Injury and illness among Norwegian Olympic athletes during preparation for five consecutive Summer and Winter Games

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ABSTRACT

Objective To describe the patterns of health problems among Norwegian Olympic candidates during their preparations for five consecutive Olympic Games (London 2012, Sochi 2014, Rio de Janeiro 2016, PyeongChang 2018 and Tokyo 2020).

Methods This was a descriptive epidemiological study using the Oslo Sports Trauma Research Center Questionnaire on Health Problems to collect data on all self-reported health problems from Norwegian Olympic candidate athletes for 12–18 months prior to each Olympic Games. Team physicians and physiotherapists followed up the athlete reports, providing clinical care and classifying reported problems according to the International Olympic Committee 2020 consensus statement on methods for recording and reporting of epidemiological data on injury and illness in sport.

Results Between 2011 and 2020, 533 athletes were included in the Norwegian Olympic team monitoring programme, with a 78% response to the weekly questionnaire. During this time, athletes reported 2922 health problems, including 1409 illnesses (48%), 886 overuse injuries (repetitive mechanism, 30%) and 627 acute injuries (traumatic mechanism, 21%). Diagnostic codes were recorded for 2829 (97%) of health problems. Athletes reported, on average, 5.9 new health problems per year (95% CI: 5.6 to 6.1), including 1.3 acute injuries (CI: 1.2 to 1.4), 1.7 overuse injuries (CI: 1.6 to 1.9) and 2.9 illnesses (CI: 2.7 to 3.0). Each year, female and male athletes lost an average of 40 and 26 days of training and competition due to health problems, respectively. The diagnoses with the highest health burden were anterior cruciate ligament rupture, respiratory infection, lumbar pain and patellar tendinopathy.

Conclusion The injury burden was particularly high among female athletes and in team sports, whereas endurance sports had the greatest burden of illness. Our data provide a compelling argument for prioritising medical care and investing in prevention programmes not just during the Olympic Games, but also the preparation period.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ There is substantial knowledge of the patterns of injury and illness among Olympic athletes during competition, but knowledge of their health during the preparations for the Olympic Games is limited.

WHAT THIS STUDY ADDS

⇒ During preparations for the Olympic Games, athletes commonly experience injuries and illnesses. Female athletes and those participating in team sports have the highest injury burden, whereas endurance athletes have the highest burden of illness.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Findings from this study may assist other national Olympic programmes in prioritising their prevention strategies and planning their medical services during their preparations for the Games.

INTRODUCTION

Injury and illness surveillance programmes represent a core element of risk management and prevention strategies in sport. At the Olympic level, surveillance data collected by the International Olympic Committee (IOC) since 2004 provide rich insights into athletes' injury and illness patterns during the competition period of 10–17 days of the Games.[1–7] However, data on Olympic athletes' health *between* the Games remain limited. Due to the diverse range of sports and high training loads, Olympic athletes are prone to a variety of different health problems, such as traumatic and gradual-onset injuries, acute and chronic illnesses, and mental health disorders. Previous studies have shown that these athletes often continue to train and compete despite having health problems, in many cases without the knowledge of doctors and physiotherapists assigned to their medical care.[8–11]

In 2011, we launched a health monitoring programme for the Norwegian Olympic and Paralympic teams.[12] The programme was designed to facilitate consistent communication between athletes and their team medical personnel (irrespective of period of the season or athlete location), and thus ensure early identification of new health problems and optimal management of known problems. This process has enabled collection of detailed injury and illness surveillance data from athletes and medical personnel, which are used to inform the development of prevention interventions and ensure effective allocation of health resources in the Norwegian team. In previous publications, we have described the programme's methods and discussed its challenges and benefits.[13] We have also recently presented detailed injury and illness data from the Norwegian Paralympic team.[14]

This paper describes the patterns of injury and illness in the Norwegian Olympic team between 2011 and 2020. Our analysis is stratified by sex, sport type (team sports, endurance sports and tactical/technical sports) and season (summer and winter sports).

METHODS

This report includes data collected between October 2011 and January 2020, during our preparations for three Olympic Summer Games (London 2012, Rio de Janeiro 2016 and Tokyo 2020) and two Olympic Winter Games (Sochi 2012 and PyeongChang 2018). In this period, the monitoring programme involved, at any given time, between 100 and 160 athletes preparing for the next Olympic Games, as well as a medical team of approximately 10 physicians and 15 physiotherapists. Approximately 12–18 months prior to each Games, national team coaches from all Olympic sports were asked to provide a list of athletes whom they consider to be candidates to qualify, and this list was reviewed every 3 months. All candidate athletes were invited to participate in the programme and followed until the start of the Games, or until they were removed from the programme by their national team coach because they were no longer considered an Olympic candidate.

