Steffen, K., Clarsen, B. M., Gjelsvik, H., Haugvad, L., Koivisto-Mørk, A., Bahr, R., Berge, H. M. (under utgivelse). Illness and injury among Norwegian Para athletes over five consecutive Paralympic Summer and Winter Games cycles: prevailing high illness burden on the road from 2012 to 2020. *British Journal of Sports Medicine*. http://dx.doi.org/10.1136/bjsports-2021-104489

Illness and injury among Norwegian Para athletes over 5 consecutive Paralympic Summer and Winter Games cycles

- prevailing high illness burden on the road from 2012 to 2020

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Key words

Monitoring, illness, injury, Para athletes, Paralympic sports, elite athletes, health protection, prevention

Word count: 3931 (excluding title page, abstract, tables and references)

Abstract

Objective To describe the illness and injury pattern of Norwegian Para athletes over 5 consecutive Paralympic Summer and Winter Games cycles, and to identify which health problems should be targeted in risk management plans with respect to impairment types.

Methods We monitored athletes from 12 to 18 months prior to each Game using a weekly online questionnaire (OSTRC-H2). We asked them to report all health problems they had experienced in the preceding 7 days, irrespective of their consequences on their sports participation or performance and whether they had sought medical attention.

Results Between 2011 and 2020, 94 candidate athletes were included in this monitoring programme and prepared to represent Norway; of these, 66 (71%) were finally selected for multiple Paralympic Games. The overall response rate to the weekly questionnaires was 87%. At any given time during the five observation cycles, 37% of the athletes (95% CI 36-38%) reported having at least one health problem. Athletes with neurological impairments (n=51) lost 10 days per year due to respiratory problems (95% CI 9-11) compared to 9 days (8-10) among those with musculoskeletal impairments (n=37). Gastrointestinal problems caused a time loss of on average 4 days per year in athletes with neurological impairments versus 1 day in athletes with musculoskeletal impairments (mean difference 2.7 days, 2.1-3.3). Musculoskeletal injuries generated a high burden for both athlete groups, in particular to the elbow, shoulder and lumbosacral regions.

Conclusion At any given time, nearly 2 out of 5 elite Norwegian Para athletes reported at least one health problem. Respiratory tract and other infections, gastrointestinal problems, and injuries to the shoulder, elbow and lumbosacral regions represented the greatest health burden. Our findings can help guide the allocation of clinical resources, which should include a broad network of medical specialists, together with dieticians and physiotherapists, to meet the health challenges in Para athletes.

Introduction

For athletes, staying healthy is critical to be able to train and compete.[1-3] We recently reported a greater burden of health problems among elite Para athletes (32 days lost from sport each year) compared to Olympic athletes (27 days).[3] Para athletes have underlying and pre-existing medical conditions, which may make them more vulnerable to illnesses in particular.[4-6]

Early identification of health problems is important to target treatment and prevention.[1-3] Injury and illness surveillance is now well established in Olympic and Paralympic Games, driven by the Medical and Scientific Commission of the International Olympic Committee (IOC) and the Medical Committee of the International Paralympic Committee (IPC). The incidence proportions of illnesses and injuries range between 5-7 illnesses and 10-13 injuries per participating 100 athletes.[7-12] However, comparable data collected during Paralympic Games are considerably higher, ranging between 12-22 illnesses[5,13-16] and 14-32 injuries per 100 athletes.[17-20]

These surveillance programs have provided some knowledge on the patterns and risk of illnesses and injuries during competition periods. In contrast, prospective longitudinal health monitoring of Paralympic-level athletes outside competition is limited.[1,2] A recent systematic review on the risk of musculoskeletal injuries among Para athletes revealed that the quality of the available evidence is low, and called for larger sample sizes and better quality studies.[21] Longitudinal data will facilitate a more comprehensive understanding of illness and injury patterns overall, enabling better planning of year-round medical services for Para athletes,[22,23] and informing initiatives to protect athlete health.

The primary aim of this paper is to describe the illness and injury pattern of Norwegian Para athletes over five consecutive Paralympic Summer and Winter Games cycles, and to identify which health problems should be targeted in risk management plans with respect to impairment types. We also discuss methodological and clinical challenges when collecting and reporting health issues among Para athletes, exemplified by data.

Methods

Data collection

Between 12 and 18 months before each of the Summer and Winter Paralympic Games between 2011 and 2020, we asked the national team coaches of all relevant sports to provide a list of athletes whom they considered to be candidates to qualify. We then informed candidate athletes (20-40 athletes each in the five Games preparation cycle), as well as their respective part-time

health providers (typically 1 physician and 3 physiotherapists), about the procedures, risks and benefits of the Norwegian Olympic and Paralympic Health Monitoring Programme. The development and implementation of the programme has previously been described in detail.[3]

We instructed athletes to report all health problems they had experienced in the preceding seven days, including ongoing problems reported earlier. Each week until final selection and the start of the Games, we collected health data from these athletes using an online questionnaire (OSTRC-H/OSTRC-H2).[24,25] The National Para team physician and physiotherapist followed up health problems reported. In a few sports, where available through the sport federations´ resources, the follow-up was done by the team physiotherapist. The methodology for data collection, using three different electronic platforms, has been described in detail.[3]

The programme was reviewed by the South-Eastern Norwegian Regional Committee for Research Ethics and approved by the Norwegian Data Inspectorate. Informed written consent was obtained from all athletes before the start of the monitoring.

