competition considerations, perceived pressure from coaches, parents, and teammates to participate in sport despite underlying health issues, a *locker room culture* normalising analgesic use, coaches' values and attitudes towards analgesics, and feeling responsible for team performance. Overbye et al. (19) identified similar themes in a mixed-methods study of Danish elite athletes, including (I) athletes legitimising the use of analgesics to compete while injured by attributing importance to specific competitions, (II) coaches persuading athletes to use analgesics, even when they were hesitant, (III) the normalisation of analgesic use as part of the mindset of making sacrifices for the sports, and (IV) using analgesics to reduce the impact of pain and injury on performance. Paper III showed no distinct analgesic consumption patterns or experiences specific to individual sports, suggesting that the use of analgesics among youth elite athletes is primarily shaped by overarching cultural structures and factors that transcend different sports disciplines, rather than participation in any specific sport or microcultures. Several factors identified in paper III and the study by Overbye et al. (19) are similar to motives for youth athletes to ignore or hide pain and injuries to enable continued sports participation. For example, injured young elite athletes often report a considerable fear of falling behind in terms of development and performance (125), and research indicates that the inclination of youth athletes to continue competing when experiencing health issues is partly attributed to perceived pressure from coaches, other athletes, and parents, (26). These findings raise several concerns. First, the use of analgesics appears to be deeply embedded within the beliefs, cultural values, and socialisation processes of elite sports, reinforcing the notion that athletes are expected to accept the risks, pain, and injuries associated with elite-level sport (23), and these trends appear to be present already at the youth level. Second, continuing athletic activity and delaying initiation of proper rehabilitation by using analgesics to suppress symptoms may increase the risk of sustaining an injury or the progression of existing injuries, potentially interfering with long-term athletic

development (126, 127). Third, previous research has identified coaches as a key social agent in establishing, constructing, and transmitting norms, values, and meanings in youth sports (128, 129). Yet, some youth athletes experienced that coaches stimulate short-term performance and results by encouraging analgesic use and expecting athletes to use analgesics rather than miss practice or competition, rather than creating a safe sports environment focusing on athlete well-being, enjoyment, participation, and retention, as emphasised by the IOC consensus statement on youth athletic development (30). However, factors promoting analgesic use was not exclusive to the sports environment. Some athletes explained how they used analgesics to balance commitments across both domains of their lives (i.e., academic and sports domains). For some, this involved using analgesics to be able to complete homework after a full day of practice and school, and others described using analgesics during school hours to relieve pain from morning practice. While dual career programs carry many psychosocial and psychological benefits for young athletes (130, 131), research has demonstrated that young athletes face numerous challenges when balancing sports and education (132, 133). Previous research has shown that competencies such as setting realistic goals, prioritising tasks, viewing setbacks as growth opportunities, and seeking advice from the right people are crucial for youth athletes to navigate dual-career challenges successfully (134). However, findings from paper III indicate that youth elite athletes may also engage in maladaptive behaviors, such as using analgesics, as a coping strategy to meet the high demands placed on them in the intersection of the two domains of their lives.

Pain management in youth: The role of analgesics beyond athletic injuries

Paper II revealed that significantly fewer athletes used analgesics to manage illness and non-sports related pain compared to students. Due to limited data comparing the prevalence of health problems between youth athletes and age-matched controls (12), it remains unclear whether this finding reflects actual differences in the prevalence of illness and non-sports related pain, or variations in the decision-making process regarding the use of analgesics to treat these symptoms. Interestingly, in both athletes and students across sex and sports disciplines, the most frequently reported reason for using analgesics was to treat non-sports related pain. While this finding may partly be explained by the high prevalence of various non-sports related pain conditions observed in adolescents, including headache, abdominal pain, musculoskeletal pain (135, 136), a meta-synthesis from 2021 revealed that adolescents also use over-the-counter analgesics alleviate stress and anxiety, and as a

coping strategy to normalise daily life (137). This finding emphasises that societal structures and factors beyond elite sports may largely contribute to young athletes' use of analgesics.

Revisiting analgesic choices: Paracetamol vs. NSAIDs in elite sports

Consistent with the findings of the IOC systematic review, paper I demonstrated that NSAIDs were not only the most frequently studied type of analgesic, but also appeared to be the most used. However, many studies either reported aggregate estimates of analgesic use, or reported *analgesics* without specifying the specific types. In papers II, III, and IV, paracetamol was the most used analgesic, accounting for ~60% of the total use, while NSAIDs accounted for only ~20% of the total use across cohort subgroups. In accordance with this finding, two previous studies examining analgesic use among Danish youth and senior elite athletes also found paracetamol to be the most used analgesic (19, 106). Two main factors may explain this discrepancy between international and Danish data. First, as highlighted in paper I and the IOC systematic review (4), much of the existing evidence on analgesic use in elite athletes has focused on NSAIDs, potentially leading to underreporting of other types of analgesics. Second, due to the lower risk profile, the Danish Health Authority recommends paracetamol over NSAIDs when purchasing over-the-counter analgesics (138). The effect of this recommendation was recently reinforced by a national survey, which found that paracetamol accounted for 61% of all purchased over-the-counter analgesics, while NSAIDs accounted for 29% (139).

Historically, NSAIDs have been the preferred choice of analgesic in athletes due to their anti-inflammatory properties, potentially facilitating a faster return-to-play (140, 141). However, research on the effect of NSAIDs on musculoskeletal healing presents conflicting findings. A 2018 meta-analysis showed significant short-term beneficial effects of NSAIDs on recovery markers after acute skeletal muscle injury, including strength loss, soreness, and blood creatine kinase levels, but highlighted a lack of high-quality human trials assessing injury markers beyond 14 days post-injury (142). Contrarily, other studies, published primarily in the 2000s, have reported negative effects on muscle protein synthesis and myogenic cell regeneration (143-145). Considering the risks associated with NSAID use and the inconsistent findings regarding their effect on musculoskeletal healing, the results presented in papers II and III, showing that paracetamol is the most used analgesic among youth elite athletes, and that their usage patterns for NSAIDs are comparable to those of students, are particularly encouraging.

Beyond over-the-counter: Exploring analgesic choices in youth elite athletes

Few athletes reported use of opioids and injectable analgesics, and the proportions of users were comparable to those of students. These findings were contextualised in interviews, in which some athletes disclosed prior use of opioids and injectable analgesics, but primarily for short-term management of postoperative pain or during diagnostic evaluations. In line with the quantitative results, the remaining athletes spoke of only using over-the-counter analgesics, often preferring topical analgesics for localised and superficial pain. In this regard, a recent systematic review and meta-analysis showed a significantly greater effect of topical analgesics compared to various oral analgesics versus placebo for pain associated with athletic injuries, thus emphasising the potential advantages of topical analgesics in this population (34). While the results of papers II and III suggest that youth elite athletes' choice of analgesics generally aligns with established international expert consensus (38), the qualitative data revealed that some athletes had inappropriate usage patterns. Some athletes spoke of prolonged and consistent use of over-the-counter analgesics, and one athlete disclosed daily use of Tramadol for over two years. Such findings highlight the limitations of relying solely on cross-sectional estimates, as identified in paper I, as well as the group-level summary estimates presented in papers II and III, and led to the trajectory analyses presented in paper IV.

Unveiling distinct trajectories of analgesic use: Identifying concerning usage patterns

To address the limitations associated with summarising and analysing data on analgesic use solely at the group level, as in papers II and III, paper IV investigated the presence of distinct trajectories of analgesic use. The results showed large differences in analgesic consumption patterns and identified four distinct trajectory groups in each cohort. Previous studies using trajectory modelling to analyse patterns of analgesic use have predominately relied on registry data of opioid prescriptions in adult and clinical populations, making direct comparisons of findings difficult. However, the results revealed that participants in persistent use groups had a greater proportion of opioid users and exhibited a higher weekly analgesic consumption frequency compared to the remaining trajectory groups. These characteristics align with those reported in the literature, with previous research demonstrating that individuals with persistent analgesic use are more likely to initiate stronger analgesics and receive higher analgesic dosages (146). Similar to the findings of paper IV, previous research has identified small groups of persistent users. For example, in studies excluding cancer patients, between 2.4% and 6.0% of individuals were classified as persistent

opioid users (146-148), and a recent study found that 10% of analgesic users among people with hip and knee osteoarthritis accounted for 45%, 50%, and 70% of the total paracetamol, NSAID, and opioid consumption, respectively (7). Paper IV revealed that most young people, regardless of their athletic status, have low, time-limited exposure to analgesics, but also identified concerning usage patterns in 21% of athletes and 14% of students, with data indicating biweekly to weekly use of analgesics, and 11-28 times higher risk of analgesic use at any given time among frequent and persistent users. In these trajectory groups, the mean weekly prevalence of analgesic use ranged from 47% to 94% and over-the-counter analgesics were the most commonly used analgesics. While long-term or frequent use of prescription analgesics may be justified when prescribed by a physician for managing a specific pain condition (149), unsupervised long-term use of over-the-counter analgesics increases the risk of adverse events (120, 150, 151), and is discouraged in both clinical guidelines (152) and by international expert consensus on pharmacological pain management in elite sports (38).

Several similarities between athlete and student trajectory groups were observed, but two important differences were identified between the cohorts. Among persistent users, greater proportions of athletes used paracetamol, NSAIDs, acetylsalicylic acid, topical analgesics, and opioids compared to students. This finding may indicate that athletes who consistently use analgesics are more inclined to use multiple types of analgesics simultaneously. This aligns with previous studies showing that concurrent administration of two or more analgesics is common in elite athletes receiving injectable analgesics during tournaments (153). In addition, athletes with persistent analgesic use showed a fluctuating consumption pattern over time, with the highest prevalences (i.e., 100%) recorded in the end of the study period. This increase coincided with the end-of-season for most of the included sports disciplines, indicating that athletes with persistent analgesic use may increase their use even further to accommodate intensified sports-related demands. This fluctuation was not observed for students with persistent analgesic use.

Methodological considerations

Paper I

Several covariates were included in the meta-regression analyses, but none were able to explain any of the heterogeneity observed in the pooled proportion estimates. Even after stratifying by analgesic type and prevalence measure and adjusting for covariates, the persistent high heterogeneity likely reflects differences in factors not accounted for by the included covariates and reduced the

confidence in the estimates, as reflected in the GRADE assessment. The limited number of studies for each type of analgesic and prevalence measure restricted the meta-regression analyses to only examining point prevalence of NSAID use, and subgroup analysis assessing the impact of performance level on proportion estimates was only possible for point prevalence of use of NSAIDs and unspecified analgesics. Additional meta-regression or subgroup analyses evaluating the impact of risk of bias, country, and sports discipline on pooled proportion estimates would have provided valuable information but was not possible due to the low number of studies available per outcome. When multiple subtypes of the analgesic were reported at the same time point (i.e., point prevalence of non-prescription and prescription NSAIDs), the subtype with the highest prevalence was included in the primary meta-analysis to avoid underestimation. Although the sensitivity analyses using the alternate estimate (i.e., with the lowest prevalence) did not significantly alter the estimates, this approach may still have resulted in an underestimation of proportion estimates, as the individual studies did not report data on the proportion of athletes using one subtype and the proportion using both. The categorisation of performance levels in the subgroup analyses relied on the terminology employed in each study, which may have introduced misclassification and potential residual confounding. However, as emphasised in a previous study, classifying and defining performance levels in sports remains challenging due to the inconsistent terminology in the literature. Finally, the pooled point prevalence estimates tended to be comparable to or greater than most period prevalence estimates. This finding may be attributed to several factors. Firstly, the poorly described and inconsistent definitions of point prevalence may have resulted in misclassification of prevalence measures. This was supported by a sensitivity analysis excluding studies with unclear definitions of point prevalence, which showed a significantly lower estimate of point prevalence of NSAID use. Secondly, current or recent analgesic use may be more accurately recalled than use over longer periods (e.g., past 3 or 6 months) (154), potentially resulting in systematic underestimation of period prevalence estimates. Finally, 61% of studies that reported point prevalence estimates focused specifically on analgesic use for managing sports-related pain and injury. For studies reporting period prevalence estimates, this was only 16%, indicating that these studies may assess a different construct.

Papers II, III, and IV

Participants

The recruitment method used in the cohort study did not allow the collection of data on the total number of potentially eligible participants, which precludes evaluation of any potential selection bias arising from non-participation. Similarly, in the recruitment process for focus group interviews, elite sports coordinators were given a list of eligible participants, but it is unclear whether all those eligible were approached about their willingness to participate. Participants for focus group interviews were also selected based on their response rate in the cohort study, specifically requiring them to have completed at least 80% of the weekly questionnaires. This criterion likely resulted in the selection of athletes who were either the most comfortable or most motivated to participate in the interviews. However, critical realism rests on the assumption of stratified ontology, and obtaining data on the *empirical* layer and the *actual* layer from the same individuals ensures that the perspectives being analysed are consistent and allows for a more detailed exploration of how these mechanisms operate in practice (i.e., the *real* layer) (75, 78). The focus group interviews included 75% female participants, but only 44% of athletes in the cohort study were female. Although there was an effort to match the sex distribution in the focus group interviews with that of the cohort study, a larger proportion of females accepted the invitation to participate in the interviews. In papers II and III, the prevalence of analgesic use was higher in females than in males, which may indicate that the sociocultural factors influencing analgesic use also differ between female and male athletes. However, in focus group interviews, there were no consistent narratives specific to sex, and as data saturation was achieved by the ninth interview, it was decided to conclude the qualitative data collection.

While the overall sample approximated the national average for sex distribution in upper secondary education institutions, the study cohorts (i.e., athletes and students) were not matched on sex, which likely impacted the results. In paper II, athletes had lower odds of analgesic use compared to students, but this finding was not replicated in the subgroup analyses stratified by sex. Regardless of athletic status, the prevalence of analgesic use was higher in females than males, and females constituted a higher proportion of the student cohort (i.e., 59%) compared to the athlete cohort (i.e., 44%).

Fifteen percent of students were involved in sports at the national or international level (i.e., engaged in elite sports without being part of an elite sports program). This introduced a degree of differential misclassification, which may have biased the analysis toward the null. This was

demonstrated in the analysis of the frequency outcome in paper II, showing no difference in the rate of analgesic use between athletes and students, but a sensitivity analysis excluding students competing at international or national level showed a statistically significantly higher rate of analgesic use in athletes compared to students. This was not observed in the analysis of the prevalence outcome. In the student cohort, 62% reported participating in sports at baseline, which aligns with national statistics that show that 60% of young people aged 16 to 19 years engage in sports (155).

While the classification of sports disciplines in paper III was informed by prior research, it may have restricted the ability to detect differences in analgesic use across these disciplines. Although data from focus group interviews aligned with the quantitative findings of paper III, showing no clear sports-specific patterns of analgesic use, the summary estimates from individual sports disciplines (Figure 6) indicate potential differences, with mean weekly prevalence estimates ranging from 12% in athletics and badminton to 44% in judo. This may suggest that the oversimplification in grouping of sports disciplines, coupled with focus group interviews that may not have fully captured the diversity in experiences within each sport, may have masked subtle, discipline-specific differences in analgesic use. However, due to the large number of individual sports disciplines included in the cohort study, it may not have feasible to identify these differences through interviews.

It remains unknown if there are systematic differences between upper secondary education institutions that offer elite sports programs and those that do not. However, as many schools were included, representing diverse geographical locations, sizes, and types of education programs, potential differences are likely to be random. Finally, the findings are specific to a Danish youth elite sports context and may not be generalisable to other cultures or settings.

Outcomes

The PAMUS questionnaire was specifically developed and content validated for youth elite athletes, with no data available on its content validity for student controls. However, to enable truthful reporting of any potential responses not identified during the development of PAMUS, an ‘other’ response option was included in the questions regarding reasons for use and types of analgesics used. Additionally, the PAMUS questionnaire did not assess analgesic dosage. Although this limits detailed analysis of consumption quantities, focus group interviews conducted during the

questionnaires' development and content validation indicated that youth elite athletes generally were unable to provide accurate information on analgesic dosage.

Monitoring analgesic use may affect awareness and consumption patterns among participants. A decrease in the prevalence of analgesic use was observed during the first eight weeks of the study. While caution is advised when interpreting first-time responses to similar questionnaires (70), previous injury surveillance research in youth athletes has also reported that injury prevalence and incidence are highest at the beginning of the season (156, 157). As 54% of athletes and 33% of students reported a sports-related injury at cohort entry, this may partly account for the higher prevalence of analgesic use observed in both athletes and students in the first weeks of the study. The varying timing of sports seasons across different disciplines included in the study may also have influenced the estimates, though the extent of this impact is unclear. However, elite sports coordinators explained that for most sports, the season approximately aligns with the academic year, spanning from August to June. The study relied exclusively on self-reported data on analgesic use, which poses a risk of information bias due to the potential for non-truthful or inaccurate reporting of analgesic consumption and misclassification of the types of analgesics used. However, it may be assumed that any potential response bias is equally distributed between cohorts, thus biasing the analysis towards the null. To minimise the risk of misclassification of analgesic types, a comprehensive list of brand names was provided for each category of analgesics, and two pharmacists reviewed this list to ensure that all relevant medications were included and easily identified.

Combining quantitative and qualitative data

Adopting a critical realism perspective reduces the challenges associated with paradigm 'switching', though it has received criticism (77). Critics argue that the critical realist approach to causality does not avoid the problem of induction at the empirical level, but instead relocates it to the level of the real (i.e., underlying mechanisms). This means that while it acknowledges the limitations of deriving generalisations from specific observations, it merely shifts the focus to the underlying mechanisms theorised to exist in the real world. (75). However, critical realism offers an important distinction as it argues that the goal of scientific inquiry is not merely to identify patterns of regularity, as in positivism, or to explore experiences and opinions, as in interpretivism, but to uncover the deeper, generative mechanisms that cause observable events (75, 77). For example, in examining analgesic use among youth elite athletes, a positivist approach might reveal a 20%

average weekly prevalence of analgesic use, with a higher prevalence among females compared to males. An interpretivist approach would add depth by exploring athletes' reflections on why they use analgesics, such as to manage pain or to meet the expectations of the coach. However, a critical realist approach probes deeper, asking *why* these influences exist and how they shape behaviour. For instance, critical realism explores the sociocultural mechanisms that impact athletes' use of analgesics, such as a coach's unspoken expectation for athletes to "push through" minor injuries, or peer influence that normalises analgesic use. It may also examine structural factors, like the competitive demands and difficulties balancing athletic and academic demands, which make analgesics appear necessary. By identifying these deeper generative mechanisms, the research can explain the overall patterns of analgesic use and the underlying norms, values, and structures that contribute to it. It has also been questioned why these mechanisms should be considered more reliable than empirical observations. In this regard, critical realism emphasises that empirical evidence alone often provides a limited, surface-level understanding of reality. While critical realism does not dismiss empirical evidence, it contends that such evidence is often shaped by more fundamental processes that are not always directly observable (75, 77). By uncovering these mechanisms, researchers can offer more robust and comprehensive explanations that account for both observable events and the mechanisms that cause them. Rather than claiming that generative mechanisms are inherently more reliable than empirical observations, critical realism suggest that they offer a more profound explanatory framework for understanding causality. Furthermore, building upon its constructivist epistemology, critical realism acknowledges the complexity and context-dependence of social phenomena. Unlike purely empirical approaches, it accepts that mechanisms may not always produce the same outcomes because they operate within specific contexts and in conjunction with other factors. In the context of youth elite athletes, critical realism helps explain why only a subset of athletes reported using analgesics as a coping strategy to handle the high demands from both their academic and athletic responsibilities. While a purely empirical approach might observe the low prevalence of this coping mechanism and conclude that it is insignificant, critical realism encourages further investigation into the conditions that make this behaviour more or less likely to emerge. For instance, critical realism considers how specific contextual factors, such as intensity of training schedules, or academic pressures during exam periods interact to make analgesic use a coping mechanism for some but not all athletes. By acknowledging that the coping behaviour is contingent on these intersecting demands and situational pressures, critical realism provides a more nuanced understanding of why this coping

strategy surfaces in some athletes and not others. This makes it a more nuanced approach when dealing with complex systems, as it avoids the oversimplification that can occur when relying solely on empirical observations (75, 77).

Clinical implications

The findings of this thesis suggest that individuals involved in youth elite sports, including coaches, physicians, physiotherapists, and dual-career counsellors should be aware of athletes' analgesic consumption patterns and have a foundational understanding of these medications. These key figures should recognise how their values and attitudes towards pharmacological management of pain, injury, and illness can significantly influence youth athletes' use of analgesics. This thesis did not investigate treatment aspects for pain and injury, but the findings likely have important clinical implications. For example, while international expert consensus provides guiding principles for pain management in elite athletes (38), these recommendations do not adequately translate to a youth setting. Youth elite athletes typically have limited access to sports medicine professionals and resources (31), which likely hinders compliance with recommendations. The setting, where the typical interventions employed for pain and injury management in this population, emphasises the need for comprehensive awareness and educational initiatives targeting youth elite athletes and their coaches regarding safe and appropriate use of analgesics. In the absence of evidence-based interventions to decrease inappropriate analgesic use in youth athletes, emphasis may be placed on providing information on overall guiding principles for analgesic use in sports, the potential consequences of analgesic use for pain and injury, and the risks associated with prolonged use. Callahan et al. highlighted the importance of health education for youth athletes, demonstrating that student-athletes who received concussion education were more likely to adopt positive social norms related to seeking care for concussions (158). This thesis showed that many youth elite athletes seem to have low, time-limited exposure to analgesics, with little indication of ongoing use, suggesting that intervening on a group level to reduce inappropriate use of analgesics is likely not justified, but providing information on safe analgesic use and encouraging these athletes to maintain their low usage levels through non-pharmacological pain relief methods could be beneficial. Contrarily, athletes with a higher use of analgesics, especially persistent users, may require more intensive and tailored pain management interventions. There is currently no direct evidence examining the utility of common interventions for managing long-term pain in athletes. Therefore, care for these athletes may be based on a combination of interventions recommended in general

pain management guidelines (38, 159) and condition-specific guidelines (160, 161). While it may be challenging to improve outcomes in athletes with long-term pain and more high-quality studies are needed (5), interventions should focus on preventing chronicity and improving function (38). In these specific cases, treatment approaches should be multidisciplinary, including physical therapy, psychological support, and regular monitoring of analgesics to prevent potential adverse events (38, 159, 162, 163). Physiotherapists play a crucial role in providing interventions that address pain without medication, promoting rehabilitation and educating young athletes on pain management strategies. However, the findings of this thesis also suggest that physiotherapists working with youth elite athletes may benefit from education on the underlying mechanisms that influence analgesic use. This knowledge would enable them to effectively address the topic in a clinical sports setting and enhance their ability to screen for ongoing analgesic use among athletes.

This thesis revealed that the most common reason for using analgesics among youth elite athletes was to treat pain not related to sports. In this regard, a literature review concluded that parents act as the primary providers of information regarding the use of over-the-counter analgesics and are the main suppliers of these medications to adolescents. The review emphasised the importance of healthcare professionals providing evidence-based information to parents on the safe use of analgesics (164). In addition, general practitioners, representing the first point of contact for people presenting with pain, play a pivotal role in recommending non-pharmacological treatment options, and educating young people on the safe use of analgesics. This is especially important as previous research has shown that analgesic use during adolescence predicts analgesic use in adulthood (165). Youth elite athletes also used analgesics to manage the demands of balancing academic and sports commitments, further emphasising that responsible use of analgesics extends beyond the sports realm. As such, coordinated efforts involving sports organisations, schools, parents, and healthcare providers may be important in fostering holistic environments focusing on youth athletes' general well-being.

Future research

This thesis has provided a comprehensive overview of existing knowledge and introduced original data to expand the understanding of analgesic use in youth elite athletes. However, it has also raised several new questions and revealed areas for future research. These questions are presented below, and recommendations are made for future research.

Targeting sociocultural influences on analgesic use: Pathways for research and interventions

This thesis has shown that while analgesic use is common among youth elite athletes at the group level, frequent or persistent use is limited to a subgroup of athletes, and specific sociocultural factors, such as pressure to participate in sport despite experiencing health problems and perceived responsibility for team performance, promote unnecessary analgesic use. There is a clear need for studies to identify features of sports environments with positive and negative influences on analgesic use and other health-related practices, focusing on sports organisational cultures, coaches, medical professionals, and interpersonal dynamics among athletes. These features may be explored through field observations followed by multiple case studies to facilitate cross-case analysis. Additional interview studies to explore the perspectives of sports organisational boards, coaches, parents, and medical professionals on analgesic use among youth elite athletes are also needed. Following the characterisation of these sports environments, the design of an intervention to reduce unnecessary analgesic use and promote sustainable pain management practices may be initiated. Such intervention may focus on educating athletes, coaches, and medical professionals about alternative pain management strategies and the potential risks of high or long-term use of analgesics. Based on the findings of paper III, which highlight the significant influence of coaches and health professionals' attitudes on youth athletes' use of analgesics, particular emphasis should be placed on training these key figures to promote responsible use. Rigorous evaluations of these interventions would be essential to assess their effectiveness in reducing unnecessary analgesic use.

Physical, mental, and cultural factors and life-long perspectives

This thesis also revealed the widespread use of analgesics to treat non-sports related pain, and the qualitative data further indicated that athletes use analgesics to manage the demands of balancing academic and sports commitments. Similarly, previous research has identified that adolescents also use analgesics to alleviate stress and anxiety, and as a coping strategy to normalise daily life (137). As such, future interventional research may focus on developing holistic interventions that address physical and mental health concerns. Expanding the scope of research to include cross-cultural comparisons of analgesic use would provide valuable insights into how analgesic use is influenced by cultural attitudes towards pain, injury, performance, and medication usage. By examining youth elite athletes in diverse cultural contexts, researchers could identify global patterns as well as unique cultural factors that influence analgesic use in youth elite sports. Although this thesis

focuses on youth elite athletes aged 15-20, exploring analgesic use patterns across younger and older age groups is essential. Tracking analgesic use across an athlete's career, from early adolescence into adulthood, could provide valuable insights into how attitudes and behaviours towards pharmacological pain management evolve as athletes progress in their careers. Such studies would help identify whether patterns of analgesic use during an athletes' early career predicts patterns of use later in life, offering important data to inform preventative strategies.

Identifying care pathways

Finally, there remains a significant knowledge gap pertaining to care pathways for youth elite athletes dealing with injury or pain. International expert consensus recommends that analgesics should be only one component of pain management (38), but there is no evidence examining which interventions are most commonly used, how they may be combined, or when more simple management protocols fail to manage pain (5). If the common use of analgesics, as reported in this thesis, is the result of insufficiency or ineffectiveness of the non-pharmacological pain management approaches available to clinicians, future research should prioritise the development and testing of new approaches, as highlighted by previous statement papers on the treatment of various sports-related injuries (160, 161). However, if the use of analgesics stems from organisational or structural factors that discourage the prioritisation of proper and timely rehabilitation, interventions should focus on addressing these systemic issues.

Conclusions

This PhD thesis provides comprehensive insights into the patterns of analgesic use in youth elite athletes. The available evidence demonstrated that analgesic use, particularly NSAIDs, is common in youth athletes across various competition levels, and is often used to manage sports-related injuries and associated symptoms. However, all studies provided cross-sectional estimates of analgesic use, and quality of evidence was very low to low, highlighting a need for more longitudinal, high-quality research in this area.

Longitudinal data involving 690 youth elite athletes confirmed that analgesics are commonly used in youth elite athletes, with weekly prevalence estimates ranging from 15 to 32% and users consuming analgesics 2.1-2.9 days per week. However, there were no differences in odds or rate of analgesic use when compared to students of the same sex. More athletes used topical gels and used analgesics to prevent or treat pain and injury in relation to sports participation compared to students.

A mixed-methods approach revealed no differences in the prevalence, frequency, or types of analgesics used between endurance athletes, technical athletes and team athletes, but fewer team athletes used analgesics to treat menstrual pain and other non-sports related pain. Athletes described diverse experiences with analgesics, from rare, non-systematic use of over-the-counter analgesics to daily, long-term use of opioids. These patterns were influenced by sociocultural factors, including the attitudes and expectations of parents, coaches, teammates, and health professionals.

Building on the qualitative insights, four distinct trajectories of analgesic use were identified in both athletes and students, including minimal/non-users, occasional users, frequent users, and persistent users. In both cohorts, the risk of analgesic use increased with higher trajectory groups, up to 20-28 times higher risk in persistent use groups compared to minimal/non-use groups. Frequent and persistent users had a higher proportion of females, higher weekly consumption frequency, and used analgesics with a higher risk of serious adverse events. These trajectories suggest that while most young people have minimal or occasional use of analgesics, 21% of athletes and 14% of students exhibit concerning usage patterns, with biweekly or weekly analgesic use.

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Appendix

Appendix 1 Interview guide, experts

Introduction	Thank you for agreeing to participate in this interview. We are interviewing you to better understand what experts within the fields of medicine, pharmacy, and questionnaire technique think are important aspects and concepts relating to use of pain medication in youth elite athletes. So, there are no right or wrong answers to any of our questions, we are interested in your own experiences and opinions. Participation in this study is voluntary. The interview should take approximately 30 minutes depending on how much information you would like to share. With your permission, I would like to record the interview. All responses will be kept confidential. This means that your interview responses will only be shared with the research team members, and we will ensure that any information we include in our report does not identify you as the respondent. You may decline to answer any question or stop the interview at any time and for any reason. Are there any questions about what I have just explained?
Interview	**Identifying overall concepts** Thinking broadly, can you name variables that you think would be important to measure in a cohort study aiming to quantify use of pain medication in youth elite athletes? In your response, please consider that respondents will be youth elite athletes aged 15-20 years. *Prompt:* Can you order those variables you just mentioned from least to most important? *Prompt:* What made you choose these variables? **Order of importance** The International Olympic Committee has published a consensus statement on management of pain in elite athletes. From this consensus statement we identified 5 overall themes including frequency of use, indications for use, types of analgesic drugs, route of obtainment (i.e., where and who do athletes get analgesics from?), and whether analgesics are used as a stand-alone treatment of pain or in combination with non-pharmacological treatment strategies. In your opinion, what are the most important aspects from a clinical and research standpoint, respectively? *Prompt:* Do you foresee any issues relating to the ability of youth athletes in answering these types of questions? *Prompt:* Considering your answers to the first question, where do you see these fit in/stand out from the themes identified from the IOC consensus statement? My next few questions aim to identify possible candidate items for the themes we just discussed. With your expertise and experiences, what are some indications for analgesic use?

	What are your thoughts on the recall period for establishing prevalence and frequency of analgesic use (e.g., seven days)? One way of identifying the types of analgesic drugs used by youth athletes is to present five broad categories with suitable examples of the most commonly used analgesics, for example paracetamol, NSAIDs, opioids, acetylsalicylic acid, and injections. What are your thoughts about this classification? *Prompt:* Is any major group of analgesic missing? *Prompt:* Do you have any other suggestions on how to classify analgesics? The International Olympic Committee lists five broad types of non-pharmacological treatments including passive modalities (e.g., massage, cryotherapy, ultrasound), exercise, psychosocial interventions (e.g., goal setting, stress management), sleep and nutrition, and surgery. Can you think of any other treatment modality that youth athletes may use for pain/injury? *If any new themes emerge, questions on candidate items were improvised* **Method of monitoring** The cohort study will consist of a weekly questionnaire on use of analgesics in the previous seven days. What are your experiences with monitoring medication use by self-report (for the pharmacy expert/medical doctor)? What are your experiences with weekly monitoring via SMS/app of this population (for questionnaire expert)? *Prompt:* What were some of the strengths of the methods you used? *Prompt:* What were some of the limitations of the methods you used?
Conclusion	Do you have any additional thoughts or experiences you would like to share before we end the interview?

Appendix 2 Interview guide, athletes

Introduction	Thank you for agreeing to participate in this interview. The aim of the interview is to gain an understanding of your knowledge of and experiences with using pain medication, both in relation to sport and unrelated to sport. This interview will provide the basis for developing a questionnaire we will be using in a research project on use of pain medication in youth elite athletes. So, there are no right or wrong answers to any of my questions, as we are interested in your own experiences. Participation in this study is voluntary. The interview should take approximately45 minutes depending on how much information you would like to share. With your permission, I would like to audio record the interview. All responses will be kept confidential. This means that your interview responses will only be shared with the research team members, and we will ensure that any information we include in our report does not identify you as the respondent. You may decline to answer any question or stop the interview at any time and for any reason. Are there any questions about what I have just explained?
Interview	Before we start, could you please state your name, age, sport, performance level, and for how long you have participated in your sport? **General understanding and knowledge of pain medication** With your own words, can you please explain what pain medication is? Can you tell me what you know about pain medication? *Prompt:* You can mention different types of pain medication, what they are used for, or how it they are used (i.e., pills, injections, topical) From where have you obtained knowledge on pain medication? Can you mention any side effects in relation to pain medication? Please tell me what you know about recommended doses of pain medication use **Consumption patterns:** How often do you use pain medication, for what reasons, and what types of analgesics you use? *Prompt:* How often is this specifically in relation to your sport? **Experiences with pain medication** Can you talk about some situations where you have used pain medication? If you can, please mention situations related to sport and situations unrelated to sport *Prompt:* Who suggested that you could use pain medication? *Prompt:* From where did you obtain pain medication? *Prompt:* What was the reason for the use? *Prompt:* What made you choose to use pain medication in this specific situation?

	Try to think about a situation where you were injured or experienced pain in relation to sport. Can you describe how this injury/pain was treated? *Prompt:* Did you seek any help or assistance to treat this injury/pain? If yes, who and what made you seek assistance/help from this person? What type(s) of pain medication have you previously used? **Attitudes and opinions** What are your opinions on using pain medication in relation to sport? *Prompt:* Can you think about a situation where you would not use pain medication in relation to sport, or where do not agree with others using it? **Sociocultural influences** Do you talk about pain medication on your team/in your sports club? *Prompt:* Do you speak about it with anyone outside of sport? *Prompt:* What do you think the people close to you think about using pain medication in relation to sport? (e.g., parents, friends, team mates, coach) *Prompt:* Who influences your use of and attitude towards use of pain medication?
Conclusion	Do you have any additional thoughts or experiences you would like to share before we end the interview? Thank you for participating and for the information you have shared today.

Appendix 3 Interview guide for cognitive interviews

Aim	Questions
Instructions - To gain insights into the respondents understanding of and the comprehensibility of the questionnaire instructions and overall theme	With your own words, please explain the questionnaire instructions Where any part of the questionnaire instructions difficult to understand? Are there any words or sentences that you would change to improve the readability and understanding of the questionnaire instructions?
Recall period - To identify if the recall period is appropriate and understandable	What does 'last seven days' mean to you? When reading 'last seven days' which days did you include in your response?
Item wording and relevance - To understand the comprehensibility and relevance of the questions from the respondent's perspective	With your own words, please explain what you understand from each of the questions Were the questions easy to read and comprehend? Were there any words that were difficult to understand? - If yes, can you think of another word or sentence construction that might make it easier to understand? In your opinion, were all questions relevant?
Answer options - To gain insights into comprehensibility of the answer options, how the respondent chooses the most appropriate answer option, and relevance of answer options	Please read out load all the answer options to the individual questions and tell me how you understand them. When responding to the questionnaire, what made you choose X answer option? Can you tell me about a situation where one of the other options would be applicable? Were the answer options easy to read and understand? Were there any words that were difficult to understand? If yes, can you think of another word or sentence construction that might make it easier to understand? In your opinion, were all answer options relevant?
Comprehensiveness/Content coverage	Do you think any relevant question is missing?

- At assess the comprehensiveness of the questions and answer options	Have you used or do you intend to use pain medication for reasons other than the ones listed in question 2? Please consider reasons for sports related use and non-sports related use of pain medication Have you used or do you intend to use other types of pain medication than the ones listed in question 3?
Formatting - To identify problems or challenges with the formatting or layout of the questionnaire	(Observe the respondent while reading the questionnaire; facial expressions, reading difficulties, duration) Do you have any suggestions to improve the layout of the that would make it easier to fill in the questionnaire?
Number of questions - To assess whether the number of questions is appropriate and feasible	What do you think of the number of questions and the time it took you to respond to the questionnaire?

Paper I

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Review

Prevalence, frequency, adverse events, and reasons for analgesic use in youth athletes: A systematic review and meta-analysis of 44,381 athletes

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ABSTRACT

Objectives: To identify the prevalence, frequency, adverse effects, and reasons for analgesic use in youth athletes.
Design: Systematic review and meta-analysis.
Methods: Systematic searches in Embase, Medline, and SPORT-Discus from inception to September 2021, screening of reference lists, and citation tracking were performed to identify observational studies including athletes aged 15–24 years and reporting data on prevalence and/or frequency of analgesic use. Study quality was assessed using the Newcastle-Ottawa Scale. Random-effect proportion meta-analyses, stratified by type of analgesic medication and prevalence measure, estimated the prevalence of analgesic use. Data on usage frequency, adverse events, and reasons for analgesic use was synthesized narratively.
Results: Forty-nine studies were included (44,381 athletes), of which 19 were good/high quality. Seven categories of analgesics were identified across 10 prevalence time-points. Meta-analyses suggested common use of NSAIDs (point prevalence 48 % [95 % CI 23 % to 73 %], in-season prevalence 92 % [95 % CI 88 % to 95 %]). The lowest prevalence was found for use of local anesthetic injections within the previous 12 months (2 % [95 % CI 1 % to 3 %]). Seven to 50 % of athletes reported weekly analgesics use. The proportion of adverse events ranged from 3.3 % to 19.2 %. Reasons for using analgesics included treatment of sports-related pain or injury, to treat illness, and to enhance performance.
Conclusions: Analgesics are commonly used in youth athletes, but estimates vary depending on type of analgesic and prevalence measure. As the majority of studies were of poor methodological quality, future high-quality research should include prospective data collection of analgesic use to understand consumption trajectories.

Practical implications

- Based on the evidence of common use of NSAIDs in youth athletes, clinicians may carefully assess their recommendation of NSAIDs use and adhere to consensus-based strategies for pain management in athletes
- Due to the common use of over-the-counter analgesics, poor awareness of benefits and harms, and perceived pressure to use analgesics, youth athletes may be educated about safe analgesic use and proper pain management strategies.
- Sports medicine clinicians must trade off the benefits, risks, burden and costs associated with analgesic management strategies, and in doing so, consider the athletes preferences and the tension between masking pain and understanding the protective role of pain in the presence of injury

1. Introduction

Analgesics, such as non-steroidal anti-inflammatory drugs (NSAIDs) and paracetamol, are among the most frequently used drugs in sports medicine,[1,2] and their use in athletes has received increasing attention in recent years. International guidelines have been developed for analgesic pain management in athletes at the elite, and mainly senior, level,[3] and the importance of athlete health protection through proper

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use of analgesics has become increasingly recognized. Unfortunately, this is not yet the case for youth athletes, where the use of analgesics has received less attention, particularly at the non-elite level.

Individual studies indicate that youth athletes regularly use analgesics.[4–8] While analgesics may be used safely and effectively as part of a multimodal treatment plan to manage sports-related pain and injury,[3] high or long-term use is associated with an increased risk of adverse events. Use of NSAIDs in athletes has been associated with a five times higher incidence of adverse events including gastrointestinal bleeding, hematuria, and cardiovascular events.[9] Long-term use of paracetamol may cause renal functioning disorder and hepatoxicity,[10,11] and even short-term use of opioids is associated with risk of addiction and cognitive disturbances.[12] Finally, previous reports indicate that youth athletes use analgesics to prevent pain and mask injury,[7,8,13] thus raising concerns of a potential increase in injury risk and progression of existing injuries.[14,15]

Despite indications of widespread use of analgesics in youth athletes and the potential health-related concerns associated with the use, no systematic review has yet been conducted to summarize the evidence on the use of analgesics in youth athletes. Accordingly, the primary aim of this systematic review and meta-analysis was to identify the prevalence of analgesics use in youth athletes. The secondary aims were to identify usage frequency, adverse events, and reasons for analgesic use in youth athletes.

2. Methods

This systematic review was guided by the recommendations for performing systematic reviews in the Cochrane Handbook[16] and reported in accordance with The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA 2020) statement[17] and the PERSiST (implementing Prisma in Exercise, Rehabilitation, Sport medicine and SporTs science) guidance.[18] The study protocol was pre-registered and made publicly available at Open Science Framework prior to initiating the literature searches (https://osf.io/4ktsr/).

2.1. Eligibility criteria

Cross-sectional studies, retrospective or prospective cohort studies, case-control studies, and case series published in full-text in peer-reviewed journals in English, Spanish, Italian, Dutch, or any Scandinavian language were eligible for inclusion. The population of interest was athletes aged 15–24 years old participating in any sports discipline at any performance level. As the definition of *youth* varies between countries and sports disciplines, we defined *youth* according to the United Nations as persons between 15 and 24 years of age.[19] Studies were excluded if they included mixed populations (i.e., athletes and non-athletes) and did not report separate data for athletes only, assessed use of analgesics in athletic population with underlying conditions or diseases not related to sport (e.g., cancer pain, dysmenorrhea), if studies only reported on non-medical use of analgesics, and if full text was not available.

2.2. Outcomes

The primary outcome was prevalence of analgesic use. Analgesics were defined as any pharmacological agent producing diminished sensation to pain without loss of consciousness,[20] and were categorized as paracetamol, non-steroid anti-inflammatory drugs (NSAIDs), acetylsalicylic acid, opioids, local anesthetic injections, mixed analgesics (if reported as more than one type of analgesic e.g., paracetamol and/or NSAIDs without the possibility to sub-classify), and unspecified analgesics (if reported simply as 'analgesics' without further specifying the type) without restrictions on route of administration. Both point prevalence (i.e., proportion of athletes reporting analgesic use at a specific point in time) and period prevalence measures (i.e., the proportion of athletes reporting analgesic use at any point during a given time period of interest)[21] were included with no restrictions on methods of reporting (e.g., athlete self-report, pharmacy record, coach reports and doping control forms) nor indications or reasons for analgesic use (i.e., both sports-related and non-sports-related reasons). Secondary outcomes were frequency of analgesic use, adverse events, and reasons for use. All approaches of estimating and reporting frequency of analgesic use, adverse events, and reasons for use were included.