Athletes' participation in the programme was voluntary, and athletes could choose to withhold their data from use in research.

Data collection

Each Sunday evening or Monday morning, depending on team preferences, athletes were sent a short message service (SMS) containing a link to the Oslo Sports Trauma Research Center (OSTRC) Questionnaire on Health Problems (OSTRC-H[12] between 2011 and June 2018, OSTRC-H2[15] from July 2018). Daily reminders were sent to non-respondents. During the study period, three different electronic platforms were used to distribute the questionnaire, including online survey software for London 2012 and Sochi 2014 (Questback V.9692, Questback, Oslo, Norway), a native smartphone application for Rio 2016 and PyeongChang 2018 (Spartanova, Ghent, Belgium) and a web application with an SMS notification system for Tokyo 2020 (AthleteMonitoring, FitStats Technologies, Moncton, Canada).

A reportable health problem was defined as any condition that reduced an athlete's normal state of full health, irrespective of its consequences on the athlete's sports participation or performance or whether the athlete sought medical attention.[16]

The questionnaire consists of four key questions on the consequences of health problems on sports participation, training modifications and sports performance, as well as the degree of symptoms the athlete has experienced in the preceding 7 days. Athletes who reported one or more health problems received a series of subsequent questions to classify reported problems (eg, injury mechanism and location, illness symptoms), record the number of days the athlete was completely unable to participate in training and competition, and to determine which medical personnel were aware of the problem (including those outside the Olympic medical team). Athletes could also provide additional free-text comments about each problem.

Whenever athletes reported a new health problem or commented on an ongoing problem, their team physician and physiotherapist received an alert and, when necessary, contacted the athlete to arrange follow-up or further investigations. The medical team were also asked to review athletes' reports and to provide a diagnostic code for each health problem.

Classification and diagnosis of reported health problems

Medical personnel used several different coding systems to record specific diagnoses of health problems reported by athletes, including the Orchard Sports Injury Classification System, V.10 (London and Sochi injuries), the International Classification of Primary Care, V.2 (London and Sochi illnesses) and the Sports Medicine Diagnostic Coding System (Rio, PyeongChang and Tokyo, all health problems). We translated the codes from each of these systems to V.13 of the Orchard Sports Injury and Illness Classification System (OSIICS-13).

Injuries were considered to have a non-specific diagnosis if the body part or tissue type was unspecified (the first or second letter of the OSIICS-13 code was Z). Illnesses were considered to have a non-specific diagnosis if the medical system or aetiology was unknown or unspecified (the second or third letter of the OSIICS-13 code was Z).

To account for inconsistencies in recorded diagnoses of respiratory illnesses, the OSIICS-13 diagnostic codes 'MPIG Pharyngitis', 'MPIT Tonsillitis', 'MPIS Sinusitis', 'MPZX Other respiratory illness not otherwise specified' and 'MPIX Other upper respiratory tract infection' were recoded to 'MPI1 Respiratory infection'. Similarly, for non-specific low back pain, 'LZN Lumbar pain/injury not otherwise specified', 'LZX Lumbar pain/injury not otherwise specified', 'LP1 Chronic lumbar functional pain', 'LM1 Lumbar spine muscle and tendon strain/spasm/trigger points', and 'LZH Lumbar pain with hamstring referral' were recoded to 'LZ1 Lumbar pain' (a non-specific diagnosis).

Data analyses and statistics

All health problems that existed at the baseline of a data collection period were removed from incidence and time loss calculations (n=137). For cases that remained unresolved at the end of data collection periods (n=112), time loss and cumulative OSTRC severity scores were replaced with the median time loss and severity scores of resolved cases with the same diagnosis. For several cases of anterior cruciate ligament (ACL) rupture, inspection of athletes' questionnaire responses revealed poor response rates during the injury period. Therefore, cases of ACL rupture with reported time loss of less than 26 weeks (n=12) were assigned the median time loss and cumulative severity scores of cases with 26 weeks or more of time loss.

As some team sizes were small, we have presented data for subgroups of sports, including team sports, endurance sports and tactical/technical sports (table 1). Data are also presented separately for male and female athletes and summer and winter athletes.