Classification and diagnosis of reported health problems

Athletes were encouraged to report every health problem, irrespective of its consequences on their sports participation or performance, and irrespective of whether they had sought medical attention.[24,26] The medical team provided a diagnostic code for every health problem reported by the athletes, including the Orchard Sports Injury Classification System, V.10 (OSICS-10, London and Sochi injuries)[27], the International Classification of Primary Care, V.2 (ICPC-2, London and Sochi illnesses)[28] and the Sports Medicine Diagnostic Coding System (SMDCS, Rio, PyeongChang and Tokyo, all health problems).[29] We retrospectively translated all diagnostic codes into V.13 of the Orchard Sports Injury and Illness Classification System (OSIICS-13).[30] Injuries were considered to have a non-specific diagnosis if the first or second letters of the OSIIC-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).

Information on impairment type and primary mode of mobility was obtained through a periodic health evaluation at the start of each Paralympic cycle. Impairments were further classified according to the consensus statement on research methodology in Para sport.[23]

Data analyses and statistics

In this paper, we present data collected in between October 2011 and January 2020. As team

sizes were small, we present data for the whole cohort of Para athletes and for sub-groups by sex, physical impairment (neurologic versus musculoskeletal),[23] mode of mobility (using a wheelchair versus being ambulatory), and competitive season (summer versus winter sports).

All data from all collection tools were consolidated into a single spreadsheet and analysed in R (version 3.6.1).[31] Descriptive data are summarized using mean, median, standard deviations, quartiles and/or 95% confidence intervals (CI), as appropriate, and is described in detail elsewhere.[3] To describe health risk across the course of the data collection periods, we calculated the weekly prevalence by dividing the number of athletes reporting a health problem by the number of questionnaire responses. We expressed incidence as the number of new cases per athlete per year, severity as the mean number of time loss days per case and burden as the number of time loss days per athlete per year. We defined health problems as substantial if they led to a moderate or severe reduction in training volume or reduction in sports performance or to complete inability to participate in sport.[32] We present sub-group analyses based on the differences of health burden with their respective 95% CI.

Results

Sports, impairment types, mode of mobility

During five consecutive Paralympic cycles, 94 Para athletes were included in the monitoring programme, from 11 summer and five winter sports (Figure 1). Of these, 66 athletes (71%) were finally selected for the Games, and 3 (2 females, 1 male) competed in multiple sports, combining Nordic skiing (Winter Games) with rowing or swimming (Summer Games) and ice sledge hockey with alpine skiing (in separate Winter Games). Half of the athletes (n=47) were monitored over multiple games cycles: 42 athletes for 2 Games, 4 athletes for 3 Games, 1 athlete for 4 Games.

Athletes presented with a variety of impairments, and the distribution of those by sex, underlying pathophysiology, primary mode of mobility and competitive season is shown in Table 1. More than half of all athletes had congenital impairments, and 44% depended predominantly on a wheelchair for transportation. Two-thirds of the athletes (68%) performed their sport in a sitting position, irrespective of their underlying impairment (23% competed ambulatory, 9% were swimmers). Most of the 51 athletes with neurological impairments, 54% of the total Para cohort, competed in ice sledge hockey (n=20), curling (n=5) or shooting (n=6). The mean age of all athletes was 32 yrs., ranging from 16 to 63 yrs.

> INSERT FIGURE 1 HERE <

Table 1 Distribution of the 94 elite Para athletes into impairment, sex, underlying pathophysiology, primary mode of mobility, and competitive season.

Impairment groups (n)	Sex		Underlying pathophysiology		Primary mode of mobility*				Competitive season**	
	Females	Males	Congenital	Acquired	Neurological		Muskuloskeletal		Summer sport	Winter sport
					WC	AM	WC	AM		
Physical (88)										
Neurological (51)										
Brain disorders	5	7	12	-	3	9	-	-	8	4
Spinal cord injury	5	13	-	18	17	11	-	-	7	12
Neuromuscular disorders	6	15	17	4	18	3	-	-	6	15
Musculoskeletal (37)										
Limb deficiency/Amputee	6	19	12	13	-	-	1	24	14	12
Impaired PROM	9	2	4	7	-	-	2	9	8	3
Short stature	-	1	1	-	-	-	1	-		
Vision (5)	1	4	4	1	-	-	-	-	4	1
Intellectual (1)	-	1	1	-	-	-	-	-	1	-
Total	32 (34%)	62 (66%)	51 (54%)	43 (46%)	38 (43%)	23 (26%)	4 (5%)	23 (26%)	49 (51%)	47 (49%)

*Depended on using a wheelchair (WC) for daily activities or being ambulatory (AM) with or without the use of assistive devices as prothesis, crutches and/or orthosis. The 6 athletes with vision and intellectual impairments were all ambulatory.

**3 athletes competed in multiple sports, combining Nordic skiing (Winter Games) with rowing or swimming (Summer Games), and ice sledge hockey with Nordic skiing (in separate Winter Games).

PROM=passive range of motion

Observation period, weekly response rate and reported cases

Within each of the five observation periods, we monitored the athletes for a period of on average 77 weeks. The overall response rate to the weekly questionnaires was 87%: 87% for London, 90% for Sochi, 89% for Rio, 84% for PyeongChang and 83% for Tokyo.

Athletes self-reported a total of 839 health problems, including 543 illnesses (65%), 196 overuse (23%) and 100 acute injuries (12%). Nearly all athletes (n=90, 97%) reported at least one health problem during their respective observation periods.

