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Methods, challenges and benefits of a health monitoring programme for Norwegian Olympic and Paralympic athletes – the road from London 2012 to Tokyo 2020

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ABSTRACT

Objective: To describe the implementation of a health monitoring programme for Norwegian Paralympic and Olympic candidates over five consecutive Olympic and Paralympic Games cycles (London 2012, Sochi 2014, Rio de Janeiro 2016, PyeongChang 2018 and Tokyo 2020).

Methods: Athletes were monitored for 12 to 18 months preparing for the games using a weekly online questionnaire (OSTRC-H2) with follow-up by physicians and physiotherapists, who provided clinical care and classified reported problems.

Results: Between 2011 and 2020, 533 Olympic and 95 Paralympic athletes were included in the monitoring programme, with an overall response of 79% to the weekly questionnaire and a total observation period of 30826 athlete weeks. During this time, 3770 health problems were reported, with a diagnosis rate of 97%. The average prevalence of health problems at any given time was 32% among Olympic athletes and 37% among Paralympic athletes. Acute traumatic injuries represented the greatest burden for Olympic team sport athletes, and illnesses represented the greatest burden for Olympic endurance and Paralympic athletes. On average, Olympic athletes lost 27 days and Paralympic athletes lost 33 days of training per year due to health problems.

Conclusion: Conducting long-term health monitoring of Olympic and Paralympic athletes is challenging, particularly because athletes travel frequently and often relate to many medical providers. This programme has been implemented and improved within Team Norway for five Olympic and Paralympic cycles and during this time we believe it has helped protect our athletes' health.

INTRODUCTION

Health surveillance programs have been conducted during the Olympic Games since 2004[1-9] and during the Paralympics since 2002,[10-19] providing rich insights into the patterns of injury and illness during the games. However, data are limited on the health problems facing Olympic and Paralympic athletes outside the actual 10-17 day games period.[20-22] This may be because collecting high-quality prospective injury and illness data relies on close and consistent contact between athletes and their medical staff, yet Olympic and Paralympic athletes are often supported by multiple medical providers (such as in their club or professional team); they often live, train and compete all over the world, and they frequently travel without medical support.

In addition to making surveillance difficult, these challenges may also hamper the quality and consistency of athlete medical care, leading to an increased risk of health problems. Therefore, there are several potential benefits from year-round monitoring of health problems among Olympic and Paralympic athletes, at both an individual and a group level. For the individual athlete, a well-functioning monitoring programme ensures consistent communication with and among their Olympic/Paralympic team medical staff and can contribute to earlier identification and more effective management of new and ongoing health problems. On a group level, data from health monitoring can provide valuable information on the risks related to sports participation, both in- and out-of-competition. This information, akin to more traditional forms of surveillance data, can assist the health team in allocating limited resources, identifying specific health challenges within various teams or subgroups, and in planning and assessing the impact of targeted prevention interventions.[20 23]

We have previously developed a questionnaire for prospective monitoring of health problems in athletes, the Oslo Sports Trauma Research Center Questionnaire on Health Problems (OSTRC-H & OSTRC-H2),[22 24] and in 2014 we briefly described how it was used to monitor Norwegian athletes preparing for the 2012 Olympic and Paralympic Games in London.[22] In this paper, we describe how these health monitoring methods have evolved over five consecutive summer and winter games cycles, and present summary data to illustrate our main outcomes and visualisation techniques. Based on these, we discuss what we believe to be the main benefits of the programme, as well as the challenges involved in successfully implementing and maintaining it over time. This information will be valuable for other elite sports organisations that are considering using or are currently using a similar monitoring approach.

METHODS

The Norwegian Olympic and Paralympic Health Monitoring Programme involves, at any given time, all candidate athletes for the next games (approximately 100-160 Olympic and 25-40 Paralympic), as well team of physicians and physiotherapists assigned to support them. This team, which we refer to as the Norwegian Olympic and Paralympic medical team, consists of approximately 10 physicians and 15 physiotherapists for Olympic athletes and 1 doctor and 3 physiotherapists for Paralympic athletes. Between 1 and 2 years before each summer and winter games, national team coaches of all relevant sports are asked to provide a list of athletes who they consider to be candidates to qualify. All athletes are then invited to participate in the programme and followed until the start of the games, or until they are removed as a candidate by their head coach. Health data are collected weekly from athletes using an online questionnaire, and followed up by physicians and physiotherapists.[22]

The project manager at the Norwegian Olympic Training Center (Olympiatoppen) and physicians and physiotherapists of the relevant national teams inform athletes about the programme's procedures and benefits. Athletes can choose not to participate in the programme, or to withhold their data from use in research.