Data collected using the OSTRC-H were transformed to match the logic and scoring system of the OSTRC-H2.[15] All analyses were performed using R (V.3.6.1).[17] Mean cumulative severity scores, mean time loss and 95% CIs were calculated by bootstrapping (R=5000), using the groupwiseMean function of the rcompanion package (V.2.4.30). CIs for incidence rates were calculated with the Byar method, using the epi. conf function in the epiR package (V.2.0.62).

Equity, diversity and inclusion statement

The author group included four women and seven men, a mix of mid-career and senior clinicians and researchers from the disciplines of physiotherapy and medicine. Nine authors were Norwegian, one Australian and one German. Our study

Table 1 Number of athletes included in each Olympic Games period, by sex, sport category and sport

Sport category	London		Sochi		Rio		PyeongChang		Tokyo	
Sport	Females	Males	Females	Males	Females	Males	Females	Males	Females	Males
Endurance sports										
Cycling	5	7			6	1			7	7
Kayak	4	3				5				3
Rowing	3	9				2			2	6
Swimming	5	5				1				3
Triathlon						1			1	4
Biathlon			12	9			13	19		
Cross-country skiing			10	13			8	3		
Nordic combined				7				8		
Speed skating			4	9			6	12		
Tactical/technical sports										
Archery		1								
Athletics	11	10			16	16			6	14
Boxing	2									
Golf									7	8
Gymnastics						2				2
Sailing	3	5			7	4			5	3
Shooting		4			2	6				
Taekwondo	1	2			1				3	3
Weightlifting	1									
Wrestling		2			1	3			1	6
Alpine skiing			4	5			8	10		
Curling				6			1	8		
Figure skating							3			
Freestyle skiing			1				3	5		
Ski jumping			5	14			4	23		
Sliding				3			1			
Snowboard			4	5				3		
Team sports										
Beach volleyball		6				5				4
Handball	24				22				30	33
Ice hockey				33				34		
Total	59	54	40	104	55	46	47	125	62	96

population included both male and female athletes from different socioeconomic backgrounds participating in elite sport, and our analysis explores the effects of sex. As Norway is a high-income country, findings may not be generalisable to settings with fewer resources. This is considered in the discussion.

RESULTS

A total of 533 athletes from 29 sports were included across the five Olympic Games cycles, including 197 females and 336 males (table 1). Of these, 393 athletes were involved in preparations for one Games, 125 two Games and 15 three Games.

The overall response to the weekly questionnaires across the five games cycles was 78%: 79% for London, 83% for Sochi, 51% for Rio, 69% for PyeongChang and 89% for Tokyo. Five hundred and six athletes reported a total of 2922 health problems, including 1409 illnesses (48%), 886 overuse injuries (repetitive mechanism, 30%) and 627 acute injuries (traumatic mechanism, 21%). A total of 2829 cases (97%) received an OSIICS-13 code, 809 of which were non-specific (28% of all cases).

Prevalence of health problems

The average weekly prevalence of health problems across all athletes and games cycles was 32% (CI: 32.1% to 32.9%) (table 2). This was higher among females than males (prevalence ratio 1.4). Among females, the prevalence of health problems was higher for winter sports, largely due to a higher prevalence of acute injuries. This pattern was reversed among males, with summer athletes having a higher prevalence of health problems, driven by overuse injuries. For both sexes, endurance athletes had a lower injury prevalence and a higher illness prevalence than athletes from team and tactical/technical sports. Compared with all other subgroups, female team athletes had the highest prevalence of acute and overuse injuries (table 2).

Incidence, severity and burden of health problems

The overall incidence of health problems was 5.9 cases per athlete per year (CI: 5.6 to 6.1), including 1.3 acute injuries (CI: 1.2 to 1.4), 1.7 overuse injuries (95% CI: 1.6 to 1.9) and 2.9 illnesses (95% CI: 2.7 to 3.0). Across the entire group, athletes lost an average of 30.8 days of training due to health problems per year (30.3 to 31.3), 16.2 days due to acute injuries (15.9 to 16.6), 5.7 days due to overuse injuries (5.5 to 5.9) and 8.9 days

Table 2 Average weekly prevalence of all and substantial health problems, presented for the whole cohort as well as for subgroups (%, 95% CI)