Diagnosis rate

With missing clinical details for 35 cases, we could assign a diagnostic OSIICS 13-code for a total of 804 health problems (96%). Of these, 542 cases were translated from SMDCS-1, 161 cases from ICPC-2 and 101 cases from OSICS-10. There were 244 cases (30%) with non-specific codes. Due to inconsistencies in the translation between coding systems, and some cases being assigned a code before a full examination had been completed, 102 out of the total 839 cases (12%) were re-coded based on their clinical records before final analysis. Out of 543 illnesses, 90 (17%) needed to be re-coded.

Eleven symptom-based diagnostic codes (14 cases) could not be translated to OSIICS-13, and the best fit code was chosen, based on journal notes. These were nausea, problems swallowing, vomiting, abdominal pain, irritable stomach, incontinence, oedema, hypertension, palpitations/anxiety, vertigo/dizziness and planned surgeries.

Average weekly prevalence of health problems

At any given time during the 5 observation periods, 37% of the athletes (95% CI 36-38%) on average reported having at least one health problem, and 18% (17-20%) reported a substantial health problem. Illnesses accounted for an average weekly prevalence of 19% (18-20%), followed by overuse injuries for 16% (15-16%) and acute injuries for 5% (4-5%) (Table 2).

The mean prevalence of health problems differed by sex and underlying impairment. As shown in Table 2 and indicated by overlapping 95% confidence intervals, athletes with neurological impairments reported more weekly illness, including substantial illness, and fewer injuries in general compared to athletes with musculoskeletal impairments. Female athletes reported a greater proportion of illnesses in general and fewer injuries compared to male athletes. The difference between winter versus summer sport athletes was minimal.

Table 2 Average weekly prevalence of all and substantial health problems among 94 elite Para athletes, presented for the whole cohort as well as for sub-groups (%, 95% CI).

	All n=94	Female n=32	Male n=62	Neurological n=51	Musculoskeletal n=37	Summer sport* n=49	Winter sport* n=48
All health problems	37.1 [35.8, 38.5]	39.5 [36.2, 42.8]	34.2 [32.6, 35.9]	41.7 [40.0, 43.3]	37.1 [35.1, 39.1]	35.4 [33.5, 37.2]	39.7 [35.8, 42.7]
All injuries	19.8 [18.9, 20.7]	16.8 [14.5, 19.1]	20.6 [19.4, 21.8]	18.1 [16.45, 19.4]	22.4 [20.7, 24.1]	18.3 [17.0, 19.6]	22.6 [19.9, 25.3]
Acute injuries	4.8 [4.3, 5.4]	3.4 [2.1, 4.6]	6.1 [5.3, 7.0]	4.3 [3.6, 5.0]	5.3 [4.4, 6.2]	4.0 [3.3, 4.8]	7.4 [4.9, 9.9]
Overuse injuries	15.2 [14.4, 16.1]	13.5 [11.5, 15.5]	14.8 [13.6, 16.1]	13.8 [12.7, 15.0]	19.4 [17.8, 21.0]	14.6 [13.3, 15.8]	15.5 [13.7, 17.4]
All illnesses	19.1 [18.0, 20.3]	25.6 [22.5, 28.6]	15.5 [14.2, 16.9]	23.5 [22.0, 25.0]	12.4 [11.1, 13.8]	18.7 [17.1, 20.3]	19.6 [17.2, 22.0]
Substantial health problems	18.3 [17.1, 19.5]	16.0 [13.8, 18.1]	19.3 [18.0, 20.7]	19.1 [17.9, 20.4]	18.7 [17.2, 20.3]	17.9 [16.2, 19.5]	18.0 [15.9, 20.1]
All injuries	8.6 [7.9, 9.3]	6.4 [4.9, 7.9]	10.4 [9.5, 11.4]	6.4 [5.5, 7.2]	12.2 [10.9, 13.5]	8.8 [7.7, 10.0]	7.6 [6.8, 8.5]
Acute injuries	2.6 [2.2, 3.0]	0.9 [0.5, 1.3]	3.7 [3.0, 4.4]	2.4 [1.9, 2.9]	3.1 [2.4, 3.8]	2.3 [1.7, 2.9]	2.7 [2.2, 3.2]
Overuse injuries	6.1 [5.4, 6.7]	5.5 [4.0, 6.9]	6.8 [5.9, 7.6]	4.0 [3.4, 4.7]	9.1 [7.9, 10.2]	6.6 [5.5, 7.7]	5.0 [4.3, 5.7]
All illnesses	10.5 [9.6, 11.4]	10.6 [8.8, 12.4]	9.8 [8.7, 10.9]	13.4 [12.1, 14.7]	7.0 [5.9, 8.0]	10.0 [8.7, 11.2]	10.9 [9.0, 12.8]

*3 athletes competed in multiple sports, combining Nordic skiing (Winter Games) with rowing or swimming (Summer Games), and ice sledge hockey with Nordic skiing (in separate Winter Games).

Incidence and severity of health issues

With 40 852 athlete-days and 839 cases recorded, the mean incidence of new or recurrent health problems was 7.5 (95% CI 7.2-7.8) per athlete per year, 0.9 for acute injuries (0.7-1.1), 1.8 for overuse injuries (1.5-2.0) and 4.8 for illnesses (4.4-5.3). The incidence of illness and musculoskeletal injury types is detailed in Tables 3 and 4.