The programme has been reviewed by the South-Eastern Norwegian Regional Committee for Research Ethics and approved by the Norwegian Data Inspectorate. All data management principles are consistent with the European Union's General Data Protection Regulation. This report includes data from five Olympic and Paralympic preparation cycles. Informed written consent has been obtained from all athletes.

Data collection methods

We launched the programme in 2011 for athletes preparing for the 2012 London Summer Olympic and Paralympic Games and have continued the same process during each summer and winter Games cycle since then. Each week, either on Sunday evening or Monday morning depending on team preferences, all athletes were sent a link to the OSTRC Questionnaire on Health Problems (OSTRC-H[22] between 2011 and June 2018, OSTRC-H2[24] from July 2018). Daily reminders were sent to non-responders. Three different electronic platforms have been used to distribute the questionnaire to athletes, including online survey software for London 2012 and Sochi 2014 (Questback V.9692, Questback AS, Oslo, Norway), a native smartphone application for Rio 2016 and PyeongChang 2018 (Spartanova N.V. Gent, Belgium) and a web application with an SMS notification system for Tokyo 2020 (AthleteMonitoring, FitStats Technologies Inc., Moncton, Canada).

The OSTRC-H2 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.[24] A range of subsequent questions to classify reported problems, record the number of days of lost training and competition, and to determine which medical personnel the athlete has contacted about the problem (including those outside the Olympic and Paralympic medical team). Athletes can also provide additional free-text comments about each problem. Athletes can record multiple problems in the same week.[25]

When athletes report a new health problem or comment on an ongoing problem, their team physician and physiotherapist receive an alert and, when necessary, contact the athlete to arrange follow-up or further investigations.

Classification and diagnosis of reported health problems

We instruct athletes to report all health problems they have experienced in the preceding 7 days, including ongoing problems reported earlier. They are encouraged to report every health problem, irrespective of its consequences on their sports participation or performance or whether they have sought medical attention.[23 24]

The first time an athlete reports a problem, he/she is asked to classify it according to predefined categories. Initially, this was limited to recording the type of health problem (injury or illness), and its location (for injuries) or symptoms (for illnesses).[22] Our most recent system also asks athletes to record the mode of injury onset (acute/traumatic or overuse) and, for acute injuries, the mechanism of injury and the activity they were performing when it occurred. Since 2018, athletes have been provided with current consensus-based definitions to assist their classification of health problem type and mode of onset.[23]

We ask team medical personnel to review athletes' reports and provide a diagnostic code for every health problem reported by their athletes. This is preferably performed after a face-to-face consultation; however, in many cases, diagnoses are recorded following telephone contact with the athlete (depending on the severity of the problem and the athlete's location). In some minor cases, where there was no clinical value in contacting the athlete, medical personnel may have chosen to record a non-specific code. Medical personnel are instructed on how to follow up athlete reports and how to assign diagnostic codes during regular Olympic and Paralympic health team meetings, and individually when they start using the system. The programme manager also provides ongoing support to medical personnel as required.

Since launching the programme, several classification systems have been used, including the Orchard Sports Injury Classification System, V.10 (OSICS-10, London and Sochi injuries)[26], the International Classification of Primary Care, V.2 (ICPC-2, London and Sochi illnesses)[27] and the Sports Medicine Diagnostic Coding System (SMDCS, Rio, PyeongChang and Tokyo, all health problems).[28] Paralympic athletes' impairments are classified according to Paralympic Games categories.[13]

Data analyses and statistics

In this paper, we present data collected in between October 2011 and January 2020. One athlete under the age of 16 was excluded from the dataset. All data collected using the OSTRC-H questionnaire were transformed to match the logic and scoring system of the OSTRC-H2.[24] All diagnostic codes were translated into the Orchard Sports Injury and Illness Classification System (OSIICS-13).[29] As athletes were shown slightly different definitions of injury and illness in the three different data collection tools, and because athletes do not always classify their health problems correctly, we cross-checked all athlete reports with OSIICS-13 diagnostic codes. If there were discrepancies between the categorisation of health problem type or injury type and the diagnostic

code, we conferred with the athlete's team medical personnel and applied currently recommended definitions[23] to adjust the categorisation.

As some team sizes were small, we have presented data for Paralympic athletes as one group and have subclassified Olympic sports into endurance, technical/tactical and team sports (see Table 1 for group compositions).

Data from all collection tools were consolidated into a single spreadsheet and analysed in R (version 3.6.1).[30] Descriptive data are summarised using mean, median, standard deviations and/or 95% confidence intervals, as appropriate. Average time loss and cumulative severity scores and their confidence intervals were calculated by bootstrapping (R=5000), using the groupwiseMean function of the rcompanion package in R.[31] Confidence intervals for incidence rates were calculated with the byar method, using the epi.conf function in the epiR package.[32] To describe the health risk across the Paralympic and Olympic groups throughout the data collection periods, data are presented as the average weekly prevalence and incidence of health problems.