	All sports	Summer sports	Winter sports	Team sports	Endurance sports	Tactical/technical sports
Female athletes						
All health problems	39.3 (37.5, 41)	37.3 (35.1, 39.5)	47.8 (44.4, 51.2)	42.8 (40.5, 45)	29.9 (27.7, 32.1)	42.2 (39.9, 44.5)
Injuries	29.0 (27.3, 30.8)	28.9 (27.1, 30.8)	37.1 (33.0, 41.1)	39.0 (36.8, 41.3)	17.5 (15.7, 19.3)	30.8 (28.7, 32.9)
Acute injuries	12.2 (10.9, 13.5)	10.9 (9.7, 12.1)	20.6 (17.0, 24.2)	17.0 (15.4, 18.6)	6.4 (4.7, 8.0)	13.2 (11.7, 14.7)
Overuse injuries	17.6 (16.4, 18.7)	18.4 (16.9, 19.9)	17.5 (15.5, 19.4)	22.5 (20.5, 24.4)	11.9 (10.6, 13.3)	18.2 (16.6, 19.7)
Illness	11.5 (10.3, 12.6)	9.5 (8.2, 10.7)	12.3 (10.4, 14.1)	4.7 (3.7, 5.7)	13.8 (12.0, 15.5)	12.8 (11.4, 14.3)
Substantial health problems	18.6 (17.3, 19.8)	18.1 (16.5, 19.7)	25.2 (22.2, 28.2)	18.6 (17, 20.2)	15.0 (13.0, 17.0)	20.9 (19.3, 22.5)
Injuries	11.9 (10.9, 13)	12.5 (11.3, 13.8)	18.4 (15.2, 21.7)	16 (14.4, 17.7)	6.0 (4.6, 7.5)	14.1 (12.7, 15.4)
Acute injuries	7.4 (6.4, 8.4)	6.5 (5.5, 7.5)	14.8 (11.6, 18)	9.5 (8.3, 10.6)	3.2 (1.8, 4.5)	8.4 (7.2, 9.6)
Overuse injuries	4.6 (4.1, 5.1)	6.1 (5.4, 6.8)	3.6 (2.6, 4.6)	6.6 (5.7, 7.5)	2.9 (2.1, 3.7)	5.8 (5.0, 6.7)
Illness	7.0 (6.1, 7.9)	5.9 (4.8, 7.0)	7.3 (6.0, 8.6)	2.8 (2, 3.7)	9.5 (7.9, 11.1)	7.5 (6.4, 8.6)
Male athletes						
All health problems	28.1 (27.1, 29.2)	29.2 (27.3, 31.0)	25.7 (24.1, 27.4)	32.7 (30.7, 34.7)	24.7 (22.9, 26.4)	29.3 (27.8, 30.8)
Injuries	20.2 (19.4, 21.1)	21.8 (20.2, 23.4)	17.7 (16.4, 19)	28.0 (26.2, 29.8)	11.9 (10.7, 13.1)	22.7 (21.2, 24.2)
Acute injuries	8.3 (7.7, 8.9)	6.1 (5.2, 6.9)	9.3 (8.5, 10.1)	13.6 (12.3, 14.8)	2.6 (2.1, 3.1)	6.8 (6.0, 7.6)
Overuse injuries	12.4 (11.6, 13.1)	16.3 (14.8, 17.8)	8.6 (7.6, 9.5)	15.4 (13.4, 17.3)	9.4 (8.3, 10.4)	16.1 (14.6, 17.6)
Illness	8.6 (7.9, 9.3)	8.1 (7.1, 9.2)	8.6 (7.7, 9.6)	5.3 (4.1, 6.4)	13.4 (11.9, 14.9)	7.5 (6.7, 8.3)
Substantial health problems	12.8 (12.2, 13.5)	14.2 (13.0, 15.3)	10.7 (9.8, 11.5)	13.8 (12.6, 15.1)	13.2 (11.6, 14.7)	12.7 (11.6, 13.7)
Injuries	8.4 (7.8, 9.1)	9.4 (8.3, 10.5)	6.8 (6.1, 7.5)	11.9 (10.8, 13.0)	4.3 (3.5, 5.0)	9.1 (8.2, 10.0)
Acute injuries	4.9 (4.4, 5.3)	4.3 (3.6, 5.0)	4.8 (4.2, 5.3)	8.0 (7.1, 9.0)	1.1 (0.7, 1.4)	3.9 (3.3, 4.4)
Overuse injuries	3.7 (3.3, 4.1)	5.3 (4.6, 5.9)	2.0 (1.7, 2.4)	4.2 (3.4, 5.0)	3.2 (2.6, 3.9)	5.2 (4.4, 6.0)
Illness	4.6 (4.2, 5.1)	5.1 (4.3, 5.8)	4.0 (3.5, 4.5)	2.1 (1.5, 2.6)	9.1 (7.7, 10.5)	3.8 (3.3, 4.3)
Both sexes						
All health problems	32.0 (31.1, 32.9)	32.8 (31.1, 34.5)	30.5 (29.1, 31.9)	34.2 (32.5, 35.9)	27.1 (25.5, 28.8)	32.9 (31.6, 34.1)
Injuries	23.6 (22.8, 24.3)	25.6 (24.1, 27.1)	21.5 (20.3, 22.7)	30.0 (28.4, 31.6)	15.0 (13.6, 16.4)	24.5 (23.5, 25.6)
Acute injuries	9.7 (9.2, 10.3)	8.3 (7.6, 9.1)	11.3 (10.4, 12.2)	15.4 (14.3, 16.4)	4.9 (3.6, 6.2)	8.8 (8.0, 9.6)
Overuse injuries	14.4 (13.7, 15.0)	17.8 (16.3, 19.2)	10.7 (9.8, 11.5)	15.3 (13.8, 16.7)	10.4 (9.5, 11.3)	16.1 (15.1, 17.0)
Illness	9.3 (8.7, 10)	8.1 (7.3, 9.0)	9.8 (8.9, 10.7)	5.0 (4.1, 5.8)	13.3 (12.1, 14.6)	9.4 (8.6, 10.1)
Substantial health problems	14.7 (14.1, 15.3)	15.6 (14.7, 16.6)	13.6 (12.8, 14.5)	14.9 (13.9, 15.9)	14.0 (12.7, 15.4)	15.1 (14.2, 15.9)
Injuries	9.8 (9.2, 10.3)	11.0 (10.1, 11.8)	8.9 (8.1, 9.7)	12.9 (12.0, 13.9)	5.4 (4.3, 6.5)	10.4 (9.8, 11.1)
Acute injuries	5.7 (5.3, 6.1)	5.4 (4.8, 6.0)	6.5 (5.7, 7.2)	8.7 (7.9, 9.5)	2.4 (1.4, 3.4)	5.2 (4.7, 5.8)
Overuse injuries	4.1 (3.8, 4.5)	5.7 (5.2, 6.2)	2.4 (2.1, 2.7)	4.4 (3.8, 4.9)	3.0 (2.6, 3.5)	5.3 (4.8, 5.8)
Illness	5.2 (4.8, 5.6)	5.0 (4.4, 5.6)	4.9 (4.4, 5.5)	2.2 (1.7, 2.6)	9.2 (8.0, 10.4)	5.0 (4.5, 5.5)