Of the 519 illnesses, 319 (61%) were clinically diagnosed as infections, and athletes with neurological impairments reported two thirds of them (208 infections), including 20 urinary tract infections. Irrespective of impairment, injuries to the shoulder (n=63, 22% of all injuries), lumbosacral region (n=35, 12%) and elbow (n=27, 9%) were most common.

Burden and risk matrix

We recorded 3 617 lost training days over the study period. This translates to an average of 32.2 days lost per athlete per year, 5 days due to acute injuries (range 0-121 days), 9 days (0-145) due to overuse injuries and 18 days (0-61) due to illnesses.

Irrespective of impairment type, respiratory and gastrointestinal problems, and shoulder and elbow injuries were the most burdensome illnesses and injuries, respectively. However, some problem types were more characteristic for either one or the other group of athletes with physical impairments.

Figure 2 shows all health problems with at least 5 cases that caused an average minimum time loss of 1 day per year. While illnesses predominated for athletes with neurological impairments (particularly respiratory and gastrointestinal problems), musculoskeletal injuries led among athletes with musculoskeletal impairments.

Sub-group analyses further revealed that athletes with neurological impairments lost 10 days per year due to respiratory problems (95% CI 9-11) compared to 9 days (8-10) among athletes with musculoskeletal impairments, and 13 days (12-15) versus 10 days (8-11) for any type of infection. The 72 gastrointestinal problems caused a time loss of on average 4 days per year in athletes with neurological impairments versus 1 day for those with musculoskeletal impairments (mean difference 2.7 days, 2.1-3.3). For winter sport athletes (13 days, 12-14), respiratory organ-related illnesses caused on average 7 more days lost from sport (6-8) compared to summer sport athletes (6 days, 5-6).

> INSERT FIGURE 2 HERE <

73 **Table 3** Illness pattern of 514 diagnostically verified cases among 94 elite Para athletes presented by organ system (all cases), aetiology and diagnosis (≥5 cases).

Organ system Etiology *Diagnosis*	Illnesses Cases	Incidence Illnesses per athlete year (95% CI)			Median time loss Days (25-75th percentile)			Burden Time loss days per athlete year (95% CI)
Cardiovascular	**2**	**0.02**	**0**	**0.06**	**1**	**0**	**1**	
Dermatological	**11**	**0.10**	**0.05**	**0.17**	**6**	**3**	**10**	**0.82 (0.64 – 0.97)**
Infection	7	0.06	0.03	0.12	6	3	14	0.62 (0.49 – 0.79)
Skin infection	6	0.04	0.01	0.08	14	10	20	0.61 (0.41 – 0.68)
Endocrinological	**5**	**0.04**	**0.02**	**0.10**	**1**	**1**	**2**	**0.06 (0.02 – 0.12)**
Gastrointestinal	**72**	**0.64**	**0.50**	**0.80**	**2**	**1**	**4**	**2.83 (2.53 – 3.15)**
Multiple	56	0.46	0.35	0.59	2	1	4	1.72 (1.47 – 1.96)
Gastrointestinal illness	47	0.42	0.31	0.55	2	1	4	1.31 (1.10 – 1.53)
Diarrhoea	9	0.08	0.04	0.15	1	1	4	0.40 (0.28 – 0.52)
Infection	9	0.08	0.04	0.14	4	3	4	0.78 (0.62 – 0.95)
Immunological/inflammatory	6	0.05	0.02	0.11	4	2	5	0.28 (0.19 – 0.40)
Genitourinary	**25**	**0.22**	**0.15**	**0.32**	**2**	**1**	**5**	**0.97 (0.80 – 1.17)**
Infection	20	0.18	0.11	0.27	1	0	5	0.61 (0.46 – 0.75)
Cystitis	18	0.16	0.10	0.25	1	0	4	0.46 (0.34 – 0.59)
Hematologic	**2**	**0.02**	**0**	**0.06**	**13**	**7**	**19**	
Multiple systems	**58**	**0.52**	**0.40**	**0.66**	**3**	**1**	**6**	**1.71 (1.46 – 1.94)**
Infection	46	0.41	0.30	0.54	3	1	6	1.46 (1.24 – 1.69)
Environmental	7	0.06	0.03	0.12	1	1	3	0.11 (0.05 – 0.18)
Neurological	**25**	**0.22**	**0.15**	**0.32**	**1**	**1**	**2**	**0.87 (0.71 – 1.06)**
Unknown, or not specified	20	0.18	0.11	0.27	2	1	2	0.86 (0.68 – 1.02)
Headache/Migraine	19	0.10	0.06	0.15	1	1	2	0.39 (0.25 – 0.53)
Other neurological problem	5	0.04	0.02	0.10	2	1	24	0.44 (0.36 – 0.62)
Ophthalmological	**1**	**0.01**	**0**	**0.04**	**0**	**0**	**0**	
Otological	**1**	**0.01**	**0**	**0.04**	**0**	**0**	**0**	
Psychiatric/psychological	**9**	**0.08**	**0.04**	**0.15**	**2**	**1**	**3**	**0.31 (0.21 – 0.42)**
Respiratory	**292**	**2.60**	**2.32**	**2.91**	**2**	**1**	**5**	**9.31 (8.76 – 9.89)**
Infection	235	2.09	1.84	2.37	2	1	4	7.46 (7.00 – 8.01)
Unknown, or not specified	48	0.43	0.32	0.56	3	0	5	1.60 (1.36 – 1.82)
Rheumatological	**8**	**0.07**	**0.03**	**0.13**	**5**	**2**	**21**	**0.81 (0.65 – 0.99)**
Unknown/not specified	**3**	**0.03**	**0.01**	**0.07**	**2**	**2**	**7**	**0.16 (0.07 – 0.21)**
ALL	**514**							

74
75

Table 4 Injury pattern of 290 diagnostically verified cases among 94 elite Para athletes presented by body region (all cases), injury type and diagnosis (≥5 cases).