2.3. Search strategy

Systematic literature searches were performed in Embase (Ovid), Medline (PubMed), and SPORT-Discus from database inception to September 17th 2021 with no language restrictions. The search strategy was developed by two authors (JRP and AB) in collaboration with a research librarian and included Medical Subject Headings (MeSH) terms and individual text words in title and abstract. The search strategy was suitably adapted to the specifications of the individual databases. The complete search strategy is presented in Supplementary Table 1. Hand-searches were performed by screening the cited references in a previous systematic review investigating analgesic use in elite athletes.[22] Finally, reference lists of included studies were screened to identify additional studies, and forward citation tracking of the included studies was performed in Web of Science.

2.4. Selection of studies

Screening was independently carried out by two authors (JRP and AA) following duplicate removal in EndNote X9 (Clarivate Analytics, Philadelphia, USA). Articles were initially screened by title and abstract for eligibility using Covidence systematic review software (Veritas Health Innovation, Melbourne, Australia). Full-text articles were then retrieved and screened for inclusion. Disagreements were solved by consensus.

2.5. Data extraction

Data were independently extracted by two authors (JRP and AA) using a standardized Excel data extraction sheet (Supplementary Table 2). Inconsistencies were solved by consensus. If unable to reach consensus, a third author (AB) was consulted. In case of several types of analgesics or multiple prevalence measures were reported in the same study, all were extracted. If relevant data was not reported in the text, the data was extracted from figures and graphs. If the data could not be extracted from the published studies, an e-mail including a list with the data of interest were sent to the corresponding author of the study. The corresponding author was contacted twice within a two-week period. If no response was obtained two weeks after the second request, the first or last listed author was contacted. Data was considered missing if no replies had been received from the authors two weeks after the second email.

2.6. Quality assessment

Two reviewers (JRP and AA) independently assessed study quality using the Newcastle-Ottawa scale (NOS) for cohort studies and the modified NOS for cross-sectional studies as described in the Cochrane Handbook for Systematic Reviews of Interventions.[16,23] These tools comprise three overall domains relating to selection of study groups, comparability of the groups, and ascertainment of the exposure/outcome of interest. For cohort studies, eight items were scored with one or two stars, for a maximum total of nine stars, leading to an overall judgement of study quality as high, moderate or low. For cross-sectional studies, seven items were scored with one or two stars, for a maximum total of 10 stars, leading to an overall judgement of study quality as very good, good, satisfactory, or unsatisfactory. Disagreements between the reviewers were solved by consensus. If unable to reach consensus, a third author (AB) was consulted. Overall quality of evidence was

evaluated for point prevalence outcomes using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) tool for systematic reviews of prognostic studies.[24,25]

2.7. Data synthesis

Pooled prevalences with 95 % confidence intervals (95 % CI) were calculated using random-effects meta-analyses with continuity corrections using the 'metaprop' command in Stata version 17 (StataCorp 2021, College Station, TX, USA). The metaprop command computes 95 % CIs by using the score statistic and the exact binomial methods and incorporates Freeman-Tukey double arcsine transformation of proportions.[26] Pooled prevalences were quantified for NSAIDs, unspecified analgesics, mixed analgesics, paracetamol, acetylsalicylic acid, opioids, and local anesthetic injections. The results were reported stratified by type prevalence measure (point prevalence, 3-days period prevalence, 7-days period prevalence, 1-month period prevalence, 3-months period prevalence, 6-months period prevalence, 12-months period prevalence, in-season, previous season, and lifetime use). In case a study reported more than one subtype of the same analgesic (e.g., prescription and non-prescription NSAIDs) at the same time point, the analgesic with the highest prevalence was included in the main analysis to avoid underestimation of pooled proportion estimates. Univariate meta-regression analyses were performed to investigate the effect of participant and study characteristics on the proportion estimates. The covariates tested in meta-regression analyses included age, percentage of female, and year of publication. In accordance with the Cochrane Handbook, meta-regression analyses were only performed when ≥10 studies were available.[16] The impact of level of sports performance level (elite (i.e., elite or professional as defined in individual studies) vs. non-elite (i.e., all other performance levels)) was investigated by subgroup analysis. Statistical heterogeneity was estimated as I-squared (I^2) and tau square (τ^2) and presented in analyses containing ≥4 studies, as the I^2 estimate is biased in meta-analyses of very few studies.[27–29] Small-study bias was assessed by visual inspection of funnel plots. Due to the low number of studies available per outcome, small study bias was only assessed for point prevalence of use of NSAIDs and unspecified analgesics, in accordance with the Cochrane Handbook.[16] Due to heterogeneity in terms of measures used, data on frequency of analgesic use, adverse events, and reasons for use was summarized narratively.

2.7.1. Sensitivity analyses

Numerous sensitivity analyses were performed to examine whether overall findings were robust to the potentially influential decisions made. Firstly, in studies reporting more than one subtype of the same analgesic at the same time point (e.g., prescription and non-prescription NSAIDs), the primary meta-analyses using the analgesic with the highest prevalence were re-run using the alternate type of analgesic (i.e., the analgesic with the lower prevalence). Secondly, due to inconsistency and unclear reporting of the definition of point prevalence, two sensitivity analyses were performed by excluding, firstly, the studies explicitly stating that they assessed current use, and secondly, the studies with unclear definitions of point prevalence. Finally, due to unclear reporting of route of administration in most studies, a sensitivity analysis was performed by categorizing local anesthetic injections by active pharmacological agent (i.e., NSAID, paracetamol, acetylsalicylic acid, mixed analgesics, opioids, or unspecified analgesics). These sensitivity analyses were not pre-registered.

3. Results

3.1. Study selection process

Following the initial literature search and duplicate removal, 10,595 records were screened by title/abstract and 287 full-text articles were considered for inclusion. After review, 39 studies were included. With the addition of three studies identified from citation tracking, and seven studies identified from reference list screening, the final number of included studies was 49 (Fig. 1). All included studies are referenced in supplementary Tables 3 and 4.

3.2. Study characteristics

Of the 49 included studies, 43 were cross-sectional studies and six were cohort studies, reporting data on a total of 44,381 athletes (range 21–11,577) (37 % were female). Data on analgesic use from all six cohort studies was cross-sectional baseline data. Studies were conducted across 19 countries, with three studies including athletes from multiple countries during international tournaments. Twenty-three studies involved multiple sports. Nine of 26 single-sport studies involved football (soccer). Other sports found in single-sport studies included swimming, softball, wrestling, handball, cycling, basketball, ice hockey, and ballet. Four studies did not specify the type of sport studied. In terms of performance level, 15 studies included elite athletes, 14 studies included collegiate athletes, four studies included competitive athletes, five studies included athletes from multiple levels, three studies included professional athletes, and two studies included recreational athletes. Subelite and amateur athletes were included in one study each, and four studies did not specify level of performance. Study characteristics are reported in Supplementary Table 3. Athlete-reported questionnaires were the most common data collection tool (40 studies), with the remaining studies obtaining data from athlete interviews, doping control forms, medical records, and urine sample testing. NSAIDs were the most commonly studied group of analgesic, followed by unspecified analgesics, mixed analgesics, local anesthetic injections, paracetamol, opioids, and acetylsalicylic acid (Supplementary Table 4). A total of 10 prevalence time points were identified, including point prevalence, 3 days-, 1 week-, 1 month, 3 months, 6 months, 12 months, in-season-, previous season-, and lifetime period prevalence. The number of available outcomes for each analgesic group stratified by type of prevalence measure is presented in Supplementary Table 5.

3.3. Study quality and overall quality of the evidence

The methodological quality of the included studies is summarized in Table 1 (cohort studies) and Table 2 (cross-sectional studies). For cohort studies, three studies were judged as high quality, two studies moderate quality, and one study low quality. For cross-sectional studies, two were judged as very good quality, 14 as good quality, 19 as satisfactory quality, and eight as unsatisfactory. The selection domain was generally scored low as studies commonly did not report information on the characteristics of non-respondents (86 %), did not provide a sample size calculation (79 %), and applied convenience sampling strategies (44 %). Conversely, the outcome domain was generally well-described as all included studies assessed the outcome either by objective measures (i.e., urine sampling) or self-report and 88 % clearly described and applied appropriate statistical analyses. Risk of small study-bias was indicated by the visual asymmetry in the funnel plot for NSAIDs (Supplementary Fig. 1). Overall quality of evidence ranged from very low to low (Supplementary Table 6). The main reasons for downgrading were inconsistency and indirectness.

3.4. Prevalence of analgesic use

3.4.1. NSAIDs

The pooled point prevalence of NSAIDs use in youth athletes was 48 % (95 % CI 23 % to 73 %: 13 studies; $tau^2 = 0.11$; $I^2 = 99.7$; very low quality of evidence). The pooled period prevalence estimates of NSAIDs use ranged from 7 % within the previous seven days (95 % CI 6 % to 8 %: two studies) to 95 % lifetime prevalence (95 % CI 92 % to 97 %: two studies) (Fig. 2).

The meta-regression analyses on point prevalence of NSAIDs use showed no impact of age (slope 0.02 [95 % CI −0.05 to 0.09];

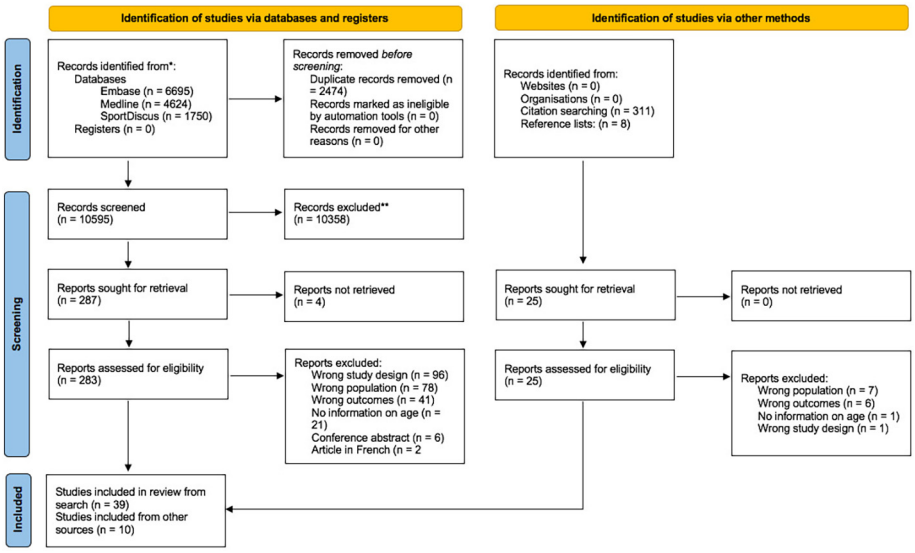

Fig. 1. Flow chart.

tau^2 = 0.13; 11 studies), % female (slope 0.00 [95 % CI −0.01 to 0.01]; tau^2 = 0.13; 12 studies), or year of publication (slope 0.00 [95 % CI −0.02 to 0.02]; tau^2 = 0.12; 13 studies). The subgroup analysis showed lower point prevalence of NSAIDs use in non-elite athletes (31 % [95 % CI 6 % to 64 %]: 7 studies) than in elite athletes (64 % [95 % CI 20 % to 97 %]: 5 studies) but did not reduce heterogeneity in the pooled estimates (I^2 = 99.7 % and 99.5 %, respectively). The sensitivity analysis on analgesic subtypes did not change the results of the main analyses (Supplementary Fig. 2). Excluding the four studies assessing current NSAIDs use on the point prevalence meta-analysis resulted in an increased, but not statistically significantly higher, point prevalence (66 % [95 % CI 0.36 to 0.89]; nine studies) and did not reduce heterogeneity (I^2 = 99.3 %) (Supplementary Fig. 3). However, excluding the nine studies with unclear definitions of point prevalence resulted in a statistically significantly lower point prevalence (12 % [95 % CI 0.01 to 0.33]; four studies) but did not reduce heterogeneity (I^2 = 99.3 %).

3.4.2. Unspecified analgesics

The pooled point prevalence of use of unspecified analgesics was 50 % (95 % CI 0.36 to 0.64: nine studies; I^2 = 97.6; low quality of evidence). The pooled period prevalence estimates ranged from 7 % within the previous three days (95 % CI 0.06 to 0.8: two studies) to 73 % in the previous season (95 % CI 0.66 to 0.80: one study) (Fig. 2). The subgroup analysis showed higher point prevalence of use of unspecified analgesics in non-elite athletes (61 % [57 % to 65 %] five studies) than in elite athletes (40 % [95 % CI 15 % to 67 %]: three studies), and also reduced heterogeneity in the pooled estimate for non-elite athletes (I^2 = 56.3, I^2 not calculated for elite athlete subgroup due to too few studies) Conversely, the 12-months period prevalence was higher in elite athletes (71 % [95 % CI 61 % to 80 %] three studies) than in non-elite athletes (36 % [95 % CI 33 % to 39 %]: two studies) (I^2 valued not calculated due to too few studies in each subgroup). The sensitivity analyses did not change the results of the main analyses nor reduce heterogeneity (Supplementary Figs. 4 and 5). As only one study assessed current use of unspecified analgesics, the impact of pooling different point prevalence measures was only investigated by excluding this one study.

3.4.3. Mixed analgesics

The pooled point prevalence of use of mixed analgesics was 54 % (95 % CI 0.29 to 0.79: five studies; low quality of evidence). The pooled period prevalence estimates ranged from 11 % within the previous seven days (95 % CI 0.08 to 0.14: two studies) to 29 % within the previous 12 months (95 % CI 0.28 to 0.30: two studies) (Fig. 2). Descriptions of the included medications is outlined in Supplementary Table 3.

3.4.4. Local anesthetic injections

The pooled 3-days period prevalence estimate for use of local anesthetic injections was 2 % (95 % CI 0.01 to 0.03: two studies). Additionally, one study reported a 12-months period prevalence of 2 % (95 % CI 0.02 to 0.02) (Fig. 2). The sensitivity analysis categorizing local anesthetic injections according to the active pharmacological agent resulted in a decreased, but not statistically significantly lower, point prevalence of unspecified analgesic use (43 % [95 % CI 0.20 to 0.67]; 11 studies). Similarly, a non-significant decrease in point prevalence of use of mixed analgesics was observed (0.43 [95 % CI 0.10 to 0.80]; six studies).

3.4.5. Paracetamol, acetylsalicylic acid, and opioids

The pooled point prevalence of paracetamol use was 21 % (95 % CI 0.17 to 0.25: two studies; very low quality of evidence). One study each reported data on paracetamol use within the previous month (34 % [95 % CI 0.30 to 0.38]), three months (3 % [95 % CI 0.00 to 0.06]) and 12 months (19 % [95 % CI 0.18 to 0.20]). In regard to acetylsalicylic acid use, one study

Table 1
Study quality for cohort studies.

Study (year)	Selection (1)	Selection (2)	Selection (3)	Selection (4)	Comparability (1)	Outcome (1)	Outcome (2)	Outcome (3)	Overall judgement
Anderson (1991)	*	*			*		*		Low
Gouttebarge (2018)	*	*	*	*	*	*	*	*	High
Mohamad Shariff (2013)	*	*	*	*	*	*	*	*	High
Schmidt (2014)	*	*		*	*		*		Moderate
Spiera (2021)	*	*		*	*	*	*		Moderate
Tso (2020)	*	*	*	*	*		*	*	High

One asterisk indicates that the domain was scored with one star.

Table 2
Study quality for cross-sectional studies.

Study (year)	Selection (1)	Selection (2)	Selection (3)	Selection (4)	Comparability (1)	Outcome (1)	Outcome (2)	Overall judgement
Aavikko (2013)	*	*	*	**	**	*	*	Very good
Alaranta (2006)	*	*		**	**	*	*	Good
Alexander (2021)	*		*	*	**	*	*	Good
Babwah (2014)	*			**	**	*	*	Good
Braun (2017)				**	**	*	*	Satisfactory
Brewer (2014)	*				**	*	*	Satisfactory
Buckman (2013)	*				**	*	*	Satisfactory
Christopher (2020)				**	**	*	*	Satisfactory
De Souza (2012)				**	**	*	*	Satisfactory
Garcin (2005)				**	**	**	*	Good
Goulet (2010)	*				**	*	*	Satisfactory
Hibberd (2013)				**	**	*	*	Satisfactory
Hill (2004)				**	**	*	*	Satisfactory
Holmes (2013)				**	**	*	*	Satisfactory
Kahlenberg (2016)	*	*			**	*	*	Satisfactory
Kordi (2012)	*	*	*		**	*	*	Good
Lazic (2011)	*			**	**	*	*	Good
Loosli (1992)	*			**	**	*	*	Good
Loraschi (2014)				**	**	*	*	Satisfactory
Malek (2014)	*		*		**	*	*	Satisfactory
Mkumbuzi (2015)				**	**	*	*	Satisfactory
O'Connor (2019)					**	*	*	Unsatisfactory
Omeragic (2021)		*		**	**	*	*	Good
Ozkan (2020)	*				**	*	*	Satisfactory
Peric (2016)					**	*	*	Unsatisfactory
Perry (2020)				**	**	*	*	Satisfactory
Qasrawi (2021)	*	*	*		**	*	*	Good
Rossi (2016)	*			**	**	*	*	Good
Rossi (2021)	*			**	**	*	*	Good
Rovere (1985)				**	**	*		Satisfactory
Sari (2021)	*	*	*	**	*	*	*	Very good
Schneider (2019)	*			**	**	*	*	Good
Sekulic (2008)					**	*	*	Unsatisfactory
Selanne (2014)					**	*	*	Unsatisfactory
Spence (1996)	*	*			**	*	*	Satisfactory
Stache (2014)					**	*		Unsatisfactory
Tricker (1996)	*				**	*	*	Satisfactory
Tricker (2000)	*				**	*		Unsatisfactory
Tscholl (2009)	*	*		**	**	*	*	Good
Warner (2002)	*			**	**	*	*	Good
Wolf (2011)	*				**	*	*	Satisfactory
Yargic (2021)					**	*	*	Unsatisfactory
Zenic (2010)					**	*	*	Unsatisfactory

One asterisk indicates that the domain was scored with one star. Two asterisks indicate that the domain was scored with two stars.

each reported data on point prevalence (25 % [95 % CI 0.19 to 0.31]; low quality of evidence), 1-month period prevalence (3 % [95 % CI 0.02 to 0.04]), 3-months period prevalence (12 % [95 % CI 0.02 to 0.22]), and 12-months period prevalence (16 % [95 % CI 0.15 to 0.17]). The pooled 12-months period prevalence of opioid use was 13 % (95 % CI 0.13 to 0.14: two studies). One study each reported data on point prevalence (3 % [95 % CI 0.01 to 0.05]: low quality of evidence) and 3-months period prevalence (3 % [95 % CI 0.00 to 0.06]) of opioid use (Fig. 2).

3.4.6. Sex specific differences in prevalence of analgesic use

Five studies reported higher prevalence of analgesic use in female athletes compared to male athletes, and two studies, reported higher prevalence in male athletes. In female athletes, the point prevalence ranged from 28 to 43 %, 1-month period prevalence from 53 to 75 %, and 12-months period prevalence from 17 to 34 %. In male athletes, these were 20–30 %, 30–60 %, and 19–39 %, respectively.

3.5. Frequency of analgesic use

Frequency of analgesic use was reported by 14 studies (Table 3). Across studies, 7 % and 50 % of athletes reporting weekly use of analgesics, and 6–35 % reported monthly use.

3.6. Adverse events

Four studies reported on adverse events associated with analgesic use. In relation to NSAIDs use, the proportion of users reporting adverse events ranged from 3.3 % to 19.2 %, and included gastro-intestinal symptoms, tiredness, light-headedness, decrease in perceived muscle power, increased sweating, increased appetite, dry mouth, exacerbation of asthma symptoms, nausea, vomiting, headache, fatigue, allergy, non-immunomodulated adverse reactions, bronchospasms, and anaphylaxis. One study reported on adverse events associated with non-NSAID analgesics (unspecified) and included non-immunomodulated adverse reactions and oral allergy syndrome reported by 6.3 % of users.

3.7. Reasons for analgesic use

Twenty studies reported on reasons for analgesics use. Athletes reported using analgesics to treat sports-related pain or injury in 16 studies, to prevent or block pain to enable participation in sport in seven studies, to manage general muscle soreness or cramps in two studies, to treat illness including fever, headaches, and colds, and to improve performance in one study each, respectively. One study presented estimates for analgesic use stratified by sports-related reasons and non-sports related reasons, with 35 % of users reporting sports-related reasons.

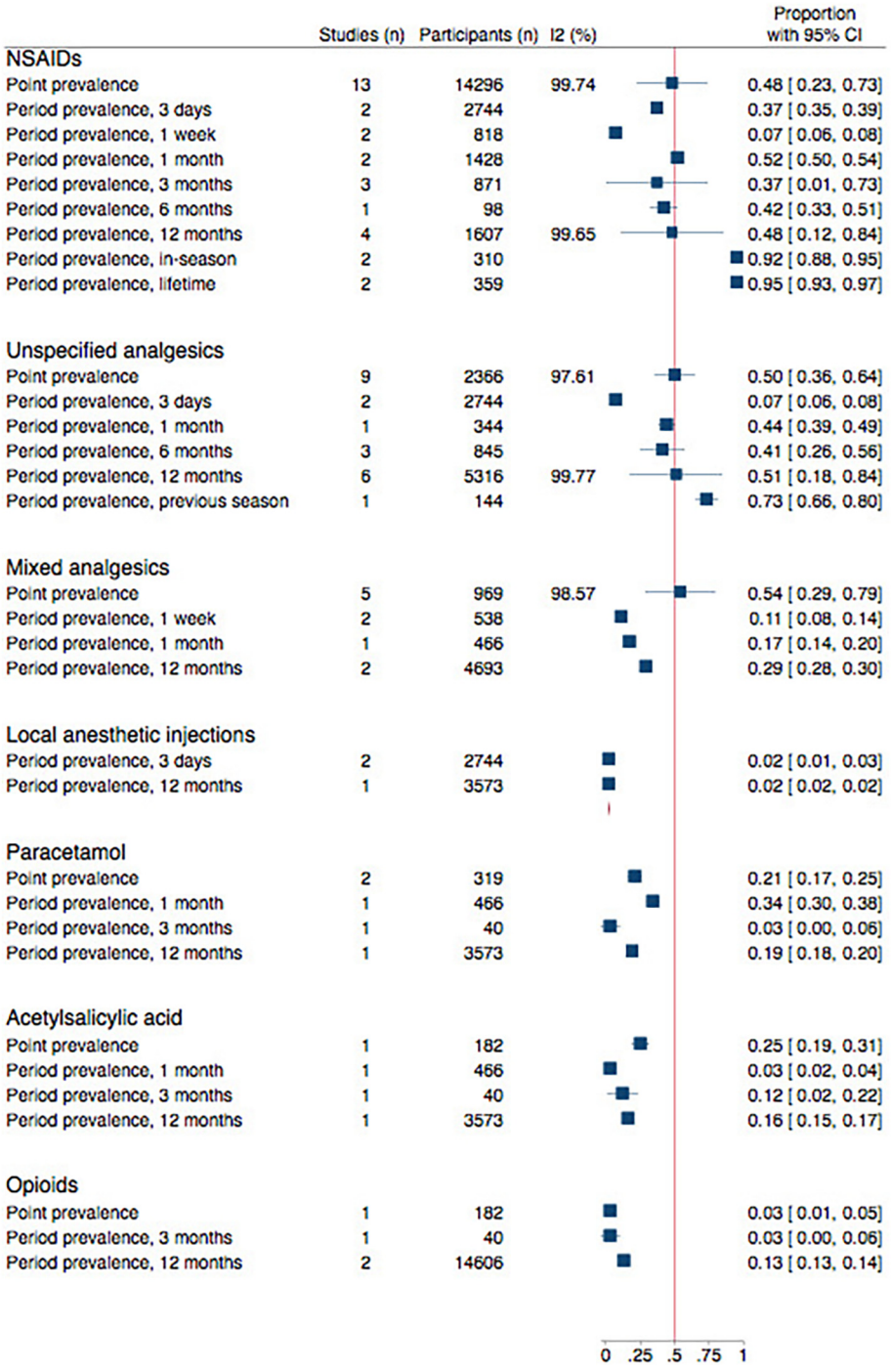

Fig. 2. Stratified prevalence meta-analysis. Rows indicate pooled estimates. Red lines represent a 50 % prevalence. The boxes indicate study weight and whiskers indicate 95 % CI.

4. Discussion

This systematic review and meta-analysis examined the prevalence, frequency, adverse effects, and reasons for analgesic use in youth athletes. NSAIDs were commonly used with the pooled proportions of athletes reporting use in the previous 3 days to 12 months ranging from 7 to 92 %. In general, other analgesics were used less commonly, with local anesthetic injections and opioids being the least commonly used groups of analgesics. Overall quality of evidence was very low to low, and the statistical heterogeneity was deemed high in the pooled estimates. Frequency of analgesic use varied widely with 7–50 % of athletes reporting weekly use and 6–35 % reporting monthly use. The proportion of athletes reporting adverse events ranged from 3.3 % to 19.2 %.

4.1. Prevalence of analgesic use

NSAIDs were the most frequently studied and reported to be the most commonly used type of analgesic, with approximately one in two youth athletes reporting NSAIDs use. These findings are in line

Table 3
Frequency outcomes.

Author (year)	Country	Sport (performance level)	Sample size	% female	Type of analgesic	Frequency (%)[a]
Brewer et al. (2014)	USA	Aerobics, jogging, resistance training, racquetball (Recreational)	263	51.7	Ibuprofen, acetaminophen, or naproxen	Once/week: 21.3 Twice/week: 9.5
Christopher et al. (2020)	USA	Mixed[b] (Collegiate, NCAA-division 1–3)	313	73.4	NSAIDs	3–7 times/week: 9.9 1–2 times/week: 20.6 1–3 times/month: 34.9
Goulet et al. (2010)	Canada	Mixed[c] (N/I)	3573	44	Aspirin Local anesthetics Tylenol Atasol Other analgesics	Aspirin Rarely: 8.5 Occasionally: 4.7 Regularly: 1.0 Local anesthetics Rarely: 0.7 Occasionally: 0.2 Regularly: 0.4 Tylenol Rarely: 9.7 Occasionally: 5.9 Regularly: 1.4 Atasol Rarely: 2.0 Occasionally: 1.0 Regularly: 0.5 Other analgesics Rarely: 1.7 Occasionally: 1.1 Regularly: 0.4
Hibberd et al. (2013)	USA	Swimming (high school elite)	102	61.7	Analgesics (unspecified)	<1 time/month: 14.7 1–3 times/month: 23.7 ≥1 times/week: 33.3
Holmes et al. (2013)	USA	Football (Collegiate, NCAA-division 1 and 3)	210	0	NSAIDs	Daily/weekly (in season): 50 Daily/weekly (out of season): 14 Usually/always (prior to match): 10.9 Usually/always (during match): 0.5 Usually/always (after match): 32.7 Usually/always (prior to practice): 5.2 Usually/always (during practice): 0.5 Usually/always (after practice): 20.4
Mkumbuzi et al. (2015)	Zimbabwe	Football (professional)	86	0	NSAIDs	Daily: 12 Weekly: 11 Twice/wk.: 0 Monthly: 6 Rarely: 43
Omeragic et al. (2021)	Bosnia and Herzegovina	Athletics, weightlifting, karate, handball, basketball, volleyball, football (competitive)	112	34.8	Analgesics (unspecified)	Daily: 19.6 Weekly: 10.7 As needed: 3.6
Peric et al. (2016)	Croatia	Ballet (elite)	21	100	Analgesics (unspecified)	Occasionally:53 Frequently: 37
Qasrawi et al. (2021)	Palestine	Mixed[d] (N/I)	227	41.4	NSAIDs	3–7 times/week: 3.5 Once/week: 7 1–2 times/month: 14.1 Few times/year: 33
Schneider et al. (2019)	Germany	Basketball (elite)	182	29.1	Mixed analgesics[e]	Frequent use: 40.1

Table 3 (*continued*)

Author (year)	Country	Sport (performance level)	Sample size	% female	Type of analgesic	Frequency (%)[a]
					Ibuprofen	15.9
					Diclofenac	21.4
					Paracetamol	6.6
					Acetylsalicylic acid	6.6
					Tramadol	0
Sekulic et al. (2008)	Serbia	Dance (N/I)	21	100	Analgesics (unspecified)	Rarely: 19.1 Often: 4.8
Tso et al. (2020)	USA	American football, endurance sports (Collegiate, NCAA division 1 and 3 and competitive high school)	286	0	NSAIDs	Daily: 11.5 Weekly: 15 Rarely: 66.7
Yargic et al. (2021)	Turkey	Wrestling (elite)	166	27.7	NSAIDs or paracetamol	1–3 days/week: 46.9 4–6 days/week: 12.6 7 days/week: 2.4
Zenic et al. (2010)	Croatia	Ballet, dance, synchronized swimming (Amateur, semi-professional, professional)	69	100	Analgesics (unspecified)	Rarely: 24.6 Occasionally: 17.4 Regularly: 10.1

[a] Expressed as a proportion of the total sample size.
[b] American football, lacrosse, rugby, basketball, football, tennis, volleyball, baseball, softball, cross country, dance, golf, swimming, track and field, triathlon.
[c] Baseball, gymnastics, swimming, basketball, hockey, skiing, athletics, soccer, speed skating.
[d] Football, basketball, volleyball, table tennis, marathon, tennis, handball, badminton, swimming, taekwondo, gymnastics, weightlifting, boxing.
[e] Defined as use of either ibuprofen, diclofenac, paracetamol, acetylsalicylic acid, or tramadol.

with the results of a previous systematic review of analgesic use in elite-level, and mainly senior, athletes.[22] The analgesic efficacy of NSAIDs has consistently been reported to be small and no better than other oral analgesics for musculoskeletal pain and acute soft tissue injuries.[30–32] This is especially of importance as high or long-term use of NSAIDs are associated with multiple severe health risks.[33] Due to these health risks, guidelines on analgesic pain management in athletes recommend paracetamol alone or in combination with NSAIDs for acute pain and highlight that in most cases there is no rationale for long-term use of NSAIDs.[3,34] Despite these recommendations, the reported rates of paracetamol use tended to be lower than estimates for NSAIDs use in studies reporting paracetamol and NSAIDs data separately.

The pooled proportions of youth athletes reporting use of opioids ranged from 3 % to 13 % across prevalence measures. Our finding of varying estimates and few studies reporting prevalence of opioid use in athletes is in line with a previous systematic review of opioid use in sport.[35] While opioids may be considered in athletes for management of severe acute pain when non-opioid medications and non-pharmacological treatment strategies are insufficient, as proposed in the International Olympic Committees consensus statement,[3,34] they are associated with serious adverse effects warranting a thorough diagnostic evaluation and considerations for regulations of substance use in sport.[34] However, as none of the included studies measuring opioid use reported the reasons for, frequency, or duration of usage, our understanding of opioid use in youth athletes remains limited. Furthermore, a recent study reported that opioid use during active athletic career predicted use and misuse in later life and retirement in former athletes,[36] further highlighting the importance of closely monitoring and cautiously prescribing opioids to youth athletes.

Similarly to our findings, a recent systematic review reported varying rates of analgesic use for musculoskeletal pain in non-athlete adolescents (≤19 years of age), with the proportion reporting analgesic use ranging from 8 to 75 % across 20 individual studies.[37] Another systematic review including 163 individual studies showed that the proportion of adolescents reporting to have self-medicated analgesics ranged from 5.4 % to 93 % across 14 different prevalence measures.[38] While previous systematic reviews synthesizing the use of analgesics in sports have been published,[22,39,40] none have assessed the use in adult athletes only, thus hindering a direct comparison between youth and adult athletes. However, our meta-regression analysis showed no impact of age, suggesting that the prevalence of analgesic use was not significantly associated with age.

4.2. Frequency of analgesic use

Weekly use of analgesics was reported by 7–50 % of youth athletes, while 6–35 % reported monthly use. These findings are of particular concern due to the increasing risk of adverse effects associated with high or long-term analgesic consumption.[11,41] Self-medication and lack of knowledge regarding adverse effects and consequences of prolonged use[5,13,42] may be important contributors to this finding. The extent of self-medication practices is supported by Sari and Pedersen et al.[4] reporting that almost 90 % of youth elite handball players obtained analgesics from home or bought it over-the-counter, while Tricker et al.[13] reported that only 14 % of college athletes obtained analgesics after consulting a physician.

4.3. Reasons for analgesic use

Reasons for using analgesics included treatment of sports-related pain and injury and associated symptoms, to treat illness, to enhance performance, and to prevent or block pain to enable participation in sport. The latter is in contrast to guidelines and recommendations for analgesic pain management in athletes stating that analgesics should not be used for pain prevention.[3,34] In this context, a main concern is that delayed reporting of pain and injury and removal from athletic activity due to analgesic use may negatively impact injury risk and the severity of existing injuries, thereby possibly leading to lifelong disability, persistent pain, and continued use of analgesics.[14,15,36] As athletes from an early age may be introduced and socialized into the sport ethic culture of playing through pain,[43,44] this finding may partly be explained by mediated cultural influences in sports communities including pain normalization, risk glorification, and external pressures, leading athletes to engage in risky behaviour by ignoring and covering signs of fatigue, pain, and injury.[8,43–47]

4.4. Implications for clinical practice

The findings from this review indicate the common use of over-the-counter analgesics, poor awareness of their benefits and harms, and perceived pressure to use analgesics.[7,13,48] Therefore, youth athletes may be educated about safe analgesic use and non-pharmacological pain management strategies. It has previously been highlighted that the existing evidence on efficacy and safety of analgesics in athletes does not provide a sufficient body of evidence to guide athletes and healthcare professionals in making analgesic treatment decisions.[22] Consequently, sports medicine clinicians must trade off the benefits, risks, and costs associated with management strategies, and in doing so, consider the athletes preferences and the tension between masking pain and understanding the protective role of pain in the presence of injury.[3,49]

4.5. Limitations

This study has limitations. Although a number of covariates were analyzed in the meta-regression analyses, we were not able to explain the heterogeneity in proportion estimates between studies. The fact that heterogeneity remained high after stratifying by type of analgesic and prevalence measure, and adjusting for relevant covariates, likely reflects differences in constructs not captured by the included covariates and may lower the confidence in the pooled estimates. However, evidence suggest that prevalence systematic reviews generally yield high measures of heterogeneity, partly due to large variations in sample sizes and diverse point estimates, but that these estimates can be biased and are not synonymous with important variability between studies.[27]

The low number of studies available per type of analgesic medication and prevalence measure prevented meta-regression analyses on other outcomes than point prevalence of NSAIDs use and subgroup analyses stratifying by level of performance was only possible a limited number of outcomes. Similarly, further subgroup or meta-regression analysis investigating the impact of type of sport, country, and risk of bias on the estimates would have provided valuable information. However, due to the limited number of studies available per stratum, this was not possible. When more than one subtype of the same analgesic was available at the same time point (e.g., point prevalence of prescription and non-prescription NSAIDs), the primary meta-analyses included the type with the highest prevalence to avoid underestimation. While the sensitivity analyses did not significantly change the pooled estimates, this approach may still have underestimated the prevalence of analgesic use as it was not possible to extract data on the proportion of athletes using only one subtype and the proportion using both. Study-specific terminology was used to guide the categorization in the subgroup analyses of performance level, which may have led to misclassification and potential residual confounding in the subgroup analyses. However, as highlighted by a recent study, defining and classifying performance levels in sport is challenged by the lack of consistent terminology in the existing literature. Reporting of population characteristics varied widely. Consequently, five studies were included despite not reporting information on age. However, as these studies were conducted in college athletes, compliance with inclusion criteria was assumed. Finally, pooled point prevalence estimates tended to be either similar to or larger than most period prevalence measures. This may partly be explained by the inconsistent and poorly described definitions of point prevalence, which may have led to misclassification. This is supported by the sensitivity analysis showing a statistically significantly lower point prevalence for NSAIDs use when excluding the studies with unclear definitions of point prevalence. Secondly, this observation may partly be explained by recall bias, as current or recent use may be more accurately recalled than longer time periods, possibly leading to an underestimation of period prevalence measures. Finally, 61 % of the studies reporting point prevalence assessed analgesic use specifically in relation to management of sports related injury or pain, whereas for studies reporting period prevalence, this was 16 %, suggesting that these studies may not measure the exact same construct.

4.6. Future research

Few high-quality studies assessing the epidemiology of analgesic use in youth athletes suggests that further high-quality research is needed before robust conclusions can be drawn. Research should focus on a wider range of analgesics and standardized survey instruments should be developed and validated in athlete populations to allow for better comparisons between studies. Prospective data collection with long-term tracking and short recall periods should be used to understand consumption patterns across different types of sports. Given the low number of studies reporting adverse events associated with analgesic use, the prevalence and incidence of adverse events should be further explored to guide athletes and health professionals in making analgesic treatment decisions. There is a lack of understanding regarding how the use of analgesics is influenced by the sociocultural context. As such, mixed-methods approaches may be adopted to elaborate on reasons for analgesic use and external factors impacting the use. As just above one third of the included athletes were female, future studies should aim to include more balanced samples of athletes and explore sex-specific differences in analgesic consumption patterns. Finally, differences in consumption patterns between athlete and non-athlete populations should be explored to determine the effect of sport as an exposure for analgesic use.

5. Conclusion

Analgesics are commonly used by youth athletes, but estimates vary across types of analgesics and prevalence measure and heterogeneity was high in the pooled estimates. Of the identified analgesics, NSAIDs appeared to be the most used type of analgesic. Across studies, 7–50 % of athletes reported weekly use. Adverse effects were reported by 3 % to 19 % of athletes. Reasons for using analgesics included treatment of sports-related pain or injury and associated symptoms, to treat illness, and to enhance performance. As the majority of the included studies were of poor methodological quality, future high-quality studies are needed to better understand prevalence, incidence, consumption trajectories, and adverse events associated with analgesic use in youth athletes.

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Role of funding bodies

The funding sources had no role in the collection, analysis or interpretation of the data, and had no rights in approving or disapproving publication of the finished manuscript.

Confirmation of ethical compliance

Not applicable to the study design.

Availability of data, code, and other materials

Template data collection form, data extracted from included studies, data used for analyses, and analytic codes are available upon reasonable request from the corresponding author.

Declaration of interest statement

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jsams.2022.08.018.