due to illnesses (8.6 to 9.1). However, the amount and causes of time loss varied considerably between athlete subgroups (figure 1).

The incidence and burden of health problems are presented for each severity category in table 3.

The OCIICS-13 diagnoses that led to the greatest amount of time loss and the highest cumulative severity scores were ACL rupture (KLA, 16 cases, 4252 time loss days, cumulative severity score (CSS): 63 388), respiratory infection (MPI1, 875 cases, 2685 time loss days, CSS: 71 777), lumbar pain (LZ1, 128 cases, 491 time loss days, CSS: 19 775) and patellar tendinopathy (KT2, 32 cases, 446 time loss days, CSS: 9567). Online supplemental tables 1 and 2 show the incidence, median time loss and burden of new injuries and illnesses, detailed by body area/organ system, tissue type/aetiology and selected diagnoses.

DISCUSSION

From the IOC Olympic injury surveillance system, we already know that injuries and illnesses are common *during* the Olympic Games. In the 2020 Summer Games, 9% of the athletes incurred at least one injury and 4% at least one illness. The 2018 Winter Games were no better; 12% suffered at least one injury and 9% at least one illness.[6 7] Our study, which reports data on a mixed-sport sample of candidates preparing for the Olympic Games, documents that injury and illness also represent a significant limiting factor for athletes' sports participation and self-reported performance *between* the Games. On average, our athletes could not fully train or compete for 1 full month each year (in team sports as many as 44 days), time they would otherwise spend improving fitness and honing their skills. Our observations extend the Games time data from the IOC injury and illness surveillance system, which most likely underestimate the impact of injury and illness on Olympic hopefuls; this surveillance 'surveys the survivors', those who made it to the Games.