Region Type *Diagnosis*	Injuries Cases	Incidence Injuries per athlete year (95% CI)			Median time loss Days (25-75th percentile)			Burden Time loss days per athlete year (95% CI)
Head	**13**	**0.11**	**0.06**	**0.19**	**1**	**0**	**6**	**0.40 (0.27 – 0.50)**
Nervous	6	0.05	0.02	0.1	5	1	9	0.28 (0.20 – 0.41)
Concussion	6	0.05	0.02	0.1	5	1	9	0.28 (0.20 – 0.41)
Neck	**25**	**0.22**	**0.15**	**0.32**	**1**	**0**	**2**	**0.41 (0.29 – 0.53)**
Non-specific								
Neck pain, not otherwise specified	14	0.12	0.07	0.20	1	0	3	0.31 (0.22 – 0.43)
Ligament/joint capsule								
Whiplash/neck sprain	5	0.04	0.02	0.10	1	0	1	0.02 (0 – 0.06)
Shoulder	**63**	**0.56**	**0.43**	**0.71**	**0**	**0**	**3**	**2.67 (2.38 – 2.98)**
Muscle/tendon	29	0.26	0.18	0.36	0	0	2	0.77 (0.61 – 0.93)
Tendinopathy/rotator cuff impingement	12	0.11	0.06	0.18	0	0	1	0.16 (0.08 – 0.22)
Tendinopathy/subacromial impingement	6	0.05	0.02	0.11	2	1	14	0.48 (0.38 – 0.65)
Muscle strains (pectoralis major, lat. dorsi, rotator cuff)	5	0.01	0	0.06	0	0	0	
Non-specific	25	0.22	0.15	0.32	0	0	2	0.70 (0.55 – 0.86)
Shoulder pain, not otherwise specified	25	0.22	0.15	0.32	0	0	2	0.70 (0.55 – 0.86)
Ligament/joint capsule	5	0.04	0.02	0.1	5	1	7	0.20 (0.14 – 0.31)
Grade 1 A/C joint sprain	5	0.04	0.02	0.1	5	1	7	0.20 (0.14 – 0.31)
Upper arm	**6**	**0.05**	**0.02**	**0.11**	**4**	**2**	**5**	**0.23 (0.15 – 0.33)**
Elbow	**27**	**0.24**	**0.16**	**0.34**	**1**	**0**	**8**	**3.79 (3.45 – 4.18)**
Muscle/tendon	8	0.07	0.03	0.13	4	0	9	1.11 (0.93 – 1.32)
Tendinopathy (distal triceps, lateral epicondyle)	8	0.07	0.03	0.13	4	0	9	1.11 (0.93 – 1.32)
Ligament/joint capsule	7	0.06	0.03	0.12	1	0	6	0.82 (0.68 – 1.02)
Elbow sprain	6							
Forearm	**16**	**0.14**	**0.08**	**0.22**	**1**	**0**	**8**	**0.60 (0.47 – 0.76)**
Muscle/tendon								
Muscle trigger points, extensor, flexor strain	10	0.09	0.05	0.16	1	0	3	0.28 (0.18 – 0.37)
Non-specific								
Forearm pain, not otherwise specified	5	0.04	0.02	0.10	1	0	6	0.21 (0.14 – 0.32)
Wrist	**18**	**0.16**	**0.10**	**0.25**	**1**	**0**	**2**	**1.38 (1.17 – 1.60)**
Muscle/tendon	7	0.06	0.03	0.12	1	0	2	0.15 (0.09 – 0.24)
Hand	**12**	**0.11**	**0.06**	**0.18**	**1**	**0**	**5**	**0.52 (0.38 – 0.64)**
Chest	**7**	**0.06**	**0.03**	**0.12**	**0**	**0**	**1**	**0.03 (0 – 0.06)**
Muscle/tendon								
Chest muscle strain	6	0.05	0.02	0.11	0	0	1	0.03 (0 – 0.06)
Thoracic spine	**12**	**0.11**	**0.06**	**0.18**	**0**	**0**	**3**	**0.30 (0.19 – 0.40)**