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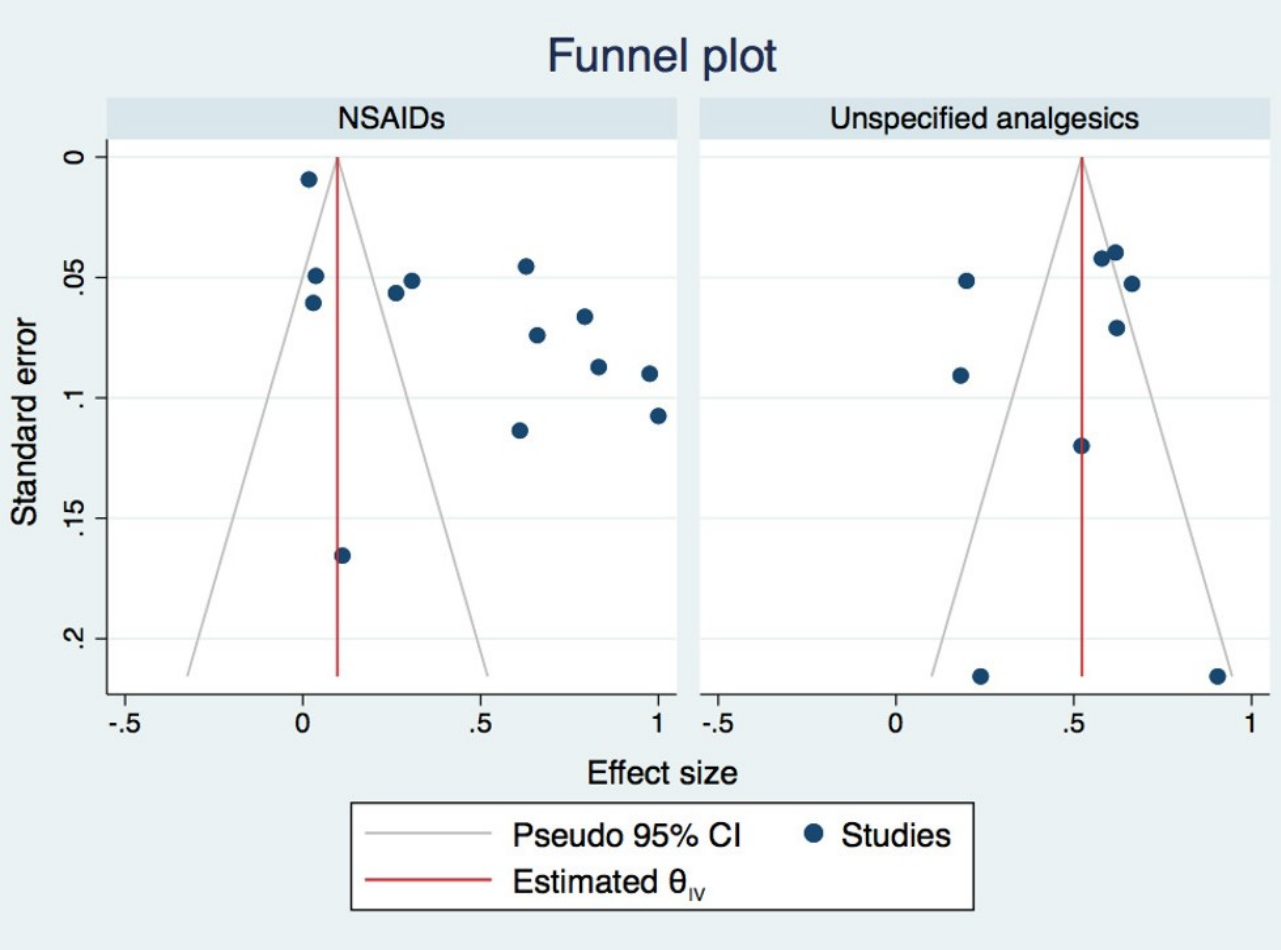
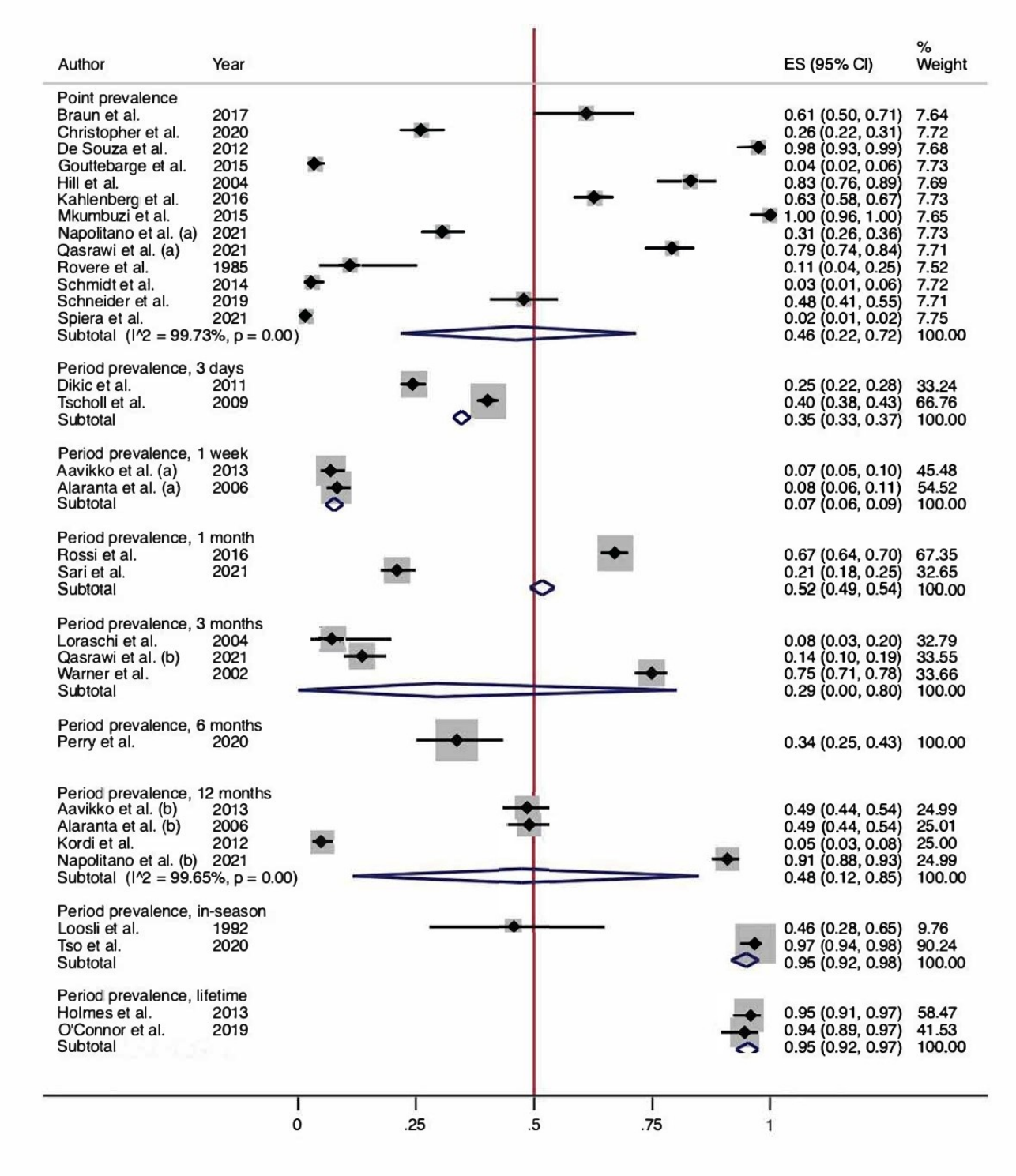
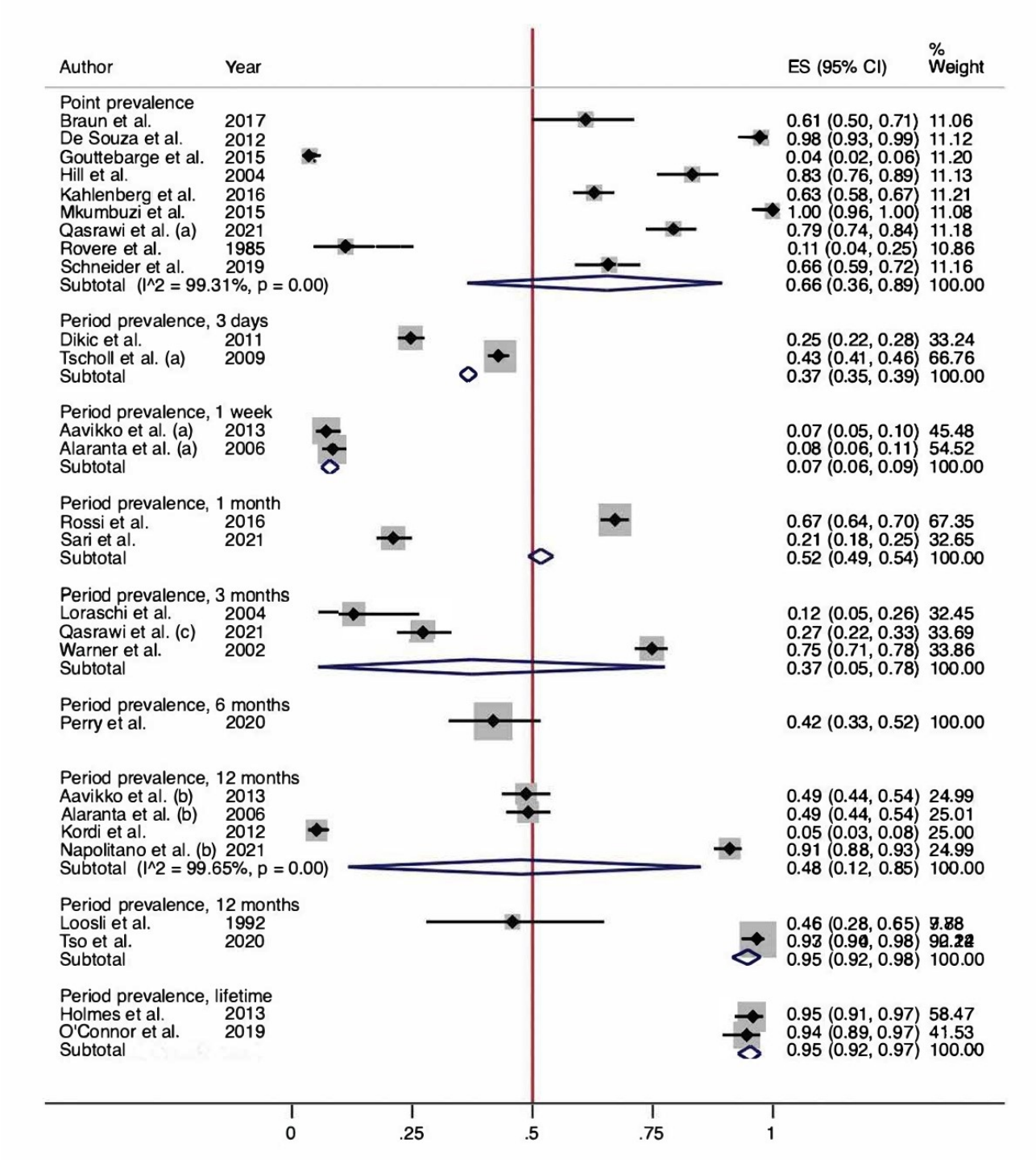


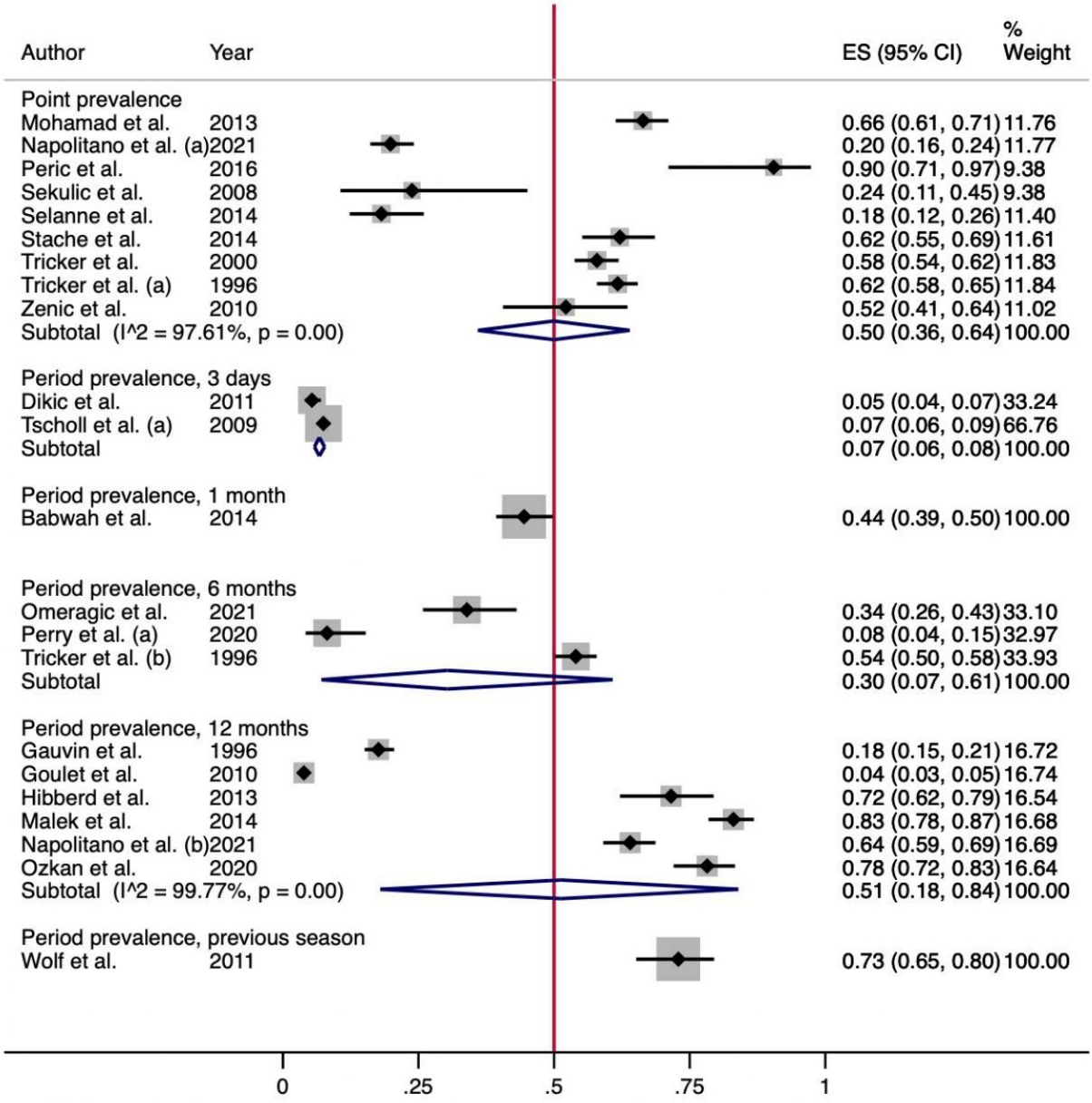
Supplementary Fig. 1 Funnel plot
NSAIDs = Non-steroidal anti-inflammatory drugs



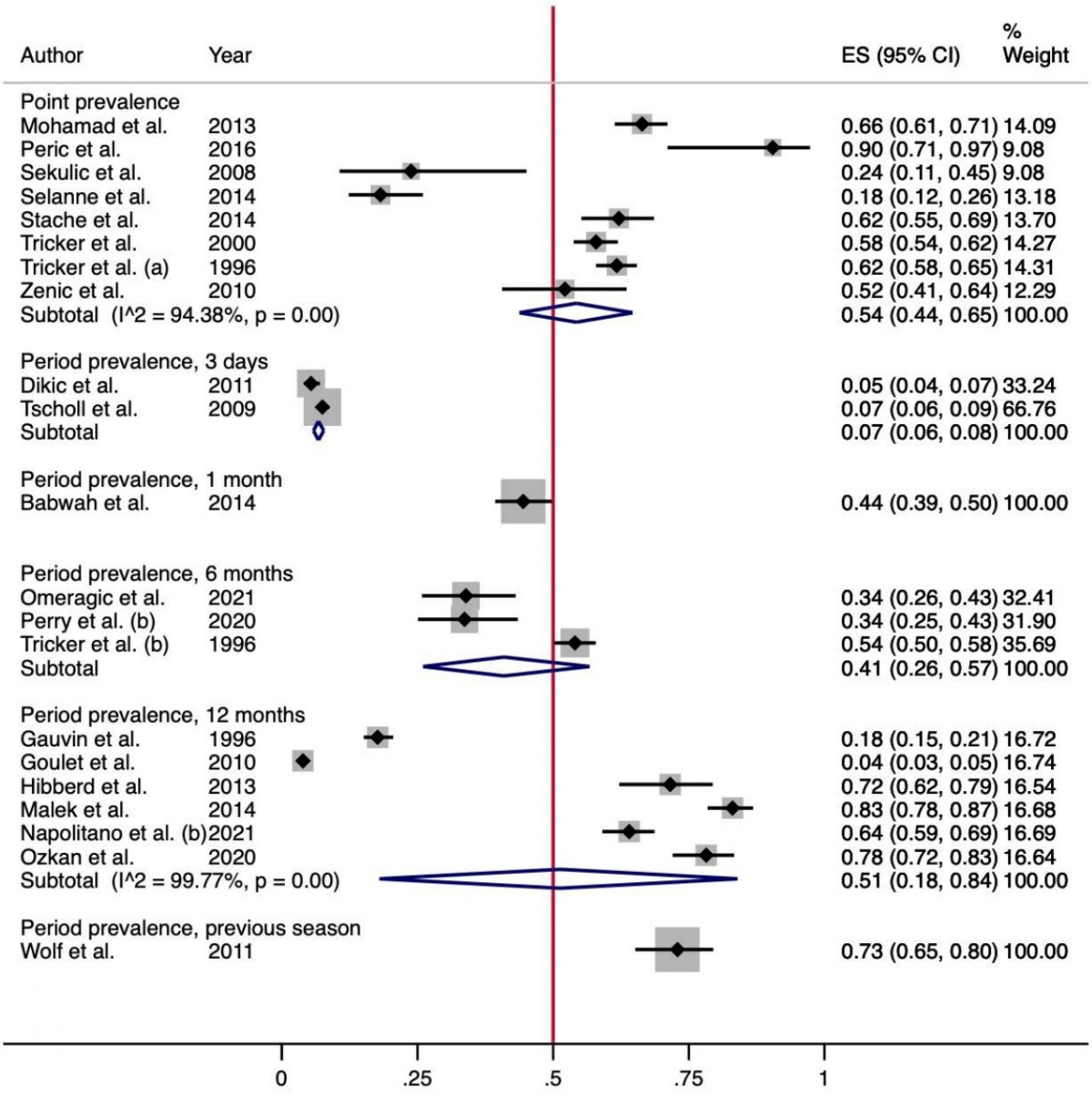
Supplementary Figure 2 Stratified sensitivity prevalence meta-analysis using alternate NSAIDs medications. Rows indicate pooled estimates. Red lines represent a 50% prevalence. The boxes indicate study weight and whiskers indicate 95% CI.



Supplementary Figure 3 Stratified sensitivity prevalence meta-analysis excluding studies with clear reporting of point prevalence. Rows indicate pooled estimates. Red lines represent a 50% prevalence. The boxes indicate study weight and whiskers indicate 95% CI.



Supplementary Figure 4 Stratified sensitivity prevalence meta-analysis using alternate unspecified medications. Rows indicate pooled estimates. Red lines represent a 50% prevalence. The boxes indicate study weight and whiskers indicate 95% CI.



Supplementary Figure 5 Stratified sensitivity prevalence meta-analysis with clear reporting of point prevalence. Rows indicate pooled estimates. Red lines represent a 50% prevalence. The boxes indicate study weight and whiskers indicate 95% CI.

Supplementary Table 1 Search strategy

EMBASE	1. Analgesic agent/ 2. Analgesic* (ti/ab) 3. Paracetamol / 4. (Acamol or Acetaminophen or Panadol or Paracetamol or Tylenol) (ti/ab) 5. Nonsteroid antiinflammatory agent / 6. (NSAID* or Non steroid* antiinflammatory agent* or Non steroid* antiinflammatory drug* or Nonsteroid* anti inflammatory agent* or Nonsteroid* anti inflammatory drug* or Non steroid* anti inflammatory agent* or Nonsteroid* anti inflammatory drug* or Nonsteroid* antiinflammatory agent* or Nonsteroid* antiinflammatory drug*) (ti/ab) 7. (Adapalene or Aspirin or Celecoxib or Diclofenac or Ibuprofen or Ketorolac or Meloxicam or Suprofen or Tolmetin) (ti/ab) 8. Ketorolac / 9. Intramuscular drug administration / 10. Intramuscular injection* (ti/ab) 11. Opiate / 12. Opioid* (ti/ab) 13. (Alfentanil or Buprenorphine or Codeine or Fentanyl or Hydrocordone or Methadone or Morphine or Oxycodone or Tramadol) (ti/ab) 14. Nonprescription drug / 15. Nonprescription drug* (ti/ab) 16. OTC drug* (ti/ab) 17. Over-the-counter drug* (ti/ab) 18. Prescription drug / 19. Prescription drug* (ti/ab) 20. Corticosteroid / 21. Corticosteroid* (ti/ab) 22. Corticoid* (ti/ab) 23. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 24. Athlete / 25. Athlete* (ti/ab) 26. Sport / 27. Sport* (ti/ab) 28. (Baseball or Basketball or Boxing or Cycling or Softball or Football or Rugby or Soccer or Golf or Gymnast* or Hockey or “Martial arts” or Tennis or Badminton or Runn* or Skating or “Track and Field” or Volleyball Wrestling or Weight-lifting) (ti/ab) 29. Recreation* (ti/ab) 30. Sports injury/ 31. Sports medicine/ 32. 24 or 25 or 26 or 27 or 28 or 29 or 30 or 31 33. 23 and 32 Total: 6695
Medline	1. Analgesics (MeSH) 2. Analgesic* (ti/ab) 3. Acetaminophen (MeSH) 4. Acetaminophen (ti/ab) 5. (Acamol or Panadol or Paracetamol or Tylenol) (ti/ab) 6. Antiinflammatory agents, non-steroidal (MeSH)

	7. (NSAID* or Non steroid* antiinflammatory agent* or Non steroid* antiinflammatory drug* or Nonsteroid* anti inflammatory agent* or Nonsteroid* anti inflammatory drug* or Non steroid* anti inflammatory agent* or Nonsteroid* anti inflammatory drug* or Nonsteroid* antiinflammatory agent* or Nonsteroid* antiinflammatory drug*) (ti/ab) 8. (Adapalene or Aspirin or Celecoxib or Diclofenac or Ibuprofen or Ketorolac or Meloxicam or Suprofen or Tolmetin) (ti/ab) 9. Ketorolac (MeSH) 10. Intramuscular injections (MeSH) 11. Intramuscular injection* (ti/ab) 12. Pain management (MeSH) 13. Pain management (ti/ab) 14. Opiate alkaloids (MeSH) 15. Analgesics, opioids (MeSH) 16. Opioid* (ti/ab) 17. (Alfentanil or Buprenorphine or Codeine or Fentanyl or Hydrocordone or Methadone or Oxycodone or Tramadol) (ti/ab) 18. Nonprescription drugs (MeSH) 19. Nonprescription drug* (ti/ab) 20. OTC drug* (ti/ab) 21. Over-the-counter drug* (ti/ab) 22. Prescription drugs (MeSH) 23. Prescription drug* (ti/ab) 24. Corticosteroid (ti/ab) 25. Corticoid (ti/ab) 26. 1 or 2 or 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 27. Athlete (MeSH) 28. Athlete* (ti/ab) 29. Sport (MeSH) 30. Sport* (ti/ab) 31. (Baseball or Basketball or Boxing or Cycling or Softball or Football or Rugby or Soccer or Golf or Gymnast* or Hockey or “Martial arts” or Tennis or Badminton or Runn* or Skating or “Track and Field” or Wrestling or Weight-lifting) (ti/ab) 32. Recreation* (ti/ab) 33. Athletic injuries (MeSH) 34. Sports medicine (MeSH) 35. 27 or 28 or 29 or 30 or 31 or 32 or 33 or 34 36. 24 and 35 Total: 4624
SportDiscus	1. Analgesics 2. (Acetaminophen or Paracetamol or Tylonol) 3. (Nonsteroidal anti-inflammatory drugs or nsaids) 4. (Opioids or Opiates or Pain medication or Morphine) 5. 1 or 2 or 3 or 4 6. Athletes 7. Sport 8. (Athletics or Baseball or Basketball or Boxing or Cycling or Softball or Football or Rugby or Soccer or Golf or Gymnast* or Hockey or “Martial arts” or Tennis or Badminton or Runn* or Skating or Wrestling or Weight-lifting) 9. 6 or 7 or 8 10. 5 and 9

	11. Filter (Academic Journals) Total: 1750

Supplementary Table 2: Data included in data extraction

Study-specific data	First author, publication year, country, study design, sample size
Population	Type of sport, performance level, age, % females, years of sports participation, weekly sports exposure hours
Outcomes	Method of reporting analgesic use (e.g., athlete self-report, pharmacy record, coach reports, doping control forms), prevalence measure (i.e., point prevalence or period prevalence), prevalence time point (if period prevalence), number and proportion of analgesic users, type of analgesic drug, route of administration, type of frequency measure (e.g., weekly, monthly), reasons for pain medication use, and adverse events.

Supplementary Table 3 Study characteristics

Author (Year)	Country	Study design	Sample size	Sport	Participation level	Age (Years)	% female
Aavikko et al. (2013)[1]	Finland	Cross-sectional	372	Mixed Olympic sports[a]	Elite	Mean (SD): 23 (4.5)	49.7
Alaranta et al. (2006)[2]	Finland	Cross-sectional	446	Mixed Olympic sports	Elite	Mean (SD): 23 (4.5)	41.5
Alexander et al. (2021)[3]	International	Cross-sectional	131	Alpine skiing, snowboard, Nordic skiing, ice hockey, curling	Elite	Range: 13-25	N/I
Anderson et al. (1991)[4]	USA	Cohort study	4321	Football, baseball, basketball, track & field, tennis, swimming, softball	Collegiate (NCAA division 1-3)	N/I	31
Babwah et al. (2014)[5]	International	Cross-sectional	344	Football	Elite	Mean (SD): 18.2(1.2)	35.8
Braun et al. (2017)[6]	USA	Cross-sectional	77	Baseball, basketball, golf, lacrosse, softball, tennis, track and field	Collegiate (NCAA division 3)	Mean (SD): 20 (1)	54.5
Brewer et al. 2014)[7]	USA	Cross-sectional	263	Aerobics, jogging, resistance training, racquetball	Recreational	Range: 18-24	51.7

Buckman et al. (2013)[8]	USA	Cross-sectional	11,003	Mixed	Collegiate (NCAA division 1-3)	Range: 18-23	0
Christopher et al. (2020)[9]	USA	Cross-sectional	313	Mixed[b]	Collegiate (NCAA division 1-3)	Mean (range): Girls 19 (18-20) Boys 20 (19.5-20.5)	73.4
De Souza et al. (2012)[10]	Brazil	Cross-sectional	123	Football	Professional	Mean (range): 20.5 (17-24)	0
Garcin et al. (2005)[11]	France	Cross-sectional	137	Sprint, cycling, running, handball	Subelite	Mean (SD): 19.3 (2.8)	39
Goulet et al. (2010)[12]	Canada	Cross-sectional	3573	Mixed[e]	N/I	Mean (SD): 15.5 (2.4)	44
Gouttebarge et al. (2018)[13]	The Netherlands	Cohort study	410	Football	Professional	Mean (SD): 24 (4)	0
Hibberd et al. (2013)[14]	USA	Cross-sectional	102	Swimming	High school elite	Mean (SD): 15.1 (1.4)	61.7
Hill et al. (2004)[15]	USA	Cross-sectional	131	Softball	Collegiate (NCAA division 1-3)	Range: 18-26	100
Holmes et al. (2013)[16]	USA	Cross-sectional	210	Football	Collegiate (NCAA division 1 and 3)	Range: 18-22	0
Kahlenberg et al. (2016)[17]	USA	Cross-sectional	484	Mixed[f]	Recreational, high school team, or club team	Mean (range): 15.9 (13-21)	41.9
Kordi et al. (2012)[18]	Iran	Cross-sectional	411	Wrestling	N/I	Mean (SD): 19.1 (4)	N/I

Lazic et al. (2011)[19]	Serbia	Cross-sectional	912	Mixed[c]	Elite	Mean (SD): 23.9 (6)	28.4
Loosli et al. (1992)[20]	USA	Cross-sectional	24	Softball	Collegiate (NCAA division 1)	Mean (range): 20 (17-23)	100
Loraschi et al. (2014)[21]	Italy	Cross-sectional	40	Cycling	Elite	Mean (SD): 20.7 (1.3)	0
Malek et al. (2014)[22]	Canada	Cross-sectional	307	Football, soccer, wrestling, track, basketball, volleyball, hockey, cross country	Collegiate	N/I	N/I
Mkumbuzi et al. (2015)[23]	Zimbabwe	Cross-sectional	86	Football	Professional	Mean (SD): 23 (2)	0
Mohamad Shariff et al. (2013)[24]	Malaysia	Cohort study	360	Track and field, field hockey, racket sports, martial arts, soccer, weightlifting, gymnastics, swimming, others	National-level, state-level, recreational	Median (IQR): 20 (14-26)	34.2
O'Connor et al. (2019)[25]	Ireland	Cross-sectional	149	N/I	Collegiate	Mean (SD): 21.2 (3.5)	N/I
Omeragic et al. (2021)[26]	Bosnia and Herzegovina	Cross-sectional	112	Athletics, weightlifting, karate, handball, basketball, volleyball, football	Competitive	Mean (SD): 22.5 (4.5)	34.8

Ozkan et al. (2020)[27]	Turkey	Cross-sectional	202	Mixed[g]	Elite	Mean (SD): 20.8 (3.61)	31.2
Peric et al. (2016)[28]	Croatia	Cross-sectional	21	Ballet	Elite	Mean (SD): 23.1 (4.5)	100
Perry et al. (2020)[29]	Australia	Cross-sectional	98	Athletics, canoeing, hockey, IASP, rowing, sailing, swimming, water polo, other	Elite and developing	Age distribution: 18-20: 46% 21-25: 35% 26-30: 16% 31+: 3%	48.9
Qasrawi et al. (2021)[30]	Palestine	Cross-sectional	227	Mixed[h]	N/I	Mean (SD): 20.4 (1.6)	41.4
Rossi et al. (2016)[31]	Finland	Cross-sectional	962	N/I	Recreational	Mean (SD): 15.5 (1)	52.8
Rossi et al. (2021)[32]	Italy	Cross-sectional	378	Football	Elite	Mean (SD): 24.8 (5.4)	0
Rovere et al. (1985)[33]	USA	Cross-sectional	36	Swimming	Competitive	Mean (SD): 17.1 (3.2)	N/I
Sari et al. (2021)[34]	Denmark	Cross-sectional	466	Handball	Elite	Mean (SD): 17 (1.1)	47
Schmidt et al. (2014)[35]	Germany	Cohort study	272	Mixed[i]	Competitive	Mean (SD): 15.4 (2)	41.5
Schneider et al. (2019)[36]	Germany	Cross-sectional	182	Basketball	Elite	Mean (SD): 15.5 (1.3)	29.1
Sekulic et al. (2008)[37]	Serbia	Cross-sectional	21	Dance	N/I	Range: 19-28	100
Selanne et al. (2014)[38]	Finland	Cross-sectional	121	Ice hockey	Elite	Mean (range): 15 (14-16)	0
Spence et al. (1996)[39]	Canada	Cross-sectional	754	Mixed[d]	Collegiate	N/I	37.4

Spiera et al. (2021)[40]	USA	Cohort study	11,577	N/I	Amateur	Mean (SD): 15.3 (0.01)	34.1
Stache et al. (2014)[41]	USA	Cross-sectional	198	Mixed[j]	Collegiate (NCAA division 1 and 3)	Mean: 19.9	28.8
Tricker et al. (2000)[42]	USA	Cross-sectional	563	N/I	Collegiate (NCAA division 1)	N/I	N/I
Tricker et al. (1996)[43]	USA	Cohort study	635	Mixed[k]	Collegiate (NCAA division 1)	N/I	31.5
Tscholl et al. (2009)[44]	International	Cross-sectional	1832	Football	Elite	Range: 15-20	0
Tso et al. (2020)[45]	USA	Cohort study	226	American football, endurance sports	Collegiate (NCAA division 1 and 3) and competitive high school	Mean (SD): 17.9 (0.7)	0
Warner et al. (2002)[46]	USA	Cross-sectional	604	Football	High school competitive	Mean: 15.7	0
Wolf et al. (2011)[47]	USA	Cross-sectional	144	Football	Collegiate (NCAA division 1)	Mean (SD): 20.2 (1.2)	0
Yargic et al. (2021)[48]	Turkey	Cross-sectional	166	Wrestling	Elite	Mean (SD): 18.9 (4.7)	27.7
Zenic et al. (2010)[49]	Croatia	Cross-sectional	69	Ballet, dance, synchronized swimming	Amateur, semi-professional, professional	Age distribution: 18-21: 59% 22-25: 22% 26-30: 4% 31+: 15%	100

*No information provided; [a] Judo, track and field, wrestling, weightlifting, boxing, taekwondo, rowing, badminton, swimming, canoeing, tennis, shooting, archery, sailing, fencing, horse riding, gymnastics, volleyball, handball, basketball, speed skating, alpine event, biathlon, cross country skiing, Nordic combined, figure skating, snowboarding, ski jumping, ice hockey; [b] American football, lacrosse, rugby, basketball, football, tennis, volleyball, baseball, softball, cross country, dance, golf, swimming, track and field, triathlon; [c] water polo, basketball, football, swimming, athletics, shooting, judo, taekwondo, karate, volleyball, wrestling, table tennis, rowing, bodybuilding, canoe, kayak, cycling,

boxing, weight lifting, kick boxing, handball, gymnastics, tennis, fencing, duathlon, bowling, American football; [d] Ice hockey, football, basketball, track and field, cross country, soccer, volleyball, swimming, other sports; [e] Baseball, gymnastics, swimming, basketball, hockey, skiing, athletics, soccer, speed skating; [f] Swimming, soccer, football, cross country, lacrosse, hockey, rowing, tennis, volleyball, basketball, track, baseball, wrestling, field hockey, fencing, golf, dance, figure skating, water polo, gymnastics, softball, bowling, badminton, rugby, ailing, weight lifting, snowboarding, canoe, diving, martial arts, frisbee, unspecified; [g] Ice hockey, swimming, soccer, diving, basketball, muay thai, weightlifting, volleyball, cycling, track, taekwondo; [h] Football, basketball, volleyball, table tennis, marathon, tennis, handball, badminton, swimming, taekwondo, gymnastics, weightlifting, boxing; [i] 31 sports including volleyball, biathlon, swimming, canoe, tobogganing, alpine skiing, short track, ice skating, figure skating, rowing; [j] Football, baseball, hockey, lacrosse, basketball, track and field, tennis, soccer, volleyball, cheerleading, field hockey; [k] Football, basketball, baseball, track, swimming, wrestling, volleyball, soccer, gymnastics, golf, tennis, cheerleading, softball, rowing;

Supplementary Table 4 Prevalence of analgesic use in youth athletes

Author (Year)	Prevalence measure	Pain medication users, %	Type of pain medication	Method of reporting
Aavikko et al. (2013)[1]	Period prevalence,			Athlete self-report (questionnaire)
	7 days	6.7	NSAIDs	
	12 months	48.7	NSAIDs	
	7 days	1.1	Other analgesics[a]	
	12 months	7.8	Other analgesics[a] (only physician prescribed)	
Alaranta et al. (2006)[2]	Period prevalence,		Physician prescribed NSAIDs	Athlete self-report (questionnaire)
	7 days	8.1		
	12 months	49.1		
Alexander et al. (2021)[3]	Point prevalence	11.4	Simple analgesics, NSAIDs, opioids, or adjuvant analgesics	Self-declared use on doping control form
Anderson et al. (1991)[4]	Period prevalence, 12 months	31.3	Tylenol, Percodan, morphine, codeine, demerol, talwin	Athlete self-report (questionnaire)
Babwah et al. (2014)[5]	Period prevalence, 1 month	45	Analgesics (unspecified)	Athlete self-report (questionnaire)
Braun et al. (2017)[6]	Point prevalence	61	NSAIDs	Athlete self-report (questionnaire)
Brewer et al. 2014)[7]	Point prevalence	36.1	Ibuprofen, acetaminophen, or naproxen	Athlete self-report (questionnaire)
Buckman et al. (2013)[8]	Period prevalence, 12 months	17.1	Vicodin, oxycontin or Percocet	Athlete self-report (questionnaire)
Christopher et al. (2020)[9]	Point prevalence	25.9	NSAIDs	Athlete self-report (questionnaire)
De Souza et al. (2012)[10]	Point prevalence	98	NSAIDs	Athlete self-report (interview)
Garcin et al. (2005)[11]	Point prevalence	9.5	Acetaminophen	Urine sample testing

Goulet et al. (2010)[12]	Period prevalence, 12 months	16 1.7 18.8 4.3 3.9	Aspirin Local anesthetics Tylenol Atasol Other analgesics	Athlete self-report (questionnaire)
Gouttebarge et al. (2018)[13]	Point prevalence	3.6	Prescription NSAIDs	Medical staff injury report
Hibberd et al. (2013)[14]	Period prevalence, 12 months	72	Analgesics (unspecified)	Athlete self-report (questionnaire)
Hill et al. (2004)[15]	Point prevalence	85.8	NSAIDs	Athlete self-report (questionnaire)
Holmes et al. (2013)[16]	Period prevalence, lifetime	95.7	NSAIDs	Athlete self-report (questionnaire)
Kahlenberg et al. (2016)[17]	Point prevalence	62.8	NSAIDs	Athlete self-report (questionnaire)
Kordi et al. (2012)[18]	Period prevalence, 12 months	5.1	Injectable NSAIDs	Athlete self-report (questionnaire)
Lazic et al. (2011)[19]	Period prevalence, 3 days	24.1 5.4 1.0	NSAIDs Analgesics-anaesthetics Corticosterioids	Self-declared use on doping control form
Loosli et al. (1992)[20]	Period prevalence, in-season	46	NSAIDs	Athlete self-report (questionnaire)
Loraschi et al. (2014)[21]	Period prevalence, 3 months	12.5 7.5 12.5 2.5 2.5	Ketoprofen Nimesulide Acetylsalicylic acid Tramadol Paracetamol	Athlete self-report (questionnaire)
Malek et al. (2014)[22]	Period prevalence, 12 months	79.7	Analgesics (unspecified)	Athlete self-report (questionnaire)
Mkumbuzi et al. (2015)[23]	Point prevalence	100	NSAIDs	Athlete self-report (questionnaire)
Mohamad Shariff et al. (2013)[24]	Point prevalence	66.4	Analgesics (unspecified)	Medical records
O'Connor et al. (2019)[25]	Period prevalence, lifetime	94	NSAIDs	Athlete self-report (questionnaire)

Omeragic et al. (2021)[26]	Period prevalence, 6 months	33.9	Analgesics (unspecified)	Athlete self-report (questionnaire)
Ozkan et al. (2020)[27]	Period prevalence, 12 months	78.2	Analgesics (unspecified)	Athlete self-report (questionnaire)
Peric et al. (2016)[28]	Point prevalence	90	Analgesics (unspecified)	Athlete self-report (questionnaire)
Perry et al. (2020)[29]	Period prevalence, 6 months	33.3 8.1 41.8 33.6	Prescription NSAIDS Prescription analgesics (unspecified) Non-prescription NSAIDs Non-prescription analgesics (unspecified)	Athlete self-report (questionnaire)
Qasrawi et al. (2021)[30]	Point prevalence	79.3 65.5	NSAIDs Paracetamol/Aspirin	Athlete self-report (questionnaire)
	Period prevalence, 3 months	13.6 26.8	Non-prescription NSAIDs Prescription NSAIDs	
Rossi et al. (2016)[31]	Period prevalence, 1 month	67.2	NSAIDs	Athlete self-report (questionnaire)
Rossi et al. (2021)[32]	Period prevalence, 12 months	91 64	NSAIDs Other analgesics (unspecified)	Athlete self-report (questionnaire)
	Point prevalence	33.7 31.8	NSAIDs Other analgesics (unspecified)	
Rovere et al. (1985)[33]	Point prevalence	13	NSAIDs	Athlete self-report (interview)
Sari et al. (2021)[34]	Period prevalence, 4 weeks	33.6 21 3.2 17	Paracetamol NSAIDs Acetylsalicyclic acid Mixed analgesics[b]	Athlete self-report (questionnaire)
Schmidt et al. (2014)[35]	Point prevalence	2.9	NSAIDs	Athlete self-report (questionnaire)

Schneider et al. (2019)[36]	Point prevalence	84.1 65.9 47.8 31.9 25.3 2.7	Mixed analgesics[c] Ibuprofen Diclofenac Paracetamol Acetylsalicylic acid Tramadol	Athlete self-report (questionnaire)
Sekulic et al. (2008)[37]	Point prevalence	23.8	Analgesics (unspecified)	Athlete self-report (questionnaire)
Selanne et al. (2014)[38]	Point prevalence	18	Analgesics (unspecified)	Athlete self-report (questionnaire)
Spence et al. (1996)[39]	Period prevalence, 12 months	17.7	Major pain medication (unspecified)	Athlete self-report (questionnaire)
Spiera et al. (2021)[40]	Point prevalence	1.7	NSAIDs	Athlete self-report (questionnaire)
Stache et al. (2014)[41]	Point prevalence	62	Non-prescription analgesics	Athlete self-report (questionnaire)
Tricker et al. (2000)[42]	Point prevalence	58	Analgesics (unspecified)	Athlete self-report (questionnaire)
Tricker et al. (1996)[43]	Period prevalence, 6 months	51	Analgesics (unspecified)	Athlete self-report (questionnaire)
	Point prevalence	54		
Tscholl et al. (2009)[44]	Period prevalence, 72 hours	45 (U17 2005) 38.7 (U17 2007) 45.6 (U20 2005) 44.4 (U20 2007)	Physician prescribed NSAIDs	Physician reported use on doping control form
		8.8 (U17 2005) 9.5 (U17 2007) 11.7 (U20 2005) 0.4 (U20 2007)	Physician prescribed analgesics (unspecified)	
		2.2 (U17 2005)	Physician prescribed	

		2 (U17 2007) 5.6 (U20 2005) 0.8 (U20 2007)	injections (corticosteroid or local anesthetic)	
Tso et al. (2020)[45]	Period prevalence, in-season	93.3	NSAIDs	Athlete self-report (questionnaire)
Warner et al. (2002)[46]	Period prevalence, 3 months	75	NSAIDs	Athlete self-report (questionnaire)
Wolf et al. (2011)[47]	Period prevalence, previous season	73	Non-prescription analgesics (unspecified)	Athlete self-report (questionnaire)
Yargic et al. (2021)[48]	Point prevalence Period prevalence, one week	75.3 57.2	NSAIDs or paracetamol	Athlete self-report (interview)
Zenic et al. (2010)[49]	Point prevalence	52.2	Analgesics (unspecified)	Athlete self-report (questionnaire)

NSAIDs: Non-steroidal anti-inflammatory drugs; wk: week; mth: month; [a] defined as paracetamol, paracetamol-codeine, tramadol, dextropropoxyphene, buprenorphine, pregabalin, amitriptyline, or nortriptyline; [b] defined as more than one analgesic including paracetamol, acetylsalicylic acid, or NSAIDs; [c] defined as use of either ibuprofen, diclofenac, paracetamol, acetylsalicylic acid or tramadol

Supplementary Table 5 Summary of outcome availability*

	Point prevalence	Period prevalence 3 days	Period prevalence 1 week	Period prevalence 1 month	Period prevalence 3 months	Period prevalence 6 months	Period prevalence 12 months	Period prevalence In-season	Period prevalence Previous season	Period prevalence Lifetime
NSAIDs	14	2	2	2	5	2	4	2		2
Paracetamol	2			1	1		1			
Acetylsalicylic acid	1			1	1		1			
Opioids	1				1		2			
Local anesthetics injections		2					1			
Analgesics (unspecified)	9	2		1		4	6		1	
Analgesics (mixed)	5		2	1			2			

*The number of available outcomes exceeded the number of studies because when several types of analgesics or multiple prevalence measures were included in a study, all were reported.

