Title: Olympic-career sports injuries and other health outcomes in 3,357 retired Olympians from 131 countries (competing London 1948 to PyeongChang 2018): a cross-sectional study

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**ABSTRACT**

Objective: To describe the prevalence and nature of Olympic-career injury, and general health, and current residual symptoms.

Methods: 3,357 retired Olympians from 131 countries completed a cross-sectional online survey, distributed by direct email through National Olympian Associations and World Olympians Association databases. Olympic sport exposure, significant training and competition injury history (lasting >1 month) and general health (e.g. depression) were recorded, including current residual musculoskeletal pain and functional limitations.

Results: 55% were men (44% women), representing 57 sports (42 summer, 15 winter), aged 44.7 years (range 16-97). 3,746 injuries were reported by 2,116 Olympians equating to 63.0% (women 68.1%, men 59.2%) reporting at least one significant injury during their Olympic career. Injury prevalence was highest in handball (82.2%), and lowest in shooting (40.0%) for summer Olympians, and highest in alpine skiing (82.4%) and lowest in biathlon (40.0%) for winter Olympians. The knee was most frequently injured (20.6%, 120 median days severity), followed by the lumbar spine (13.1%, 100 days) and shoulder/clavicle (12.9%, 92 days). 6.6% of Olympians said they had experienced depression during their career. One-third of retired Olympians reported current ongoing pain (32.4%) and functional limitations (35.9%).

Conclusions: Almost two-thirds of Olympians reported at least one Olympic-career significant injury with the knee, lumbar spine and shoulder/clavicle the most commonly injured anatomical locations. One-third of Olympians attributed current residual pain and functional limitations to Olympic-career injury. Further investigation of the risk factors associated with long-term musculoskeletal and general health outcomes for Olympians is needed.

244

**INTRODUCTION**

Elite athletes are cumulatively exposed to high physiological training and competition loads, including repeated mechanical stresses and impacts. [1, 2] While these loads and impacts can vary by sport, it is known that sport participation, in particular elite level participation, is associated with an increased risk of acute and overuse musculoskeletal injury. [3, 4, 5, 6] Sports injury prevention and the protection of athlete health is a key mandate for the World Olympians Association, International Olympic Committee and International Federations, [7, 8, 9] and there are numerous studies describing elite athlete injury patterns seasonally [10, 11, 12] and during major sporting events. [4, 5, 13, 14] However, little is known about injury and health patterns across an elite athlete’s entire sporting career.

While former elite athletes are generally reported to present a lower overall morbidity risk and better self-reported health in later years compared with the general population, [15, 16, 17] ongoing pain and musculoskeletal dysfunction from significant injuries are thought to be precursors to the development of longer-term issues such as osteoarthritis (OA). [18, 19, 20, 21] Increasing our understanding of the characteristics and aetiology of the injuries faced by athletes across the whole of their career will help inform strategies [22] aimed at mitigating the risk of injury and their long-term consequences. [23, 24, 25] Therefore, the aims of this study were to describe the prevalence and nature of Olympic-career related injuries, injury related residual symptoms and general health status, across an Olympian’s entire sporting career.

**METHODS**

This was a cross-sectional study collecting self-report data using an online questionnaire available in eight languages (English, French, German, Spanish, Russian, Chinese, Japanese and Korean). Data collection was conducted between April 2018 and February 2019, recruiting athletes who had participated in at least one summer and/or winter Olympic Games (Olympians), who were aged 16 years of age or older, and considered themselves retired from Olympic level training and competition.

**Implementation**

The survey was promoted to Olympians globally through World Olympians Association (WOA) and International Olympic Committee (IOC) communication platforms. Channels included the Olympic-athlete network Olympians.org, National Olympians Associations (NOAs), National Olympic Committees (NOCs), International Federations (IFs), Athlete 365 and the Olympic Studies Centre.  Study promotion asked Olympians who were interested in taking part in the survey and who considered themselves retired from Olympic participation to register with the World Olympians Association OLY database, if they were not already registered. Registration to the WOA database involves verification of each individual’s status as an Olympian. A password protected survey link was then sent by direct email to all Olympians on the database. Additionally, the WOA engaged with National Olympians Associations, who then also sent the survey by direct email to their countries Olympians.

Detailed study information, including information on data handling and confidentiality, was provided at the start of the survey. It was explicitly outlined that completion and submission of the questionnaire implied consent for the participants’ information to be used anonymously for the purposes of the study.

**Questionnaire survey**

The questionnaire was an online web-based survey hosted by SurveyMonkey©, containing four main sections 1) baseline demographics, 2) Olympic-career sport participation and injury history, 3) current musculoskeletal health, and, 4) current general health and quality of life.