Capturing and reporting athlete exposure: Exposure was expressed in *athlete-years* by multiplying the number of questionnaire responses (i.e. *athlete-weeks*) by 52.

Response rate: We calculated weekly and overall response rates as proportions, based on the number questionnaire responses divided by the number of invitations.

Diagnosis rate: We expressed the diagnosis rate as the proportion of cases that were assigned a diagnostic code by team medical staff. Injuries were considered to have a non-specific diagnosis if the first or second letters of the OSIICS-13 code was Z (body part or tissue type unspecified). Illnesses were considered to have a non-specific diagnosis if the second or third letters of the OSIICS-13 code was Z (medical system or aetiology unknown or unspecified).

Expressing risk: For each outcome of interest, we calculated the average weekly prevalence as the proportion of athletes reporting a health problem divided by the number of returned weekly responses. As other exposure data were incomparable between sports, we expressed incidence as the number of new cases per athlete per year.

Severity of health problems: To obtain a measure on the impact of a health problem for an athlete, we calculated a severity score ranging from 0-100, based on the four key questions of the OSTRC-H2 (see Clarsen et al 2020[24] for the scoring system). The cumulative severity score for each case was calculated as the sum of the weekly reported severity scores. We defined problems which lead to a moderate or severe reduction in training volume or reduction in sports performance or to complete inability to participate in sport as *substantial* injuries and illnesses.[22] For each health problem, we recorded its duration as weeks reported, as well as the number of days lost to sports (complete inability to train or compete), which we used as a secondary measure of severity.

Burden of health problems: Defined as the cross product of their incidence and their severity (expressed as both the average number of time loss days and the average cumulative severity score), and visualised in a risk matrix.[33]

RESULTS

Between October 2011 and January 2020, 533 Olympic and 95 Paralympic athletes were included in the programme, with a total observation period of 30 826 athlete weeks. Figure 1 shows the number of athletes included in each Games cycle and Table 1 shows the number of athletes by sex, sport and sport category. Four-hundred and forty-one athletes were included for one Games cycle, 167 for two, 19 for three and one athlete was included for four Games cycles. Of the participants, 204 (41%) Olympic and 66 (73%) Paralympic athletes were selected to represent Norway at the Games in 30 Olympic and 17 Paralympic sports (this excludes Tokyo 2020 athletes, for whom qualification has been postponed).

Paralympic athletes represented seven impairment groups: 33% les autre, 27% limb deficiency, 18% spinal cord injury, 14% central neurological injury and 7% visual, intellectual impairment or short stature.

Table 1. Number of athletes included in the programme by sport category, sport and sex

Sport category/Sport	**Olympic athletes**		**Paralympic Athletes**	
	Female	Male	Female	Male
Endurance sports				
Biathlon	20	22		2
Canoe/Kayak	4	7		
Cross-country skiing	13	15	5	5
Cycling	15	13	1	2
Nordic combined		9		
Rowing	5	12	1	
Speed skating	7	16		
Swimming	5	8	4	4
Triathlon	1	4		
Tactical/technical sports				
Alpine skiing	9	11		3
Archery		1		2
Athletics	22	29	2	3
Badminton			1	
Boccia				1
Boxing	2			
Equestrian			7	1
Figure skating	3			
Freestyle skiing	3	5		
Golf	7	8		
Gymnastics		3		
Luge		3		
Sailing	10	8	1	3
Shooting	2	7	6	4
Skeleton	1			
Ski jumping	7	31		
Snowboard	4	7		1
Table tennis			3	3
Taekwondo	5	5		
Weightlifting	1			
Wrestling	1	9		
Team sports				
Beach volleyball		11		
Curling	1	9	2	4
Handball	49	33		
Ice hockey		50		
Ice sledge hockey			1	27
Total*	197	336	34	65

* Several athletes have participated in multiple sports at the Paralympic Games: One female in rowing and cross-country skiing, one female in swimming and cross-country skiing, one male in cross-country skiing and ice sledge hockey, and two males in cross-country skiing and biathlon

Figure 1. Number of Olympic and Paralympic candidate athletes included in the monitoring programme, overall and for each games cycle: London 2012, Sochi 2014, Rio 2016, PyeongChang 2018 and Tokyo 2020.

Questionnaire response and health problem diagnosis rate

Between 2011 and 2020, the overall response rate to the weekly questionnaires was 79%, with substantial variation between games , ranging from 58% to 88% (Figure 2). Athletes reported a total of 3 770 health problems, of which 1 955 were illnesses, 1 087 were overuse injuries and 728 were acute injuries. A total of 3 641 health problems (97%) were assigned a diagnosis code. Of these, 991 (27%) were non-specific codes.

Nearly all the Paralympic (n=90, 95%) and Olympic athletes (n=506, 95%) reported at least one health problem during their respective observation periods.