Supplementary Table 6 Overall quality of evidence for point prevalence measures

Number of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Number of participants	Proportion (95% CI)	Certainty
NSAIDs[a]									
13	Cohort and cross-sectional	Not serious	Serious[b]	Not serious	Serious[c]	Risk of small study bias[d]	14296	48% (23-73%)	Very low
Unspecified analgesics[e]									
9	Cohort and cross-sectional	Not serious	Serious[f]	Not serious	Not serious	None	2366	50% (36-64%)	Low
Mixed analgesics[g]									
5	Cross-sectional	Not serious	Serious[b]	Not serious	Serious[c]	Undetected	969	54% (29-79%)	Low
Local anaesthetic injections[h]									
2	Cross-sectional	Not serious	Not serious	Serious[i]	Not serious	Undetected	2744	2% (1-3%)	Low
Paracetamol[j]									
2	Cross-sectional	Not serious	Serious[a]	Serious[i]	Not serious	Undetected	319	21% (17-25%)	Very low
Acetylsalicylic acid[k]									
1	Cross-sectional	Not serious	Not serious	Serious[i]	Not serious	Undetected	182	25% (19-31%)	Low
Opioids[l]									
1	Cross-sectional	Not serious	Not serious	Serious[i]	Not serious	Undetected	182	3% (1-5%)	Low

Explanations:
[a] Eight other prevalence measures were available with pooled proportions ranging from 7% to 95%
[b] Downgraded one level due to variability of point estimates
[c] Downgraded one level due to wide confidence intervals
[d] Downgraded one level due to risk of small study bias
[e] Five other prevalence measures were available with pooled proportions ranging from 7% to 73%
[f] Downgraded two levels due to large variability of point estimates
[g] Three other prevalence measures were available with pooled proportions ranging from 11% to 29%
[h] One other prevalence measures were available with a pooled proportion of 2%
[i] Downgraded two levels due to indirectness caused by few included studies
[j] Three other prevalence measures were available with proportions from single studies ranging from 3% to 34%
[k] Three other prevalence measures were available with proportions from single studies ranging from 3% to 16%
[l] Two other prevalence measures were available with pooled proportions ranging from 3% to 13%

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Paper II

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Popping Pills in Youth Elite Sports—Fact or Fiction? A 36-Week Prospective Cohort Study of Analgesic Use in 1195 Youth Elite Athletes and Student Controls

OBJECTIVE: To investigate analgesic use in a cohort of Danish youth elite athletes and compare weekly analgesic use over 36 weeks to student controls. We also investigated and compared reasons for analgesic use and types of analgesics used.

DESIGN: Prospective cohort study.

METHODS: Six hundred ninety youth elite athletes (44% females) and 505 student controls (59% females) (aged 15-20 years) provided weekly reports on analgesic use over 36 weeks. We asked about the number of days with analgesic use, reasons for use, and types of analgesics used. Prevalence and frequency of analgesic use was compared between youth elite athletes and student controls using mixed-effects logistic regression and mixed-effects Poisson regression models. Reasons for and types of analgesics used were compared between groups using chi-square tests. Subgroup analyses were performed, stratified by sex.

RESULTS: Overall, athletes had lower odds of analgesic use (odds ratio = 0.78; 95% confidence interval [CI], 0.64 to 0.95) compared with student controls. The overall usage rate was similar between the groups (incidence rate ratio = 1.04; 95% CI, 0.99 to 1.11). Subgroup analyses suggested no statistically significant differences in the odds of analgesic use. Significantly more athletes reported using analgesics to prevent or treat pain or injury in relation to sports participation and to use topical gels compared with student controls.

CONCLUSION: Participating in youth elite sports was associated with lower odds of analgesic use compared to student controls, but usage rate was similar between the groups. Reasons for use and types of analgesics used differed between athletes and student controls. *J Orthop Sports Phys Ther 2024;54(8):551-559. Epub 9 May 2024. doi:10.2519/jospt.2024.12407*

KEY WORDS: *analgesics, athletes, pain management, sports*

In sports medicine, analgesic use has been a topic of debate for years.[2,13,39] In 2018, a systematic review identified widespread use of analgesics in elite athletes but also highlighted the need for high-quality longitudinal data as the current evidence on analgesic use is based on low-quality studies such as retrospective surveys, data from doping control forms, and cross-sectional studies during tournaments.[16,43] Studies have predominately focused on athletics, football, or rugby and on the use of nonsteroidal anti-inflammatory drugs (NSAIDs).[16,43] In youth elite athletes, knowledge on analgesic use is based on very few studies.[16,33,43]

To ensure that youth elite athletes can train and compete at the highest level, pain management must be both effective and safe to support short- and long-term health and performance. While analgesics can be part of a multimodal treatment plan to manage sports-related pain and injury,[15] relying solely on analgesics may increase the risk of adverse events, including gastrointestinal adverse events, renal functioning disorder, liver damage, and dependence,[6,20,21,26] while failing to address the underlying condition.[15,25] Youth elite athletes may use analgesics to mask injury or prevent pain,[33] raising concerns about an increased injury risk and potential progression of existing injuries.[17,23]

Understanding differences in analgesic use between youth elite athletes and nonathletes can provide insights into the influence of elite sports participation on pain management strategies and support the development of interventions

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to promote safe and effective pharmacological pain management practices. We aimed to investigate analgesic use in a cohort of Danish youth elite athletes and compare weekly prevalence and frequency of analgesic use over 36 weeks to student controls. In addition, we investigated and compared reasons for use and types of analgesics used.

METHODS

This 36-week prospective cohort study reports the primary findings from the analgESic uSE iN youTh elIte AthLetes (ESSENTIAL) cohort. A study protocol was made publicly available prior to finalization of data collection (https://osf.io/k5spz/). The Regional Scientific Ethics Committee of the region of Southern Denmark waived the need for ethical approval as only self-reported data were collected (case number 20202000-176). The project was approved by The Danish Data Protection Agency via the University of Southern Denmark's Research and Innovation Office (case number 11.642). Informed consent was obtained, and participants' rights were protected. The STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guideline was followed when reporting the study.[38]

Participants and Recruitment

Thirty high schools offering elite sports programs (ie, dual career) to student-athletes were invited to participate in the study in March 2022. Elite sports coordinators from interested high schools (n = 24) were invited to attend a one-to-one online meeting for further information. Inclusion of participants and collection of baseline data were carried out during on-site visits at each high school during the enrollment period from August to October 2022. We included youth elite athletes aged between 15 and 20 years, as this is the usual age range of students enrolled in a Danish youth educational program.

Athletes were considered *elite* if they were approved by Team Denmark or any local/regional youth elite sports program (ie, dual career). These programs allow talented young athletes to combine education with elite sports by offering prolonged educational programs, support from dual-career counselors, and flexible schedules to accommodate training and traveling schedules to support young athletes in pursuing full-time careers as professional athletes.

We recruited a reference group of students (aged 15-20 years) from the same high schools. We included athletes and student controls of similar age and representative of the sex distribution at Danish youth educational institutions. We recruited athletes and student controls from the same years (ie, first, second, or third school year) within each participating institution and student controls from a variety of student specializations (eg, language science, social science, musical science, and natural science classes).

Participants had to be able to read and speak Danish and receive and respond to text messages using Short Message Service (SMS) on their mobile phone. Participants were recruited by convenience sampling.

Data Collection

At inclusion, all participants completed an electronic baseline questionnaire distributed via a QR code during the physical meeting with the principal investigator concerning contact information, demographics, and sports history. Every Sunday evening, starting from the week of inclusion (ie, participants were enrolled continuously from August to October 2022 and received the first questionnaire in the same week as they were included in the study) to April 23, 2023, participants responded to a standardized weekly questionnaire on their use of analgesics in the preceding 7 days via SMS (www.smstrack.com). Participants not responding received reminder text messages 24 and 72 hours after the first text message. Participants not responding for 3 consecutive weeks were contacted by phone to encourage continued participation. We used a continuous enrollment strategy, so that participants received the first questionnaire in the same week as they were included. This resulted in the number of participants increasing every week during the first 8 weeks of the study (ie, the enrollment period **SUPPLEMENTAL MATERIAL S8**).

Analgesic Use

As no validated questionnaires on analgesic use in youth elite athletes were identified in a systematic literature search,[33] we specifically developed the PAin Medication Use in youth Sports (PAMUS) questionnaire for this study to measure self-reported weekly use of analgesics. The development of the PAMUS questionnaire is described in **SUPPLEMENTAL MATERIAL S1**. The questionnaire contained between 1 and 3 standardized questions on analgesic use in the preceding 7 days. The first question was "How many days in the previous 7 days did you use analgesics?" Answer options were 0, 1, 2, 3, 4, 5, 6, or 7 days. A gatekeeper logic was applied to avoid inconsistent replies, so if a participant replied 0 days of use, the questionnaire was finalized for the week. If a participant replied 1-7 days of use, they received 2 additional questions on reasons for use and types of analgesics used (**SUPPLEMENTAL MATERIAL S2**). For these questions, participants were asked to select all relevant responses.

Sample Size

We estimated a need for 388 participants per group to detect a 10% difference in the proportion reporting analgesic use (0 days of use/≥1 day of use) between the groups per week, with a 2-sided significance level of .05 and 80% power. This sample size also allowed us to detect a difference of 1 day's analgesic use between the groups per week (n = 128 per group, $\alpha = .05$, power = 90%). Anticipating dropouts, we aimed to recruit at least 500 participants in each group. We had no prespecified hypotheses.

Statistical Analysis

Baseline demographics were presented as means ± standard deviation, medians,

and interquartile range or as frequency and percentage distribution as appropriate. Potential group differences in baseline demographics were tested using independent *t* tests and chi-square tests. Data on analgesic use were first analyzed descriptively by visually presenting weekly prevalence of analgesic use (defined as 0 days of use/≥1 day of use) and weekly mean consumption frequency (based on participants reporting 1-7 days of use) during the full 36-week study period, stratified by athletic status and gender. Next, mixed-effects logistic regression, expressing odds ratios (ORs) with 95% confidence intervals (CIs), and mixed-effects Poisson regression, expressing incidence rate ratios (IRRs) with 95% CIs, were used to assess between-group differences in prevalence and frequency of analgesic use between youth elite athletes and student controls during the full 36-week study period, respectively. Only individual ID was included as a random effect. As we had a high weekly response rate with relatively few missing data and as mixed-effects models are robust toward missing data and only require the missing-at-random assumption, missing data were not imputed.[14]

Subgroup analyses were performed, stratified by sex. Two sensitivity analyses were performed. First, we omitted the enrollment period (ie, the first 8 weeks of the study where new participants were included weekly). This sensitivity analysis was based on a similar weekly data collection method, showing that first-time responses should be interpreted with caution[9] and considering the smaller sample size during these weeks potentially resulting in less robust estimates. Second, student controls reporting to compete in a sport on a national or international level, but not being part of an elite sports program (n = 74), were excluded. Prior to collecting baseline data, a directed acyclic graph approach was used to identify potential confounding factors, but we identified no common causes of the exposure and the outcome (**SUPPLEMENTAL MATERIAL S3**). Reasons for use and types of analgesics used were reported, first, as proportions of participants, with 95% CIs, reporting each reason/type at least once during the 36-week study period and tested using chi-square tests and, second, descriptively as frequency and percentage distribution based on the total number of responses during the study period. Both were stratified by athletic status and sex. Due to the exploratory nature of this study, no multiplicity adjustment was performed.[5] The statistical analyses were performed in Stata version 17 (StataCorp 2021, College Station, TX).

RESULTS

In total, 735 youth elite athletes and 545 student controls completed the baseline questionnaire and were included in the ESSENTIAL cohort. Of the 1280 participants, 690 athletes (94%) and 505 student controls (93%) completed the prospective registration of analgesic use and were included in the analysis (**FIGURE**). The average weekly response rate was 88% (range, 80%-99%) among athletes and 85% (range, 77%-97%) among student controls. Athletes had a mean age of 17.1 years, 44% were female, and 54% entered the study with a sports-related injury. Forty-six sports disciplines were represented, with soccer (17%), handball (14%), and swimming (10%) being the most common.

Student controls had a mean age of 17.4 years, 59% were female, and 62% reported participating in sport, of which 24% (n = 74) competed in their sport at the national or international level. One in 3 student controls entered the study with a sports-related injury (**TABLE 1**). Baseline characteristics of included participants were similar to those lost to follow-up (**SUPPLEMENTAL MATERIAL S4** and **S5**).

Prevalence of Analgesic Use

In athletes, the mean weekly prevalence of analgesic use was 20% (range, 15%-32%), with a mean prevalence of 29%

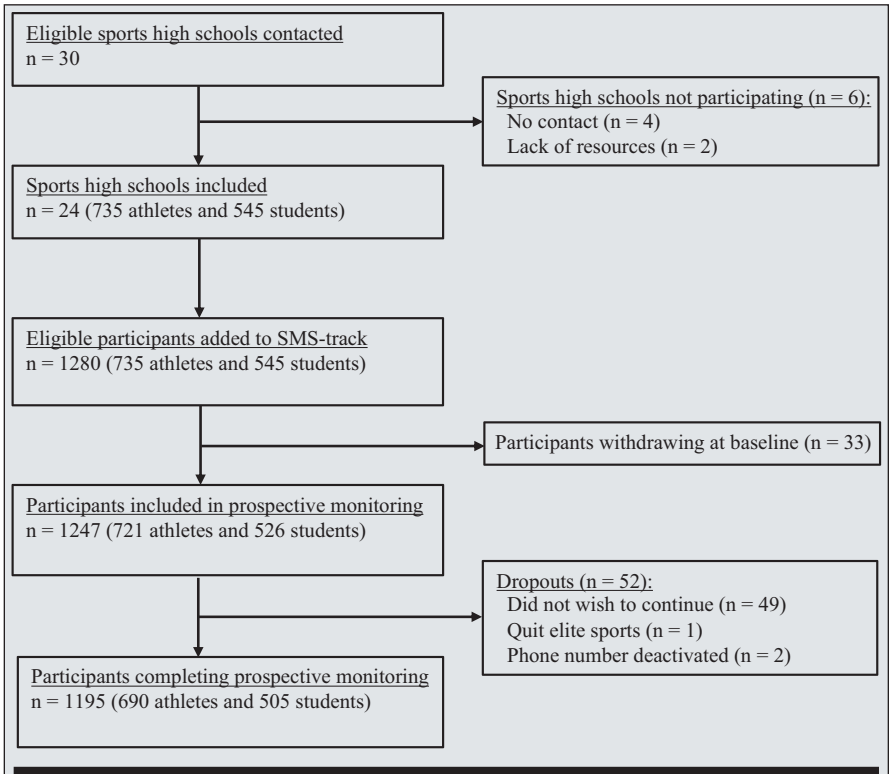

FIGURE. Flow chart.

TABLE 1 Baseline Characteristics of Included Participants

Variable	All Athletes (n = 690)	All Students (n = 505)	Female Athletes (n = 305)	Female Students (n = 299)	Male Athletes (n = 385)	Male Students (n = 206)
Age, mean (SD): years	17.1 (0.4)	17.4 (0.4)	17.1 (1.1)	17.3 (0.9)	17.1 (1.1)	17.6 (0.9)
Female, n (%)	305 (44.2)	299 (59.2)	305 (100)	299 (100)	0 (0)	0 (0)
BMI, mean (SD)	21.9 (0.1)	21.9 (0.2)	21.7 (3.4)	21.6 (3.8)	22.2 (2.3)	22.4 (3.4)
Weekly sports exposure, mean (SD): hours[b]	16.2 (6.3)	6.7 (4.6)	16.1 (6.6)	5.8 (4.5)	16.2 (6.2)	7.8 (4.6)
Students' participation in a specific sport, n (%)	N/A		N/A		N/A	
Yes		313 (62)		153 (51)		160 (78)
No		192 (38)		146 (49)		46 (22)
Type of sport, n (%)	[a]	[b]		[b]	[a]	
Team sport	323 (47)	143 (46)	122 (40)	61 (41)	201 (52)	82 (51)
Endurance sport	137 (20)	18 (6)	73 (24)	11 (7)	64 (17)	7 (4)
Technical sport	229 (33)	150 (48)	110 (36)	79 (52)	119 (31)	71 (45)
Athlete competition level, n (%)		N/A		N/A		N/A
Regional	47 (7)		17 (6)		30 (8)	
National	327 (47)		141 (46)		186 (48)	
International	316 (46)		147 (48)		169 (44)	
Student competition level, n (%)[d]	N/A		N/A		N/A	
Recreational		188 (60)		85 (55)		103 (64)
Regional		51 (16)		24 (15)		27 (17)
National		65 (21)		38 (25)		27 (17)
International		9 (3)		6 (5)		3 (2)
Age at sports debut, mean (SD): years	7.5 (3.2)	N/A	7.2 (.9)	N/A	7.6 (3.4)	N/A
Age at sports specialization, mean (SD): years	13.0 (2.3)[c]	N/A	12.9 (2.3)[a]	N/A	13.1 (2.2)[b]	N/A
Baseline sports-related injury, n (%)[e]						
No	318 (46)	337 (67)	130 (43)	201 (67)	188 (49)	136 (66)
Yes, but the injury did not affect sports participation	179 (26)	80 (16)	83 (27)	44 (15)	96 (25)	36 (18)
Yes, the injury affected sports participation in less than 4 weeks	81 (12)	39 (8)	32 (11)	23 (8)	49 (13)	16 (8)
Yes, the injury affected sports participation in more than 4 weeks	81 (12)	37 (7)	41 (13)	26 (9)	40 (10)	11 (5)
Yes, time-loss injury	31 (4)	12 (2)	19 (6)	5 (1)	12 (3)	7 (3)
Previous frequent use of analgesics (ie, use on a weekly basis), n (%)						
No	464 (67)	347 (69)	187 (61)	190 (63)	277 (72)	157 (76)
Yes	226 (33)	158 (31)	118 (39)	109 (37)	108 (28)	49 (24)

Abbreviations: BMI, body mass index; N/A, not applicable.
[a]*Missing n = 1.*
[b]*Missing n = 2.*
[c]*Missing n = 3.*
[d]*This proportion is calculated based on the 313 student controls reporting to participate in a specific sport.*
[e]*Answer options relating to affected sports participation were defined as being able to participate in sport but with altered intensity/frequency, and time-loss was defined as complete absence from sport.*

(range, 23%-40%) for females and 14% (range, 7%-28%) for males, respectively. In student controls, the mean weekly prevalence of analgesic use was 23% (range, 15%-52%), with a mean prevalence of 29% (range, 18%-59%) for females and 14% (range, 7%-42%) for males, respectively (**SUPPLEMENTAL MATERIAL S6**). Overall, athletes had lower odds of using analgesics compared with student controls (OR = 0.78; 95% CI, 0.64 to 0.95; $P = .015$), but when this analysis was stratified by sex, there were no statistically significant differences between female athletes and female student controls or male athletes and male student controls (**TABLE 2**). The sensitivity analyses did not alter the interpretation of the results (**TABLE 2**).

Frequency of Analgesic Use

In athletes, the mean number of days with analgesic use per week was 2.5 (range, 2.1-2.9), with a mean of 2.6 (range, 2.3-3.0) days for females and 2.4 (range, 1.9-3.0) days for males. In student controls, the mean number of days with analgesic use per week was 2.4 (range, 2.1-3.0), with a mean of 2.4 (range, 2.1-2.8) days for females and 2.4 (range, 1.0-3.4) days for males (**SUPPLEMENTAL MATERIAL S7**). We observed no difference in the overall rate of analgesic use between athletes and student controls (IRR = 1.04; 95% CI, 0.99 to 1.11; $P = .095$) (**TABLE 2**). There were no differences when stratified by sex. The sensitivity analysis excluding student controls competing in sports at a national or international level showed a statistically significant higher rate of analgesic use in athletes compared with student controls. The sensitivity analysis omitting the enrollment period did not alter the estimate (**TABLE 2**).

Reasons for Analgesic Use

Compared with student controls, significantly more athletes reported using analgesics to treat pain or injury prior to (39% versus 13%; $P = <.001$) or after (42% versus 21%; $P = <.001$) sports participation and to prevent pain during sports participation (22% versus 7%; $P = <.001$). Significantly fewer athletes reported using analgesics to treat pain not related to sport (53% versus 65%; $P = <.001$), menstrual pain (21% versus 33%; $P = <.001$), and illness (44% versus 52%; $P = .004$) compared with student controls (**TABLE 3**). Similar differences were observed when stratified by sex (**TABLE 3**). In both groups, the most frequently reported reason was to treat pain not related to sport (27% in athletes, 40% in student controls) (**SUPPLEMENTAL MATERIAL S9**).

Types of Analgesics

Compared with student controls, significantly more athletes reported using topical gels (28% versus 13%; $P = <.001$). Significantly fewer athletes reported using paracetamol (74% versus 80%; $P = .015$) and acetylsalicylic acid (11% versus 17%; $P = .003$) compared with student controls (**TABLE 3**). Similar differences were observed when stratified by sex (**TABLE 3**). In both groups, the most frequently reported type of analgesic was paracetamol (59% in athletes, 64% in student controls) (**SUPPLEMENTAL MATERIAL S2**).

TABLE 2 Comparison of Prevalence and Frequency of Analgesic Use

Prevalence of Analgesic Use			
Variable	**OR**	**95% CI**	***P* Value**
Athletes versus student controls	0.78	0.64 to 0.95	.015
Female athletes versus female student controls	0.95	0.74 to 1.21	.700
Male athletes versus male student controls	0.98	0.74 to 1.31	.936
Sensitivity analysis, exposure[a]			
Athletes versus student controls	0.80	0.65 to 0.98	.039
Sensitivity analysis, enrollment period omitted			
Athletes versus student controls	0.82	0.66 to 1.01	.068
Frequency of Analgesic Use			
Variable	**IRR**	**95% CI**	***P* Value**
Athletes versus students	1.04	0.99 to 1.11	.095
Female athletes versus female student controls	1.04	0.97 to 1.11	.235
Male athletes versus male student controls	1.08	0.98 to 1.20	.112
Sensitivity analysis, exposure[a]			
Athletes versus student controls	1.06	1.00 to 1.13	.028
Sensitivity analysis, enrollment period omitted			
Athletes versus student controls	1.04	0.98 to 1.11	.156

Abbreviations: CI, confidence interval; IRR, incidence rate ratio; OR, odds ratio.
[a]*The sensitivity analysis of exposure status excluded student controls reporting to compete in a sport at a national or international level.*

DISCUSSION

In this 36-week prospective cohort study investigating analgesic use in Danish youth elite athletes and student controls, we observed that participating in youth elite sports was associated with lower odds of analgesic use compared to student controls, but use rates were similar between the groups. There were no differences in odds of analgesic use between the groups when stratified by sex. Reasons for use and types of analgesics used seem to differ between athletes and student controls.

We investigated weekly prevalence and frequency of analgesic use for 36 weeks in youth elite and student controls. On average, 1 in 5 participants, regardless

TABLE 3 Reasons for and Types of Analgesics Used (Proportions of Participants Reporting Each Reason and Type at Least Once During the 36-Week Study Period)

	All Athletes (n = 690)	All Students (n = 505)	*P* Value	Female Athletes (n = 305)	Female Student Controls (n = 299)	*P* Value	Male Athletes (n = 385)	Male Student Controls (n = 206)	*P* Value
Reasons for Use, n (% [95% CI])									
To treat pain or injury after participating in sport	289 (42 [38-46])	107 (21 [18-25])	<.001	161 (53 [47-58])	67 (22 [17-27])	<.001	128 (33 [28-38])	40 (19 [14-25])	<.001
To treat pain or injury prior to participating in sport	271 (39 [35-43])	67 (13 [10-16])	<.001	141 (46 [40-52])	43 (14 [10-18])	<.001	130 (34 [29-38])	24 (12 [7-16])	<.001
To prevent pain that might occur during sports participation	154 (22 [19-25])	38 (7 [5-10])	<.001	84 (27 [22-32])	25 (8 [5-12])	<.001	70 (18 [14-22])	13 (6 [3-10])	<.001
To treat pain not related to sport (eg, headache, back pain)	368 (53 [49-57])	332 (65 [61-69])	<.001	207 (68 [62-73])	232 (78 [72-82])	.007	161 (42 [37-47])	100 (48 [41-55])	.117
To treat menstrual pain	147 (21 [18-24])	169 (33 [29-37])	<.001	147 (48 [42-53])	169 (56 [50-62])	.041	N/A	N/A	N/A
To treat illness	304 (44 [40-48])	265 (52 [48-56])	.004	166 (54 [48-60])	186 (62 [56-67])	.053	138 (36 [31-40])	79 (38 [31-45])	.547
Other reasons	87 (12 [10-15])	113 (22 [18-26])	<.001	58 (19 [14-23])	80 (27 [22-32])	.024	29 (7 [5-10])	33 (16 [11-21])	.001
Types of Analgesics, n (%)									
Paracetamol	509 (74 [70-77])	403 (80 [76-83])	.015	262 (86 [81-89])	266 (89 [84-92])	.257	247 (64 [59-68])	137 (66 [60-72])	.568
Nonsteroidal anti-inflammatory drugs	288 (42 [38-46])	192 (38 [34-42])	.195	179 (59 [53-64])	147 (49 [43-55])	.019	109 (28 [23-33])	45 (22 [16-28])	.088
Topical gels	193 (28 [25-31])	64 (13 [10-16])	<.001	109 (36 [30-41])	42 (14 [10-18])	<.001	84 (22 [18-26])	22 (11 [7-15])	.001
Acetylsalicylic acid	77 (11 [9-14])	86 (17 [14-20])	.003	43 (14 [10-18])	68 (23 [18-28])	.006	34 (9 [6-12])	18 (9 [5-13])	.970
Opioids	33 (5 [3-6])	35 (7 [5-9])	.113	21 (7 [4-10])	27 (9 [6-12])	.330	12 (3 [1-5])	8 (4 [2-7])	.623
Injections	30 (4 [2-6])	26 (5 [3-7])	.518	21 (7 [4-10])	16 (5 [2-8])	.432	9 (2 [1-4])	10 (5 [2-8])	.098
Other	33 (5 [3-6])	35 (7 [5-9])	.113	21 (7 [4-10])	23 (8 [5-11])	.703	12 (3 [1-5])	12 (6 [3-9])	.112

Abbreviations: CI, confidence interval; N/A, not applicable.

of athletic status, reported analgesic use in any given week, with an average of 2.4-2.5 days per week with analgesic use. In both athletes and student controls, the average weekly prevalence of analgesic use was higher among females than among males. While this aligns with previous findings in Scandinavian nonathlete adolescents,[18,22] findings regarding sex differences in analgesic use in youth athletes have been inconsistent.[33] Further comparisons between the results of the present study and those of previous literature are challenging due to large variation in population demographics, settings, and study designs.

Our prospective data and previous studies collectively suggest that use of analgesics is high in both athlete[33] and nonathlete youth populations,[3] raising potential health concerns. Although most analgesics are generally considered safe when used for short periods and in doses according to recommendations for use, long-term or high use may pose safety hazards. Few studies have reported on the occurrence of adverse events in youth athletes[33] and in the general youth population,[3] highlighting the lack of knowledge on the potential impact on short- and long-term health. Relying on analgesics early in life could interfere with the development of healthy pain management strategies and increase the risk of continued use later in life, as reported in studies of both elite athletes[11,24] and nonathlete populations.[4]

We compared the odds and rates of analgesic use between youth elite athletes and student controls. While there was no difference in the rate of analgesic use between the groups, we observed lower odds of analgesic use in youth elite athletes compared with student controls, which was not replicated in the gender-stratified analyses. These contrasting findings are likely explained by several factors, including smaller sample sizes

in the subgroup analyses resulting in reduced statistical power; the largest difference in mean weekly prevalence of analgesic use being observed between female student controls and male youth elite athletes; and non-collapsibility of the OR, suggesting that the marginal measure of association does not equal a weighted average of the stratum-specific measures of association.[41]

We investigated and compared reasons for analgesic use and types of analgesics used between youth elite athletes and student controls. Supporting previous findings, athletes frequently reported using analgesics to treat pain or injury prior to or after sports participation or to prevent pain during sports participation.[33] While international guidelines recommend that analgesics should not be used to prevent pain and that the health of athletes prevails over competitive considerations,[15] factors including high injury rates in youth sports[10,28] and sociocultural norms that glorify risk,[40] normalize pain,[40] and demand high performance[7,27] may partly explain the high proportion of athletes using analgesics to cope with pain and injury in relation to sports participation. This finding gives rise to concerns about a potential increase in injury risk and secondary progression of existing injuries due to continued athletic activity.[17,23] The importance of remaining injury free to allow for sustained sports participation and athletic development is highlighted by the comprehensive body of research into injury prevention initiatives in youth sports[19] and qualitative studies showing that injured young athletes experience a fear of falling behind their peers in terms of development and performance.[12] Our results point to a culture of "playing through pain," where athletes prioritize short-term performance over long-term health and well-being.[40] Identifying detrimental cultural norms may provide the basis for continued development of sustainable youth athlete environments. Significantly fewer athletes are reporting use of analgesics to treat illness and pain not related to sport compared with student controls. As limited knowledge exists regarding differences in the prevalence and incidence of health problems in youth elite athletes and nonathlete controls,[30] it remains unknown whether this finding reflects true differences in the occurrence of illness and non–sports-related pain or variations in the decision-making process to use analgesics for these reasons.

In our study, paracetamol was the most frequently reported analgesic, accounting for approximately 60% of the total use, while NSAIDS accounted for only approximately 20%. Similarly, 2 previous studies of analgesic use in Danish youth and senior elite athletes also found that paracetamol was the most commonly used analgesic.[32,34] In a recent systematic review, we found that NSAIDs were the most frequently used analgesic among international youth athletes from varying performance levels.[33] The discrepancy between Danish and international data may mainly be attributed to 2 factors. First, the existing literature on analgesic use in elite athletes has predominately assessed NSAIDs use,[16,33] potentially resulting in underreporting of other types of analgesics. Second, due to the more favorable risk profile, the Danish Health Authority generally recommends paracetamol when purchasing over-the-counter analgesics.[36] This was recently supported by a national survey showing that 61% of all over-the-counter analgesics purchased were paracetamol, while NSAIDs accounted for 29%.[8]

Significantly more athletes used topical analgesics compared to student controls. A recent systematic review and meta-analysis found that topical analgesics were significantly better at reducing pain compared to oral analgesics versus a placebo in injured athletes.[31] While the low use of NSAIDs relative to paracetamol is in accordance with international guidelines,[15] athletes may consider using topical analgesics for more effective pain control and even lower risk of adverse events.[31]

Clinical Implications

Understanding the scope of analgesic use in youth elite athletes is essential for developing informed strategies to promote safe and effective pain management practices.[43] Our results, alongside findings from previous studies reporting common use of analgesics, poor awareness of potential adverse events, and perceived pressure to use analgesics among youth athletes,[33,35,37,42] suggest that well-defined and clinically applicable guidelines should be developed to support sports medicine professionals, coaches, and athletes in the decision-making process of using analgesics.

Limitations

The PAMUS questionnaire was designed and content-validated specifically for use in youth elite athletes, and we have no data on the content validity for student controls. However, to enable reporting of responses that may not have been identified during the development of the questionnaire, we included an "other" response option in the questions regarding reasons for use and types of analgesics used. Data on analgesic dosage were not collected using the PAMUS questionnaire, which precludes detailed interpretation of consumption patterns.

Surveillance of analgesic use could affect awareness among the participants. We observed a decrease in the prevalence of analgesic use during the first 8 weeks of the study. While it has been described that first-time responses to similar questionnaires should be interpreted with caution,[9] previous injury surveillance studies in youth athletes have also shown that injury incidence and prevalence is highest in the beginning of the season.[1,29] This may partly explain the higher prevalence of analgesic use observed among athletes in the first weeks of the study period, as 54% reported to have a sports-related injury at baseline. Similarly, 33% of student controls reported entering the study with a sports-related injury.

Fifteen percent of the student controls competed in a sport at a national or international level. This overlap in sports participation may have biased the analyses toward the null. This was observed

in the analysis of frequency of analgesic use where the main analysis showed no evidence of statistically significant differences in the rate of analgesic use between athletes and student controls, but the sensitivity analysis excluding student controls competing in their sport at a national or international level resulted in a statistically significantly higher rate among athletes. However, this was not observed in the analysis of the prevalence outcome. Due to the recruitment method, we were unable to obtain information on the total number of potentially eligible participants, and it was not possible to assess potential nonparticipation selection bias.

It is unknown whether there are systematic differences between high schools offering elite sports programs and high schools that do not. However, considering the large number of included high schools with diverse geographical location, size, and type of education programs, it is plausible that any potential differences may be random. Finally, the findings are specific to a Danish youth elite sports setting and may not be applicable in other cultures, sports, or youth elite sports/dual-career settings.

CONCLUSION

Analgesic use was common in both youth elite athletes and student controls, with a mean weekly prevalence of approximately 20%. Participating in youth elite sports was associated with lower odds of analgesic use compared to student controls, but the usage rate was similar between the groups. There were no differences in odds of analgesic use between the groups when stratified by sex. ◉

KEY POINTS

FINDINGS: Analgesic use is prevalent in both youth elite athletes and the general youth population, with an average weekly prevalence of approximately 20%. Danish youth elite athletes had lower odds of analgesic use compared with student controls, but this was not replicated in sex-stratified analyses. Rates of analgesic use were similar between the groups. Participating in youth elite sports may affect reasons for use and types of analgesics used.

IMPLICATIONS: Due to the high proportion of youth elite athletes using analgesics in relation to sports participation, athletes should be informed about safe use of analgesics. Clinically applicable guidelines should be developed to support sports medicine professionals, coaches, and athletes in the decision-making process of using analgesics.

CAUTION: The findings are specific to a Danish youth elite sports setting. The PAin Medication Use in youth Sports (PAMUS) questionnaire was designed and content-validated specifically for use in youth elite athletes, and we have no data on the content validity for student controls.

STUDY DETAILS

AUTHOR CONTRIBUTIONS: Julie Rønne Pedersen and Drs Møller, Storm, Koes, and Thorlund were responsible for the conception and design of the study and data collection; Julie Rønne Pedersen and Drs Thorlund and Mohammadnejad were involved in the processing and statistical analysis of data; Julie Rønne Pedersen was involved in the drafting of the manuscript; and all authors contributed to the interpretation of the data for the work and revising it critically for important intellectual content. All the authors finally approved the manuscript. Julie Rønne Pedersen was responsible for obtaining project funding and takes responsibility for the integrity of the work as a whole. All authors have read and agreed to the published version of the manuscript.

DATA SHARING: There are no data available.

PATIENT AND PUBLIC INVOLVEMENT: Danish elite sports high schools and Team Denmark provided input on the study plan and helped with participant recruitment. A group of youth elite athletes took part in the development of the PAin Medication Use in youth Sports (PAMUS) questionnaire. Neither had any influence on the analysis, interpretation of results, or manuscript preparation.

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Supplementary material 1 PAMUS development

As no validated questionnaires on analgesic use in youth elite athletes was identified in a systematic literature search, we specifically developed the PAin Medication Use in youth Sports (PAMUS) questionnaire for this study to measure self-reported weekly use of analgesics. The development and content validation process of the PAMUS questionnaire was performed following the COSMIN guidelines for developing and validating patient-reported outcome measurement instruments[1] and the guidelines by Patrick et al.[2 3] in the following steps:

1) The construct to be measured (analgesic use), context of use (digital monitoring tool intended for weekly administration), and the population of interest (youth elite athletes between 15-20 years of age) were defined, and a literature search was conducted to identify components of analgesic use in youth athletes.
2) A conceptual model was identified, and a hypothesized conceptual framework was developed to identify overarching concepts, hypothesized domains, and candidate item content. Based on the hypothesized conceptual framework, two interview guides were developed
3) One-to-one interviews were performed with three researchers and focus group interviews were performed with seven members of the target population (i.e., youth elite athletes aged 15-20 years).
4) The interview data was analyzed using content analysis. Eight overall themes were identified from the athlete interviews, including types of analgesics, sources of knowledge, adverse events, frequency of usage, reasons for sports-related use of analgesics, reasons for non-sports related use of analgesics, sociocultural influences on analgesic use, and other interventions received for pain/injury. Based on expert opinion, it was deemed unnecessary to monitor adverse events on a weekly basis due to high chances of symptoms misclassification and it was hypothesized that it would be sufficient to assess sources of knowledge at baseline as this is unlikely to change over a shorter period of time. Similarly, while numerous external influences and sources on knowledge on analgesic use were identified in the focus group interviews, no consistent patterns or experiences were found within the data, thus hindering further conceptualization. As a result, it was decided that aspects related to sociocultural influences and the impact of the athlete environment on analgesic use should be explored through qualitative research methods. Finally, it was deemed inappropriate to ask about other interventions used for sports-related pain and injury, as analgesics may be used for other purposes than the treatment of sports-related pain and injury.

5) Based on the remaining 4 themes, a questionnaire containing a maximum of three questions (frequency of analgesic use, reasons for use, and types of analgesic used) was drafted and pilot tested using one-to-one cognitive interviewing in another group of youth elite athletes (n=7). These interviews showed that the participants were positive towards the questionnaire and found the items and related response options clear and unambiguous. All participants were satisfied with the total number of questions and felt that all were relevant to them. The interviews revealed that no adjustment was necessary to finalize the questionnaire. Detailed information on the development and content validation process will be reported in a separate publication.