Baseline questions requested Olympians demographics including age (years), sex, country of birth and country of residence. Current and previous height (cm) and weight (kgs) were collected to calculate current and Olympic-career body mass index (BMI kg/m2). Olympic sport participation included sport and Olympic Games participated in, country competed for, total years competing in sport, years of international participation (at senior level), and date of retirement from Olympic sport. Olympic-career related training and competition injury history questions were collected in line with recent International Olympic Committee injury surveillance methods and included anatomical location, injury type, severity, cause (acute vs overuse) and mechanism (e.g. contact with static object). [6, 26, 27] Pressure to return to sport during injury and current residual symptoms from injury (e.g., lasting pain, functional limitation) were also recorded. The presence of disease (e.g., depression, asthma) during an Olympian’s career was ascertained by asking ‘During your Olympic career did you ever suffer from any of the following diseases’.

**Definitions**

An individual’s Olympic-career was defined as the period of training and competition (e.g. preparation and qualification) from the lead up to their first Olympic Games until retirement following their last Olympic Games. The definition for a retired Olympian in this study was “an Olympian who considered themselves retired from Olympic competition (i.e., those who no longer intended to qualify for or compete at any upcoming summer or winter Olympic Games)” Significant “injury” was defined as ’any injury causing significant pain and/or dysfunction for a period of one month (or more) where ongoing sport participation during that time was disrupted’. Injuries lasting less than one month were not recorded. For the purposes of the present study only injuries occurring during training for or competition in their Olympic sport, during the athletes Olympic-career were included. Training referred to any/all conditioning activities in addition to Olympic sport-specific activities. Injury severity was defined by the estimated total number of days between the day of injury and the athletes return to full fitness/sport participation.

**Patient and public involvement**

A patient advisory group of nine retired Olympians provided input in the face validation of the questionnaire content and design. A draft form of the survey was piloted for question understanding and clarity, and overall questionnaire length and acceptability. At the end of the test period comments from the patient advisory group were incorporated into the final version of the survey.

**Ethics and confidentiality**

Ethical approval for the study was obtained from Edinburgh Napier University ethics committee (SAS/00011). No identifying parameters were recorded, and individual Olympians were not identifiable at any stage of the research. All data were treated confidentially, ensuring athlete anonymity at all times.

**Data analysis**

Descriptive statistics are presented as frequencies (proportion) for categorical variables, and mean and standard deviation, or median and range where data are not normally distributed, for numerical variables. For severity (days) median and mean are presented together, the latter to allow comparison to other studies. Injury prevalence was calculated dividing the number of injured athletes by the total number of athletes and presented as percentage (%) with 95% confidence intervals (CI). Prevalence ratios (PR) with 95% CI were reported between groups. Significant differences in values for numerical variables were analysed by t tests, or Mann-Whitney where appropriate, and comparisons between groups for categorical variables were conducted by ꭓ2 test. [28] Significance was accepted at p*<*0.05 (equal variances assumed).

**RESULTS**

**Olympian characteristics**

At the close of the survey there were 4,735 Olympian online survey entries. 1,388 ineligible (i.e., blank, incomplete, duplicate) entries were removed leaving 3,357 (70.9%) completed questionnaires for data analysis. Olympians completing the survey (55% men, 44% women, 1% (n=29) sex not reported) represented 131 countries and 57 Olympic Sports (42 summer, 15 winter). Respondents had a median age of 44.7 years (range; 16-97), mean 10.4 years (SD 5.6) of Olympic/International level participation (Table 1). Olympian participation spanned 36 summer and winter Olympic Games from London 1948 to PyeongChang 2018, with 61.0% of Olympians participating in one Olympic Games, 26.5% in two, and 11.9% competing in 3 to 6 Olympic Games.

Table 1. Olympian characteristics.

|  |  |  |  |
| --- | --- | --- | --- |
|  | women, n=1488 | men, n=1840 | all, n=3357\* |
| Anthropometrics |  |  |  |
|  Age (years), median (range) | 43.1 (16 to 94) | 47.9 (21 to 97) | 44.7 (16 to 97) |
|  Height (cm), mean (SD) | 167.9 (8.8) | 179.2 (11.6)† | 174.5 (11.8) |
|  Weight (kgs), mean (SD) | 67.7 (14.3) | 86.5 (15.8)† | 78.1 (17.8) |
|  Current BMI (kg/m2), mean (SD) | 24.1 (5.3) # | 27.0 (5.2)†# | 25.7 (5.4) |
|  Olympic career BMI (kg/m2), mean (SD) | 22.4 (4.7) | 24.7 (4.3)† | 23.7 (4.6) |
| Sport exposure |  |  |  |
|  Athletes by summer/winter sport, n (%) | 1264/224 | 1562/278 | 2851 (85%)/506 (15%) |
|  Number of all years doing Olympic sport, mean (SD) | 16.7 (6.2) | 17.7 (6.7) | 17.3 (6.60) |
|  Number of International years doing Olympic sport, mean (SD) | 9.9 (5.1) | 10.7 (5.9) | 10.4 (5.6) |
|  Number of years retired from Olympic participation, mean (SD) | 15.8 (13.3) | 20.3 (14.8) | 18.3 (14.3) |
| (\*n=29 sex unknown; †p=<0.05 men to women, # p=<0.05 Olympic career to current) |  |