In a recent study, Ranson *et al* report 4-year injury and illness data from 1247 Olympic summer sports athletes from the UK.[18] Their data contain many similar patterns to ours, such as a high burden posed by major knee ligament injuries and low back pain. However, there are also several striking differences between studies, such as the incidence of minor injuries and illnesses (those leading to 1–7 days of time loss), which were 6 and 11 times higher in our dataset, respectively. The likely explanation for this discrepancy is the different methods used. The UK data were derived from the electronic medical records of Olympic team doctors and physiotherapists and health problems were only recorded if they lead to time loss from training or competition. In contrast, our data collection methods allowed us to capture problems for which athletes either did not seek medical

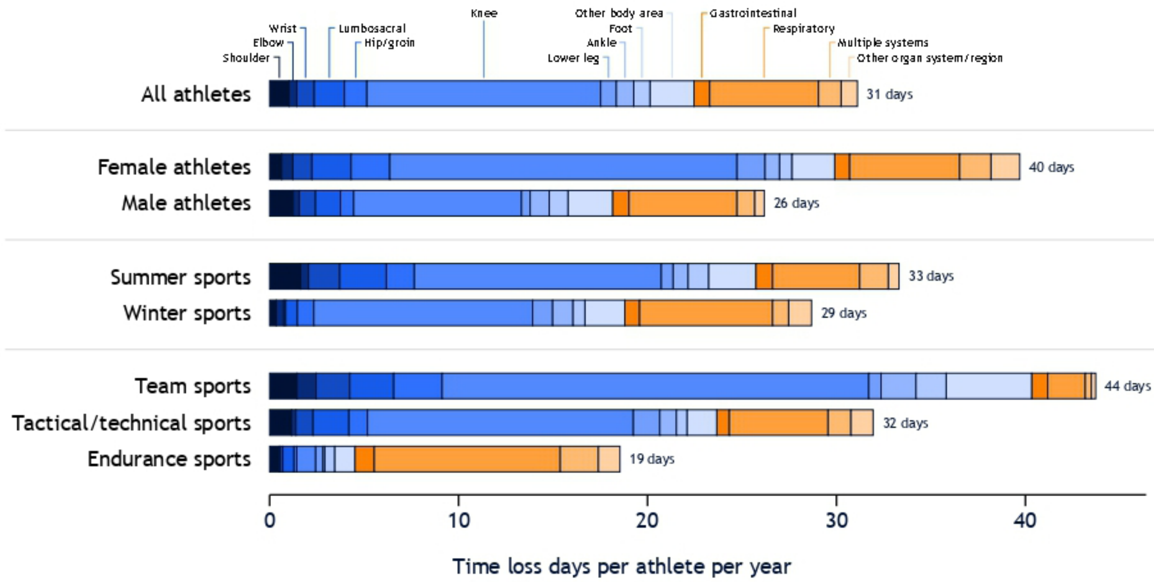

Figure 1 Average time loss per athlete per year, decomposed by body area of injury and organ system of illnesses.

attention or sought help from medical practitioners outside of the Olympic programme. Further, because we recorded all health problems (including those that did not cause time loss) and quantified the degree of training modification, performance reduction and symptoms associated with each case, we demonstrated that health problems that do not lead to time loss still represent a substantial proportion (14%) of the overall health burden in this population.

Our findings have several implications. First, providing optimal medical care is paramount, to protect the health of the athlete. Second, the data point clearly to prevention targets and opportunities. Third, there may be a potential performance advantage for national Olympic committees (NOCs) succeeding in reducing the number of days lost to injury and illness—through effective prevention programmes and by providing better care to allow swift and safe return to sport.

Know your sports: health patterns vary between sports, seasons and sexes

As shown in table 1, the Norwegian Olympic team is not one of the largest, nor smallest. Of the 57 current Olympic sports disciplines, 42 in the Summer Games and 15 in the Winter Games, our athlete sample represents 29 (19 summer and 10 winter). Still, the team represents a large sample with a representative balance between males and females (197 vs 336), summer and winter sports (19 vs 10) and team, tactical/technical and endurance sports (191 vs 274 vs 223). Our data should therefore also have value for other NOCs planning their medical support and prevention programmes.

One notable finding is the large sex difference in injury burden (figure 1). Female athletes lost on average 40 days each year to injury and illness, compared with 26 days for men. The main cause for this difference in injury burden was knee injuries, especially ACL injuries, which resulted in a time loss of more than 250 days per injury. This is not unexpected, as it is well documented that females have a larger risk of ACL injuries than males.[19–21] Two sports with a high risk of ACL injuries are handball[19 22 23] and alpine skiing/snowboarding,[24–28] and this is also demonstrated by knee injuries causing a substantial burden in team sports (handball was the largest team sport on Team Norway) and tactical/technical sports (alpine skiing, freestyle skiing, snowboard and ski jumping). However, traumatic knee injuries can also be expected by other NOCs represented by other team sports, such as football, rugby or basketball.[29–32] It should also be noted that female team athletes reported a higher prevalence of acute injuries and overuse injuries than males in every subcategory, and a higher prevalence of illness in every subcategory except team sports.