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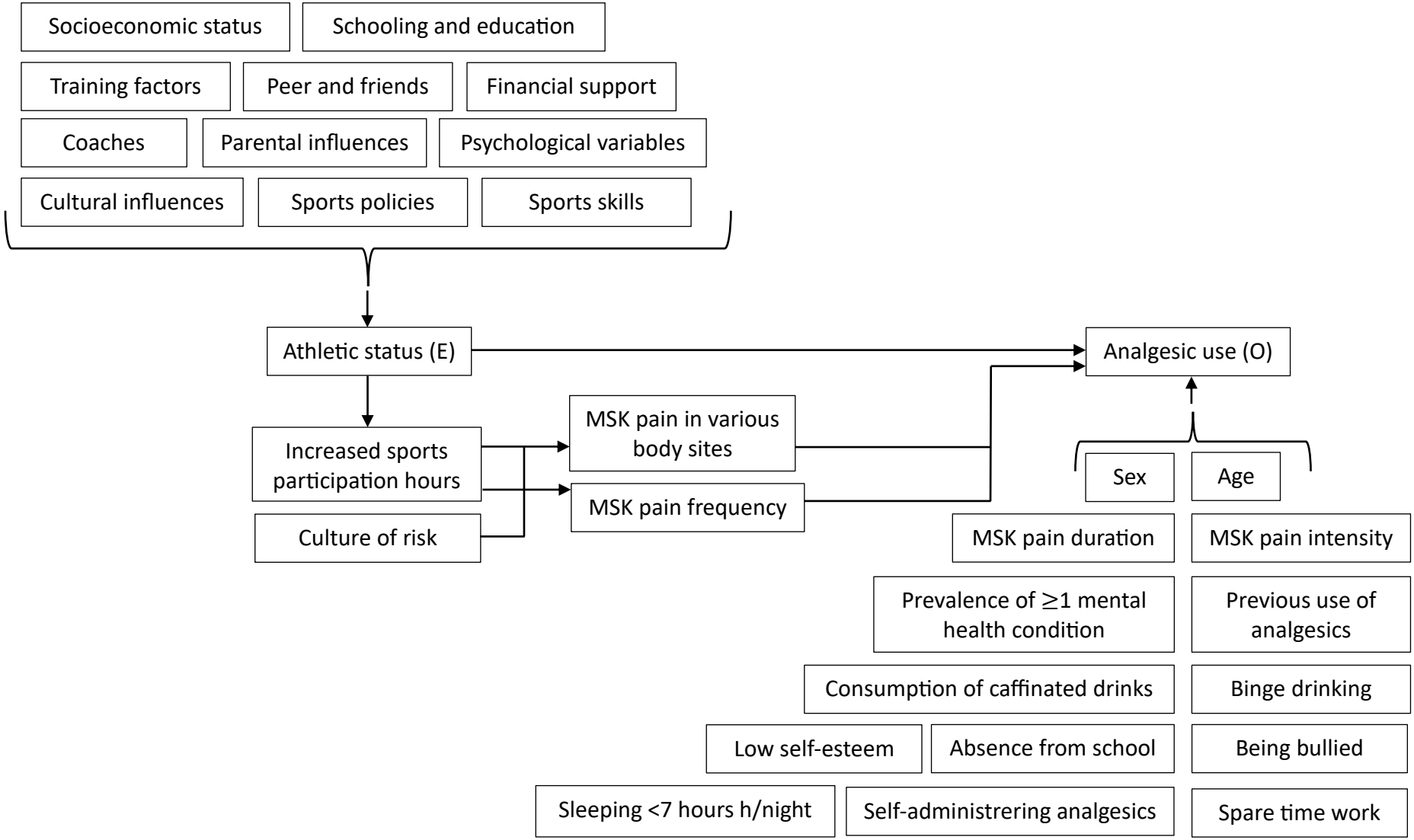
Supplementary material 2 PAMUS questionnaire

Questions	Answer options
How many days have you used pain medication during the past 7 days?	0 (questionnaire finalized) 1 2 3 4 5 6 7
Why did you use pain medication? (choose all relevant response options)	1) To treat pain or injury after participating in sport 2) To treat pain or injury prior to participating in sport 3) To prevent pain that might occur during sports participation 4) To treat pain not related to sport (e.g., headache, back pain) 5) To treat menstrual pain 6) To treat illness 7) Other reasons
What type(s) of pain medication did you use? (choose all relevant response options)	1) Paracetamol (e.g., panodil, pamol, paracetamol, pinex) 2) Non-steroidal anti-inflammatory drugs (e.g., ipren, ibuprofen, ibumetin, diclofenac, naproxen) 3) Gels (e.g., voltaren gel, ipren gel, ibutop) 4) Acetylsalicylic acid (e.g., treo, triplo, kodimagnyl) 5) Opioids (e.g., tramadol, codein, fentanyl, oxycodone) 6) Injections 7) Other (e.g., antiepileptic medicine [gabapentin, pregabalin], antidepressive medicine [amitryptilin, duloxetine])

Supplementary material 3 Directed Acyclic Graph



Supplementary material 4 Drop-out analysis, youth elite athletes

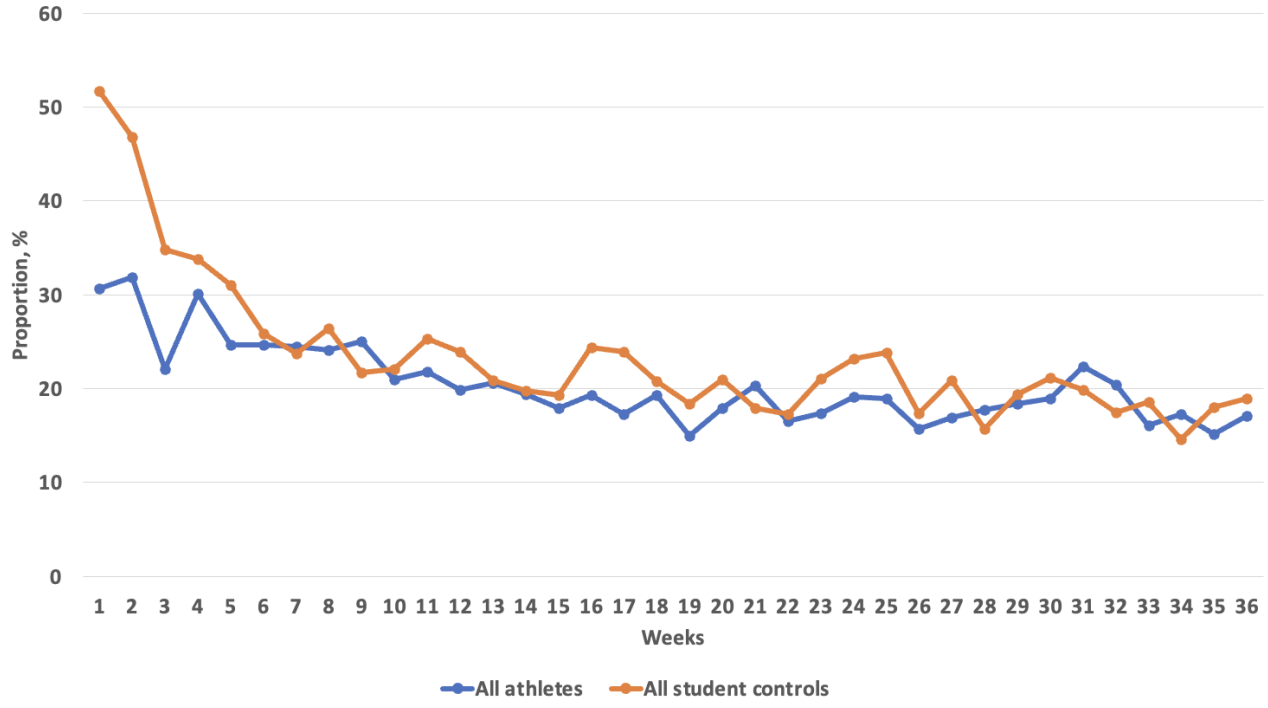
	Participants retained in the study (n=690)	Participants dropped out or excluded (n=45)	Difference (95% CI) or p-value
Age, mean (SD): years	17.1 (0.4)	17.2 (0.1)	0.1 (-0.1 to 0.4)
Female, n (%)	305 (44%)	13 (28%)	P=0.03
BMI, mean (SD)	21.9 (0.1)	21.6 (0.2)	0.3 (-0.5 to 1.1)
Weekly sports exposure, mean (SD): hours	16.1 (0.2)	15.5 (0.7)	0.6 (-1.3 to 2.5)
Type of sport, n (%)			P=0.31
Team sport	323 (47%)	25 (56%)	
Endurance sport	137 (20%)	5 (11%)	
Technical sport	229 (33%)	15 (33%)	
Competition level, n (%)[b]			P=0.98
Regional	47 (7%)	3 (7%)	
National	327 (47%)	22 (49%)	
International	316 (46%)	20 (44%)	
Age at sports debut, mean (SD): years	7.4 (0.1)	7.3 (0.4)	0.1 (-0.8 to 1.1)
Age at sports specialization, mean (SD): years	12.9 (0.1)	12.2 (0.3)	0.7 (0.01 to 1.4)
Baseline sports-related injury, n (%)			P=0.83
No	318 (46%)	21 (47%)	
Yes, but the injury did not affect sports participation	179 (26%)	10 (22%)	
Yes, the injury affected sports participation in less than 4 weeks	81 (12%)	7 (15%)	
Yes, the injury affected sports participation in more than 4 weeks	81 (12%)	4 (9%)	
Yes, time-loss injury	31 (4%)	3 (7%)	

Supplementary material 5 Drop-out analysis, student controls

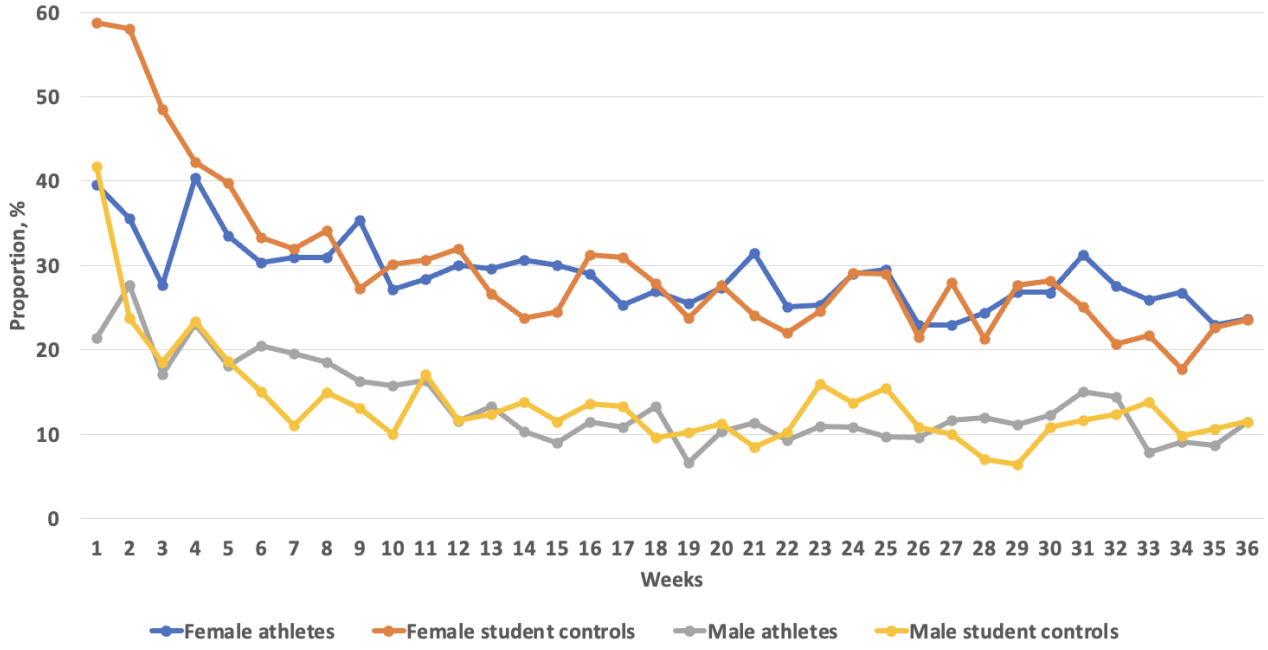
	Participants retained in the study (n=505)	Participants dropped out or excluded (n=40)	Difference (95% CI) or p-value
Age, mean (SD): years	17.4 (0.0)	17.5 (0.1)	0.1 (-0.2 to 0.4)
Female, n (%)	299 (59.2%)	20 (50%)	P=0.04
BMI, mean (SD)	21.9 (0.1)	21.8 (0.5)	0.05 (-1.1 to 1.2)
Participation in a specific sport, n (%)			P=0.72
No	192 (38%)	13 (33%)	
Yes	313 (62%)	27 (67%)	
Weekly sports exposure, mean (SD): hours	6.6 (0.2)	7.8 (0.8)	1.1 (-0.4 to 2.6)
Type of sport, n (%)			P=0.41
Team sport	143 (46%)	14 (52%)	
Endurance sport	18 (6%)	0 (0%)	
Technical sport	150 (48%)	13 (48%)	
Baseline sports-related injury, n (%)			P=0.66
No	337 (67%)	26 (65%)	
Yes, but the injury did not affect sports participation	80 (16%)	9 (23%)	
Yes, the injury affected sports participation in less than 4 weeks	39 (8%)	1 (2%)	
Yes, the injury affected sports participation in more than 4 weeks	37 (7%)	3 (8%)	
Yes, time-loss injury	12 (2%)	1 (2%)	

Supplementary material 6A+B Weekly prevalence of analgesic use stratified by (A) athletic status and (B) athletic status and sex. The number of participants at each assessment time-point is available in Supplementary material 8.

A

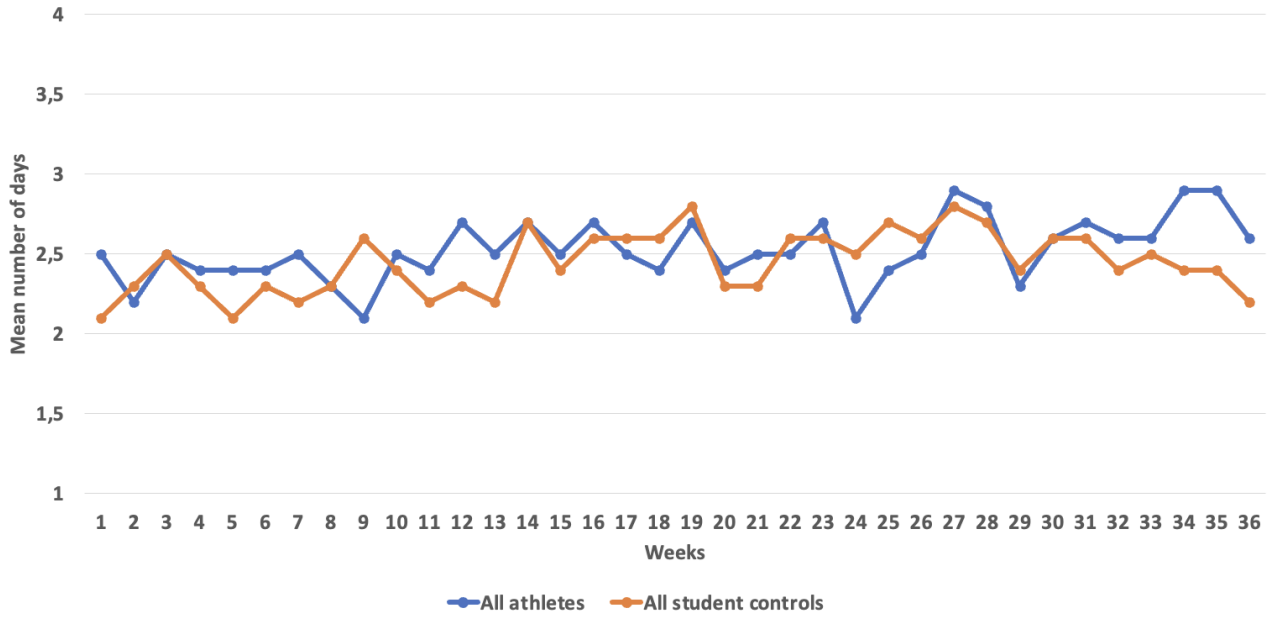


B

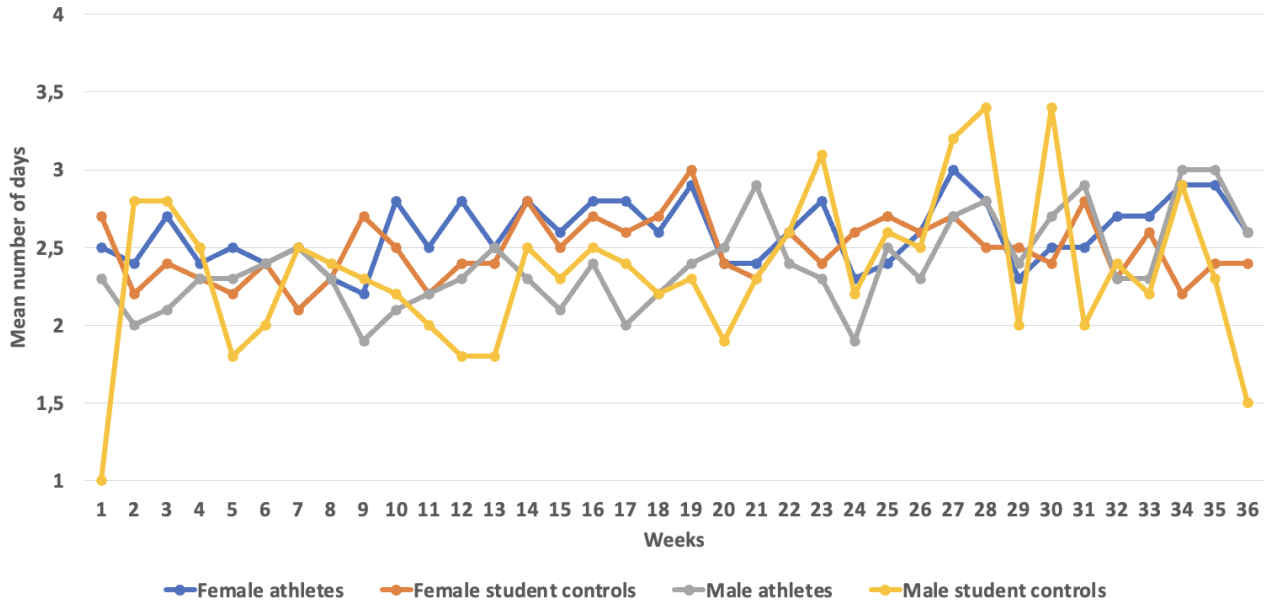


Supplementary material 7A+B Weekly frequency of analgesic use among analgesic stratified (A) athletic status and (B) and athletic status and sex. Both graphs are based on participants reporting analgesic use every week (i.e., ≥1 days use). The number of participants at each assessment time-point is available in Supplementary material 8.

A



B



Supplementary material 8 Overview of number of participants at each assessment time-point

Week	Total	Youth elite athletes	Student controls
Prevalence			
1	153	115	30
2	219	152	67
3	426	242	184
4	777	417	360
5	943	508	435
6	997	539	458
7	1052	572	480
8	1106	602	504
9-36	1195	690	505
Frequency[a]			
1	50	35	15
2	77	47	30
3	114	52	62
4	236	120	116
5	249	121	128
6	234	126	108
7	214	122	92
8	256	137	119
9	257	161	96
10	235	135	100
11	255	140	115
12	234	126	108
13	221	129	92
14	205	119	86
15	195	111	84
16	225	120	105
17	208	105	103
18	205	116	89
19	168	90	78
20	195	107	88
21	196	121	75
22	170	97	73
23	191	102	89
24	207	110	97
25	207	108	99
26	157	87	70
27	181	96	85
28	163	101	62
29	181	104	77
30	193	109	84
31	207	128	79
32	183	115	68
33	161	89	72
34	153	96	57
35	154	84	70
36	174	98	76

[a] Number of participants for the frequency outcome is based on participants reporting ≥1 days use of analgesics (i.e., non-users omitted)

Supplementary material 9 Reasons for and types of analgesics used (total number of times each response option was reported during the full 36-weeks study period)

Reasons for use, n (%)	**All athletes (n=690)**	**All students (n=505)**	**Female athletes (n=305)**	**Female student controls (n=299)**	**Male athletes (n=385)**	**Male student controls (n=206)**
To treat pain or injury after participating in sport	1014 (21%)	283 (8%)	610 (19%)	180 (6%)	404 (24%)	103 (14%)
To treat pain or injury prior to participating in sport	812 (17%)	168 (5%)	471 (15%)	95 (3%)	341 (21%)	73 (10%)
To prevent pain that might occur during sports participation	407 (8%)	64 (2%)	235 (7%)	44 (2%)	172 (10%)	20 (3%)
To treat pain not related to sport (e.g., headache, back pain)	1323 (27%)	1435 (40%)	947 (29%)	1108 (40%)	376 (23%)	327 (44%)
To treat menstrual pain	452 (9%)	619 (18%)	452 (14%)	619 (22%)	N/A	N/A
To treat illness	765 (16%)	745 (21%)	438 (13%)	574 (21%)	327 (20%)	171 (23%)
Other reasons	163 (3%)	232 (7%)	119 (4%)	177 (6%)	44 (3%)	55 (7%)
Total	4936	3546	3272	2797	1664	749
Types of analgesics, n (%)						
Paracetamol	2924 (59%)	2369 (64%)	1971 (59%)	1850 (63%)	953 (59%)	519 (66%)
Non-steroidal anti-inflammatory drugs	1037 (21%)	761 (21%)	782 (24%)	623 (21%)	255 (16%)	138 (18%)
Topical gels	614 (12%)	123 (3%)	345 (10%)	84 (3%)	269 (17%)	39 (5%)
Acetylsalicylic acid	186 (4%)	209 (6%)	101 (3%)	183 (6%)	85 (5%)	26 (3%)
Opioids	72 (2%)	69 (2%)	55 (2%)	51 (2%)	17 (1%)	18 (2%)
Injections	39 (1%)	26 (1%)	27 (1%)	16 (1%)	12 (1%)	10 (1%)
Other	61 (1%)	153 (4%)	47 (1%)	114 (4%)	14 (1%)	39 (5%)
Total	4933	3710	3328	2921	1605 (100)	789

*The percentages may not add up to 100% due to rounding

Paper III

Title page

Title

It may not be the smartest thing to do, but sometimes it's the only option: A longitudinal mixed-methods study of analgesic use in youth elite athletes

Authors

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Abstract

Objectives: To compare analgesic use over 36 weeks between endurance athletes, technical athletes, and team athletes, and explore experiences and sociocultural factors impacting analgesic use.

Design: Longitudinal mixed-methods study

Methods: 689 youth elite athletes (44% females, 15-20 years) provided weekly reports on number of days with analgesic use, reasons for use, and types of analgesics used for 36 weeks. Prevalence and frequency of analgesic use was compared between athletes from team sports, endurance sports, and technical sports using mixed effects logistic and Poisson regression models. Reasons and types of analgesics used were compared between groups using Chi-square tests. Nine focus group interviews with 32 participants were conducted and analyzed using thematic analysis.

Results: There were no differences in odds of analgesic use between endurance athletes (reference group), technical athletes (OR 0.94 [95% CI 0.65-1.37), and team athletes (OR 0.88 [95% CI 0.62-1.25]). Similarly, there were no differences in rate of analgesic use between endurance athletes (reference group), technical athletes (IRR 0.97 [95% CI 0.87-1.07]), or team athletes (IRR 1.93 [95% CI 0.94-1.14]). Reasons for use varied between groups, but the types of analgesics used was similar. Athletes described diverse experiences with analgesics. Sociocultural factors impacting analgesic use were, for example, considering the potential consequences of using analgesics for pain and injury, and feeling responsible for team performance.

Conclusion: Analgesics are commonly used among youth elite athletes, but generally does not vary between team athletes, endurance athletes, and technical athletes. Several norms, values, and structures in sports environments impact analgesic use.

Key words

Athletes; Analgesics; Pain management; Adolescent

Introduction

In the field of sports medicine, there is increasing concern about the use of analgesics among youth athletes[3, 11, 25]. A systematic review from 2022 concluded that analgesic use is widespread in youth athletes, with 92% of athletes reporting use within a season, and point prevalence estimates ranging from 21% to 54% across various over-the-counter analgesics[25]. However, several limitations in the existing evidence were identified, including the need for high-quality longitudinal studies, as the current evidence is based exclusively on cross-sectional studies[25]. Another limitation is the lack of sufficient data on variations in analgesic consumption patterns between youth athletes from different sports disciplines. A study of Finnish elite athletes found a lower 7-day period prevalence of analgesic use among team sport athletes (n=152, 28.3%) compared to speed and power athletes (n=113, 41.6%)[1]. Additionally, previous research suggest that athletes' willingness to engage in risk-taking behavior by competing despite underlying health problems varies across different sports disciplines[16, 17], and an association between this practice, also known as *willingness to compete hurt*, and analgesic use in youth athletes, has been documented[26]. This may suggest that variations in analgesic use between overarching sports categories may also exist. In addition, the prevalence and severity of injuries and illness may differ between youth athletes from team sports, technical sports, and endurance sports[21] and as analgesics are commonly used to manage these conditions[25], patterns of analgesic use may also differ across sports categories. Finally, in the systematic review, it was reported that youth athletes often use analgesics to manage sports-related pain and injury, to prevent or block pain to enable sports participation, to improve performance, and to treat symptoms of illness[25]. While these findings enhance our understanding of the contexts in which youth athletes use analgesics, there remains a significant gap in the literature addressing the specific social and cultural context and the complex interactions and interdependencies that influence analgesic use in youth athletes[25].

Identifying longitudinal patterns of analgesics use and the underlying causes of use may provide important insights for initiatives to promote safe, appropriate, and effective pain management strategies for youth athletes. In this mixed-methods study, we compared analgesic use over 36 weeks between youth team athletes, endurance athletes, and technical athletes, and explored experiences with analgesic use and sociocultural influences on the use.

Methods

Study design

In this mixed-methods study we used data from the analgESic uSE iN youTh elIte AthLetes (ESSENTIAL) cohort. We combined data from this 36-weeks prospective cohort study with focus group interviews. A study protocol is available at Open Science Framework (https://osf.io/k5spz/). The Regional Scientific Ethics Committee of the Region of Southern Denmark deemed the study exempt from ethical approval (case number 20202000-176). The project was approved by The Danish Data Protection Agency (case number 11.642). Informed consent was obtained and the rights of the participants were protected. The STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guideline for cohort studies[28] and the CHecklist for statistical Assessment of Medical Papers (CHAMP) statement were used in the reporting of the study[15].

Participants and recruitment

A detailed description of the participant recruitment has previously been described (Pedersen et al., 2024). In short, youth elite athletes from 24 Danish high schools offering elite sports programs (i.e., dual-career programs combining education and elite sports) were recruited during the period from August to October 2022. Athletes were eligible for inclusion if they were I) enrolled in an elite

sports program; II) between 15 and 20 years of age; III) able to read and write Danish; and IV) able to receive and respond to text messages using Short Message Services (SMS). *Elite* was defined as being accepted into an elite sports or dual-career program. Athletes were categorized into three major categories (i.e., endurance (e.g., swimming, rowing), technical (e.g., badminton, golf), and team (e.g., handball, football) sports) in accordance with previous studies using heterogeneous groups of athletes (Clarsen et al., 2014; Moseid et al., 2018). Selection of participants for focus group interviews represented the first integration point of the quantitative and qualitative methods of the study. These athletes were recruited through purposeful sampling from eight of the participating high schools, ensuring representation from various geographical locations, sizes, and types of educational programs. Participants were eligible for inclusion if they I) were included in the cohort study; and II) had a high weekly response rate (defined as <20% missing data). Additionally, athletes for interviews were recruited to represent diversity in terms of analgesic use, age, sex, and types of sport.

Weekly surveillance of analgesic use

At inclusion, participants completed an electronic baseline questionnaire concerning contact information, demographics, and sports history. Every Sunday, starting from the week of inclusion to April 23rd 2023, participants completed the PAin Medication Use in youth Sports (PAMUS) questionnaire (Appendices 1 and 2), containing standardized questions on number of days with analgesic use, reasons for use, and types of analgesics used in the preceding seven days via SMS (www.sms-track.com). Participants received reminder text messages 24 and 72 hours after the first text message if no response was obtained. Participants not responding for three consecutive weeks were contacted by phone to encourage continued participation.

144 *Focus group interviews*

145 Nine semi-structured focus group interviews with 32 athletes (2-5 participants per interview) were
146 conducted by JRP and ACL in February and March 2023. The interviews were conducted face-to-
147 face, audio recorded, and facilitated through using an interview guide in classrooms during teaching
148 hours and lasted between 45 and 60 minutes. Development of the interview guide represented the
149 second integration point of the quantitative and qualitative methods. As we aimed to gain a deeper
150 and more nuanced contextual understanding of youth elite athletes' analgesic use, the interview
151 guide was informed by preliminary results from the cohort study, thereby using empirical insights
152 to explore coherent and plausible explanations[12, 18]. The full interview guide is available in
153 Appendix 3. Data saturation was used as a criterion for discontinuing the data collection, meaning
154 no new significant findings emerged.

155

156 *Data analysis*

157 Baseline demographics were reported as means ± standard deviation (SD), medians and
158 interquartile range (IQR) or as frequency and percentage distribution, as appropriate. Data on
159 analgesic use was, firstly, analyzed descriptively by summarizing mean weekly prevalence (defined
160 as 0 days use/≥1 days use) and frequency of analgesic use (based on participants reporting 1-7 days
161 use) during the full 36-weeks study period stratified by sports category and sex. Secondly, mixed
162 effects logistic regression, expressing odds ratios (OR) with 95% confidence intervals (CI), and
163 mixed effects Poisson regression, expressing incidence rate ratios (IRR) with 95% CI, were used to
164 assess between-group differences in prevalence and frequency of analgesic use between endurance
165 athletes (reference group), technical athletes, and team athletes during the full 36-weeks study
166 period, respectively (Appendix 4). Subgroup analyses were performed stratified by sex. Individual
167 ID was included as a random effect. No confounding factors were identified a-priori, and the

analyses were therefore not adjusted. Because of the consistently high weekly response rate and minimal missing data, and considering the robustness of mixed effects models to missing data, imputation of data was not performed[9]. Reasons for use and types of analgesics used were reported in two ways. First, as the proportions of participants with 95% CIs reporting each reason/type at least once during the 36-week study period and between-group differences were tested using Chi-square tests. Second, as frequency and percentage distribution based on the total number of responses obtained during the study period. Due to the exploratory nature of this study, multiplicity adjustment was not performed[2]. The statistical analyses were performed in Stata version 18 (StataCorp 2023, College Station, TX, USA).

The qualitative data were analyzed using a thematic analysis approach within a critical realism framework[4, 5, 13] and proceeded in six stages. First, the audio records were transcribed verbatim, and JRP and ACL familiarized themselves with the data. Second, initial codes were generated across the dataset. Third, codes were organized and sorted into potential themes and subthemes, which were then reviewed by LKS to challenge the initial interpretation of the data. This stage represented the third integration point of the quantitative and qualitative methods to reveal different levels of reality, including actual (observable events), empirical (athlete experiences), and real (causal mechanisms)[13]. Fourth, themes were reviewed for applicability to the coded extracts and across the entire dataset. Fifth, themes were refined and defined. Sixth, the themes were revised a final time to provide a coherent story of the data within and across themes.

Patient and Public Involvement

Danish elite sports high schools and Team Denmark provided input on the study plan and assisted participant recruitment. A group of youth elite athletes took part in the development of the PAMUS questionnaire.

Results

In total, 735 youth elite athletes were included in the ESSENTIAL cohort. Forty-five athletes (6%) were lost to follow-up and one athlete was excluded due to missing data on type of sport, leaving 689 (94%) athletes available for this analysis (Figure 1). The average weekly response rate was 88% (range 80-99%). The athletes had a mean age of 17.1 (SD 0.4) years and 44% were female (Table 1). Forty-six sports disciplines were represented, with 137 athletes (20%) from endurance sports, 229 (33%) from technical sports, and 323 (47%) from team sports. More males were lost to follow-up or excluded compared with females. There were no other differences in baseline characteristics between included athletes and those excluded or lost to follow-up (Appendix 5).

Prevalence of analgesic use

The mean weekly prevalence of analgesic users was 20% (range 12% to 31%) for endurance athletes, 21% (range 15% to 33%) for technical athletes, and 20% (range 13% to 43%) for team athletes (Figure 2). Across all sports categories, females had higher weekly prevalence of use than males (Appendix 6-8). Overall, there were no differences in the odds of analgesic use between sports endurance athletes (reference group), technical athletes (OR 0.94 [95% CI 0.65-1.37]), and team athletes (OR 0.88 [95% CI 0.62-1.25]). Similarly, no differences in odds when stratified by sex.

Frequency of analgesic use

In endurance athletes, the mean number of days with analgesic use per week was 2.4 (range 1.8 to 3.6), in technical athletes 2.5 (range 1.9 to 3.8), and in team athletes 2.6 (range 2.0 to 3.3) (Appendix 10). Across all sports categories, the mean number of days with analgesic use per week

were similar between females and males (Appendix 11-13). Overall, there were no differences in the rate of analgesic use between endurance athletes (reference group), technical athletes (IRR 0.97 [95% CI 0.87-1.07]), or team athletes (IRR 1.93 [95% CI 0.94-1.14]). When stratified by sex, rate of analgesic use was statistically significantly higher in female team athletes compared with female endurance athletes (Appendix 9).

Reasons for analgesic use

More endurance athletes reported using analgesics to treat pain not related to sport (p=0.027) and to treat menstrual pain (for females) (p=0.049) compared to team athletes and technical athletes. Compared with team athletes and endurance athletes, more technical athletes used analgesics for other reasons (p=0.038) (Table 2). When stratified by sex, statistically significantly differences were observed in the proportions of female athletes across sports categories reporting to use analgesics to treat illness (p=0.047) (Appendix 14). For all sports categories, the most frequently reported reason for analgesic use was to treat pain not related to sport, constituting 24-30% of the total number of reported reasons (Appendix 15)

Types of analgesics

No differences were observed in the types of analgesics used between sports categories or sex (Table 2 and Appendix 14). For all sports categories, paracetamol was the most frequently reported type of analgesic used, constituting 58-60% of the total number of reported types of analgesics (Appendix 15).

Experiences with analgesics and sociocultural influences on the use

Thirty-two athletes (75% female) aged 16-19 representing BMX, gymnastics, dance, karate, football, swimming, golf, sailing, figure skating, handball, cycling, badminton, and basketball were included in focus group interviews. The athletes described diverse experiences with analgesics, from rare, non-systematic use of over-the-counter analgesics to daily, long-term use of opioids. All athletes highlighted experiences with using analgesics to manage symptoms of illness, pain not related to sport, or to treat or prevent pain and injury in relation to sports participation. In addition, most athletes described using only over-the-counter analgesics, with few accounts of prescribed opioid use or administration of injectable analgesics. While most athletes felt a high degree of autonomy in relation to analgesic use, several also described consulting parents, coaches, doctors, or physiotherapists to obtain information on analgesic type and/or dosage. Twelve themes relating to sociocultural factors impacting analgesic use were developed. Some factors either increased or decreased analgesic use, while others revealed more complex interactions between the athletes and their environments. Themes were, for example, *physiotherapists' long-term perspective and focus on rehabilitation*, *normalization of analgesic use within team and club culture*, and *analgesic use under pressure to participate in sport despite pain, injury, or illness*. Themes and exemplary quotes are presented in Table 3. All supportive qualitative data are available in Appendix 16.

Discussion

In this study of Danish youth elite athletes, we observed no differences in the odds or rate of analgesic use or types of analgesics used between team athletes, endurance athletes, and technical athletes. More endurance athletes reported using analgesics to treat pain not related to sport and menstrual pain compared to team athletes and technical athletes. Several sociocultural factors impacting analgesic use were identified.

The lack of association between type of sport and analgesic use may indicate that the sociocultural factors influencing youth elite athletes' analgesic use are universal across sports, or if variations exist, that the resulting effect on analgesic use is negligible. While previous studies have not explored this association, research on other social practices in youth sports has yielded conflicting results. For example, Mayer et al. reported that athletes from technical sports were more willing to compete despite underlying health problems compared to athletes from other types of sport[16]. However, this finding was not replicated in a previous study on our cohort[26]. The lack of association between type of sport and analgesic use was further supported by the qualitative data, where no consistent sports-specific patterns or experiences were identified. This contrasts with prior research proposing that the extent of various risk-taking behaviors in sports is shaped by sport-specific performance constraints and norms, which differently mediate the characteristics of a culture defined by risk acceptance, pain normalization, and performance expectations[16, 19, 22, 29].

To our knowledge, reasons for analgesic use in youth elite athletes has exclusively been investigated using quantitative methods[11, 25]. Consistent with previous results,[11, 25] our survey data showed that athletes often used analgesics to treat pain and injury in relation to sports participation. Integrating numerical data with detailed narratives revealed the social and cultural context of this usage, including perceived pressure to participate in sport despite underlying health issues, competition and performance considerations, and feeling responsible for team performance. Several of these factors have previously been identified as motives for athletes to hide or ignore injuries and pain to continue playing[8, 30]. These findings suggest that analgesics may be considered an ingrained part of a set of beliefs, cultural values, and processes of athletic socialization in elite sport conveying the message that athletes should accept the risks, injuries, and pain associated with elite-level sport[22].

In interviews, athletes explained that both coaches and physiotherapists impacted their use of analgesics, highlighting the importance of cultural leadership in youth sport. Previous research has identified the coach as a key social agent in the establishment, transmission, and construction of values, norms, and meanings in youth sport[14, 20, 27]. This influence has previously been demonstrated in the implementation of injury prevention initiatives in youth sports, where coaches are often identified as key barriers or facilitators[14, 20]. Likewise, athletes described polarizing approaches by their coaches and physiotherapists regarding analgesic use, from strictly cautioning against analgesic use to frequent encouragement, expecting athletes to use analgesics rather than miss practice or competition. Notably, none of these approaches are consistent with international expert consensus, outlining that while athletes' health prevails over competitive considerations, pharmacological pain management is circumstantially indicated and necessary[10].

Few athletes (5%) reported using opioids, aligning with international guidelines cautioning against their use except for acute, severe pain unresponsive to first-line treatments[10]. This observation was contextualized in interviews, where some athletes disclosed previous opioid use, but mostly for limited periods of time to manage post-surgery pain. In accordance with the quantitative results, the remaining athletes spoke about using only over-the-counter analgesics, often favoring topical applications for superficial and localized pain. Linking to this, a recent systematic review and meta-analysis highlighted the potential benefit of using topical analgesics in this population by demonstrating a significantly better pain reliving effect of topical analgesics compared to oral analgesics versus placebo for various athletic injuries[23]. While the common use of over-the-counter analgesics is likely attributed to their accessibility, the qualitative data suggested that sharing analgesics among teammates and receiving analgesics from the coach is in some environments

311 considered normal practice, potentially facilitating even greater access to these medications.
312 Although our results indicate participants' choice of analgesics seem to align with guidelines[10], the
313 qualitative data also revealed inappropriate usage patterns not captured by the quantitative data
314 analysis. Several athletes spoke of consistent and prolonged use of over-the-counter analgesics and
315 one athlete even reported having used Tramadol daily for more than two years. These findings
316 highlight the limitations of the existing evidence consisting solely of cross-sectional estimates of
317 analgesic use and prompts for trajectory analyses to identify distinct subgroups of users.
318
319 **Clinical implications**
320 Our results suggest a need for comprehensive education and awareness initiatives targeting youth
321 elite athletes, parents, coaches, and support staff regarding appropriate use of analgesics. Emphasis
322 should be placed on understanding the potential consequences of analgesic use for pain and injury,
323 as well as the risks associated with prolonged or inappropriate use of certain medications. The
324 importance of health education in youth athletes was highlighted by Callahan et al., showing that
325 student-athletes' exposure to concussion education was associated with more favorable social
326 norms surrounding concussion care seeking[6]. In addition, recognizing and addressing sociocultural
327 factors influencing analgesic use among youth elite athletes is crucial. Healthcare providers should
328 approach discussions about pain management and analgesic use with sensitivity to cultural norms,
329 values, and beliefs within the sports environment. Regular monitoring and surveillance of analgesic
330 use patterns among youth elite athletes are essential for identifying trends, potential misuse, and
331 areas for intervention. Healthcare providers should incorporate questions about analgesic use into
332 routine assessments and screenings, particularly in sports where there may be heightened pressure
333 to perform despite pain or injury.
334

Limitations

The classification of sports disciplines into overarching categories, although informed by prior research[7, 21], may have limited our ability to identify different analgesic use patterns across sports. Focus group interviews consisted of 75% females, though only 44% of participants in the cohort study were female. We aimed to match the sex-distribution in the focus group interviews to that of the cohort study, but a larger proportion of females agreed to participate in interviews.

Due to the recruitment method for the cohort study, we were unable to obtain information on the total number of potentially eligible participants, limiting our ability to assess potential non-participation selection bias. Similarly, to be eligible for inclusion in the focus group interviews, athletes had to have responded to at least 80% of the weekly questionnaires in the cohort study. This criterion may have resulted in selection of those athletes who are most motivated or comfortable to participate in the interviews. Finally, due to the large number of sports disciplines included in this study, the timing of sports seasons was heterogeneous, and it remains unclear how this may have affected the presented estimates.

Conclusion

We observed no differences in the odds of analgesic use or types of analgesics used between team athletes, endurance athletes, and technical athletes. More endurance athletes reported using analgesics to treat pain not related to sport and menstrual pain compared to team athletes and technical athletes. Athletes described diverse experiences with analgesics and several sociocultural factors impacting analgesic use were identified.

Key points

Findings

- Throughout a 36-week period, there were no differences in odds or rate of analgesic use between youth elite athletes from team sports, endurance sports, and technical sports.
- Youth elite athletes' experiences with analgesics vary widely, from rare use of over-the-counter analgesics to long-term use of opioids, but is influenced by several sociocultural factors.

Implications

- Our results suggest a need for comprehensive education and awareness initiatives targeting youth elite athletes, parents, coaches, and support staff regarding appropriate use of analgesics. In addition, regular monitoring and surveillance of analgesic use patterns among youth elite athletes are essential for identifying trends, potential misuse, and areas for intervention.

Caution

- The findings are specific to a Danish youth elite sports setting.