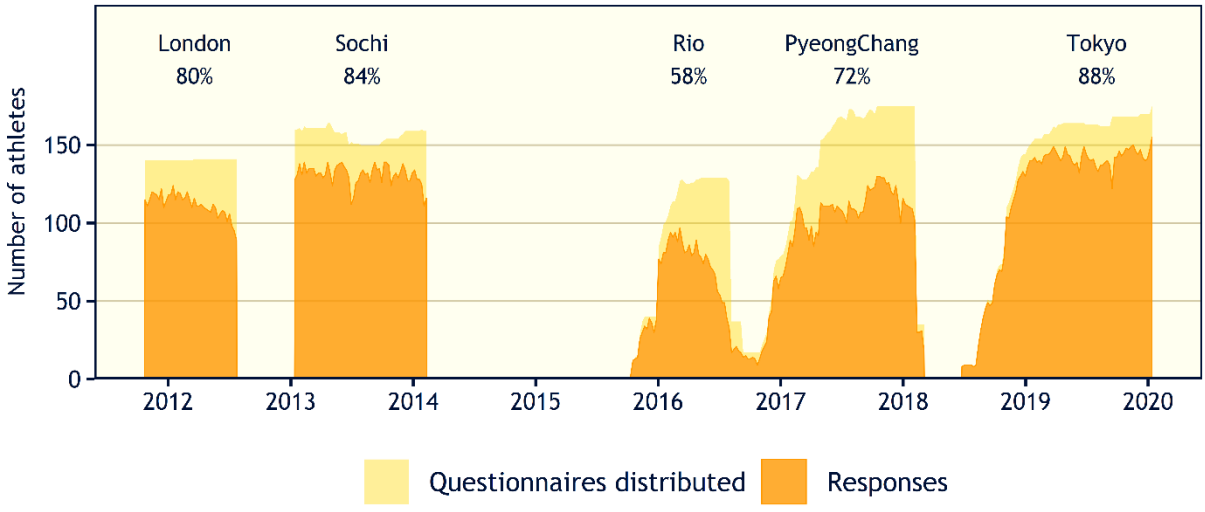

Figure 2.

Number of invitations, number of responses and overall response rates for each of the five Olympic and Paralympic Games cycles.

Prevalence of health problems

The average weekly prevalence of all health problems was 32% among Olympic athletes and 37% among Paralympic athletes. The average weekly prevalence of substantial health problems in these groups was 15% and 18%, respectively (Table 2).

Table 2. Average weekly prevalence (% of athletes affected [95% CI]) of all health problems and substantial problems reported, as well as the prevalence of injury, acute injury, overuse injury and illness among Olympic and Paralympic athletes and each of the three subgroups of Olympic athletes

			Olympic athletes		
	Paralympic athletes (n = 95)	Olympic athletes (n = 533)	Endurance sports (n = 176)	Tactical/technical sports (n = 214)	Team sports (n = 143)
All health problems	37.1 [35.8, 38.5]	32.0 [31.1, 32.9]	27.1 [25.5, 28.8]	32.9 [31.6, 34.1]	34.2 [32.5, 35.9]
Injuries	20.1 [19.1, 21]	23.6 [22.8, 24.3]	15.0 [13.6, 16.4]	24.5 [23.5, 25.6]	30.0 [28.4, 31.6]
Acute injuries	4.8 [4.2, 5.4]	9.7 [9.2, 10.3]	4.9 [3.6, 6.2]	8.8 [8, 9.6]	15.4 [14.3, 16.4]
Overuse injuries	15.6 [14.7, 16.5]	14.4 [13.7, 15]	10.4 [9.5, 11.3]	16.1 [15.1, 17]	15.3 [13.8, 16.7]
Illness	18.9 [17.7, 20]	9.3 [8.7, 10]	13.3 [12.1, 14.6]	9.4 [8.6, 10.1]	5.0 [4.1, 5.8]
Substantial health problems	18.4 [17.2, 19.5]	14.7 [14.1, 15.3]	14.0 [12.7, 15.4]	15.1 [14.2, 15.9]	14.9 [13.9, 15.9]
Injuries	8.6 [7.9, 9.4]	9.8 [9.2, 10.3]	5.4 [4.3, 6.5]	10.4 [9.8, 11.1]	12.9 [12, 13.9]
Acute injuries	2.6 [2.2, 3]	5.7 [5.3, 6.1]	2.4 [1.4, 3.4]	5.2 [4.7, 5.8]	8.7 [7.9, 9.5]
Overuse injuries	6.1 [5.4, 6.8]	4.1 [3.8, 4.5]	3.0 [2.6, 3.5]	5.3 [4.8, 5.8]	4.4 [3.8, 4.9]
Illness	10.5 [9.6, 11.5]	5.2 [4.8, 5.6]	9.2 [8, 10.4]	5.0 [4.5, 5.5]	2.2 [1.7, 2.6]

The average prevalence of acute injuries was highest among Olympic athletes, whereas the prevalence of illnesses (all problems), substantial illnesses and overuse injuries was higher among Paralympic athletes.