Muscle/tendon								
Thoracic muscle strain, spasm, trigger points	6	0.05	0.02	0.11	0	0	0	0.01 (0 – 0.03)
Non-specific								
Thoracic pain, not otherwise specified	5	0.04	0.02	0.10	2	0	4	0.09 (0.04 – 0.16)
Lumbosacral	**35**	**0.31**	**0.22**	**0.43**	**3**	**0**	**5**	**1.12 (0.93 – 1.32)**
Non-specific								
Lumbar pain, not otherwise specified	21	0.19	0.12	0.28	3	1	4	0.48 (0.35 – 0.60)
Muscle/tendon								
Muscle and tendon strain, spasm, trigger points	9	0.08	0.04	0.15	2	0	5	0.33 (0.22 – 0.44)
Abdomen	**5**	**0.04**	**0.02**	**0.10**	**1**	**0**	**1**	**0.04 (0.01 – 0.08)**
Hip/groin	**3**	**0.03**	**0.01**	**0.07**	**0**	**0**	**2**	**0.03 (0 – 0.06)**
Thigh	**14**	**0.12**	**0.07**	**0.20**	**0**	**0**	**2**	**0.16 (0.09 – 0.24)**
Muscle/tendon	8	0.07	0.03	0.13	2	0	3	0.16 (0.09 – 0.24)
Knee	**15**	**0.13**	**0.08**	**0.21**	**2**	**0**	**6**	**1.33 (1.15 – 1.58)**
Cartilage/synovium/bursa								
Meniscal tear, patellofemoral chondral pain/injury	5	0.04	0.02	0.10	3	2	8	0.27 (0.20 – 0.41)
Lower leg	**9**	**0.08**	**0.04**	**0.15**	**1**	**1**	**2**	**0.22 (0.14 – 0.31)**
Ankle	**4**	**0.04**	**0.01**	**0.08**	**2**	**1**	**7**	**0.22 (0.11 – 0.28)**
Foot	**6**	**0.05**	**0.02**	**0.11**	**1**	**0**	**2**	**0.06 (0.02 – 0.11)**
Non-specific								
Foot pain, not otherwise specified	6	0.05	0.02	0.11	1	0	2	0.06 (0.02 – 0.11)
ALL	**290**							

Discussion

This study represents the most comprehensive and largest national data set on illnesses and injuries among elite Para athletes. In line with the few available long-term health monitoring studies among elite Para athletes,[1,2] illnesses represented the greatest health burden in our cohort, particularly respiratory tract infections and gastrointestinal problems. Our analyses also revealed that health problems were related to impairment, sex and competitive season. Compared to athletes with musculoskeletal impairments, athletes with neurologic impairments had a higher prevalence of illness, and many of these illnesses had substantial consequences on athletes' sports performance and training quality. Musculoskeletal injuries generated a high burden for both athlete groups, in particular to the elbow, shoulder and lumbosacral regions.

Comparison with other national health monitoring projects in elite Para sport

When interpreting epidemiological data on Para athletes, impairment type, sport and the prevalence of underlying co-morbidities must be considered. The average weekly prevalence of health problems in Norwegian Para athletes (37%) was higher than in elite German Para athletes (28%).[1] Compared to the Norwegian cohort, 1 in 10 German athletes reported an illness at any time, likely indicating a group of athletes with fewer underlying conditions. The Norwegian athletes also had a generally higher incidence of health problems compared to the German[1] and Swedish elite-level cohorts,[2] which were monitored for 29 and 52 weeks, respectively. In Norway, illnesses represented as much as a burden for the Para athletes, as did acute injuries for Olympic-level team sport athletes.[3] However, the incidences in general were lower than those published from Paralympic games,[5,13-17,19,20,33] which in view of a well-documented increased injury risk during competitions is not surprising. Also, high-risk Paralympic sports, such as 5- and 7-a-side football, judo, wheelchair rugby, basketball, alpine skiing or snowboard,[17-20] were not represented in our cohort or with only a single athlete competing in that sport.

Most burdensome health problems

Respiratory problems, mainly as infections, was the most burdensome illness category. For winter sport athletes, two thirds of them having underlying neurological impairments, respiratory illnesses were the leading cause for the observed 13 time loss days per athlete per year. Even though most of those problems were minor (approx. 2 days lost from sport participation), they likely impact athletes' development and performance over time.

It is well known that respiratory dysfunction from neurological impairments or congenital malformations may increase infection risk and limit the ability for endurance training.[35,36]

However, as not many of the Norwegian Para athletes represented endurance sports or were tetraplegic, we still do not have a reasonable explanation for the high burden of respiratory problems among the athletes with neurologic impairments. It is currently unknown whether asthma is underdiagnosed in Para athletes or if asthma limits performance more than it does in able-bodied athletes. Climate and competitive seasons are also discussed as risk factors for upper respiratory tract infections, even though it appears that elite endurance athletes experience fairly similar infection rates, regardless of their competition season.[37,38]

Gastrointestinal problems were the second most burdensome illness type among athletes, and posed a high burden for athletes with neurological impairments specifically. However, unpublished Norwegian data from the field revealed that gastrointestinal challenges can be successfully targeted. The ice sledge hockey players alone, most of them with neurological impairments, reported on average 13 lost training days per year due to gastrointestinal problems in the months before the PyeongChang Paralympic Games in 2018. These problems were not often related to gastrointestinal infections or poor hygiene, but rather to nutritional shortcomings. As examples, poor food item choices, inappropriate fibre intake and sub-optimal meal timing could further trigger e.g. a neurogenic bowel related to athletes' underlying pathophysiology. Less than a year after implementing a range of nutritional and medical measures, the burden of gastrointestinal problems was reduced to 2 days per athlete per year.