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Table 1 Baseline characteristics of included participants

	All athletes (n=689)	Endurance athletes (n=137)	Technical athletes (n=229)	Team athletes (n=323)	P-value
Age, mean (SD): years	17.1 (1.1)	17.0 (1.1)	17.1 (1.1)	17.2 (1.0)	0.18
Sex, n (%)	305 (44%)	73 (53%)	110 (48%)	122 (38%)	0.003
BMI, mean (SD)	21.9 (2.9)	21.8 (2.7)	21.8 (3.7)	22.1 (2.2)	0.22
Weekly sports exposure, mean (SD): hours	16.2 (6.4)	20.4 (6.6)	16.9 (6.9)	13.8 (4.7)	<0.001
Type of sport, n (%)					
Team sport	137 (20%)	N/A	N/A	N/A	N/A
Endurance sport	229 (33%)				
Technical sport	323 (47%)				
Athlete competition level, n (%)					
Regional	47 (7%)	6 (4%)	10 (4%)	31 (9%)	p=<0.001
National	327 (47%)	66 (46%)	87 (38%)	177 (55%)	
International	315 (46%)	68 (50%)	132 (58%)	115 (36%)	
Age at sports debut, mean (SD): years	7.5 (3.2)	7.1 (3.8)	8.2 (3.1)	7.1 (2.9)	p=<0.001
Age at sports specialization, mean (SD): years	13.0 (2.3)	12.1 (2.6)	13.1 (2.4)	13.3 (1.9)	p=<0.001
Baseline sports-related injury, n (%)					
No	317 (46%)	82 (60%)	116 (51%)	119 (37%)	p=<0.001
Yes, but the injury did not affect sports participation	179 (26%)	26 (19%)	47 (21%)	106 (33%)	
Yes, the injury affected sports participation in less than 4 weeks	81 (12%)	14 (10%)	23 (10%)	44 (14%)	

Yes, the injury affected sports participation in more than 4 weeks	81 (12%)	12 (9%)	33 (14%)	36 (11%)
Yes, time-loss injury	31 (4%)	3 (2%)	10 (4%)	18 (5%)

Table 2 Reasons for and types of analgesics used stratified by sports category (proportions of athletes reporting each reason/type at least once during the full 36-weeks study period)

Reasons for use, n (% [95% CI])	**Endurance athletes (n=137)**	**Technical athletes (n=229)**	**Team athletes (n=323)**	**p-value**
To treat pain or injury after participating in sport	52 (38% [29-47])	101 (44% [38-50])	135 (42% [36-47])	0.514
To treat pain or injury prior to participating in sport	46 (34% [26-42])	89 (39% [33-45])	135 (42 % [36-47])	0.254
To prevent pain that might occur during sports participation	24 (18% [12-24])	56 (24% [19-30])	74 (23% [18-28])	0.289
To treat pain not related to sport (e.g., headache, back pain)	84 (61% [53-69])	127 (55% [48-62])	156 (48% [43-53])	0.027
To treat menstrual pain	36 (26% [19-34])	55 (24% [18-30])	56 (17% [13-21])	0.049
To treat illness	71 (52% [43-60])	102 (45% [38-51])	131 (41% [35-46])	0.083
Other reasons	12 (9% [4-14])	39 (17% [12-22])	36 (11% [8-15])	0.038
Types of analgesics, n (% [95% CI])				
Paracetamol	100 (73% [65-80])	168 (73% [67-79])	240 (74% [69-79])	0.947
Non-steroidal anti-inflammatory drugs	53 (39% [30-47])	104 (45% [39-52])	131 (41% [35-46])	0.371
Topical gels	36 (26% [19-34])	69 (30% [24-36])	88 (27% [22-32])	0.667
Acetylsalicylic acid	20 (15% [9-21])	29 (13% [8-17])	28 (9% [6-12])	0.124
Opioids	8 (6% [2-11])	9 (4% [1-7])	16 (5% [3-7])	0.697
Injections	8 (6% [2-11])	9 (4% [1-7])	13 (4% [2-6])	0.635
Other	4 (3% [0-7])	12 (5% [2-8])	17 (5% [3-8])	0.519

Table 3 Themes and exemplary quotes

Theme	Exemplary quotes
Theme 1 Analgesic use driven by team performance responsibility: Some athletes felt that low player availability or fear of letting the team down impacted their view on absence legitimacy and personal responsibility for team performance, prompting them to use analgesics when experiencing health issues.	Q1: '*I feel like I have a responsibility towards the team and if I have to withdraw from playing, then we are missing a part of the tactic. So that's why I have also done it [used analgesics] to prevent pain, because I can't withdraw from the match'* (P12) Q2: *'You collect points for the club, so you are not just playing for yourself, but for the team and it's kind of your fault if something goes wrong and that is why you want to be able to perform for the team. And then you use a bit [analgesics] beforehand'* (P15) Q3: *'Football is a team sport, so to be there for your teammates and not just say 'I'm injured' [reason for using analgesics], because sometimes when your back hurts, that's not a big injury, so I don't think that's reason enough to not show up'* (P19)
Theme 2 Normalization of analgesic use within team and club culture: Analgesics were described as a normal and natural part of the sport environment by several athletes. For some, analgesics were normalized to the point where they were openly exchanged among athletes in the locker room.	Q1: *'If someone is not feeling well, then the others [teammates] are like 'then take some analgesics so you can participate'. It's not like you're trying to hide it'* (P7) Q2: *'We're getting it [analgesics] from each other in locker room. It has become this thing'* (P25) Q3: *'It has become this thing that you just do (P27) It's very normal, it's not like 'oh my god she's using analgesics', it's like, everyone uses analgesics'* (P26) Q4: *'Then we're four boys in the locker room before a match just grabbing some analgesics'* (P32)
Theme 3 Competition and performance considerations as drivers of analgesic use: Several athletes described using analgesics as means to enable optimal performance and mitigate the potential negative impact of pain, injury, or illness on short-term individual performance [own performance during upcoming practice or competition] or performance relative to other athletes (i.e., ranking in competition, fighting for the same spots on the team).	Q1: *'I 100% take it [analgesics] to be able to perform in relation to all the people having their eyes on me'* (P15) Q2: *'For the past two years, I have had to do it [take analgesics] more or less before every match, as I feel like when you're playing a match, then you have to perform'* (P32) Q3: *'I can be happy with my own performance, but if there's someone who's better than me, then I'm thinking 'I need to work harder to get there'. And then you may have to use something [analgesics] to treat the pain'* (P18)

Theme 4 Analgesic use under pressure to participate in sport despite pain, injury, or illness: When experiencing pain, injury, or illness, several athletes felt either direct or indirect pressure from people within their environment to continue participating in their sport and explained that this perceived pressure was a driving factor behind their use of analgesics. Contrarily, other athletes described coaches prioritizing athlete health and well-being by advocating for rest or lower training intensity, rather than use of analgesics to allow for continued sports participation.	Q1: *'Last year I had a head injury and was at this hardcore dance camp, where I felt that I couldn't sit this one out. I had been told that I shouldn't increase my heart rate for at least a month, but I started dancing sooner than I should, as I felt I was falling behind and I felt a pressure from the coach. So I took more analgesics than I probably should have'* (P3) Q2: *'My coach told me that if I couldn't make it to practice due to my pain, then I would get kicked off the team. So I used paracetamol as much as I could, the highest dosage, to be able to participate in practice'* (P16) Q3: *'I have had a lot of pain in my arm and have been like 'I'm in pain, I don't think I can play' and my teammates were like 'just use some analgesics, then you'll play'* (P18) Q4: *'I also feel that it might as well be your parents that can be like 'you're going to take some pills [analgesics] and then you're going to play'* (P19) Q5: *'I was playing the next day and my dad was like 'no, you can do it. Take some analgesics' and I was like 'no, I can't' and then I went to practice the day after what happened to my knee and I couldn't even kick a ball, and then they [coach and physiotherapist] were like 'this is probably not going to work' and then the physiotherapist got involved'* (P19) Q6: *'It's not something you discuss with your teammates or coach [using analgesics], at least I don't discuss it with my coach, because then he would just tell me that I shouldn't play as much'* (P6) Q7: *'Usually the coach will say that if you're injured in any way then you're gonna sit this one out [practice or competition], because there are so many races during the season. So unless it's one of the big races, then it's a really bad idea to use it [analgesics] and risk becoming even more injured'* (P24)
Theme 5 Coaches' influence on athletes' use of analgesics: Athletes spoke of their coaches' varying approaches to analgesics. Some athletes expressed that their coaches explicitly endorsed the use of	Q1: *'My coach would rather that we use analgesics and come to practice than not show up, because if you don't show up to practice then it will be hard to keep up'* (P11) Q2: *'If we're not feeling well prior to a game, then our coach will say 'take some analgesics and go play'* (P17)

analgesics and described being told to use analgesics to suppress symptoms of pain, injury, or illness prior to competition. Others expressed that the coach preferred them to use analgesics instead of missing practice. Contrarily, some coaches were not directly involved in decisions regarding sports-related use of analgesics. Some athletes described that their coaches promoted athlete autonomy by granting complete discretion to the individual athlete in the choice to use analgesics. Others mentioned that their coaches acknowledged their limited knowledge of proper use of analgesics and encouraged their athletes to seek medical advice from other sources.	Q3: *'If you say 'okay, I'm not feeling will', then he [coach] will say 'we have both blue and yellow pills, so just take one and then you will be ready for the match' and also during practice then it's not like 'go sit on the bench', it's more like 'take a pill and you will be ready again'* (P17) Q4: *'When something is wrong, my coach usually says 'talk to your mom about it' or something because he is not a specialist in that area [analgesics]'* (D1) Q5: *'Our coaches are pretty open about it, and like, it's up to us to decide whether we need it or not [analgesics], because, as I said, we're the ones who can feel if we need it or not'* (P9) Q6: *'If it was something long-term, then I don't think they would recommend anything [analgesics]. I think they would tell us to ask elsewhere'* (P2)
Theme 6 High degree of autonomy in addition to a strong personal drive to participate in sport: There appeared to be an interplay between a high degree of autonomy and a strong personal drive in athletes' decisions to use analgesics. Athletes demonstrated a sense of self-determination in managing their pain and injuries, making independent decisions to use analgesics to continue training or competing, despite the potential risks. This autonomy was closely linked to their internal motivation and strong desire to participate in sport, even when faced with physical limitations.	Q1: *'I think it was three days after breaking my arm, I wanted to participate in practice, but it still hurt a bit, so I just took two pills [analgesics]'* (P6) Q2: *'It was the Danish championships a year ago, and I had just returned to sport after my ankle injury and during the first three matches the pain in my foot just got worse, but as I really wanted to play, I took analgesics knowing that it might get worse afterwards'* (P10) Q3: *'It's mostly internal, if I really want to go to a race or I feel like I'm not well-prepared, then I will likely use some analgesics and go to the last training sessions before the race to be sure that I'm in shape to get a good result at the race'* (P24)
Theme 7 The role of the perceived importance of training and competition on analgesic use: The perceived importance of a specific competition or preceding training	Q1: *'Especially before competitions like the Danish Championships, that's really important and something you have been training for, so you don't feel like you can just stay at home being sick, then it's easier to use a lot of analgesics and then go out and do the best you can'* (P16)

session also had an impact on the athletes' willingness to use analgesics. Some athletes described that they only resorted to analgesics to mask symptoms of pain, injury, or illness in relation to competitions that were important to them.	Q2: *'I rarely use analgesics, and if I do, then it's because something is really hurting or if I'm going to an important competition and have an injury. Then I will also use analgesics, but I rarely use it for practice'* (P28) Q3: *'I used it when I twisted my ankle the day before an important match. So I used oral and topical analgesics multiple times, but I only did it because it was an important match to me'* (P29)
Theme 8 Balancing academic and athletic pressures by using analgesics: Balancing commitments in both the academic and sports domains influenced the athletes' use of analgesics. For some, this involved using analgesics to complete homework after a full day of school and practice. Others described using analgesics during school hours to not be in so much pain after morning practice.	Q1: *'With late training sessions, then you get home and do your school homework until late and often get a headache, and then it is easier to use analgesics and try to push through rather than making it worse'* (P10) Q2: *'Sometimes morning training sessions are from 06:30, and if I then also have a long day at school, then it can be a bit too much with my legs hurting, so sometimes I will use analgesics to make it hurt less and not get worse during the day'* (P11)
Theme 9 Training adaptations over analgesic pain management: When experiencing pain, injury, or illness, some athletes described that they preferred to modify their training activities according to their physical complaints rather than resorting to analgesics for symptom suppression.	Q1: *'I actually never use analgesics if I'm training. Then I will modify my training according to how my body is feeling'* (P15) Q2: *'I have a close relationship with my coach, and we often talk about how my body is feeling. Before a training session starts, we will assess how my body is feeling on a scale from 1-10, and for example, if it's a two-hour session, if I can handle it or perhaps the intensity should be reduced'* (P15) Q3: *'If my physiotherapist has told me that it [pain or injury] can become worse if I keep training, then I don't want to use analgesics. In general, if I'm feeling any pain, then I try to modify my training accordingly'* (P28)
Theme 10 Considering the potential risks of using analgesics for pain and injury: In conjunction with modifying training activities in accordance with physical complaints, some athletes spoke of refraining from analgesics when dealing with	Q1: *'If it's an injury, then I will also do a check-up with the physiotherapist and ask if the injury can become worse if I keep training. And if it can, then I will usually not use analgesics, but if it's something where I just have to wait and then it's gonna go away by itself, then I'll use analgesics'* (P28)

injuries that had the potential to worsen and cause long-term issues.	Q2: *'If I'm sick, then I don't think it can get worse, it's more so if I'm in pain, then I'm afraid that it can turn into a severe injury, otherwise I don't think about it'* (P25) Q3: *'You take it very seriously [considering using analgesics to treat pain or injury] if someone tells you that it can cause problems in the future if you don't take a break'* (P13)
Theme 11 Athletes' acceptance of pain and management without analgesics: Some athletes spoke of pain and injury as an inherent part of sport and did not view it as necessarily requiring treatment with analgesics.	Q1: *'I don't know if others use it [analgesics], but we are some tough guys who usually shut up about it [pain], and then you don't need them [analgesics]. If you're whining, then you're going home'* (P1) Q2: *'I don't really use analgesics in relation to sport. If I am hurting, I can endure it without using analgesics'* (P10) Q3: *'I would be lying if I said that my knees are great, because they certainly are not. So I am in pain and do get a lot of bruises, but it's not something I use anything [analgesics] for, as it eventually will go away by itself'* (P17) Q4: *'Even though I'm in pain or have been beaten up during a match, I often choose to train anyways… I often choose to participate and just not let anyone know that I'm in pain. I often choose to not use analgesics as well, as I think it needs to be something that has been going on for a long time, you know, a long-term injury'* (P13)
Theme 12 Physiotherapists' long-term perspective and focus on rehabilitation: When discussing how other people may influence the athletes' analgesic use, some described that their physiotherapists actively discouraged the use of analgesics and instead emphasized the importance of proper rehabilitation and long-term health and well-being.	Q1: *'We have been told by the physiotherapist that the reason they are strongly against using analgesics is because we are still youth players. He says that if we use it now and do not become professional football players, then maybe we well get a life-long injury if we keep playing with injuries or pain'* (P5) Q2: *'He (i.e., physiotherapist) would prefer if I did not use anything and he has told me many times that I should get off the analgesics and exercise, exercise, exercise'* (P16) Q3: *'I want to get back to on the court as soon as possible if I'm injured. But I think it's nice that these physiotherapists are more concerned with the future, than right now'* (P10)

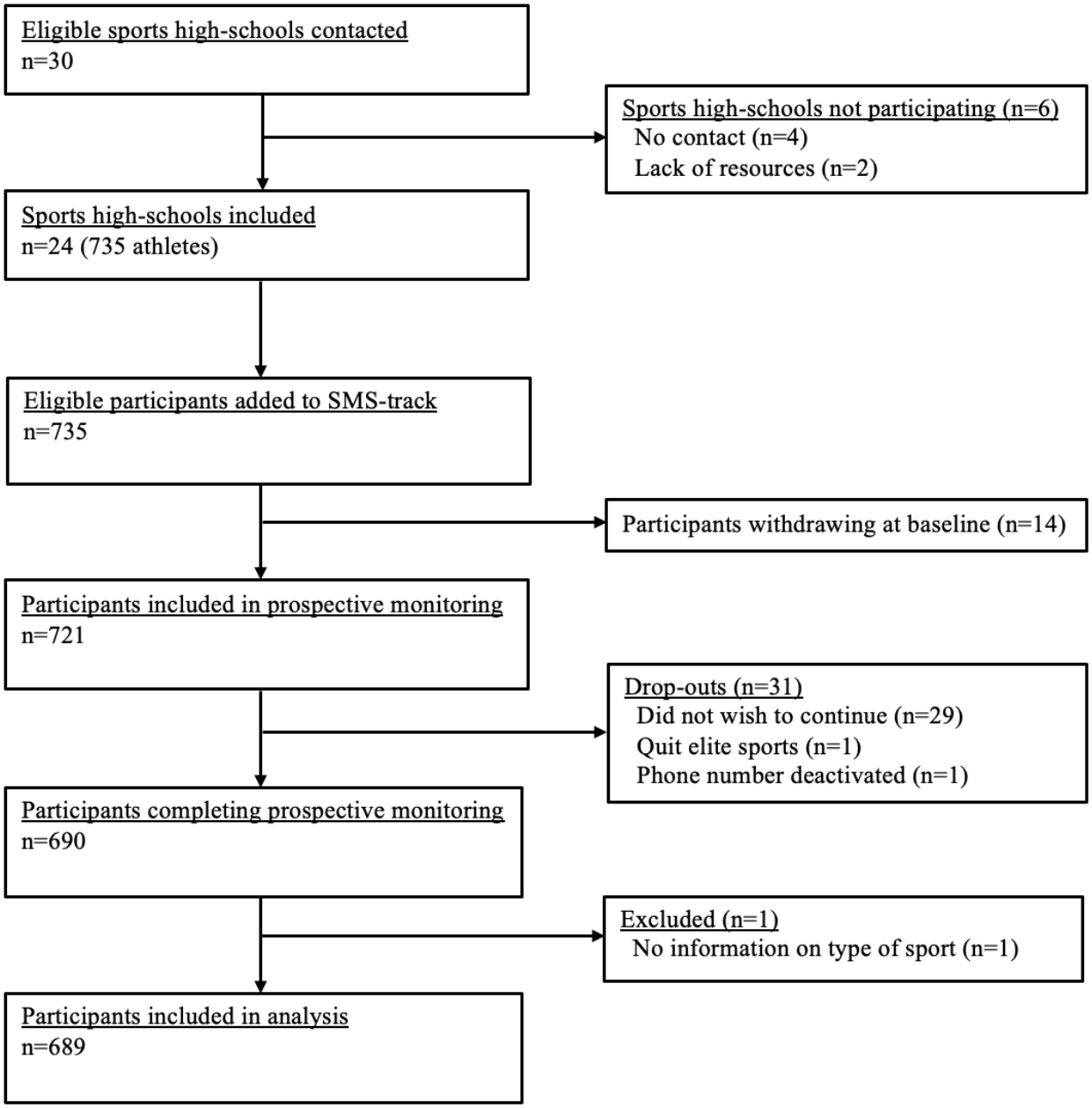

Figure 1 Flow chart

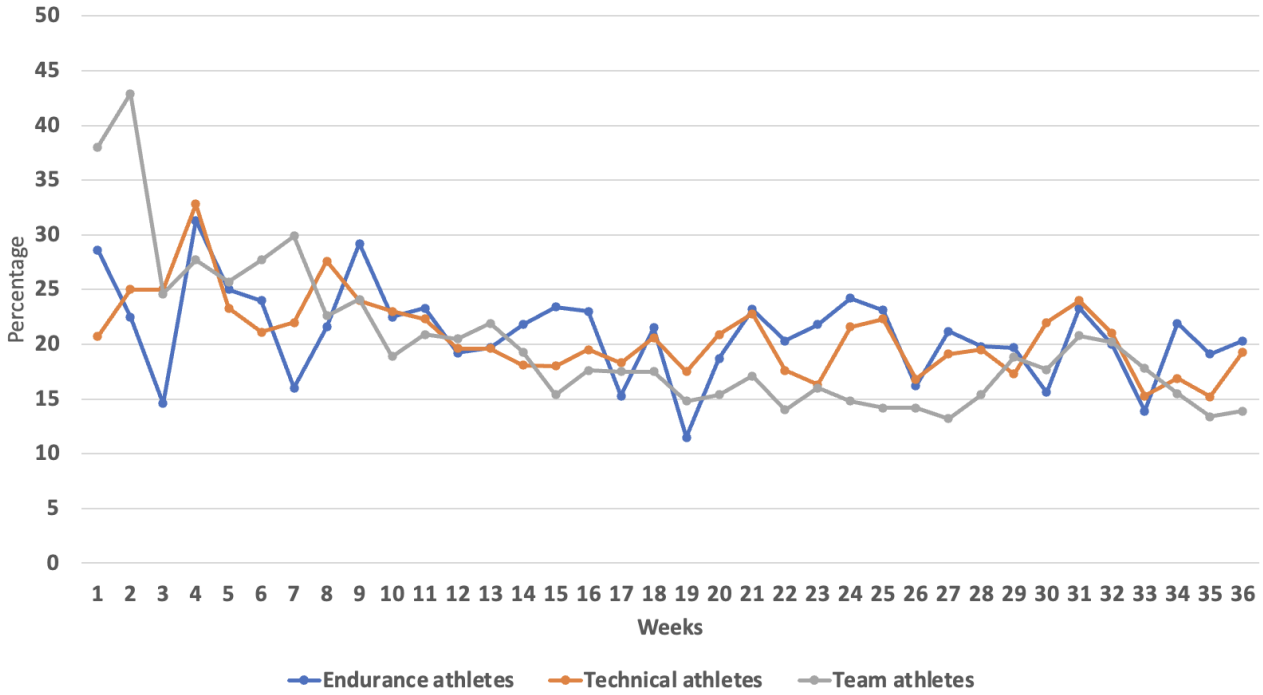

Figure 2 Prevalence of analgesic by sports category

Appendix 1 PAMUS development

As no validated questionnaires on analgesic use in youth elite athletes was identified in a systematic literature search, we specifically developed the PAin Medication Use in youth Sports (PAMUS) questionnaire for this study to measure self-reported weekly use of analgesics. The development and content validation process of the PAMUS questionnaire was performed following the COSMIN guidelines for developing and validating patient-reported outcome measurement instruments[1] and the guidelines by Patrick et al.[2 3] in the following steps:

1) The construct to be measured (analgesic use), context of use (digital monitoring tool intended for weekly administration), and the population of interest (youth elite athletes between 15-20 years of age) were defined, and a literature search was conducted to identify components of analgesic use in youth athletes.
2) A conceptual model was identified, and a hypothesized conceptual framework was developed to identify overarching concepts, hypothesized domains, and candidate item content. Based on the hypothesized conceptual framework, two interview guides were developed
3) One-to-one interviews were performed with three researchers and focus group interviews were performed with seven members of the target population (i.e., youth elite athletes aged 15-20 years).
4) The interview data was analyzed using content analysis. Eight overall themes were identified from the athlete interviews, including types of analgesics, sources of knowledge, adverse events, frequency of usage, reasons for sports-related use of analgesics, reasons for non-sports related use of analgesics, sociocultural influences on analgesic use, and other interventions received for pain/injury. Based on expert opinion, it was deemed unnecessary to monitor adverse events on a weekly basis due to high chances of symptoms misclassification and it was hypothesized that it would be sufficient to assess sources of knowledge at baseline as this is unlikely to change over a shorter period of time. Similarly, while numerous external influences and sources on knowledge on analgesic use were identified in the focus group interviews, no consistent patterns or experiences were found within the data, thus hindering further conceptualization. As a result, it was decided that aspects related to sociocultural influences and the impact of the athlete environment on analgesic use should be explored through qualitative research methods. Finally, it was deemed inappropriate to ask about other interventions used for sports-related pain and injury, as analgesics may be used for other purposes than the treatment of sports-related pain and injury.

5) Based on the remaining 4 themes, a questionnaire containing a maximum of three questions (frequency of analgesic use, reasons for use, and types of analgesic used) was drafted and pilot tested using one-to-one cognitive interviewing in another group of youth elite athletes (n=7). These interviews showed that the participants were positive towards the questionnaire and found the items and related response options clear and unambiguous. All participants were satisfied with the total number of questions and felt that all were relevant to them. The interviews revealed that no adjustment was necessary to finalize the questionnaire. Detailed information on the development and content validation process will be reported in a separate publication.

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2) Patrick DL, Burke LB, Gwaltney CJ, et al. Content validity--establishing and reporting the evidence in newly developed patient-reported outcomes (PRO) instruments for medical product evaluation: ISPOR PRO good research practices task force report: part 1--eliciting concepts for a new PRO instrument. Value Health. 2011;14(8):967–77. doi: 10.1016/j.jval.2011.06.014
3) Patrick DL, Burke LB, Gwaltney CJ, et al. Content validity--establishing and reporting the evidence in newly developed patient-reported outcomes (PRO) instruments for medical product evaluation: ISPOR PRO Good Research Practices Task Force report: part 2--assessing respondent understanding. Value Health. 2011;14(8):978–88. doi: 10.1016/j.jval.2011.06.013

Appendix 2 PAMUS questionnaire

Questions	Answer options
How many days have you used pain medication during the past 7 days?	0 (questionnaire finalized) 1 2 3 4 5 6 7
Why did you use pain medication? (choose all relevant response options)	1) To treat pain or injury after participating in sport 2) To treat pain or injury prior to participating in sport 3) To prevent pain that might occur during sports participation 4) To treat pain not related to sport (e.g., headache, back pain) 5) To treat menstrual pain 6) To treat illness 7) Other reasons
What type(s) of pain medication did you use? (choose all relevant response options)	1) Paracetamol (e.g., panodil, pamol, paracetamol, pinex) 2) Non-steroidal anti-inflammatory drugs (e.g., ipren, ibuprofen, ibumetin, diclofenac, naproxen) 3) Gels (e.g., voltaren gel, ipren gel, ibutop) 4) Acetylsalicylic acid (e.g., treo, triplo, kodimagnyl) 5) Opioids (e.g., tramadol, codein, fentanyl, oxycodone) 6) Injections 7) Other (e.g., antiepileptic medicine [gabapentin, pregabalin], antidepressive medicine [amitryptilin, duloxetine])

Appendix 3 interview guide, focus group interviews

General information
Thank you for consenting to participate in this interview. The aim of this interview is to delve into your experiences with analgesic use and to explore the factors that influence it. I am eager to hear your perspectives, and please note that there are no right or wrong answers during this interview. This interview is part of a PhD project where we combine a weekly survey, in which you are all involved, with interviews to enhance our understanding of analgesic use among young athletes.

It is 100% voluntary to participate in this interview and you can withdraw your consent at any time for any reason. I expect the interview to last about one hour. With your permission, I would like to make an audio recording of the interview. Please be assured that the audio records will be kept confidential, meaning that your anonymized answers will only be shared among the research team and any data included in research papers, thesis, and other types of communications and documents will be anonymous. You have the right to decline to answer any question or terminate your participation in the interview at any time. All information shared during the interview is confidential and is not to be disclosed to others, neither by myself or by any of you. Do you have any questions about what I have just explained?

Introduction	
Interviewee information	Please start by introducing yourselves - Name - Age - Type of sport - School year - For how long you have been doing your sport and for how long you have been involved in an elite sports program
Ice-breaker	**Can you tell me about being an young elite athlete?** - What challenges are you facing? - What works? I have brough different types of analgesics. **Can each of you tell me what you know about these analgesics?**
Interview	
Types of analgesics	**Let's take a closer look at these analgesics. What are you currently using and what have you used previously?** - Who makes these decisions? - Are you familiar with any adverse events associated with different types of analgesics? If yes, does that influence your decision on what type of analgesic you use? From the weekly survey you are involved in, we know that paracetamol, NSAIDs, and topical analgesic gels are some of the most commonly used types of analgesics. Can you tell me when you use these different types of analgesics? - Do you use different analgesics for different situations? - In what situations do you use topical analgesic gels?

Sports-related and non-sports related reasons for analgesic use. In what situations and with what reasoning?	- Has any of you ever used opioids or other strong analgesics? If yes, what situation? - Has any of you ever received an injectable analgesic? If yes, what situation? **Could you tell me about some situations where you have used or are using analgesics?** (both sports-related and non-sports related) - Why did/do you use analgesics in that/those particular situation(s) - Who decides if/when you use analgesics? - In which situations do you not use analgesics? Based the weekly survey and prior research, we know that there are mainly two sports-related reasons for using analgesics: to treat pain or injury either prior to or after participating in sport, and to prevent pain - What are your thoughts on this? Are there other reasons for using analgesics in relation to sport? - Do you or have you used analgesics any of these two reasons? Why/why not? Please tell me about some situations. - What factors do you take into account when deciding to use or refrain from using analgesics in these situations?
Influencing factors	**What influences your use of analgesics in relation to sport?** *Probes:* - Own performance expectations - Viewing sport as a fundamental part of one´s identity - Acknowledgement of pain and injury as an inevitable part of sport - Risk taking behavior - The expectations of others' We know that, among various factors, the type of sport, age, perception of societal pressure, and coach opinions are associated with a higher willingness to participate in sport despite injury, pain, or illness, which may involve using analgesics to enable sports participation. Have you used analgesics to be able to participate in sport despite being injured, ill or in pain? - Does it happen often? - In what situation is it normal for you to use analgesics to enable (optimal) sports participation? - Have you reflected on the potential risk of exacerbating an injury by using analgesic to cover pain and other signs of injury?

Micro-environment	- Does your willingness to use analgesics to enable (optimal) sports participation vary based on the severity of the injury? In relation to your life as a student-athlete, who are the most important people to you? *Probes:* - Academic development - Dual-career - General well-being - Injury/pain management Why are these people important to you? Do they have any influence on your use of analgesics? Can you tell me more or give an additional example? **How would you describe their role in relation to your use of analgesics?** - When/in what situations does this persons opinions affect your use of analgesics? - Are you aware of this persons opinion on using analgesics in relation to sport? If yes, please elaborate **Could you describe how analgesics are typically utilized in your sports club? What is typical practice?** - How is a severe injury typically treated? - How is pain typically dealt with or treated? - How does your club deal with athletes who are injured or in pain? Who is providing assistance or guidance regarding treatment of pain and injury? Why this person? *Probes:* - Coach - Physiotherapist - Medical doctor - Team mates - Friends - Teachers - Family
Macro environment	You are all members of a broader sports-related culture, encompassing aspects such as the portrayal of elite-level sport in the media and the idolization of athletes. How would you describe this culture overall? *Probes:* - Performance - Risk-taking behavior - Pain and injury

	- Mental robustness - Priorities/sacrifice - Individualism How does these aspects influence your use of analgesics? In addition to the sports-specific culture, you are immersed in the broader youth culture. How is analgesics used within this context? Does this culture impact your own patterns of usage?
Closing	
	Is there anything else you would like to share, any stories or perspectives that we have not touched upon in this interview?

Appendix 4 Different sports disciplines categorized into three major categories (n)

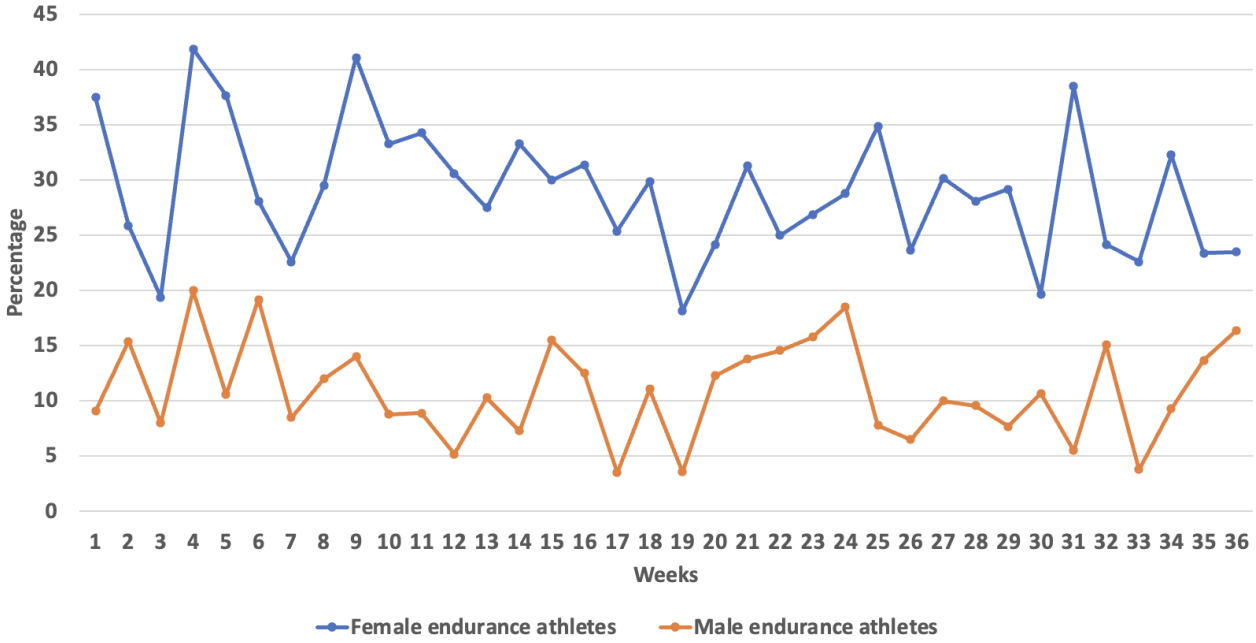
Endurance sports (n=137)	**Technical sports (n=229)**	**Team sports (n=323)**
Swimming (75)	Badminton (42)	Football (113)
Kayak (21)	Athletics (26)	Handball (100)
Cycling (14)	Golf (19)	Basketball (51)
Skiing/speed skating (13)	Sailing sports (18)	Volleyball (28)
Orienteering (8)	Tennis (17)	Ice hockey (17)
Rowing (4)	Gymnastics (17)	American football (4)
Triathlon (2)	Equestrian sports (14)	Floorball (4)
	Table tennis (13)	Cheerleading (2)
	Dance (8)	Beach volleyball (1)
	Karate (8)	Curling (1)
	Judo (6)	Lacrosse (1)
	Mountain bike (6)	Rugby (1)
	Olympic weightlifting (5)	
	Climbing (4)	
	Motor sports (4)	
	Wrestling (4)	
	Archery (3)	
	BMX (3)	
	Fencing (3)	
	Taekwondo (3)	
	Dart (2)	
	Boxing (1)	
	Thai boxing (1)	
	Trampoline (1)	
	Windsurf (1)	

Appendix 5 Drop-out analysis

	Included participants (n=689)	Participants lost to follow-up or excluded (n=46)	Difference (95% CI) or p
Age, mean (SD): years	17.1 (1.1)	17.2 (0.9)	-0.1 (-0.45 to 0.17)
Sex, n (%)	305 (44%)	13 (28%)	p=0.03
BMI, mean (SD)	21.9 (2.9)	21.6 (1.9)	0.36 (-0.47 to 1.20)
Weekly sports exposure, mean (SD): hours	16.2 (6.4)	15.7 (4.8)	0.5 (-1.39 to 2.37)
Type of sport, n (%)[a]			
Team sport	137 (20%)	5 (11%)	p=0.31
Endurance sport	229 (33%)	15 (33%)	
Technical sport	323 (47%)	25 (56%)	
Athlete competition level, n (%)			
Regional	47 (7%)	3 (6%)	p=0.99
National	327 (47%)	22 (48%)	
International	315 (46%)	21 (46%)	
Age at sports debut, mean (SD): years	7.5 (3.2)	7.5 (3.3)	-0.01 (-0.99 to 0.97)
Age at sports specialization, mean (SD): years	13.0 (2.3)	12.3 (2.3)	0.66 (-0.01 to 1.34)
Baseline sports-related injury, n (%)			
No	317 (46%)	22 (48%)	p=0.82
Yes, but the injury did not affect sports participation	179 (26%)	10 (22%)	
Yes, the injury affected sports participation in less than 4 weeks	81 (12%)	7 (15%)	
Yes, the injury affected sports participation in more than 4 weeks	81 (12%)	4 (9%)	
Yes, time-loss injury	31 (4%)	3 (6%)	

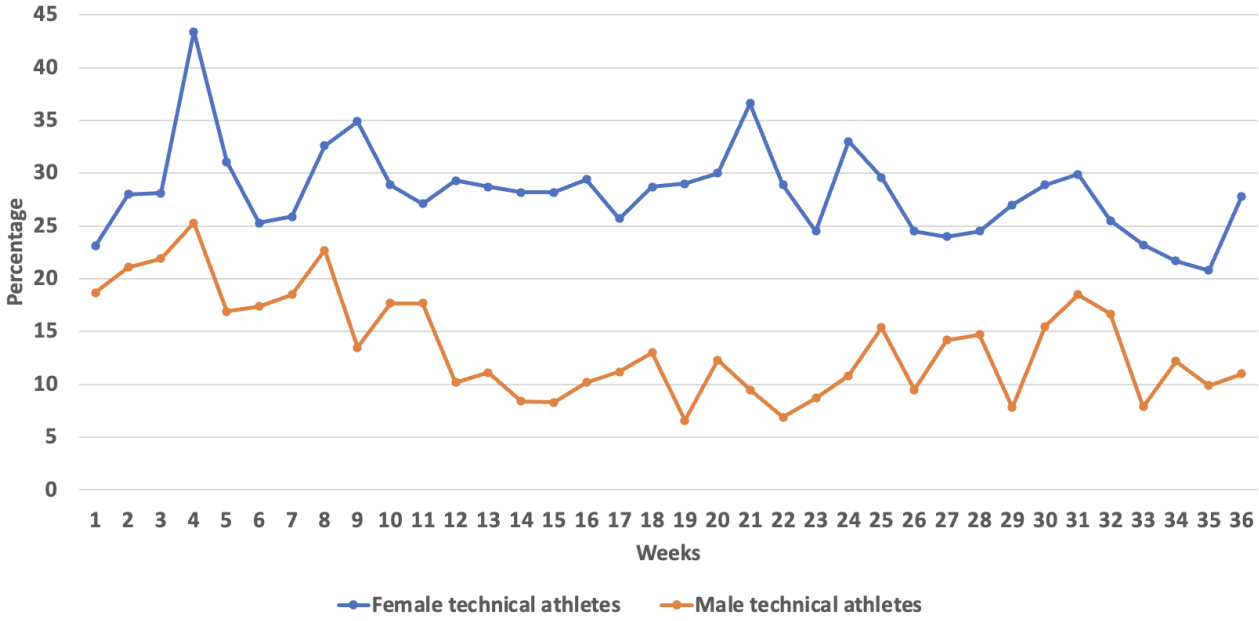
[a] missing n=1

Appendix 6 Prevalence of analgesic use in endurance athletes stratified by sex



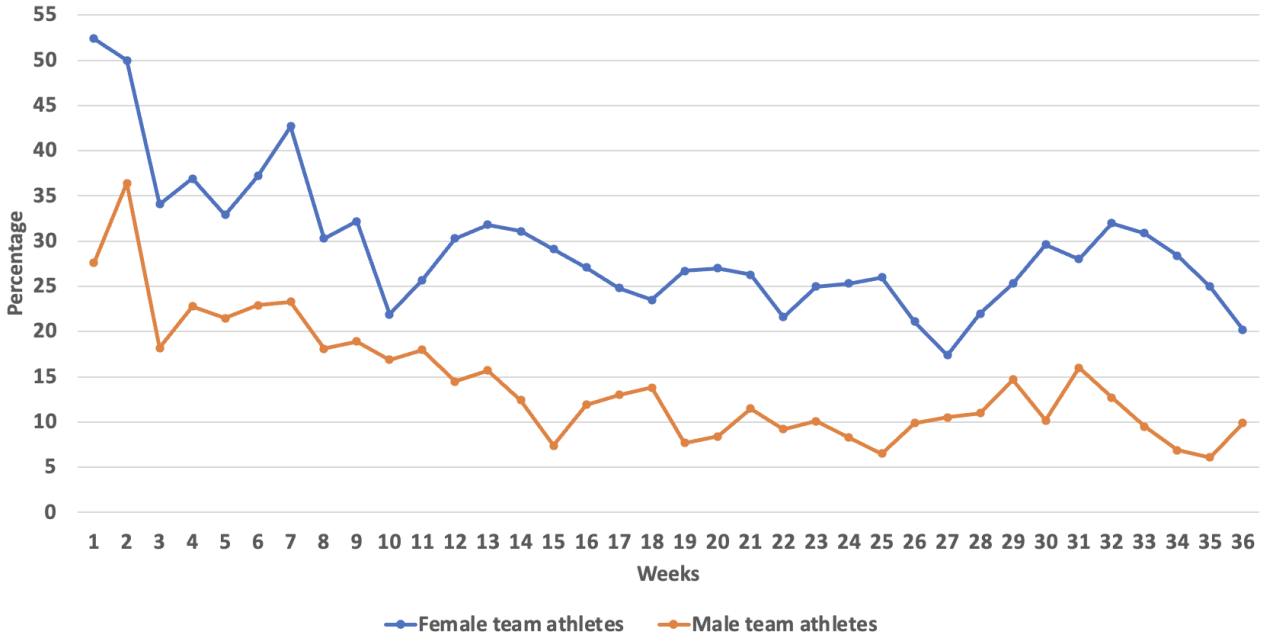
*Mean weekly prevalence in females: 29.0%, males: 11.0%

Appendix 7 Prevalence of analgesic use in technical athletes stratified by sex



*Mean weekly prevalence in females: 28.2%, males: 13.7%

Appendix 8 Prevalence of analgesic use in team athletes stratified by sex



*Mean weekly prevalence in females: 29.2%, males 14.3%

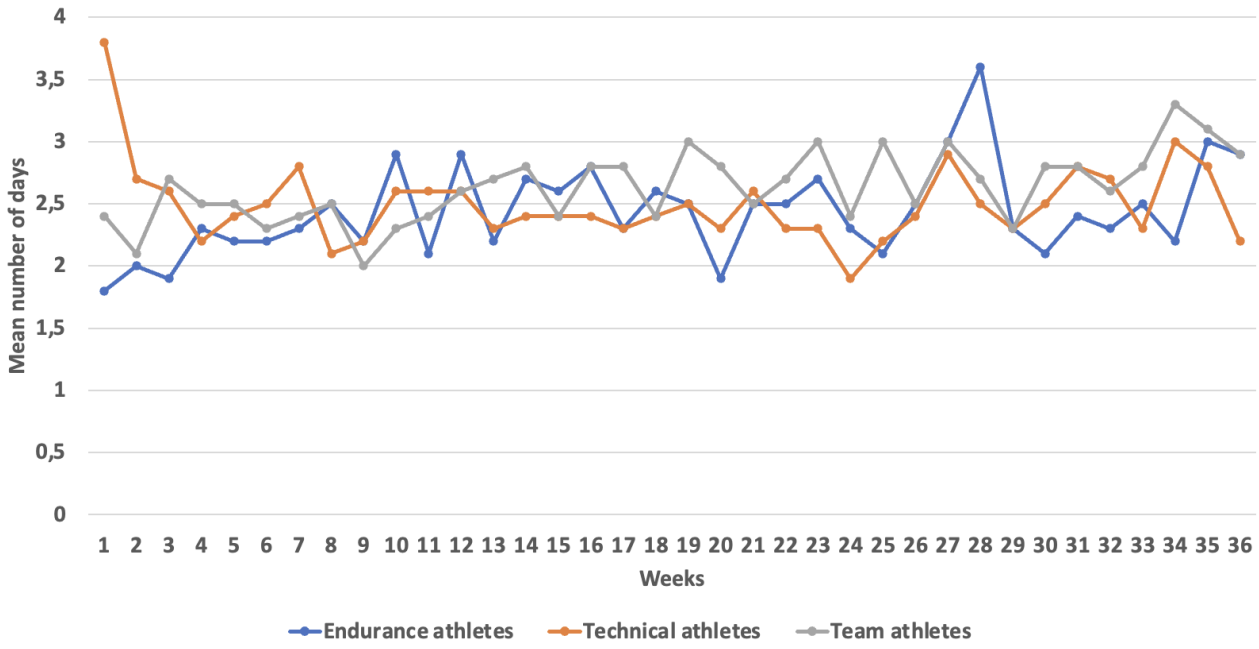
Appendix 9 Statistical comparisons of prevalence and frequency of analgesic use