Another notable finding was that the total time loss was much lower for endurance athletes (19 days per year) than other sport categories, less than half of that for team sports (44 days). The pattern was also distinctly different, the illness burden in team athletes is remarkably low (9% of the total burden of health problems, compared with 27% for tactical/technical sports and 76% for endurance sports).

Table 3 Injury and illness incidence and burden by time loss severity categories (rates per athlete per year (95% CI))

	Time loss severity category				
	0 days	1–7 days	8–28 days	29–90 days	>90 days
Injuries					
Incidence (number)	1.4 (1.3, 1.5)	1.2 (1.1, 1.2)	0.3 (0.2, 0.3)	0.1 (0.1, 0.1)	0.1 (0, 0.1)
Burden (time loss, days)	–	3.2 (3, 3.4)	3.7 (3.5, 3.9)	3.5 (3.4, 3.7)	11.9 (11.6, 12.2)
Burden (severity score, arbitrary units)	83 (82, 84)	156 (155, 157)	111 (110, 112)	69 (68, 70)	174 (173, 175)
Illness					
Incidence (number)	0.8 (0.7, 0.9)	1.9 (1.8, 2)	0.2 (0.2, 0.2)	0.02 (0.01, 0.04)	–
Burden (time loss, days)	–	5.7 (5.5, 5.9)	2 (1.9, 2.2)	1.1 (1, 1.2)	–
Burden (severity score, arbitrary units)	28 (27, 28)	150 (149, 151)	38 (38, 39)	20 (20, 21)	–

In other words, the current data document that injury and illness patterns differ substantially between sports and athlete groups, with significant implications when planning medical support and developing prevention programmes.

Planning NOC medical services

Olympic athletes are strongly motivated to return to sport as quickly as possible after injury or illness. They are also likely to continue to train through injury or illness, especially overuse injuries. Access to specialist sports medicine care is therefore key. While most NOCs send a well-organised medical team to the Olympic Games and are supported by the extensive medical services provided by the host city *during* the Games, our data emphasise the need for an extensive medical support programme also *between* Games.

Although this may naturally occur in the highest profile and professional sports, our monitoring programme provides a framework for supporting smaller and lower-profile sports that are often poorly covered outside of major competitive periods.

The injury and illness data shown in online supplemental tables 1 and 2 illustrate how athletes suffer from a wide variety of health problems. The diagnoses causing the greatest burden in this mixed-sport population of athletes included acute injuries (52% of the burden in days lost), overuse injuries (20%) and illnesses (28%) spanning from knee ligament injury, patellar tendinopathy, hamstring strain, ankle ligament injury and concussion to respiratory infection, gastrointestinal infection and chronic fatigue syndrome. The list of the most common problems often boils down to a few in single sports; beach volleyball is an example where three problems, shoulder pain, patellar tendinopathy and low back pain, completely dominate.[8] Still, caring for a *mixed-sport* NOC requires a multidisciplinary team of specialists well versed in sports medicine, physical therapy and nutrition (or easy access to a network of specialists). Optimally, this includes orthopaedic surgeons to manage the surgical cases, generalist sports physicians with particular experience managing respiratory and gastrointestinal infections, pulmonary physicians with specialist training in airway dysfunction and sports cardiologists, psychiatrists (mental problems are most certainly under-reported in the current data set), dietitians and sports physical therapists. Within single sports, our data highlight that team sport federations need doctors and physiotherapists with good knowledge of injury management and prevention, whereas within endurance sports, the focus is more on infections. The key factor for the athlete, though, is undoubtedly easy and affordable access to this team. A close monitoring programme such as the current may also help nip injuries in the bud.[13]

An opportunity for better performance?

Beyond the obvious that some athletes may not be able to return to play before the start of the Games and therefore miss the Games altogether, and that some may not be able to participate in the events necessary to qualify (in some sports, the qualification period runs for 1.5 years before the Games), significant health problems will limit the ability to prepare optimally. While the link between injuries, illness and performance cannot be examined based on the current data, it seems reasonable to assume that athletes who manage to stay healthy have a better chance of performing their best at Games time.