Incidence of health problems

The incidence of health problems was 6.1 cases per athlete per year (95% CI: 5.9 to 6.3) for Olympic athletes and 7.5 cases per athlete per year (95% CI 7.0 to 8.0) for Paralympic athletes. For time-loss problems, the incidence was 3.7 (3.6 to 3.9) and 5.3 (4.9 to 5.7) cases per athlete per year for Olympic and Paralympic athletes, respectively.

Severity and burden of health problems

Athletes reported a total of 16 682 time-loss days: 6 007 days (36%) due to acute injuries, 4 193 days (25%) due to overuse injuries and 6 482 days (39%) due to illnesses, respectively.

The average time loss was 8 days for acute injuries (95% CI: 6 to 10, range: 0 to 322), 4 days for overuse injuries (95% CI: 3 to 5, range: 0 to 259) and 3 days for illnesses (95% CI: 3 to 4, range: 0 to 84).

Olympic athletes lost, on average, 27 days of training or competition per year due to health problems: 11 to acute injury (range: 0-322 days), 7 to overuse injury (0-259 days) and 9 to illness (0-84 days). Paralympic athletes lost an average of 33 days per year: 5 to acute injury (0-121 days), 9 to overuse injury (0-145 days) and 19 to illness (0-61 days).

Figure 3 shows risk matrices by sporting group and health problem type. As illustrated, the health problem types representing the greatest burden were illnesses among Paralympic athletes and acute injuries among Olympic team sport athletes, irrespective of the severity measure used.