Prevalence of analgesic use

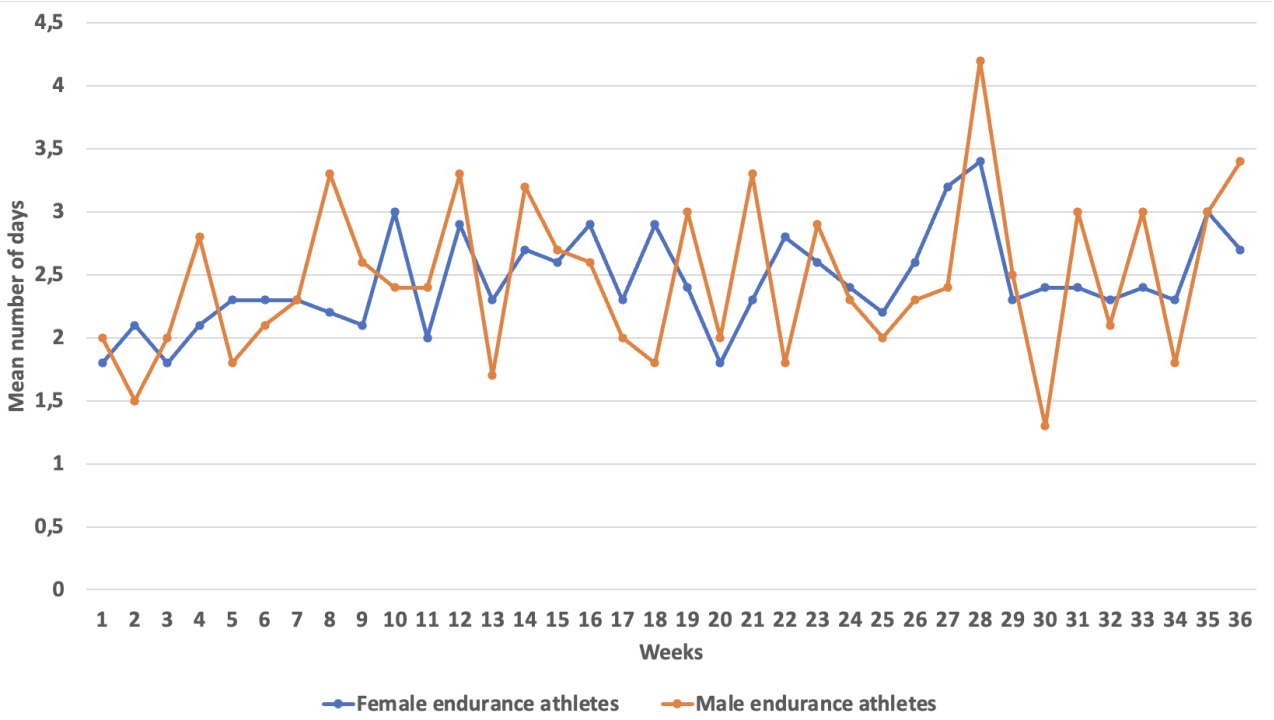
	OR	95% CI	P-value
Female endurance athletes vs. female technical athletes	0.89	0.56 to 1.40	0.63
Female endurance athletes vs. female team athletes	0.88	0.56 to 1.37	0.58
Male endurance athletes vs. male technical athletes	1.27	0.76 to 2.13	0.35
Male endurance athletes vs. male team athletes	1.43	0.88 to 2.31	0.14

Frequency of analgesic use			
	IRR	**95% CI**	**P-value**
Female endurance athletes vs. female technical athletes	0.99	0.88 to 1.12	0.94
Female endurance athletes vs. female team athletes	1.12	1.00 to 1.27	0.05
Male endurance athletes vs. male technical athletes	0.92	0.77 to 1.09	0.36
Male endurance athletes vs. male team athletes	0.92	0.78 to 1.09	0.37

Appendix 10 Frequency of analgesic use by sports category

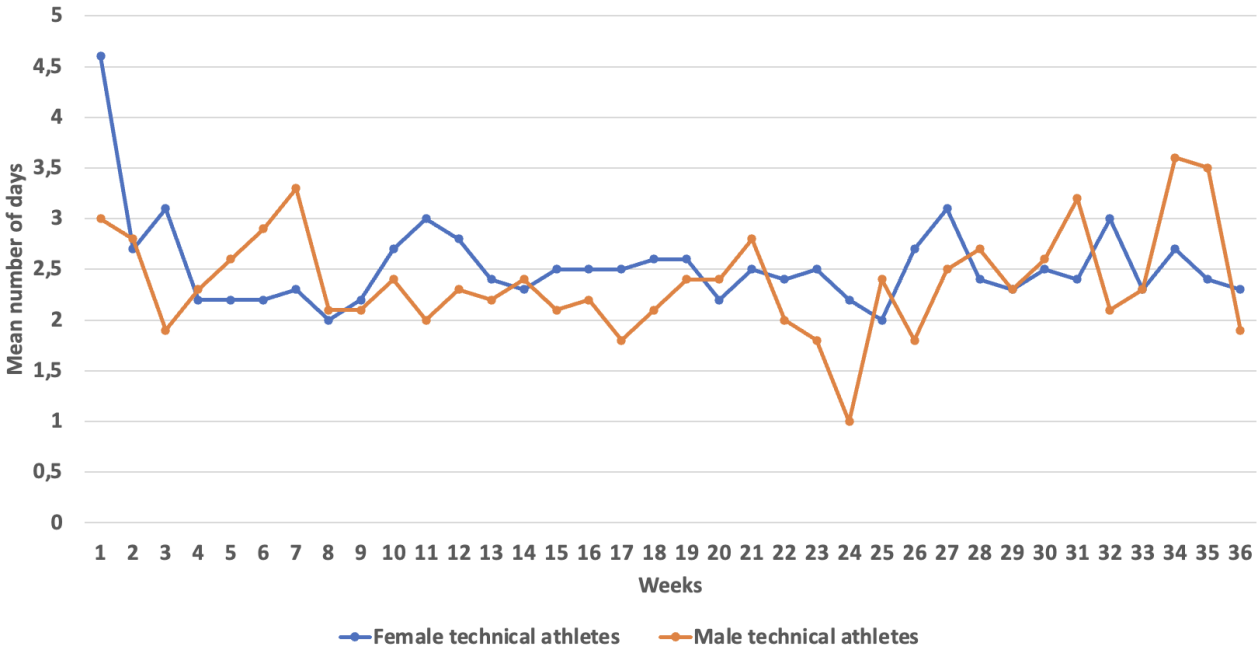


Appendix 11 Frequency of analgesic use in endurance athletes stratified by sex

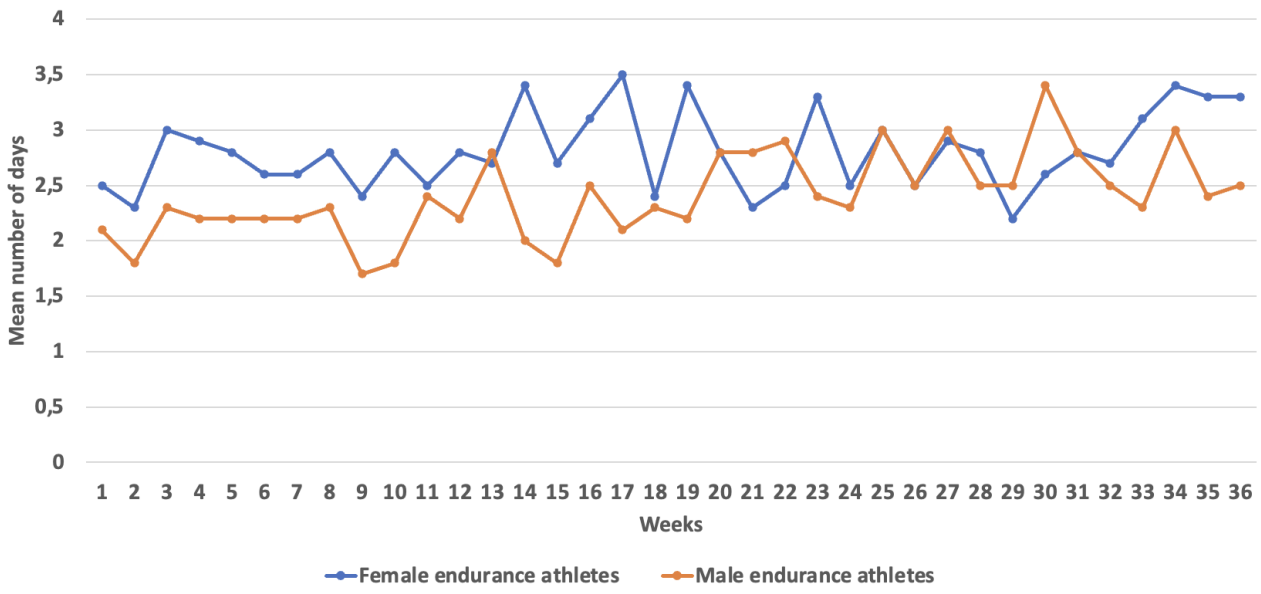


*Mean number of days with analgesic use in females: 2.4, males 2.4

Appendix 12 Frequency of analgesic use in technical athletes stratified by sex



Appendix 13 Frequency of analgesic use in team athletes stratified by sex



*Mean number of days with analgesic use in females: 2.8, males 2.4

Appendix 14 Reasons for and types of analgesics used stratified by sports category and sex (proportions of athletes reporting each reason/type at least once during the full 36-weeks study period)

Reasons for use, n (% [95% CI])	**Female endurance athletes (n=73)**	**Female technical athletes (n=110)**	**Female team athletes (n=122)**	**p-value**	**Male endurance athletes (n=64)**	**Male technical athletes (n=119)**	**Male team athletes (n=201)**	**p-value**
To treat pain or injury after participating in sport	38 (52% [40-64])	55 (50% [40-60])	68 (56% [46-64])	0.675	14 (22% [12-33])	46 (39% [29-48])	67 (33% [26-40])	0.070
To treat pain or injury prior to participating in sport	32 (44% [32-56])	50 (45% [35-55])	59 (48% [39-58])	0.811	14 (22% [12-33])	39 (33% [24-42])	76 (38% [31-45])	0.061
To prevent pain that might occur during sports participation	17 (23% [14-35])	35 (32% [23-41])	32 (26% [18-34])	0.412	7 (11% [4-21])	21 (18% [11-26])	42 (21% [15-27])	0.195
To treat pain not related to sport (e.g., headache, back pain)	55 (75% [64-85])	76 (69% [59-78])	76 (62% [53-71])	0.159	29 (45% [33-58])	51 (43% [34-52])	80 (40% [33-47])	0.702
To treat menstrual pain	35 (48% [36-60])	54 (49% [39-59])	54 (44% [35-53])	0.746	N/A	N/A	N/A	N/A
To treat illness	48 (66% [54-76])	60 (55% [45-64])	58 (48% [38-57])	0.047	23 (36% [24-48])	42 (35% [26-44])	73 (36% [30-43])	0.983
Other reasons	9 (12% [5-22])	25 (23% [15-31])	24 (20% [13-27])	0.208	3 (5% [0-13])	14 (12% [6-18])	12 (6% [3-10])	0.106
Types of analgesics, n (% [95% CI])								
Paracetamol	66 (90% [81-96])	93 (84% [76-91])	103 (84% [76-90])	0.447	34 (53% [40-66])	75 (63% [54-72])	137 (68% [61-75])	0.089
Non-steroidal anti-inflammatory drugs	41 (56% [44-68])	68 (62% [52-71])	70 (57% [48-66])	0.697	12 (19% [10-30])	36 (30% [22-39])	61 (30% [24-37])	0.173
Topical gels	26 (36% [25-48])	42 (38% [29-48])	41 (34% [25-43])	0.768	10 (16% [7-26])	27 (23% [15-31])	47 (23% [17-29])	0.411
Acetylsalicylic acid	13 (18% [9-29])	19 (17% [10-25])	11 (9% [4-15])	0.114	7 (11% [4-21])	10 (8% [4-14])	17 (8% [5-13])	0.813
Opioids	5 (7% [2-15])	6 (5% [2-11])	10 (8% [4-14])	0.712	3 (5% [0-13])	3 (3% [0-7])	6 (3% [1-6])	0.714

Injections	6 (8% [3-17])	7 (6% [2-12])	8 (6% [2-12])	0.874	2 (3% [0-10])	2 (2% [0-5])	5 (2% [0-5])	0.812
Other	3 (4% [0-11])	6 (5% [2-11])	12 (10% [5-16])	0.236	1 (2% [0-8])	6 (5% [1-10])	5 (2% [0-5])	0.328

Appendix 15 Reasons for and types of analgesics used stratified by sports category (total number of times each reason/type was reported during the full 36-weeks study period)

Reasons for use, n (%)	**Endurance athletes (n=137)**	**Technical athletes (n=229)**	**Team athletes (n=323)**
To treat pain or injury after participating in sport	182 (17%)	393 (22%)	437 (21%)
To treat pain or injury prior to participating in sport	152 (15%)	254 (14%)	405 (19%)
To prevent pain that might occur during sports participation	81 (8%)	147 (8%)	179 (9%)
To treat pain not related to sport (e.g., headache, back pain)	313 (30%)	507 (28%)	502 (24%)
To treat menstrual pain	112 (11%)	189 (11%)	159 (8%)
To treat illness	187 (18%)	249 (14%)	329 (16%)
Other reasons	20 (2%)	55 (3%)	86 (4%)
Total	1047	1794	2097
Types of analgesics, n (%)			
Paracetamol	641 (58%)	997 (58%)	1282 (60%)
Non-steroidal anti-inflammatory drugs	229 (21%)	347 (20%)	461 (22%)
Topical gels	142 (13%)	220 (13%)	252 (12%)
Acetylsalicylic acid	46 (4%)	92 (5%)	48 (2%)
Opioids	25 (2%)	14 (1%)	33 (2%)
Injections	10 (1%)	9 (0.5%)	20 (1%)
Other	4 (0.4%)	35 (2%)	22 (1%)
Total	1097	1714	2118

*The percentages may not add up to 100% due to rounding

Appendix 16 Themes and supporting quotes

Theme	Quotes
Theme 1 Analgesic use driven by team performance responsibility: Some athletes felt that low player availability or fear of letting the team down impacted their view on absence legitimacy and personal responsibility for team performance, prompting them to use analgesics when experiencing health issues.	Q1: '*I feel like I have a responsibility towards the team and if I have to withdraw from playing, then we are missing a part of the tactic. So that's why I have also done it (i.e., used analgesics) to prevent pain, because I can't withdraw from the match'* (P12) Q2: *'You collect points for the club, so you are not just playing for yourself, but for the team and it's kind of your fault if something goes wrong and that is why you want to be able to perform for the team. And then you use a bit (i.e., analgesics) beforehand'* (P15) Q3: *'Football is a team sport, so to be there for your team mates and not just say 'I'm injured' (i.e., reason for using analgesics), because sometimes when your back hurts, that's not a big injury, so I don't think that's reason enough to not show up'* (P19) Q4: *'If we have a tactical meeting, then I don't want to be sick at home because I think you are letting the others down by not being there'* (P17) Q5: *'When playing team matches, then I have an entire team with me and if I'm not able to play, then everyone will have to rotate'* (P18) Q6: *'Yes, I feel like, if I weren't able to play, then the girl who would have to take my place, you know, if I played a bad match, then I'll probably still be better than her (i.e., reason for using analgesics when injured)'* (P19) Q7: *'We are a huge team where we are all practicing together and if one of my team mates are not able to be there because she's a little ill, then it sucks because we won't be able to practice as a team (i.e., reason for using analgesics)* (P20) Q8: *'We're playing 5 versus 5, so it is quite essential to be 10 people for practice, so it can be quite*

	important whether you show up or not (i.e., reason for using analgesics)' (P26)
Theme 2 Normalization of analgesic use within team and club culture: Analgesics were described as a normal and natural part of the sport environment by several athletes. For some, analgesics were normalized to the point where they were openly exchanged among athletes in the locker room.	Q1: *'If someone is not feeling well, then the others (i.e., teammates) are like 'then take some analgesics so you can participate'. It's not like you're trying to hide it'* (P7) Q2: *'We're getting it (i.e., analgesics) from each other in locker room. It has become this thing'* (P25) Q3: *'It has become this thing that you just do (P27) It's very normal, it's not like 'oh my god she's using analgesics', it's like, everyone uses analgesics'* (P26) Q4: *'Then we're four boys in the locker room before a match just grabbing some analgesics'* (P32) Q5: *'I see a lot of people use that one (i.e., topical analgesic gel)* (P17)*... 'Yes, I was about the say the same thing. I think almost everyone on my team have Voltaren (i.e., topical analgesic gel) in their bags'* (P16) Q6: *'People were just like "I'm just gonna go grab some analgesics", it's not something they are trying to hide'* (P16) Q7: *'But I also feel that it is just as much your parents saying 'just grab some analgesics, then you'll play'* (P19)*… That was my team mates saying that to me'* (P18) Q8: *'My team mates are a bit older than me, and one of them gave me analgesics and said "here, take these and you'll be ready in a minute". So that's what I did… I think it was ibuprofen and paracetamol at the same time, it was a proper dose.. it just had to go away* (P18) Q9: *'We often see people take something (i.e., analgesics) in the locker room, because some had been injured to a long time'* (P21) Q10: *'It just like "does anyone have any paracetamol because my knee is really hurting?"* (P25)*.. I also see that when I take analgesics out my bag, the others will be like "can I have one?"'* (P26)

	Q11: *'It's not like we hiding it (i.e., using analgesics), and it's not like a taboo, it's just normal'* (P32)
Theme 3 Competition and performance considerations as drivers of analgesic use: Several athletes described using analgesics as means to enable optimal performance and mitigate the potential negative impact of pain, injury, or illness on short-term individual performance [own performance during upcoming practice or competition] or performance relative to other athletes (i.e., ranking in competition, fighting for the same spots on the team).	Q1: *'I 100% take it (i.e., analgesics) to be able to perform in relation to all the people having their eyes on me'* (P15) Q2: *'For the past two years, I have had to do it (i.e., take analgesics) more or less before every match, as I feel like when you're playing a match, then you have to perform'* (P32) Q3: *'I can be happy with my own performance, but if there's someone who's better than me, then I'm thinking 'I need to work harder to get there'.. And then you may have to use something (i.e., analgesics) to treat the pain'* (P18) Q4: *'For example, in my sport there are ranks, so you have to have participated in a specific number of competitions and placed well to be selected for other competitions. If you know it's an important practice and you are injured or something, then you really don't want to miss that practice and you want to be able to perform at that practice'* (i.e., reason for using analgesics) (P3) Q5: *'In karate, one person from each group in Denmark can be selected for the European or Danish Championships, so you consistently have to be the best, and to be the best, you have to beat all the others (i.e., reason for using analgesics), and when we are trying to qualify, then you have to beat the other fighters from the national team to be selected for the European or World Championships, so there is a lot of competition'* (P4) Q6: *'If I, for example, use paracetamol prior to a game, then it because I have a minor injury, then I will be able to participate and also perform* (P5)… *I agree, to be able to perform better and not feel the pain (i.e., reason for using analgesics)* (P7) Q7: *'I played a match yesterday where I used paracetamol prior because I have a minor knee injury.. But it was to perform'* (P5)

	Q8: *'It might not be the smartest thing to do, that because your knee hurts or something, then just to use analgesics and keep going, but sometimes, I don't know what to say, then it's the only option, because you want to be able to perform'* (P4) Q9: *'When you are trying to qualify, then it's important to perform and you can't really be struggling with anything (i.e., pain, injury, illness) as it is important to be ready and in good shape (i.e., reason for using analgesics)* (P4)…. *Yes, I have tried taking analgesics because I was in a bad period or when you don't have time to be injured'* (P5) Q10: *'You use it (i.e., analgesics) to perform better, or, at least I do, so that is the reason I use it, to compete better'* (P7). Q11: *'I have tried once at the World Championships where we are sailing for multiple days in a row and I had back pain and then I had to use analgesics to alleviate the symptoms in order to be able to perform better the next morning'* (P9) Q12: *'As I also said previously, then I'm the one in charge of when I use analgesics. If I don't feel well, then I'd rather stay home from practice and get well instead of using paracetamol, but if it is a competition, then I want to be able to perform, yes, using paracetamol or something else'* (P9) Q13: *'It was often prior to a game (i.e., used analgesics) to be able to perform properly without having to think about the pain'* (P12) Q14: *'You collect points for the club, so you are not just playing for yourself, but for the team and it's kind of your fault if something goes wrong and that is why you want to be able to perform for the team. And then you use a bit (i.e., analgesics) beforehand'* (P15) Q15: *'And also just to perform better at practice, but also during competitions.. You just perform better (i.e., if using analgesics) than you would if you were in pain, so using analgesics so that the pain won't be what sets the limit as to what you can and cannot do'* (P14) Q16: *'I do think that if affects me if I know that I have to perform, then I will be using analgesics'* (P12) Q17: *' In general, I think you use analgesics a bit more if you are serious about your sport'* (P15)

	Q18: *'I don't use it (i.e., analgesics) that much, it is mostly if I have an injury prior to practice or a game, but mostly for games, because that's where you have to perform'* (P25) Q19: *'I don't know if I'm in pain every day, but I currently have an ankle injury, so that is hurting all the time, but for some reason I don't feel the need to use analgesics because I'm not going to practice. So I am currently using less analgesics than if I were going to practice, even though I'm in more pain. But that is because I don't have to perform'* (P26) Q20: *'Like P29, I don't think I use it (i.e., analgesics) for pain that often, it's more if I'm sick, then I'm more likely to think "I have to get rid of this headache, because I have to be ready to perform". Then I have used something (i.e., analgesics) if I have been ill, had a headache, or because of period pain'* (P31) Q21: *'For the past two years, I have more or less been compelled to use it (i.e., analgesics) prior to every game, because I feel like I have to perform during a match and if I'm constantly thinking about how much my knee or shin hurts, then I can't play to my full potential'* (P32)
Theme 4 Analgesic use under pressure to participate in sport despite pain, injury, or illness: When experiencing pain, injury, or illness, several athletes felt either direct or indirect pressure from people within their environment to continue participating in their sport and explained that this perceived pressure was a driving factor behind their use of analgesics. Contrarily, other athletes described coaches prioritizing athlete health and	Q1: *'Last year I had a head injury and was at this hardcore dance camp, where I felt that I couldn't sit this one out. I had been told that I shouldn't increase my heart rate for at least a month, but I started dancing sooner than I should, as I felt I was falling behind and I felt a pressure from the coach. So I took more analgesics than I probably should have'* (P3) Q2: *'My coach told me that if I couldn't make it to practice due to my pain, then I would get kicked off the team. So I used paracetamol as much as I could, the highest dosage, to be able to participate in practice'* (P16) Q3: *'I have had a lot of pain in my arm and have been like 'I'm in pain, I don't think I can play' and my teammates were like 'just use some analgesics, then you'll play'* (P18) Q4: *'As I said, it was worst when I was at sports college and used a lot of analgesics and that's also where we had a Russian coach who was very tough and we were just out on the ice no matter what and if we fell, for example, and hurt our knee or maybe landed wrong on the ice, then we just used*

well-being by advocating for rest or lower training intensity, rather than use of analgesics to allow for continued sports participation.	*analgesics instead of taking a break. So that was just what we did to be able to skate again. Not much to discuss about that'* (P16) Q5: *'As elite athletes we have a lot of willpower and discipline to go practice, and everyone counts on you being there, especially in the time leading up to competition such as the Danish Championships, then it's extremely important, you know, it's something you work really hard for and your coach has put in much time and effort, so you can't really, you don't feel like you can just stay home being sick, then it's easier to just take lots of analgesics and do the best you can'* (P16) Q6: *'With our previous coach, being injured wasn't really legitimate, he didn't really have any sympathy for that. It was something like.. He'd prefer us being in the game.. and if you were in pain, you'd use analgesics, and most of us did'* (P21) Q7: *'I also think the coach could influence it (i.e., use of analgesics), if you felt pressured to return from an injury'* (P22) Q8: '*I just think it's his way of coaching, and as D32 said, it's not like he says it directly to us (i.e., to use analgesics), because it is probably very few people who openly encourage using analgesics, but it is more indirect as we always have to be ready to train or compete. Most days of the week we train 2,5 hours per day, so you are kind of have to do it (i.e., use analgesics) to be able to give it all you got every time.. In general, we are under a lot of pressure, there are high expectations from your coach, and that can sometimes make you play even though you are injured or just not physically ready to perform at the required level'* (D29) Q9: *'There are such high expectations, so you can't really avoid using it (i.e., analgesics) if you are in a lot of pain* (D31). Q10: *'I also feel that it might as well be your parents that can be like 'you're going to take some pills (i.e., analgesics) and then you're going to play'* (P19)

	Q11: *'I was playing the next day and my dad was like 'no, you can do it. Take some analgesics' and I was like 'no, I can't' and then I went to practice the day after what happened to my knee and I couldn't even kick a ball, and then they (i.e., coach and physiotherapist) were like 'this is probably not going to work' and then the physiotherapist got involved'* (P19) Q12: *'My dad very much advocates for paracetamol.. And he always comes with me for competitions, so he will often be like "grab some paracetamol"'* (P15) Q13: *'My mom is a typical mom and doesn't want me to use analgesics and instead stay at home, but my dad is like "go go go, take these (i.e., analgesics)", then he hands them to me and we go to practice'* (P25) Q14: *'It's not something you discuss with your team mates or coach (i.e., using analgesics), at least I don't discuss it with my coach, because then he would just tell me that I shouldn't play as much'* (P6) Q15: *'Usually the coach will say that if you're injured in any way then you're gonna sit this one out (i.e., practice or competition), because there are so many races during the season. So unless it's one of the big races, then it's a really bad idea to use it (i.e., analgesics) and risk becoming even more injured'* (P24) Q16: *'If you're severely injured, then our coach really wants to protect us, so he won't put pressure on us to do something we can't do, but if it's like "I'm having a bit of pain here and there" then we can participate'* (P4) Q17:*'I don't really experience pressure from anyone, I can easily skip practice without anyone really reacting to it'* (P28)
Theme 5 Coaches' influence on athletes' use of analgesics: Athletes spoke of their coaches' varying approaches to analgesics. Some athletes	Q1: *'My coach would rather that we use analgesics and come to practice than not show up, because if you don't show up to practice then it will be hard to keep up'* (P11) Q2: *'If we're not feeling well prior to a game, then our coach will say 'take some analgesics and go play'* (P17)

expressed that their coaches explicitly endorsed the use of analgesics and described being told to use analgesics to suppress symptoms of pain, injury, or illness prior to competition. Others expressed that the coach preferred them to use analgesics instead of missing practice. Contrarily, some coaches were not directly involved in decisions regarding sports-related use of analgesics. Some athletes described that their coaches promoted athlete autonomy by granting complete discretion to the individual athlete in the choice to use analgesics. Others mentioned that their coaches acknowledged their limited knowledge of proper use of analgesics and encouraged their athletes to seek medical advice from other sources.	Q3: *'If you say 'okay, I'm not feeling will', then he (i.e., coach) will say 'we have both blue and yellow pills, so just take one and then you will be ready for the match' and also during practice then it's not like 'go sit on the bench', it's more like 'take a pill and you will be ready again'* (P17) Q4: *'My coach is very.. He just wants us to do it (i.e., use analgesics), and like, what to say, we just have to push through, so if we do not show up for practice then we have to come in for an extra session, and then I'd rather use paracetamol than wake up early on Friday morning to go to practice'* (P7) Q5: *'I fell while ice skating, that's where it all started, then I was told (i.e., by coach) to take some paracetamol so I could get out on the ice again'* (P16) Q6: *''As I said, it was worst when I was at sports college and used a lot of analgesics and that's also where we had a Russian coach who was very tough and we were just out on the ice no matter what and if we fell, for example, and hurt our knee or maybe landed wrong on the ice, then we just used analgesics instead of taking a break. So that was just what we did to be able to skate again. Not much to discuss about that'* (P16) Q7: *'If I'm not feeling well prior to practice then I might use paracetamol instead of staying at home, because I want to go to practice and, also, if we're not feeling well prior to a match our coach might say "grab some analgesics and go play"'* (P17) Q8: *'Looking back, it is absolutely awful that I had a coach who cared so little about my health in regard to potential adverse events (i.e., from analgesics), but mostly focused on winning'* (P16) Q9: *'I don't really think about the fact that my coach is like "just take some pills and go play" because everyone on the team just want to play, so of course they take it, but I do think it's a bit wrong of him not to be understanding when we're sick at home. It's not like there anyone who doesn't want to show up for practice'* (P17)

	Q10: *'My coach asked me why I wasn't participating that day and I told him that I had played two matches and had just returned from an injury. He then asked me whether I was in pain and I said "I don't know if it's pain, but I'm tired" and then he tells me to grab some analgesics and then I can participate in practice lasting 1.5 hours…. He thought analgesics was the solution'* (P22, one month after undergoing second ACL reconstructive surgery) Q11: *'I think our coach is extreme is year. There is a huge pressure, and sometimes an unfair pressure, so I have been feeling like I have to be 100% ready, so when it has been necessary to use analgesics, I've done it'* (P29) Q12: *'When something is wrong my coach usually says 'talk to your mom about it' or something because he is not a specialist in that area (i.e., analgesics)'* (D1) Q13: *'Our coaches are pretty open about it, and like, it's up to us to decide whether we need it or not (i.e., analgesics), because, as I said, we're the ones who can feel if we need it or not'* (P9) Q14: *'If it was something long-term, then I don't think they would recommend anything (i.e., analgesics). I think they would tell ask to ask elsewhere'* (P2) Q15: *'I think my coaches er quite open about it, like, it's up to us to decide whether we need it (i.e., analgesics) or not, because we're the ones feeling the pain'* (P9) Q16: *'I don't think my coach has ever encouraged it (i.e., using analgesics), but I also think it's because my mom knows a lot about these things, so she's the one in charge'* (P3) Q17: *'It's not something (i.e., analgesics) you discuss with your teammates or coach. At least I don't discuss it with my coach, because then he would just tell me to play less'* (P6) Q18: *'I spoke to my coach about it (i.e., using analgesics), but I'm the one making the decision because I'm the one who can feel the pain'* (P9)

	Q19: *'They (i.e., coaches) don't really interfere with our use of analgesics'* (P31) Q20: *'I don't think my coach has ever pressured me to use analgesics if I've been injured or ill'* (P23)
Theme 6 High degree of autonomy in addition to a strong personal drive to participate in sport: There appeared to be an interplay between a high degree of autonomy and a strong personal drive in athletes' decisions to use analgesics. Athletes demonstrated a sense of self-determination in managing their pain and injuries, making independent decisions to use analgesics to continue training or competing, despite the potential risks. This autonomy was closely linked to their internal motivation and strong desire to participate in sport, even when faced with physical limitations.	Q1: *'I think it was three days after breaking my arm, I wanted to participate in practice, but it still hurt a bit, so I just took two pills (i.e., analgesics)'* (P6) Q2: *'It was the Danish championships a year ago, and I had just returned to sport after my ankle injury and during the first three matches the pain in my foot just got worse, but as I really wanted to play, I took analgesics knowing that it might get worse afterwards'* (P10) Q3: *'It's mostly internal, if I really want to go to a race or I feel like I'm not well-prepared, then I will likely use some analgesics and go to the last training sessions before the race to be sure that I'm in shape to get a good result at the race'* (P24) Q4: *'I feel like it's wrong to do (i.e., using analgesics), but it's just because I really want to compete, so if I just take some, then my body won't be completely smashed'* (P1) Q5: *'It has mostly been in relation to competition (i.e., use of analgesics). But in my club it's not like, like if you are too sick to participate, it's mostly because I really want to participate'* (P2) Q6: *'I have done it (i.e., used analgesics) at least 1-2 times per week for a year because I had an injury, but no one really knew what it was and it could not be fixed, so I just choose to play anyway'* (P12) Q7: *'I thinks that the primary reason (i.e., for using analgesics). It's not like my mom is telling me to use analgesics, because she wants me to stay at home if I'm ill. But I just really want to go to practice'* (P17)

	Q8: *'I don't really think about the fact that my coach is like "just take some pills and go play" because everyone on the team just want to play, so of course they take it'* (P17)
Theme 7 The role of the perceived importance of training and competition on analgesic use: The perceived importance of a specific competition or preceding training session also had an impact on the athletes' willingness to use analgesics. Some athletes described that they only resorted to analgesics to mask symptoms of pain, injury, or illness in relation to competitions that were important to them.	Q1: *'Especially before competitions like the Danish Championships, that's really important and something you have been training for, so you don't feel like you can just stay at home being sick, then it's easier to use a lot of analgesics and then go out and do the best you can'* (P16) Q2: *'I rarely use analgesics, and if I do, then it's because something is really hurting or if I'm going to an important competition and have an injury. Then I will also use analgesics, but I rarely use it for practice'* (P28) Q3: *'I used it when I twisted my ankle the day before an important match. So I used oral and topical analgesics multiple times, but I only did it because it was an important match to me'* (P29) Q4: *'I had a shoulder injury a few months ago where I all of the sudden experienced pain, so I had an ultrasound scan, laser treatments, and lastly an injectable analgesics because it was the week up to the World Championships'* (P4) Q5: *'Yes, for example, when you're trying to qualify, then it's important that you perform and it's not going to work if you're currently struggling with anything (i.e., pain, injury, illness), so it's very important to be at your best (i.e., reason for using analgesics)'* (P4) Q6: *'It was the Danish championships a year ago, and I had just returned to sport after my ankle injury and during the first three matches the pain in my foot just got worse, but as I really wanted to play, I took analgesics knowing that it might get worse afterwards, but I also thought to myself "the season is soon over, so they will have longer time to fix it"'* (P10) Q7: *'I never use analgesics for practice, then I will adapt my training to my physical capacity. But if I'm using anything, then it's for competitions where there is more pressure'* (P15)

	Q8: *'If it's the Danish Championships or something you have been training for, for an entire year, then the pain has to be really severe before you give up, because you have been fighting for it for so long, so then you have to find another solution (i.e., use analgesics)'* (P14) Q9: *'I played internationally for the first time this year and I felt an old injury flare up, so I called her (i.e., physiotherapist) and asked if it was alright to take some paracetamol and then play and she told me that it was alright just this one time because it was in Portugal and, you know, it's not cool to travel that far and then have to withdraw'* (P15) Q10: *'Especially in the time leading up to competition such as the Danish Championships, then it's extremely important, you know, it's something you work really hard for and your coach has put in much time and effort, so you can't really, you don't feel like you can just stay home being sick, then it's easier to just take lots of analgesics and do the best you can'* (P16) Q11: *'If it's something important… Something that you really want to participate in and be 100% ready (i.e., reason for using analgesics)* (P21) Q12: *'If it's important, if you have a match that week and have an important practice, then you might have to take some paracetamol and go to practice'* (P26) Q13: *'It's mainly if it's something important, I will usually not use analgesics if it's just regular practice'* (P28) Q14: *'A few years ago I used it (i.e., analgesics) when I twisted my ankle a few days prior to an important match, so I used both analgesics (i.e., oral) and Voltaren (i.e., topical analgesic gel) multiple times, but I only did it because it was an important match to me'* (P29)
Theme 8 Balancing academic and athletic pressures by using analgesics: Balancing commitments in both the academic and sports domains	Q1: *'With late training sessions, then you get home and do your school homework until late and often get a headache, and then it is easier to use analgesics and try to push through rather than making it worse'* (P10)

influenced the athletes' use of analgesics. For some, this involved using analgesics to complete homework after a full day of school and practice. Others described using analgesics during school hours to not be in so much pain after morning practice.	Q2: *'Sometimes morning training sessions are from 06:30, and if I then also have a long day at school, then it can be a bit too much with my legs hurting, so sometimes I will use analgesics to make it hurt less and not get worse during the day'* (P11) Q3: *'Sometimes I have practice twice a day, so if I have morning practice and am in a lot of pain afterwards and have to go to school, then I might use some paracetamol so I can get back on the ice after school'* (P11) Q4: *'I have very early morning practice and then I have to perform all day in relation to both school and practice, and that can give me a headache, so I use paracetamol every now and then'* (P10) Q5: *'To be able to sleep afterwards (i.e., practice/match), that's definitely influences my use (i.e., of analgesics), because if I'm in a lot of pain, then I won't be able to sleep and that negatively affect me in school and my everyday life'* (P13) Q6: *'I sometimes think that considerations regarding absence from school can have an influence (i.e., on use of analgesics). I got my period on Friday and it hit quite hard in the second period, and we had five that day, and I was like "no way am I going to be absent because of this" (due to absence from sport commitments) and then I thought "you know what, it's easier to just grab something (i.e., analgesics) and just try and survive the rest of the day"'* (P31) Q7: *'I think it's the environment (i.e., school and sport) and pressure that creates this need (i.e., for analgesics). This week, for example, I had match yesterday, match today, and potentially also matches Thursday and Saturday. That's a lot. So when you're in these types of situations where you have to play this much, then it can get out of control and you have to remember to use analgesics'* (P32)
Theme 9 Training adaptations over analgesic pain management: When experiencing pain, injury, or illness, some athletes described	Q1: *'I actually never use analgesics if I'm training. Then I will modify my training according to how my body is feeling'* (P15)

that they preferred to modify their training activities according to their physical complaints rather than resorting to analgesics for symptom suppression.	Q2: *'I have a close relationship with my coach, and we often talk about how my body is feeling. Before a training session starts, we will assess how my body is feeling on a scale from 1-10, and for example, if it's a two hour session, if I can handle it or perhaps the intensity should be reduced'* (P15) Q3: *'If my physiotherapist has told me that it (i.e., pain or injury) can become worse if I keep training, then I don't want to use analgesics. In general, if I'm feeling any pain, then I try to modify my training accordingly'* (P28) Q4: *'If it's not a match or just regular practice, then they (i.e., physiotherapists) might say 'maybe you should go for a walk or a jog instead of using analgesics'* (P21)
Theme 10 Considering the potential risks of using analgesics for pain and injury: In conjunction with modifying training activities in accordance with physical complaints, some athletes spoke of refraining from analgesics when dealing with injuries that had the potential to worsen and cause long-term issues.	Q1: *'If it's an injury, then I will also do a check-up with the physiotherapist and ask if the injury can become worse if I keep training. And if it can, then I will usually not use analgesics, but if it's something where I just have to wait and then it's gonna go away by itself, then I'll use analgesics'* (P28) Q2: *'If I'm sick, then I don't think it can get worse, it's more so if I'm in pain, then I'm afraid that it can turn into a severe injury, otherwise I don't think about it'* (P25) Q3: *'You take it very seriously (i.e., considering using analgesics to treat pain or injury) if someone tells you that it can cause problems in the future if you don't take a break'* (P13) Q4: *'We've been told by the physio that the reason they strongly discourage us from using analgesics is because we are still youth players, whereas the senior team, they can take it for all kinds of injuries because they are already professional. He says that if we use it now and do not become professional football players, then maybe we well get a life-long injury if we keep playing with injuries or pain'* (P5) Q5: *'Exactly. As long as I can perform in a few years, I actually don't have a perform at top level right now, so it's better to take care of the injury and do rehab instead of going straight back and ruin it again'* (P10)

	Q6: *'Especially if it can hurt your position on the team in the future. You think about it (i.e., potentially worsening an injury by using analgesics to cover symptoms) if you're told that it can affect you for the rest of your career, or even just for longer than right now'* (P14) Q7: *'Typically, my coach will say that if you're injured in any way, then it's better to sit this one out, because there are so many races during a season, so unless it's one of the big ones, then it's a really bad idea to use it (i.e., analgesics) and risk becoming even more injured'* (P24) Q8: *'If my physiotherapist had told me that it (i.e., injury) would become worse if I did not take a break, then I won't use analgesics, because then I would like to feel when and how much it hurts'* (P28) Q10: *'In general I won't use analgesics and neither if it's an injury that may become more severe'* (P28)
Theme 11 Athletes' acceptance of pain and management without analgesics: Some athletes spoke of pain and injury as an inherent part of sport and did not view it as necessarily requiring treatment with analgesics.	Q1: *'I don't know if others use it (i.e., analgesics), but we are some tough guys who usually shut up about it (i.e., pain), and then you don't need them (i.e., analgesics). If you're whining, then you're going home'* (P1) Q2: *'I don't really use analgesics in relation to sport. If I am hurting, I can endure it without using analgesics'* (P10) Q3: *'I would be lying if I said that my knees are great, because they certainly are not.. So I am in pain and do get a lot of bruises, but it's not something I use anything (i.e., analgesics) for, as it eventually will go away by itself'* (P17) Q4: *'Even though I'm in pain or have been beaten up during a match, I often choose to train anyways… I often choose to participate and just not let anyone know that I'm in pain. I often choose to not use*

	analgesics as well, as I think it needs to be something that has been going on for a long time, you know, a long-term injury' (P13) Q5: *'I don't really use it (i.e., analgesics) in relation to injuries. Because, like, if you can play, then it's just because it hurts. I just think that I'm not afraid of pain like that'* (P29) Q6: *'I never use analgesics if it's something like that (i.e., pain), but I have probably pushed myself sometimes, but I have never used analgesics to be able to participate in sport.. Then I just have to push through or use tape or something'* (P1) Q7: *'I don't use it (i.e., analgesics) in relation to sport that much, I don't get that many injuries, and if I do, then I try to push through, so it's mostly for headaches and period pain and so on'* (P9)
Theme 12 Physiotherapists' long-term perspective and focus on rehabilitation: When discussing how other people may influence the athletes' analgesic use, some described that their physiotherapists actively discouraged the use of analgesics and instead emphasized the importance of proper rehabilitation and long-term health and well-being.	Q1: *'We have been told by the physiotherapist that the reason they strongly against using analgesics is because we are still youth players.. He says that if we use it now and do not become professional football players, then maybe we well get a life-long injury if we keep playing with injuries or pain'* (P5) Q2: *'He (i.e., physiotherapist) would prefer if I did not use anything and he has told me many times that I should get off the analgesics and exercise, exercise, exercise'* (P16) Q3: *'I want to get back to on the court as soon as possible if I'm injured.. But I think it's nice that these physiotherapists are more concerned with the future, than right now'* (P10) Q4: *'If you ask football physios, I don't think any of them will tell you that it's a good idea (i.e., to use analgesics), they will probably recommend against it'* (P5) Q5: *'I played internationally for the first time this year and I felt an old injury flare up, so I called her (i.e., physiotherapist) and asked if it was alright to take some paracetamol and then play and she told me that it was alright just this one time because it was in Portugal and, you know, it's not cool to travel that far and then have to withdraw'* (P15)

	Q6: *'I think they (i.e., physiotherapists) would rather avoid it (i.e., using analgesics) and do rehab instead'* (P13) Q7: *'I also feel like it's very much dependent on the culture you're in, because when I played in (anonymized club) we weren't allowed to use analgesics without getting advised by the physio, but where I'm currently playing, no one is really managing it, it's more up to us to decide. But I remember in (anonymized club), if we took something (i.e., analgesics) we had to tell him'* (P19) Q8: *'If it's an injury, then I will also do a check-up with the physiotherapist and ask if the injury can become worse if I keep training. And if it can, then I will usually not use analgesics, but if it's something where I just have to wait and then it's gonna go away by itself, then I'll use analgesics'* (P28)

Paper IV

TITLE PAGE

Title: Large variations in trajectories of analgesic use in youth elite athletes: a 28-week prospective cohort study

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ABSTRACT

Question

To identify trajectories of analgesic use among Danish youth elite athletes and a reference group of students.