Given that we used a multifactorial and individualised approach, we could not identify which of our strategies were most effective. Despite the success of our interventions, we still observed that bowel dysfunction represented a leading cause of absence from training among athletes with neurologic impairments. This was observed particularly among athletes whose sport necessitated high intraabdominal pressures, where we noted a greater risk of urinary and bowel incontinence. Increased knowledge on gastrointestinal and bowel dysfunction in Para athletes is necessary.[39,40]

With on average 2-7 days lost from sport each year, elbow and shoulder injuries represented the most burdensome injuries, particularly for athletes with musculoskeletal impairments. It is likely that the burden of upper-limb injuries is even higher in other groups of Para athletes; both among those dependend on use a wheelchair and/or crutches for transportation and those competing in wheelchair sports or other high risk sports associated with the shoulder injury mechanism of a throwing athlete.[41] Also, most of the athltes with musculoskeletal impairments were ambulatory, however competed in ice sledge hockey, which is known for high injury rates to the elbow and shoulder.[16,17]

Methodological considerations

Our data represent the largest and most comprehensive data set on health problems among Para athletes during out-of-competition periods, with individual observation periods for an average of 1.5 years. Half of the athletes followed over multiple Games cycles, though for a maximum of 18 months for each of thoses cycles. This setting provided unique long-term data both on an individual and a group level, to react to health challenges all year round. The weekly monitoring allowed us to build a close relationship between athlete and care provider, intervene early on health problems reported and monitor the response to treatment and rehabilitation. The early identification of health problems is of significant importance for conditions with a gradual onset, which athletes typically do not acknowledge and seek help for too late.[3] Another strength of the present data is that all unspecified diagnoses were reviewed and re-coded if neccessary before final analyses.

On the other hand, the low number of athletes and their heterogeneity clearly affected our sub-group analyses. Sports were presented with an unbalanced number of athletes, sexes and impairments. Consequently, our data set will not be representative for other Paralympic teams, as impairments and underlying co-morbidities, and the athletes´ classifications in sport will vary significantly between countries and teams.

With individual reporting thresholds existing and health problems being self-reported, we are aware of that our data may be affected by reporting bias. Also, underreporting of health problems may have affected our data set. Athletes with chronic underlying clinical conditions may perceive their health issues as a "normal" part of daily life and may not report them every week. We also know that the risk for cardiovascular disease is increased for many athletes with neurological impairments,[6,42] but we could not identify cardiovascular or other diseases in our monitoring, as athletes often are asymptomatic. However, we capture life-long and normally well-managed medical conditions, as e.g. hypertension, diabetes, asthma or eating disorders, during the pre-participation health examination (PHE).

Diagnostic coding represents a challenge in health monitoring programmes. The standard coding systems used in general health care either include too many rare diagnoses to be practical in the sports setting (ICD-11 includes apx. 55 000 codes) or, like ICPC-2, do not contain specific codes for many diagnoses commonly seen in sports. To rectify this, two new diagnostic coding systems, SMDCS and OSICS were developed in the early 1990s. The new versions of SMDCS (V.2) and OSIICS (V.13) include approximately 1 000 and 1 500 codes, respectively. While these are more practical than ICD and ICPC codes for the sports setting, it means that specific codes are missing for a range of health conditions, particularly illnesses and chronic conditions not

related to sports participation. These are more common among Para than able-bodied athletes, and while they are still few and do not change the overall injury and illness pattern substantially, the result is that they will be lumped into various "other" categories. Another issue common to monitoring systems is that some, particularly minor cases are classified with a general symptom-based diagnosis, e.g nausea, without further investigations.

We therefore encourage clinicians and research groups working with Para athletes who are aware of conditions commonly affecting this cohort to supply suggestions for specific codes to be added to OSIICS/SMDC.[43,44]

Practical implications, benefits and risk management

The potential benefits of the health monitoring programme for Olympic and Paralympic athletes both on the individual and group level have been discussed in detail.[3] Given large international in-competition studies exist in Para sport,[13-20,33,34] there is the need for them out of competition as well, and scientific guidance is available to develop and facilitate a more accurate understanding of illness and injury patterns for Para athletes.[23]

The present data also provide guidance on how to prioritize staffing for a Paralympic medical team based on the most common and burdensome health issues present. Clinical teams in the support of Para athletes should include different specialties within infectious and gastrointestinal medicine, neurology, endocrinology and urology, together with dieticians and physiotherapists. Also, gathering data on health problems continuously can help medical support teams answer questions such as "how many athletes are likely to be sick or injured?", "what types of health problems are we likely to encounter" and "which ones need to be addressed with targeted mitigating strategies?"[3,22] Effective communication of athletes´ health data is important to reach the needs of all stakeholders in a tailored form.[3.]

As already mentioned, to complement the monitoring programme, the Norwegian athletes are also invited to an extensive PHE upon programme entry and when starting a new Paralympic cycle, providing additional medical and practical information on e.g. travel and high-altitude experiences. These data can be combined for targeting purposes, both identifying at-risk athletes as well as their risk profile. The following example illustrates some of the potential clinical benefits of this interplay.

Numerous reports of gastrointestinal and other nutrition-related challenges following the PHE led to further assessments, revealing that 15 of 23 Norwegian athletes (65%) had poor bone mineral density (z-score <-1[43]); 10 of these displayed osteoporotic values (z-score ≤-2[43]) in either

the lumbar spine and/or hips (unpublished data). It is well known that reduced skeletal loading increases the risk for osteoporosis and fracture.[43] Spinal cord injury is associated with a marked increase in bone loss and risk of osteoporosis development short-term after injury.[44,45] However, factors beyond the mechanical aspects likely contributed to low bone density in our cohort.[46-49] The identification of the underlying causal factors of poor bone health in Para athletes requires a broad understanding of metabolic, endocrine and biomechanical factors, as well the medical, dietary and training history.[46,50] One limitation is that there are no reference values or guidelines available for identifying, monitoring or treating bone health in Para athletes.

The high incidence and burden of respiratory infections and infections in general, including skin infections, warrant concern and often demand antibiotic treatment, surgery and long-lasting rest when not identified early.[5,51] Athletes should therefore be encouraged to take regular precautions for infection.[1] Establishing good routines and habits in e.g. using urinary sticks regularly or having proper clothing and gear to skift after training/competiton and adjusted to the individual and environmental conditions.