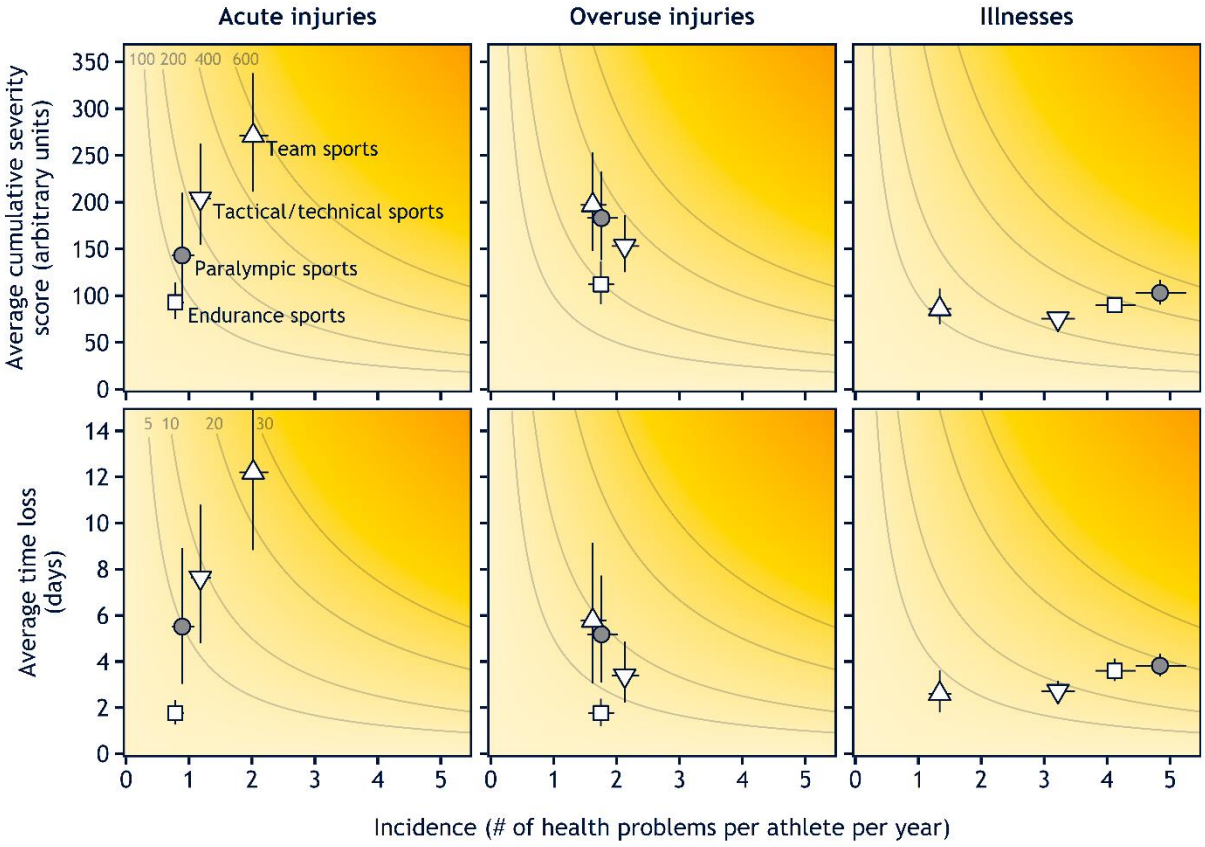

Figure 3. Risk matrices depicting the relationship between incidence (number of health problems per athlete per year) and severity for Paralympic athletes and three sports categories of Olympic endurance sports, technical sports and team sports. In the 3 top panels, severity is expressed as the average cumulative severity score for each type of health problem. In the 3 lower panels, severity is expressed as the average time loss. The darker the colour, the greater the burden. In the top panels, isobars represent a cumulative severity score of 100, 200, 400 and 600 per athlete year. In the lower panels, isobars depict a burden of 5, 10, 20 and 30 days per athlete year, respectively. Error bars represent 95% confidence intervals.

DISCUSSION

Over the past decade we have implemented and maintained a health monitoring programme for all Olympic and Paralympic candidate athletes in Norway. In our experience, the programme offers two main benefits. First, by facilitating consistent communication between athletes and their national team medical staff, we believe that health problems are often identified and acted upon earlier. This is particularly relevant for conditions with a gradual onset, which athletes are typically slow to acknowledge and seek help for. Second, we continuously gather detailed data on health patterns within our various sports and athlete subgroups. This has helped us identify specific problem areas, such as particularly high rates of gastrointestinal conditions among our Paralympic athletes and lower limb overuse injuries in our ski jumping team. In response, we involved relevant experts and initiated a range of targeted strategies, including medical, dietary and travel interventions for the Paralympians, and dietary interventions, technique change and load management for the ski jumpers. The programme has also helped us to identify athletes with frequently recurring conditions and to track the status of athletes with chronic problems or during a long rehabilitation period.

We believe that our monitoring approach would offer similar benefits to other elite sports organisations, particularly national Olympic and Paralympic centres. However, successful implementation of this programme demands substantial resources and requires collaboration between athletes, medical personnel, and coaches. For maintained success, programme managers must continuously address several important questions.

How are athletes motivated to respond to the questionnaire?

Our monitoring approach is dependent on athletes responding consistently to the weekly health questionnaire. As such, the response rate is one of the key indicators of the programme's overall success. We achieved high response rates for the first two Games cycles, 80% for London and 84% for Sochi. However, the response fell to 58% and 72% for the Rio and PyeongChang preparation periods, respectively, and we were forced to address a range of factors to regain a high response from our Tokyo athletes (88%).

A major premise for compliance is having reliable, intuitive and secure technology to deliver questionnaires, using a platform that athletes are likely to use. Ongoing technical support is also essential. We initially developed the programme using "off-the-shelf" survey software, which delivered invitations and reminders to athletes by email. While this data collection approach was reliable, it involved manual processing of questionnaire responses and there was a time lag of several days between when an athlete reported a health problem and when their medical personnel were informed of it. Additionally, during that time (2011-2014), we experienced that athletes changed their preferred means of digital communication from email to SMS messages and other smartphone applications. In 2014, therefore, we began developing a smartphone application to deliver questionnaires to athletes, and an accompanying web-application that included automatic alerts and summary dashboards for medical personnel. Unfortunately, the first attempt at app development was marred by a range of technical issues, such as incompatibility with certain types of smartphones, unreliable alert systems and problems summarising and displaying collected information. These issues frustrated many of our athletes and medical personnel and were responsible for the fall in response rates during the Rio and PyeongChang Games cycles.

In late 2017 a new web application was developed, which proved to be far more reliable and user-friendly. Since this application was launched in June 2018, we have had very few technical issues and our response rate has been the highest ever. As technology evolves and adapts to athletes' preferred means of communication, refinement of our data collection methods is likely to be an ongoing process. For example, we are yet to provide good solutions for athletes with visual and intellectual impairment when completing weekly questionnaires.

Although necessary to achieve a high response, well-functioning technology is not a guarantee. Most of the time, participation in the programme only requires a few seconds of each athlete's time each week. Nonetheless, in our experience, athletes only continue to respond to the questionnaires over time if they feel that by doing so, their medical care (and ultimately, their chance of sporting success) is improved. To this end, we encourage team medical personnel to respond quickly and consistently whenever an athlete reports a new problem or sends a message through the system. Even when the problem appears to be minor or under control, it is important for athletes to know that a trusted person is receiving their reports. We also engage coaches and other support staff to continuously encourage athletes to respond.

How are medical personnel engaged in the programme?