Design

Prospective cohort study

Methods

690 youth elite athletes (44% females) and 505 students (59% females) aged 15-20 years provided weekly reports on their use of analgesics for 28 weeks. Group-based trajectory modelling was used to classify trajectories of analgesic use based on weekly prevalence of analgesic use. Mixed effects robust Poisson regression models estimated the relative risk of analgesic use between trajectory groups. Gender distribution, consumption frequency, and types of analgesics used were analyzed for each trajectory group.

Results

Four trajectories of analgesic use were identified for both athletes and students: minimal/non-users (48% of athletes/53% of students), occasional users (31%/33%), frequent users (19%/11%), and persistent users (2.5%/3.2%). Compared to athlete minimal/non-users, the relative risk of analgesic use was significantly higher for occasional users (RR=6.2 [95% CI 5.5-7.2]), frequent users (RR= 15.1 [95% CI 13.3-17.2]), and persistent users (RR=28.3 [95% CI 24.6-32.5]), with a similar pattern observed among students. The mean weekly prevalence of analgesic use varied across trajectory groups, ranging from 3% to 88% in athletes and 5% to 94% in students.

Conclusion

Approximately half of both youth elite athletes and students reported no or minimal use of analgesics, while 21% of athletes and 14% of students were categorized as either persistent or frequent users. These groups had 11 to 28 times higher risk of analgesic use at any given time compared to minimal/non-users.

Key words

Athletes; Youth; Sport; Analgesics; Pain management

INTRODUCTION

Despite international expert consensus emphasizing the importance of non-pharmacological treatment strategies to manage pain and injury in elite athletes,[1] use of analgesics is widespread in youth elite athletes across sports, countries, and settings.[2,3] Between 21% and 54% of youth athletes use over-the-counter analgesics at any given time, and up to 92% report in-season use.[2] While most types of analgesics are considered safe when taken for short durations and in recommended doses, there are particular concerns about persistent use of analgesics, with known risks including renal functioning disorder, liver damage, gastrointestinal adverse events and dependence, in the case of opioids.[4-7]

Previous studies have attempted to quantify rates of persistent analgesic use among youth athletes by assessing frequency of usage.[2] These efforts have, until recently, been limited to cross-sectional studies using heterogeneous methods, resulting in a wide range of estimates of persistent use.[2] For example, in a systematic review, the proportion of youth athletes reporting weekly use of analgesics ranged from 7% to 50% across 14 studies.[2] To overcome the limitations of these cross-sectional estimates, we recently conducted the first longitudinal study on analgesic use in youth elite athletes. Over a 36-week period, the weekly prevalence of analgesic use ranged from 15% to 32%, with users consuming analgesics 2.1 to 2.9 days per week.[3] However, group-based summary measures preclude detailed interpretation of consumption patterns and identification of groups with distinct trajectories. This limitation has been demonstrated in other populations. In one study of 16,000 people with knee and hip osteoarthritis, 62% self-reported using analgesics within three months prior to initiating an exercise therapy and patient education program.[8] However, using registry data revealed that 10% of analgesic users accounted for 45%, 50%, and 70% of the use of paracetamol, non-steroidal anti-inflammatory drugs, and opioids, respectively.[9]

Obtaining insights into different trajectories of analgesic use is important to generate information to support targeted non-pharmacological interventions to treat pain and injury, and to minimize inappropriate use of analgesics in youth elite sports. In this prospective cohort study, we aimed to identify trajectories of analgesic use among Danish youth elite athletes and a reference group of students. In addition, we examined differences in risk of analgesic use, gender distribution, consumption frequency, and types of analgesics used between trajectory groups.

METHODS

Study design

In this prospective cohort study, we used data from the analgESic uSE iN youTh elIte AthLetes (ESSENTIAL) cohort (study protocol: https://osf.io/k5spz/). The Regional Scientific Ethics Committee of the Region of Southern Denmark waived the need for ethical approval as only self-reported information was collected (case number 20202000-176). The project was approved by The Danish Data Protection Agency (case number 11.642). Written informed consent was obtained from all participants. The reporting of the study followed the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) guideline for cohort studies.[10]

Participants and recruitment

A detailed description of the participant recruitment process has previously been published [3]. In short, youth elite athletes from 24 high schools offering elite sports programs (i.e., dual career) in addition to regular academic programs were recruited between August and October 2022. To be eligible, athletes had to be I) enrolled in an elite sports program and; II) between 15 and 20 years of age. Additionally, a reference group of students (15-20 years of age) from the same high schools

was recruited. All participants had to be able to read and speak Danish, and receive and respond to text messages using Short Message Services (SMS) on their mobile phone. Participants were recruited by convenience sampling.

Data collection

At inclusion, participants completed an electronic baseline questionnaire covering contact information, demographics, and sports history. Every Sunday, starting from the week of inclusion to April 23rd 2023, participants completed a standardized weekly questionnaire on their use of analgesics in the preceding seven days via SMS (www.sms-track.com). Reminder messages were sent 24 and 72 hours after the initial text message if no response was received. Participants who did not respond for three consecutive weeks were contacted by phone. As participants received the first questionnaire in the same week as they were included in the study, the number of participants increased every week during the first eight weeks of the study (i.e., the enrolment period from August to October 2022). For this study, we included data from week 9 to 36 (i.e., 28 weeks) to ensure that participants contributed with the same number of weeks.

Outcomes

As no validated questionnaires on analgesic use in youth elite athletes were identified in a systematic literature search,[2] the PAin Medication Use in youth Sports (PAMUS) questionnaire was developed for use in the ESSENTIAL cohort to measure self-reported weekly use of analgesics. The development of the PAMUS questionnaire is described in Appendix 1. The questionnaire includes three standardized questions regarding number of days with analgesic use in the preceding seven days, reasons for use, and types of analgesics used. The full PAMUS questionnaire is available in Appendix 2.

Statistical analysis

Group-based trajectory modelling was used to analyze developmental trajectories of analgesic use and to identify distinct trajectories of analgesic users.[11] Two logistic models (i.e., prevalence of analgesic users among I) youth elite athletes and II) students) were developed in four steps. First, the optimal number of groups for each model were determined based on pre-specified hypotheses and statistical tests including K=1-7 groups. For both models, we assessed Bayesian Information Criteria values and the number of included participants in each subgroup. Second, the optimal shapes of each trajectory based on the polynomial functions were determined, testing intercept, linear, quadratic, and cubic functions. The functions were varied if there were non-significant trajectories according to their polynomial function. Third, Average Posterior Probability Assignment and Odds of Correct Classification statistics were used to assess absolute model fit, with criteria set at APPA >70% and OCC >5.0 for each class. Finally, graphical presentations were investigated and assessed for substantial interpretation. Model fit statistics are available in Appendix 3. Mixed effects Poisson regression models with robust standard errors were used to estimate risk ratios (RR) of analgesic use between trajectory groups, with minimal/non-users serving as reference groups.[12] Gender distribution in each trajectory group was presented as frequencies and percentage distribution. Data on frequency of analgesic use was presented as the weekly median (interquartile range, IQR) consumption frequency for each trajectory group across the 28-weeks study period. Data on types of analgesics were reported as the proportions of participants with 95% CIs within each trajectory group reporting use of each type of analgesic at least once during the 28-week study period. To account for time-limited exposure to analgesics due to injuries, illness or surgery, a sensitivity analysis was conducted defining users as participants reporting use of the same analgesic at least three times during the 28-week study period (i.e., recurrent users of the same type of

analgesic). The statistical analyses were conducted in Stata version 18 (StataCorp 2023, College Station, TX, USA).

Sex/gender-based terminology

As the participants' ages spanned across 18 years old, an age typically considered the transition point for using the terms *girls/boys* versus *women/men*, this paper refers to participants as *female* and *male*, even though participants reported information on gender identify, rather than biological attributes associated with physical or physiological features.

RESULTS

Baseline characteristics

In total, 735 youth elite athletes and 545 students were included in the ESSENTIAL cohort. Of the 1280 participants, 690 athletes (94%) and 505 students (93%) completed the full study period and were included in the analysis (Figure 1). The average weekly response rate was 86% (range 80-93%) in athletes and 82% (range 77-90%) in students. Athletes had a mean age of 17.1 years, 44% were female, and they participated in 46 different sports disciplines. Students had a mean age of 17.4 years, 59% were female, and 62% participated in sports (Table 1). Baseline characteristics of included participants were similar to those lost to follow-up (Appendices 4 and 5).

Trajectories of analgesic use

Four distinct trajectories of analgesic use were identified in both youth elite athletes and students: minimal/non-users, occasional users, frequent users, and persistent users (Figures 2A and 2B). Among athletes, the relative risk of analgesic use was statistically significantly higher for occasional users (RR=6.2 [95% CI 5.5-7.2]), frequent users (RR= 15.1 [95% CI 13.3-17.2]), and

persistent users (RR=28.3 [95% CI 24.6-32.5]) compared to minimal/non-users. Mean weekly prevalence of analgesic use ranged from 3% to 88% across athlete trajectory groups, with median consumption frequencies ranging from 0 to 3 days per week (Table 2). Similar patterns were observed among students, with increased risk of analgesic use for occasional users (RR=5.4 [95% CI 4.7-6.1]), frequent users (RR=11.3 [95% CI 10.1-12.8]), and persistent users (RR=20.2 [95% CI 17.9-22.8]) compared to minimal/non-users. Mean weekly prevalence ranged from 5% to 94% across student trajectory groups, with median consumption frequencies ranging from 0 to 4 days per week (Table 2).

In both athletes and students, minimal/non-use groups were the only groups with larger proportions of males compared to females (Appendix 6). Across all trajectory groups in both athletes and students, paracetamol was the most commonly used analgesic (Table 3). In athletes, the proportion of users of topical gels, acetylsalicylic acid, opioids, and *other* analgesics increased with higher trajectory groups. This was also observed among students for the use of topical gels, opioids, and injectable analgesics (Table 3). The sensitivity analysis assessing the proportion of recurrent users of the same type of analgesic revealed similar patterns, though the proportions of users were lower across all types of analgesics (Appendix 7).

DISCUSSION

We identified four distinct trajectories of analgesic use among both youth elite athletes and students. Approximately half of both athletes and students had minimal or no use of analgesics, while 21% of athletes and 14% of students were categorized as frequent or persistent users. In both athletes and students, the risk of analgesic use increased with higher trajectory groups. Frequent and persistent

users had a higher proportion of females, had higher weekly consumption frequency, and used analgesics with higher risk of adverse events.

To our knowledge, this is the first study to investigate the presence of distinct trajectories of analgesic use in a young population. Previous research using trajectory modeling to identify analgesic use patterns have predominately focused on opioid prescriptions in adult populations, making direct comparisons difficult. However, similar to our findings, these studies identified small persistent use groups. For example, in studies excluding people with cancer, between 2.4% and 6.0% of cohort members were categorized as persistent opioid users.[13-15] Similarly, a small proportion of analgesic users among people with knee and hip osteoarthritis accounted for up to 70% of the total use of paracetamol, non-steroidal anti-inflammatory drugs, and opioids.[9] We have previously reported that the mean weekly prevalence of analgesic use was ~20% in both youth elite athletes and students, implying that 1 in 5 use analgesics in any given week.[3] However, the current findings suggest that most youth elite athletes and students have low, time-limited exposure to analgesics. This was further supported by the sensitivity analysis applying an alternate user definition (i.e., recurrent use of the same type of analgesic) showing fewer users across all types of analgesics. This decrease was most pronounced among minimal/non-users and occasional users indicating that many participants in these trajectory groups do not consistently use specific types of analgesics. In contrast, 21% of athletes and 14% of students exhibited concerning usage patterns, characterized by biweekly to weekly analgesic use, and 11 to 28 times higher risk of analgesic use at any given time compared to minimal/non-users. Among these participants, over-the-counter analgesics were the most commonly type of analgesics used. While frequent or long-term use of prescription analgesics may be considered rational if it aims to alleviate a medical condition evaluated by a physician,[16] unsupervised long-term use of over-the-counter analgesics without

proper medical examinations or supervision is not recommended due to the increasing risk of serious adverse events.[1,4,5,17]

We observed several similarities between athletes and students in their use of analgesics. The proportions of participants in each trajectory group were comparable, and the frequency of analgesic consumption was similar within trajectory groups, with paracetamol and NSAIDs being the most commonly used analgesics. However, two main differences were observed between the cohorts. First, among persistent users, more athletes reported using paracetamol, NSAIDs, topical analgesics, acetylsalicylic acid, and opioids compared to students. This may suggest that athletes with high analgesic use are more likely to use multiple types of analgesics concurrently, aligning with previous research showing that simultaneous administration of two or more analgesics is common in elite athletes receiving injectable analgesics during a major tournament.[18] Second, contrary to students, athletes with persistent use exhibited a varying consumption pattern over time, with the highest prevalences (i.e., 100%) observed in the final weeks of the study period. This rise coincided with end-of-season for most sports disciplines, which may suggest that athletes with high analgesic use may increase their usage even further to meet heightened sports-related demands.

Clinical implications

The findings that the majority of youth elite athletes and students aged 15-20 years seem to have low, time-limited exposure to analgesics, with little indication of ongoing use is positive, but has implications. First, intervening on a group-level to reduce use of analgesics is likely not justified, but providing information on safe analgesic use and encouraging these individuals to maintain their low usage levels through non-pharmacological pain relief methods could be beneficial. Second, young people with a higher use of analgesics, especially persistent users, may require more

intensive and tailored interventions. Persistent users, in particular, may benefit from multidisciplinary approaches including physical therapy, psychological support, and regular monitoring to manage pain and prevent dependence.[1,19,20] Third, in youth elite sport, coaches and physiotherapists should pay close attention to analgesic use in individual athletes, and intervene if inappropriate use is identified. In the absence of evidence-based interventions to decrease analgesic use in youth athletes, emphasis may be placed on providing information on the potential consequences of analgesic use for pain and injury, and the risks associated with prolonged or inappropriate use, as well as providing access to non-pharmacological pain management approaches. Physiotherapists, who often represent the first point of health care contact for youth athletes, play a crucial role in providing interventions that address pain without medication, promoting rehabilitation and educating patients on pain management strategies[21].

Limitations

This study has limitations. Research suggest that factors such as daily pain and high pain intensity are associated with frequent analgesic use.[14,22] We collected data on sports-related injuries, injury severity, presence of pain within seven days prior to cohort entry, and pain intensity only at baseline. This limited our ability to capture changes over time in injury and pain status and assess how these variables influence analgesic use. In addition, the relatively crude outcome measure did not account for the analgesic dosage or how many times per day participants used analgesics. We relied solely on self-reported information on analgesic use, which introduces a risk of information bias in terms of non-truthful reporting of analgesic consumption and misclassification of analgesic types. However, the PAMUS questionnaire was developed and content validated in collaboration with youth elite athletes, and two pharmacists provided feedback to ensure all relevant analgesics were included and identifiable. Due to the recruitment method, we were unable to obtain

information on the total number of potentially eligible participants. This precludes assessment of potential non-participation selection bias.

CONCLUSION

We observed that approximately half of both youth elite athletes and students had minimal or no use of analgesics. However, 21% of athletes and 14% of students exhibited concerning analgesic consumption patterns with biweekly or weekly analgesic use, and 11 to 28 times higher risk of analgesic use compared to minimal/non-users. Frequent and persistent users also had a higher proportion of females, higher weekly consumption frequency, and used analgesics with higher risk of serious adverse events.

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Authors' contributions

JRP Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing – Original Draft, Writing – Review & Editing, Project administration, Funding acquisition; **AM** Methodology, Software, Validation, Formal analysis, Writing – Review & Editing, Supervision; **MM** Conceptualization, Methodology, Writing – Review & Editing, Supervision; **LKS** Conceptualization, Methodology, Writing – Review & Editing, Supervision; **BK** Conceptualization, Methodology, Writing – Review & Editing, Supervision; **JBT** Conceptualization, Methodology, Formal analysis, Resources, Writing – Review & Editing, Supervision, Funding acquisition.

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Table 1 Baseline characteristics of included participants

	Athletes (n=690)	Students (n=505)
Age, mean (SD): years	17.1 (0.4)	17.4 (0.4)
Female, n (%)	305 (44.2)	299 (59.2)
BMI, mean (SD)	21.9 (0.1)	21.9 (0.2)
Weekly sports exposure, mean (SD): hours[b]	16.2 (6.3)	6.7 (4.6)
Students' participation in a specific sport, n (%)	N/A	
Yes		313 (62%)
No		192 (38%)
Type of sport, n (%)	[a]	[b]
Team sport	323 (47%)	143 (46%)
Endurance sport	137 (20%)	18 (6%)
Technical sport	229 (33%)	150 (48%)
Athlete competition level, n (%)		N/A
Regional	47 (7%)	
National	327 (47%)	
International	316 (46%)	
Student competition level, n (%)	N/A	
Recreational		188 (60%)
Regional		51 (16%)
National		65 (21%)
International		9 (3%)
Age at sports debut, mean (SD): years	7.5 (3.2)	N/A
Age at sports specialization, mean (SD): years	13.0 (2.3) [c]	N/A
Baseline sports-related injury, n (%)		
No	318 (46%)	337 (67%)
Yes, but the injury did not affect sports participation	179 (26%)	80 (16%)
Yes, the injury affected sports participation for less than 4 weeks	81 (12%)	39 (8%)
Yes, the injury affected sports participation for more than 4 weeks	81 (12%)	37 (7%)
Yes, time-loss injury	31 (4%)	12 (2%)
Previous frequent use of analgesics (i.e., use on a weekly basis), n (%)		
No	464 (67%)	347 (69%)
Yes	226 (33%)	158 (31%)

[a] missing n=1, [b] missing n=2, [c] missing n=3

Table 2 Mean weekly prevalence and median consumption frequency in trajectory groups across the 28-week observation period

Groups	Mean weekly prevalence (95% CI)	Median consumption frequency (no. of days, IQR)
Athletes		
Minimal/non-users (n=332)	3% (1-5%)	0 (0-0)
Occasional users (n=213)	19% (14-25%)	0 (0-0)
Frequent users (n=128, percent of athletes)	47% (38-56%)	1 (0-2)
Persistent users (n=17)	88% (63-99%)	3 (2-6)
Students		
Minimal/non-users (n=265)	5% (2-8%)	0 (0-0)
Occasional users (n=168)	25% (18-32%)	0 (0-1)
Frequent users (n=56)	53% (39-67%)	1 (0-2)
Persistent users (n=16)	94% (70-100%)	4 (2-7)

Table 3 Proportion of athletes and students reporting use of each type of analgesic at least once during the 28-week observation period

	Minimal/non-users	Occasional users	Frequent users	Persistent users
Athletes (n, %)				
Paracetamol	164 (49%)	204 (96%)	125 (98%)	16 (94%)
NSAIDs	66 (20%)	111 (52%)	98 (77%)	13 (76%)
Topical gels	39 (12%)	77 (36%)	64 (50%)	13 (76%)
Acetylsalicylic acid	14 (4%)	24 (11%)	32 (25%)	7 (41%)
Opioids	3 (1%)	10 (5%)	15 (12%)	5 (29%)
Injections	5 (2%)	12 (6%)	12 (9%)	1 (6%)
Other	4 (1%)	14 (7%)	13 (10%)	2 (12%)
Students (n, %)				
Paracetamol	169 (64%)	165 (98%)	54 (96%)	15 (93%)
NSAIDs	45 (17%)	92 (55%)	44 (79%)	11 (69%)
Topical gels	19 (7%)	28 (17%)	13 (23%)	4 (25%)
Acetylsalicylic acid	21 (8%)	38 (23%)	22 (39%)	5 (31%)
Opioids	6 (2%)	20 (12%)	6 (11%)	3 (19%)
Injections	8 (3%)	7 (4%)	7 (13%)	4 (25%)
Other	11 (4%)	10 (6%)	9 (16%)	5 (31%)

Figure 1 Flow chart

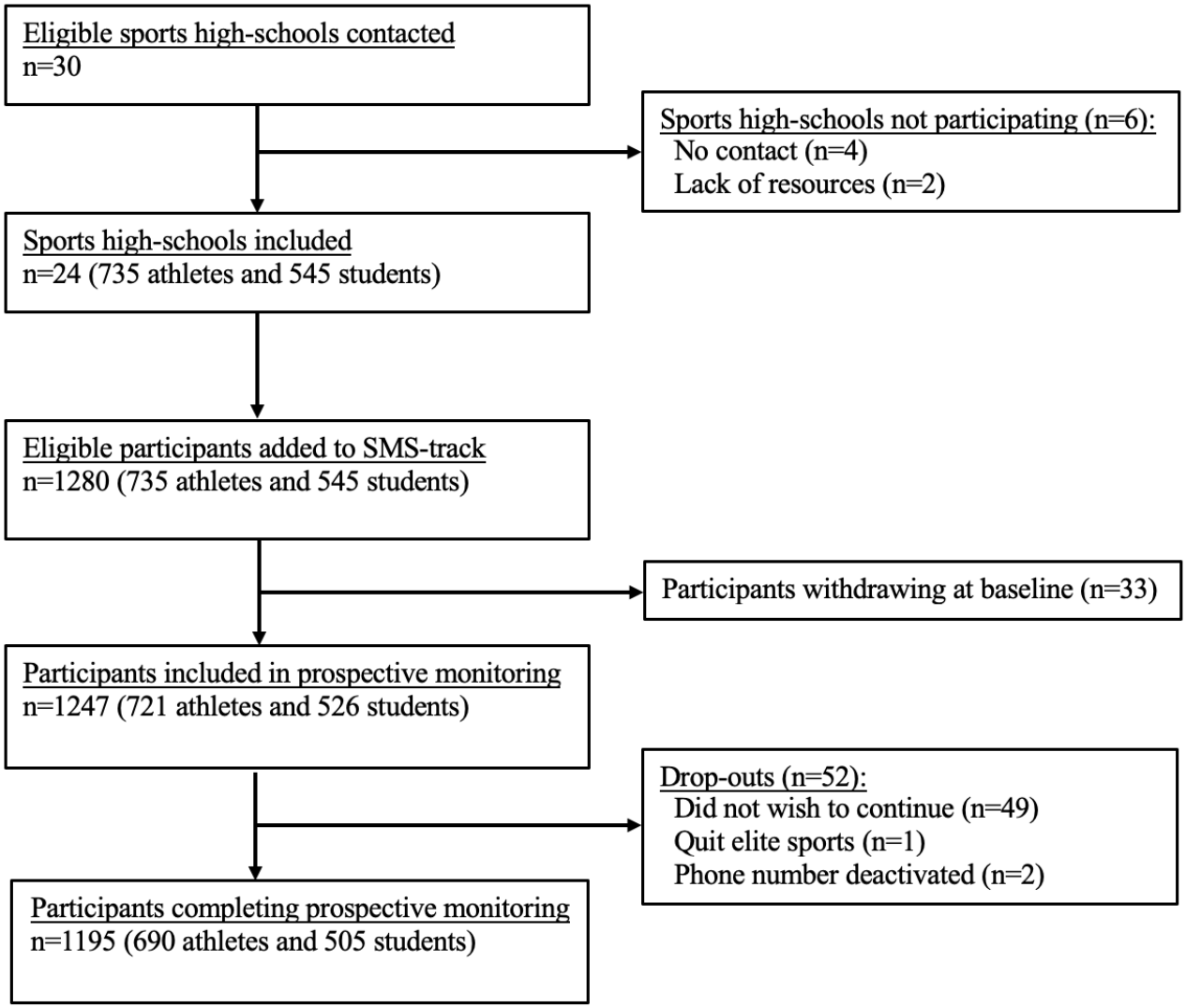


Figure 2A Athlete trajectory groups: Minimal/non-users (n=332), occasional users (n=213), frequent users (n=128), persistent users (n=17). Dotted lined indicate 95% CI. Figure in color in print

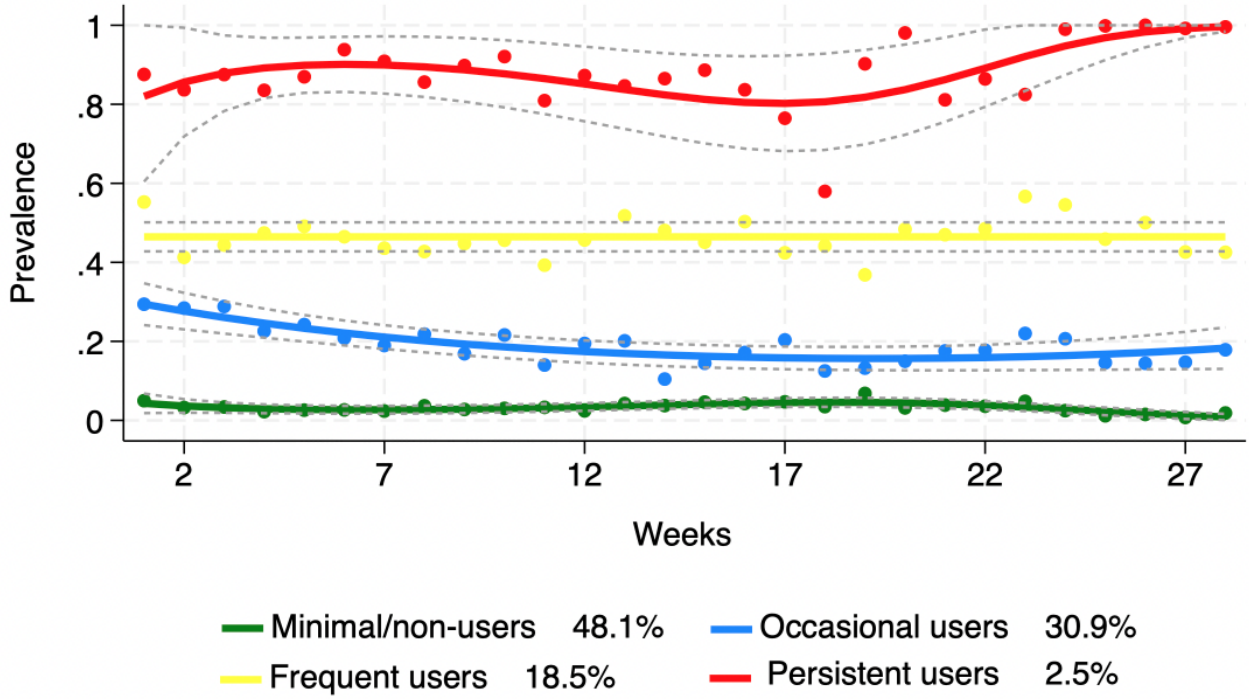
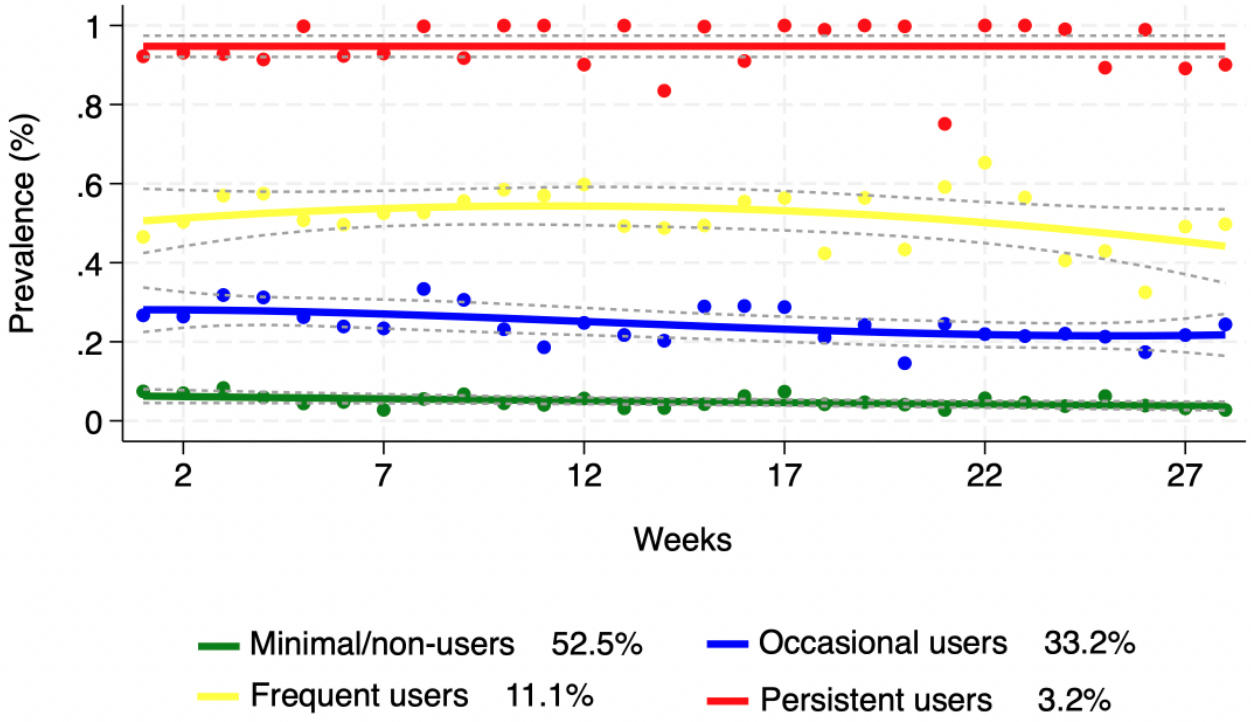


Figure 2B Student trajectory groups: Minimal/non-users (n=265), occasional users (n=168), frequent users (n=56), persistent users (n=17). Dotted lined indicate 95% CI. Figure in color in print



APPENDIX

Title

Large variations in trajectories of analgesic use in young people: a 28-week prospective cohort study

Authors

Julie Rønne Pedersen, Afsaneh Mohammadnejad, Merete Møller, Louise Kamuk Storm, Bart Koes, Jonas Bloch Thorlund

Appendix 1 PAMUS development

As no validated questionnaires on analgesic use in youth elite athletes was identified in a systematic literature search, we specifically developed the PAin Medication Use in youth Sports (PAMUS) questionnaire for this study to measure self-reported weekly use of analgesics. The development and content validation process of the PAMUS questionnaire was performed following the COSMIN guidelines for developing and validating patient-reported outcome measurement instruments[1] and the guidelines by Patrick et al.[2 3] in the following steps:

1) The construct to be measured (analgesic use), context of use (digital monitoring tool intended for weekly administration), and the population of interest (youth elite athletes between 15-20 years of age) were defined, and a literature search was conducted to identify components of analgesic use in youth athletes.
2) A conceptual model was identified, and a hypothesized conceptual framework was developed to identify overarching concepts, hypothesized domains, and candidate item content. Based on the hypothesized conceptual framework, two interview guides were developed
3) One-to-one interviews were performed with three researchers and focus group interviews were performed with seven members of the target population (i.e., youth elite athletes aged 15-20 years).
4) The interview data was analyzed using content analysis. Eight overall themes were identified from the athlete interviews, including types of analgesics, sources of knowledge, adverse events, frequency of usage, reasons for sports-related use of analgesics, reasons for non-sports related use of analgesics, sociocultural influences on analgesic use, and other interventions received for pain/injury. Based on expert opinion, it was deemed unnecessary to monitor adverse events on a weekly basis due to high chances of symptoms misclassification and it was hypothesized that it would be sufficient to assess sources of knowledge at baseline as this is unlikely to change over a shorter period of time. Similarly, while numerous external influences and sources on knowledge on analgesic use were identified in the focus group interviews, no consistent patterns or experiences were found within the data, thus hindering further conceptualization. As a result, it was decided that aspects related to sociocultural influences and the impact of the athlete environment on analgesic use should be explored through qualitative research methods. Finally, it was deemed inappropriate to ask about other interventions used for sports-related pain and injury, as analgesics may be used for other purposes than the treatment of sports-related pain and injury.

5) Based on the remaining 4 themes, a questionnaire containing a maximum of three questions (frequency of analgesic use, reasons for use, and types of analgesic used) was drafted and pilot tested using one-to-one cognitive interviewing in another group of youth elite athletes (n=7). These interviews showed that the participants were positive towards the questionnaire and found the items and related response options clear and unambiguous. All participants were satisfied with the total number of questions and felt that all were relevant to them. The interviews revealed that no adjustment was necessary to finalize the questionnaire. Detailed information on the development and content validation process will be reported in a separate publication.

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Appendix 2 PAMUS questionnaire

Questions	Answer options
How many days have you used pain medication during the past 7 days?	0 (questionnaire finalized) 1 2 3 4 5 6 7
Why did you use pain medication? (choose all relevant response options)	a) To treat pain or injury after participating in sport b) To treat pain or injury prior to participating in sport c) To prevent pain that might occur during sports participation d) To treat pain not related to sport (e.g., headache, back pain) e) To treat menstrual pain f) To treat illness g) Other reasons
What type(s) of pain medication did you use? (choose all relevant response options)	a) Paracetamol (e.g., panodil, pamol, paracetamol, pinex) b) Non-steroidal anti-inflammatory drugs (e.g., ipren, ibuprofen, ibumetin, diclofenac, naproxen) c) Topical gels (e.g., voltaren gel, ipren gel, ibutop) d) Acetylsalicylic acid (e.g., treo, triplo, kodimagnyl) e) Opioids (e.g., tramadol, codein, fentanyl, oxycodone) f) Injections g) Other (e.g., antiepileptic medicine [gabapentin, pregabalin], antidepressive medicine [amitryptilin, duloxetine])

Appendix 3 Model fit statistics

Athletes

Model fit, number of groups

Nr of groups	**BIC**	**G < 5%**
1	-7994	No
2	-6900	No
3	-6751	No
4	-6697	Yes
5	-6698	Yes
6	-6689	Yes
7	-6695	Yes

Model fit, polynomial function

Model	**Polynomial function**	**BIC**	**G < 5%**
1	3-3-3-3	-6707	Yes
2	2-3-2-3	-6702	Yes
3	2-3-1-3	-6699	Yes
4	2-3-0-3	-6696	Yes

Absolute model fit statistics

		APPA				**OCC**			
Model	Polynomic function	T1	T2	T3	T4	T1	T2	T3	T4
1	3-3-3-3	0.82	0.88	0.88	0.91	10.1	9.3	29.1	387.3
2	2-3-2-3	0.83	0.88	0.87	0.88	10.3	9.4	28.2	305.5
3	2-3-1-3	0.83	0.88	0.88	0.87	10.2	9.2	31.4	292.3
4	2-3-0-3	0.83	0.88	0.88	0.87	10.3	9.2	30.7	294.2

Students

Model fit, number of groups

Nr of groups	BIC	G < 5%
1	-5907	No
2	-5184	No
3	-5008	No
4	-4959	Yes
5	-4961	Yes
6	-4967	Yes
7	-4987	Yes

Model	Polynomial function	BIC	G < 5%
1	3-3-3-3	-4981	Yes
2	2-3-2-2	-4972	Yes
3	1-3-1-1	-4967	Yes
4	1-3-0-0	-4961	Yes
5	1-3-2-0	-4966	Yes

Absolute model fit statistics

		APPA				OCC			
Model	Polynomic function	T1	T2	T3	T4	T1	T2	T3	T4
1	3-3-3-3	0.85	0.88	0.87	0.93	10.7	7.8	48.4	389.5
2	2-3-2-2	0.85	0.88	0.88	0.93	10.6	7.7	52.1	385.0
3	1-3-1-1	0.88	0.84	0.87	0.93	7.8	10.4	45.8	380.3
4	1-3-0-0	0.88	0.84	0.88	0.93	8.0	10.1	55.4	398.2
5	1-3-2-0	0.88	0.84	0.88	0.93	7.7	10.3	49.9	397.9

Appendix 4 Drop-out analysis, youth elite athletes

	Participants retained in the study (n=690)	Participants dropped out or excluded (n=45)	Difference (95% CI) or p-value
Age, mean (SD): years	17.1 (0.4)	17.2 (0.1)	0.1 (-0.1 to 0.4)
Female, n (%)	305 (44%)	13 (28%)	P=0.03
BMI, mean (SD)	21.9 (0.1)	21.6 (0.2)	0.3 (-0.5 to 1.1)
Weekly sports exposure, mean (SD): hours	16.1 (0.2)	15.5 (0.7)	0.6 (-1.3 to 2.5)
Type of sport, n (%)			P=0.31
Team sport	323 (47%)	25 (56%)	
Endurance sport	137 (20%)	5 (11%)	
Technical sport	229 (33%)	15 (33%)	
Competition level, n (%)[b]			P=0.98
Regional	47 (7%)	3 (7%)	
National	327 (47%)	22 (49%)	
International	316 (46%)	20 (44%)	
Age at sports debut, mean (SD): years	7.4 (0.1)	7.3 (0.4)	0.1 (-0.8 to 1.1)
Age at sports specialization, mean (SD): years	12.9 (0.1)	12.2 (0.3)	0.7 (0.01 to 1.4)
Baseline sports-related injury, n (%)			P=0.83
No	318 (46%)	21 (47%)	
Yes, but the injury did not affect sports participation	179 (26%)	10 (22%)	
Yes, the injury affected sports participation in less than 4 weeks	81 (12%)	7 (15%)	
Yes, the injury affected sports participation in more than 4 weeks	81 (12%)	4 (9%)	
Yes, time-loss injury	31 (4%)	3 (7%)	

Appendix 5 Drop-out analysis, students

	Participants retained in the study (n=505)	Participants dropped out or excluded (n=40)	Difference (95% CI) or p-value
Age, mean (SD): years	17.4 (0.0)	17.5 (0.1)	0.1 (-0.2 to 0.4)
Female, n (%)	299 (59.2%)	20 (50%)	P=0.04
BMI, mean (SD)	21.9 (0.1)	21.8 (0.5)	0.05 (-1.1 to 1.2)
Participation in a specific sport, n (%)			P=0.72
No	192 (38%)	13 (33%)	
Yes	313 (62%)	27 (67%)	
Weekly sports exposure, mean (SD): hours	6.6 (0.2)	7.8 (0.8)	1.1 (-0.4 to 2.6)
Type of sport, n (%)			P=0.41
Team sport	143 (46%)	14 (52%)	
Endurance sport	18 (6%)	0 (0%)	
Technical sport	150 (48%)	13 (48%)	
Baseline sports-related injury, n (%)			P=0.66
No	337 (67%)	26 (65%)	
Yes, but the injury did not affect sports participation	80 (16%)	9 (23%)	
Yes, the injury affected sports participation for less than 4 weeks	39 (8%)	1 (2%)	
Yes, the injury affected sports participation for more than 4 weeks	37 (7%)	3 (8%)	
Yes, time-loss injury	12 (2%)	1 (2%)	

Appendix 6 Sex distribution across trajectory groups

	Male	Female	p-value
Athletes (n, %)			
Minimal/non-users	245 (74%)	87 (26%)	
Occasional users	100 (47%)	113 (53%)	
Frequent users	38 (30%)	90 (70%)	
Persistent users	2 (12%)	15 (88%)	<0.001
Student controls (n, %)			
Minimal/non-users	150 (57%)	115 (43%)	
Occasional users	46 (27%)	122 (73%)	
Frequent users	8 (14%)	48 (86%)	
Persistent users	12 (13%)	15 (87%)	<0.001

Appendix 7 Sensitivity analysis of the proportion of athletes and student controls reporting use of each type of analgesic (i.e., ≥3 times during 28-week study period).

	Minimal/non-users	Occasional users	Frequent users	Persistent users
Athletes (n, %)				
Paracetamol	29 (9%)	157 (73%)	121 (95%)	16 (94%)
NSAIDs	5 (2%)	47 (22%)	66 (52%)	10 (59%)
Topical gels	7 (2%)	25 (12%)	34 (27%)	7 (41%)
Acetylsalicylic acid	0 (0%)	5 (2%)	9 (7%)	3 (18%)
Opioids	1 (0.5%)	0 (0%)	1 (1%)	3 (18%)
Injections	0 (0%)	1 (0.5%)	1 (1%)	0 (0%)
Other	0 (0%)	2 (1%)	2 (2%)	2 (12%)
Student controls (n, %)				
Paracetamol	46 (17%)	144 (86%)	53 (95%)	13 (81%)
NSAIDs	7 (3%)	45 (27%)	32 (57%)	9 (56%)
Topical gels	0 (0%)	10 (6%)	4 (7%)	2 (13%)
Acetylsalicylic acid	1 (0.5%)	11 (7%)	9 (16%)	3 (19%)
Opioids	1 (0.5%)	3 (2%)	2 (4%)	1 (6%)
Injections	0 (0%)	0 (0%)	0 (0%)	0 (0%)
Other	0 (0%)	2 (1%)	1 (2%9	4 (25%)