Based on our experiences, nutritional action plans to better cope with bowel dysfunction and to avoid accidental leakage and flatulence in daily training should include individulized dietary plans. Other plans should consider specific dietary advices related to gastrointestinal distress, as e.g. a low FODMAP approach for athlets with irritable bowel syndrome,[40,52] and strategies to prevent travel related gastrointestinal and urinary challenges, as e.g. dehydration, constipation.

Injuries not only pose a limitation on sports performance, but also an additional barrier to activities of daily living for athletes depending on a wheelchair or crutches for mobility.[21] Shoulder, trunk and back injury prevention is of outmost importance and should be implemented in regular training for all athletes with high loads on the upper body.[53,54] Our suggestion for injury prevention training for Para athletes are the freely available resources with the *Get Set – Train Smarter application* and *www.fittoplay.org*. The implementation of preventive strategies should involve athletes, coaches, medical staff and sport organizations.[2]

Conclusion

In any given week during their preparations for the Paralympic Games, nearly 2 out of 5 elite Norwegian Para athletes reported health problems. Respiratory tract and other infections, gastrointestinal problems, and injuries to the shoulder, elbow and lumbosacral regions represented the greatest health burden. Our findings can help guide the allocation of clinical

resources, which should include a broad network of medical specialists, together with dieticians and physiotherapists, to meet the health challenges in Para athletes.

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TABLE CAPTIONS

Table 1 Distribution of the 94 elite Para athletes into eligible impairment, sex, underlying pathophysiology, primary mode of mobility, and competitive season.

Table 2 Average weekly prevalence of all and substantial health problems among 94 elite Para athletes, presented for the whole cohort as well as for sub-groups (%, 95% CI).

Table 3 Illness pattern of 514 diagnostically verified cases among 94 elite Para athletes presented by organ system (all cases), aetiology and diagnosis (≥5 cases).

Table 4 Injury pattern of 290 diagnostically verified cases among 94 elite Para athletes presented by body region (all cases), injury type and diagnosis (≥5 cases).

FIGURE CAPTIONS

Figure 1 Flowchart of eligible female (F) and male (M) Para athletes (n=94) monitored for Paralympic Games periods prior to 3 Summer Games (London 2012, Rio 2016, Tokyo 2020) and 2 Winter Games (Sochi 2014, PyeongChang 2018). Athletes are presented with their primary mode of mobility as using predominately a wheelchair or being ambulatory.

*3 athletes competed in multiple sports, combining Nordic skiing (Winter Games) with rowing or swimming (Summer Games), and ice sledge hockey with Nordic skiing (in separate Winter Games). The 6 athletes with vision and intellectual impairments were all ambulatory (5 summer and 1 winter sport athletes).

Figure 2 Risk matrix depicting the relationship between incidence (number of health problems per athlete per year) and severity (average time loss per case in days) for the group of athletes with neurological (white symbols, N) and musculoskeletal impairments (black symbols, MSK), separately for illnesses (left panel) and injuries (right panel). All health problems with ≥5 cases and a burden of ≥1 day lost per year are visualized. The darker the background colour, the greater the burden. Isobars represent a burden of 1, 2 5 and 10 days per athlete year, respectively. Error bars represent 95% confidence intervals.

WHAT ARE THE NEW FINDINGS

- Illnesses represent a prevailing burden for elite Para athletes
- Compared to non-paraplegic athletes, paraplegic athletes had a higher prevalence of illness with respiratory tract and other infections and gastrointestinal problems predominant
- Musculoskeletal injuries generated a high burden for both athlete groups, in particular to the elbow, shoulder and lumbosacral regions (all athletes)

HOW MIGHT IT IMPACT ON CLINICAL PRACTICE IN THE FUTURE?

- Long-term health monitoring throughout an entire season provides valuable information for the athlete and his/her entourage to early identify health problems and enable guidance on season planning, treatment and prioritization of preventive strategies
- Our examples illustrate clinical benefits of a multidisciplinary approach on athlete health care
- Our findings can help guide the allocation of clinical resources, which should include a broad network of medical specialists, together with dieticians and physiotherapists

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.

FUNDING

The Norwegian Olympic and Paralympic team health monitoring program has been supported by a generous grant from Olympic Solidarity since 2016. The Norwegian Olympic Training Center (Olympiatoppen) also highly appreciate having received funding from Stiftelsen VI.

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

KS, HMB, BC and RB planned and designed the study, and all authors contributed to data collection and interpretation. HMB reviewed all diagnostic codes with input from HG. AKM followed up all the dietetical needs. KS analysed the data and drafted the paper with editorial input from HMB, BC and RB. All authors provided critical revisions and contributed to the final manuscript. KS and HMB are the guarantors.

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ACKNOWLEDGEMENTS

The authors acknowledge the supportive health personnel, coaches and management at Olympiatoppen, particularly Monica Viker Brekke and Berit Lian Berntzen. We also thank the athletes and team physiotherapists involved in data collection for their vital role in the success of this program.

The Oslo Sports Trauma Research Center has been established at the Norwegian School of Sport Sciences through generous grants from the Royal Norwegian Ministry of Culture, the

South-Eastern Norway Regional Health Authority, the International Olympic Committee, the Norwegian Olympic Committee & Confederation of Sport and Norsk Tipping AS.