Successful implementation of our monitoring approach does not only depend on athlete engagement; team medical personnel must also review their athletes' reports, act on them when necessary, and enter diagnostic information into the system. This represents a substantial burden on their time, particularly because we follow up and classify all complaints irrespective of severity, and considering that, in many teams, medical personnel are engaged in part-time or voluntary positions.

Our diagnosis rate of 97% for 3 770 reported health problems (73% with a specific diagnosis) documents that we have successfully engaged team medical personnel in the monitoring programme. This could be attributed to several factors, such as having a well-organised medical team defined well in advance of each Olympic and Paralympic Games and having a strong tradition of collaboration between the national training centre and national sports federations. But perhaps most importantly, the programme makes it easier for medical personnel to do their job by giving them a constant overview of their team's health, irrespective of how often they are in touch with their athletes. Again, technology plays a vital role. Initially, due to the time delay between athletes' reports and manual notifications to medical personnel, not all teams experienced the reporting system's clinical benefit. However, since 2018, all medical personnel receive immediate SMS and/or email alerts whenever one of the athletes reports a new health problem, and they have constant access to a live, secure platform to view and enter information from any smartphone or PC. This platform also provides medical personnel with summaries and visualisations of athletes' data on a group and individual level.

Are all relevant athletes included?

As we aim to include all athletes who will represent Norway at the upcoming Olympic or Paralympic Games, athlete identification is an ongoing challenge for the programme manager, team coaches and the management of the Norwegian Olympic Training Center (Olympiatoppen). For example, talented young athletes may only rise

to prominence shortly before the Games. Deciding how many athletes to include is a question of each team's available resources; in some sports all athletes deemed to have *any* chance of qualifying for the Games are included, whereas in other sports only those *most likely* are followed. Deciding which athletes to include in the programme will remain a fine balance, and despite our best efforts to maintain an updated overview of all candidates, 19% of Olympic athletes and 4% of Paralympic athletes who have represented Norway at the Games since 2012 were not included in the programme.

Do all teams have adequate medical coverage?

One of the responsibilities of the Chief Medical Officers for each Olympic and Paralympic Games is to ensure that each team has a doctor and physiotherapist available to monitor athlete health during the preparation period. As not all sports (particularly Paralympic sports) have the resources to employ year-round medical personnel, staff from Norwegian Olympic Training Center (Olympiatoppen)'s health department may be assigned to follow specific sports in the final 1-2 years before the Games. This represents a limitation of our programme, as we can only follow these sports for a maximum of 2 years per 4-year Olympic cycle.

How to communicate results to stakeholders?

Injury and illness data collected through this programme have proven valuable to a range of stakeholders in several different contexts. For example, during our annual periodic health evaluations, each athlete's health reports over time provide team medical personnel with a detailed medical history for review. Similarly, in recent years, we have offered team-level data to coaches and support staff during pre- and post-season evaluations in an effort to identify specific health challenges in each team.[34] Chief Medical Officers and other Olympic and Paralympic team managers have also used aggregate data to plan Norway's participation in the Games, helping to answer questions such as "how many athletes are likely to be sick or injured at the Games?", "what types of health problems are we likely to encounter" and which ones need to be addressed with targeted mitigating strategies? A risk matrix can serve as a powerful tool for risk assessment.[33]

Our athletes lost approximately one month of training and competition each year due to health problems, an outcome that should alert both athletes and coaches and presents an example of health data only being useful if presented appropriately and understandably. Effective communication of the data should be tailored to the preferences of the user. This varies between context and intended audience and remains an ongoing challenge for the programme managers.

Are our data confidential and secure?

Since we launched this programme, we used various tools to collect the current data, reflecting real-world challenges and a changing electronic communication and data security landscape. Over time, there has been an increased focus on data confidentiality and security, particularly since the European Union's General Data Protection Regulation (GDPR) law was implemented in 2018. As the information collected through this monitoring system can be particularly sensitive, it is paramount that all data collection, transfer and storage

routines are secure and compliant with local laws and regulations. Our system is secure and compliant, and ensuring this remains a large part of the programme manager's role.

How to analyse collected data?

In previous publications, we have drawn attention to some of the challenges involved in collecting and analysing injury and illness data collected using the OSTRC-H2 questionnaire.[22 24] While a thorough discussion of these issues is beyond the scope of this paper, this knowledge is essential for anyone considering the application of our monitoring methods. In particular, data analysis methods need to account for missing questionnaire data and the possibility of athletes having multiple coexisting health problems. Diagnoses should be recorded using the Sport Medicine Diagnostic Coding System (SMDCS) or the Orchard Sports Injury and Illness Classification System (OSIICS),[29] and data should be summarised and presented according to the IOC Consensus Statement on methods for recording and reporting of epidemiological data on injury and illness in sport.[23]

Will this work in other countries?