These data should therefore be read as a call for systematic injury prevention efforts. The NOCs with the best injury prevention programmes may gain an important edge in the tight competition that is the Olympic Games. The injury burden is substantial, and it is well documented that injuries can be prevented effectively.[33] We grant that injury prevention in such an elite, well-trained group of athletes requires more than simple, one-size-fits-all exercise programmes. To be effective, it will require a systematic approach and thorough planning.[34] And although the medical team can have important input to help identify risks, the ownership and leadership of such a programme need to be embraced by the coaching team and athletes themselves to be effective. Research on injury prevention methods in elite sports is limited; there is an urgent need to develop frameworks assisting teams to develop custom-made programmes for Olympic-level teams and athletes.

The current data predate the COVID-19 pandemic. But the pandemic has shown that respiratory (and gastrointestinal) infections, the number one illness culprits in sports, can be prevented effectively in elite athletes. The overall incidence of illness in the Tokyo Olympic Games, which were organised under strict prevention protocols, was the lowest (3.9 illnesses per 100 athletes) we have recorded in the Games[7]—lower than in PyeongChang 2018 (9.4)[6] Rio 2016 (5.4),[5] Sochi 2014 (8.9),[4] London 2012 (7.2)[3] and Vancouver 2010 (7.2).[2] This effect was caused primarily by a reduction in respiratory infections; only 0.4% of the Tokyo athletes incurred a respiratory infection (4.8% in PyeongChang, 1.9% in Rio, 4.2% in Sochi, 1.9% in London, 1.1% in Vancouver). The data from the 2022 Beijing Winter Games are expected to be even more convincing, with the extraordinarily stringent infection protocols in place there. Interestingly, after a disastrous Winter Olympic Games in Torino in 2006, with multiple infections, the Norwegian Olympic team instituted a protocol incorporating many of the now standard COVID-19 countermeasures for the 2010 Vancouver Games and with similar results (from 17.3% to 5.1% illness prevalence).[35] During subsequent Winter Games, the corresponding figures are 7% for Sochi 2014, 6% for PyeongChang 2018 and 4% for Beijing 2022 (Bahr 2022, personal communication). The current data suggest that infection prevention protocols have been maintained also *between* Games, with an average illness prevalence of 7%. In other words, even if the COVID-19 pandemic may be a thing of the past, the infection countermeasures should not be, at least not for elite athletes.

Methodological considerations

Although there have been many short-duration epidemiological studies in individual Olympic sports and during tournament periods, our results represent the most comprehensive dataset on injury and illness patterns among Olympic athletes during out-of-competition periods. The data were collected through a health monitoring programme that serves both as a clinical communication platform and a risk management and research tool. Although in previous publications we have discussed the programme's benefits and challenges involved in implementing and maintaining it over time,[12–14] several methodological factors should be considered when interpreting the data in this paper. First, the method is dependent on a high response from athletes to the weekly health questionnaires. Although the overall response across all five Games periods was 78%, due to technical challenges with questionnaire distribution, the response was only 51% during preparations for Rio 2016 and 69% for PyeongChang 2018. Although the prevalence and incidence of health problems during these periods were similar to periods with a higher response, the data are less precise. Second, because athletes sometimes stopped responding to the weekly questionnaires during long periods of rehabilitation, we estimated time

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loss for several cases of ACL injury. We believe this approach gives us a more valid picture of the most burdensome diagnosis in our team. However, one consequence of this decision is that the severity and burden estimates for ACL injuries are less certain than they are for other, less severe diagnoses. Third, because data were collected using a system designed to improve athletes' medical coverage, it is possible that the burden of injury and illness was lower in our team than it otherwise would have been if athletes' injury and illness reports had not been acted upon.

Finally, because of the small number of athletes in some of our sports, to ensure data privacy, we were unable to present data on an individual sport level. To overcome this challenge, pooling of similar data collected by multiple countries would be necessary.

CONCLUSION

The current data, documenting how Olympic athletes lose 1 month of training to injury and illness every year, provide a compelling argument for prioritising medical care and investing in prevention programmes.

The injury burden was particularly high among female athletes and in team sports, whereas endurance sports had the greatest burden of illness. Our data provide a compelling argument for prioritising medical care and investing in prevention programmes not just during the Olympic Games, but also the preparation period.

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Patient and public involvement Patients and/or the public were involved in the design, or conduct, or reporting, or dissemination plans of this research. Refer to the Methods section for further details.

Patient consent for publication Not required.

Ethics approval This study involves human participants and was approved by the South-Eastern Norwegian Regional Committee for Research Ethics and the Norwegian Data Inspectorate. The data management routines were consistent with the European Union's General Data Protection Regulation (GDPR). Informed written consent was obtained from all athletes.

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