Our experience with this programme in Norway cannot necessarily be replicated in all other countries and contexts. We are fortunate to have a moderate-sized, centrally organised elite sport structure, and a strong tradition of collaboration between national sports federations and the national Olympic Training Centre. In larger or more decentralised organisations, it would be possible to apply the methods to a smaller group of athletes, such as a single team or sport or a single training centre.

Nevertheless, we are aware of similarly intensive monitoring programmes of Olympic and Paralympic athletes in the Netherlands, Germany, Sweden, Australia and the USA, and believe there is great value in this approach for many other national and elite sporting organisations.

We encourage other organisations using similar methods to share their experiences in implementing their system.

Limitations

In this paper we highlight strengths and limitations of our health monitoring programme, based on our experiences as developers, managers and day-to-day users of the programme (12 of 13 authors have been team medical personnel). Our conclusions are not based on a formal programme evaluation framework, thus any reference to perceived outcomes is based on our own subjective opinion.

CONCLUSION

Conducting long-term health monitoring of Olympic and Paralympic athletes is challenging, particularly because they travel frequently and often relate to many medical providers. For the past five Olympic and Paralympic cycles, we have implemented and improved a monitoring programme for all Norwegian candidate athletes. We believe the programme has contributed to both primary and secondary injury and illness prevention during this time, and that the approach can help protect the health of elite athletes in other organisations.

TABLE CAPTIONS

Table 1. Number of athletes included in the programme by sport category, sport and sex

Table 2. Average weekly prevalence (% of athletes affected [95% CI]) of all health problems and substantial problems reported, as well as the prevalence of injury, acute injury, overuse injury and illness among Olympic and Paralympic athletes and each of the three subgroups of Olympic athletes

FIGURE CAPTIONS

Figure 1. Flowchart of Olympic (n=533) and Paralympic candidate athletes (n=95) monitored for Paralympic (PG) and Olympic Games (OG) periods prior to 3 Summer Games (London 2012, Rio 2016, Tokyo 2020) and 2 Winter Games (Sochi 2014, PyeongChang 2018).

Figure 2. Number of invitations, number of responses and overall response rates for each of the five Olympic and Paralympic Games cycles.

Figure 3. Risk matrices depicting the relationship between incidence (number of health problems per athlete per year) and severity for Paralympic athletes and three sports categories of Olympic endurance sports, technical sports and team sports. In the 3 top panels, severity is expressed as the average cumulative severity score for each type of health problem. In the 3 lower panels, severity is expressed as the average time loss. The darker the background colour, the greater the burden. In the top panels, isobars represent a cumulative severity score of 100, 200, 400 and 600 per athlete year. In the lower panels, isobars depict a burden of 5, 10, 20 and 30 days per athlete year, respectively. Error bars represent 95% confidence intervals.

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WHAT ARE THE NEW FINDINGS

- We present new data on the type and burden of health problems affecting Olympic and Paralympic athletes during their preparation period for the Games
- It is possible to implement and maintain a health monitoring programme for Olympic and Paralympic athletes, however it demands substantial resources and requires collaboration between athletes, medical personnel, and coaches.

HOW MIGHT IT IMPACT ON CLINICAL PRACTICE IN THE FUTURE?

- Long-term health monitoring provides valuable information for the athlete, his/her coach and the health care team, enabling risk mitigation and prioritisation of targeted preventive strategies

- By facilitating consistent communication between athletes and their national team medical staff, health problems can often be identified and acted upon earlier
- Prospective data collected through a monitoring programme helps to evaluate preventive measures and allows follow-up of screening results.
- We believe that our monitoring approach would offer benefits to other elite sports organisations, particularly other national Olympic and Paralympic centres.

COMPETING INTERESTS

Kathrin Steffen is the co-editor of the British Journal of Sports Medicine – Injury Prevention and Health Protection. In the period these data were collected, the Oslo Sports Trauma Research Center has had non-financial research partnerships with SpartaNova (2013-2016) and FitStats Technologies Inc. (2017 – present).

PROVENANCE AND PEER REVIEW

Non-commissioned; peer reviewed.

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ETHICS APPROVAL

This long-term program has been launched after obtaining approval from the Norwegian Data Inspectorate and reviewed by the South-Eastern Norwegian Regional Committee for Research Ethics.

DATA AVAILABILITY STATEMENT

Requests to access the data will be considered by the authors, within the constraints of privacy and consent.

PATIENT CONSENT FOR PUBLICATION

All participants have given their consent.

CONTRIBUTOR STATEMENT

BC and RB planned and designed the study, and all authors contributed to data collection and interpretation. BC and KS analysed the data and drafted the paper with editorial input from HMB and RB. All authors provided critical revisions and contributed to the final manuscript. BC and RB are the guarantors.

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