**Injuries by sport**

There were 3,746 injuries reported by 2,116 Olympians equating to 63.0% [95% CI: 61.4-64.7] of Olympians reporting at least one significant Olympic-career related injury, with the prevalence of career injury significantly greater in women (68.1% [65.7-70.4]) than men (59.2% [57.0-61.5]; PR=1.15 [1.12-1.18]; p=<0.001). Overall, each Olympian reported a mean of 1.1 injuries (women 1.25, men 1.01) during their Olympic-career, with the majority of injuries 63.8% (n=2389) attributed to training (Table 2). Injury prevalence was lower for summer Olympians 62.0% [60.2-63.8] compared with winter Olympians 69.0% [64.9-73.0] (PR=0.90 [0.87-0.93]; p=<0.001). By sport, injury prevalence was highest in handball (82.2% [71.1-93.4]), badminton (78.4% [65.1-91.6]), judo (77.4% [68.9-85.9]), wrestling (73.1% [56.0-90.1]), athletics (72.2% [68.3-76.1]) and artistic gymnastics (71.1% [61.3-80.0]) for summer Olympians. For winter Olympians prevalence was highest for alpine skiing (82.4% [73.3-91.4]), freestyle skiing (81.6% [69.3-93.9]), snowboarding (77.3% [59.8-94.8]), short track speed skating (75.0% [60.9-89.1]), luge (74.4% [60.6-88.1]) and bobsleigh (69.7% [59.4-80.1]). Conversely, injury prevalence was lowest for shooting (40.0% [27.6-52.4]) and swimming (48.5% [44.1-52.8]), and biathlon (40.0% [22.5-57.5]) and curling (54.3% [37.8-70.8]) for summer and winter Olympians, respectively (sports with n≥20 participants). By decade of Olympic Games participation injury prevalence for summer and winter Olympians steadily increased 25.9% to 65.7% and 33.3% to 75.4% (respectively) between the 1950s and 2010s (Figure 1).

Table 2. Injuries by sport.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | athletes (n; w/m) | Injuries (n) | c / t / u (%) | Injuries per athlete (mean n) | Injured athletes (n; w/m) | Injury prevalence(95%CI) |
| **Summer Sports** |  |  |  |  |  |
| Archery | 42 (15/27) | 34 | 2.9, 88.3, 8.8 | 0.81 | 24 (11/13) | 57.1% (42.2 to 72.1) |
| Athletics | 507\* (203/298) | 640 | 25.6 / 63.1 / 11.3 | 1.26 | 366\* (153/210) | 72.2% (68.3 to 76.1) |
| Aquatics |  |  |  |  |  |  |
|  Diving | 67\* (37/28) | 78 | 17.9 / 71.8 / 10.3 | 1.16 | 45 (24/21) | 67.2% (56.0 to 78.4) |
|  Swimming | 497\* (235/255) | 345 | 10.4 / 76.5 / 13.1 | 0.69 | 241\* (119/119) | 48.5% (44.1 to 52.8) |
|  Synchronised swimming | 67 (67/0) | 66 | 9.1 / 83.3 / 7.6 | 0.99 | 44 (44/0) | 65.7% (54.3 to 77.0) |
| Badminton | 37 (16/21) | 48 | 29.2 / 56.2 / 14.6 | 1.30 | 29 (13/16) | 78.4% (65.1 to 91.6) |
| Baseball | 12 (0/12) | 18 | 61.1 / 22.2 / 16.7 | 1.50 | 10 (0/10) | **-** |
| Basketball | 47 (31/16) | 61 | 50.8 / 41 / 8.2 | 1.30 | 32 (21/11) | 68.1% (54.8 to 81.4) |
| Beach volleyball | 19 (12/7) | 36 | 52.8 / 36.1 / 11.1 | 1.89 | 18 (12/6) | **-** |
| Boxing | 23 (2/21) | 24 | 25 / 66.7 / 8.3 | 1.04 | 15 (1/14) | 65.2% (45.8 to 84.7) |
| Canoe slalom | 19 (2/17) | 21 | 9.5 / 85.7 / 4.8 | 1.11 | 12 (2/10) |  |
| Canoe sprint | 81 (37/44) | 67 | 1.5 / 92.5 / 6 | 0.83 | 43 (21/22) | 53.1% (42.2 to 64.0) |
| Cycling |  |  |  |  |  |  |
|  BMX | 1 (0/1) | 1 | 100 / 0 / 0 | 1.00 | 1 (0/1) | **-** |
|  MTB | 4 (3/1) | 7 | 42.9 / 57.1 / 0 | 1.75 | 4 (3/1) | **-** |
|  Road | 40 (19/21) | 27 | 51.9 / 44.4 / 3.7 | 0.68 | 21 (10/11) | 52.5% (37.0 to 68.0) |
|  Track | 34 (7/27) | 39 | 66.7 / 30.8 / 2.5 | 1.15 | 21 (6/15) | 61.8% (45.4 to 78.1) |
| Equestrian | 8 (4/4) | 11 | 54.5 / 18.2 / 27.3 | 1.38 | 5 (3/2) | - |
| Fencing | 67\* (19/ 47) | 67 | 38.8 / 52.2 / 9 | 1.00 | 44\* (13/30) | 65.7% (54.3 to 77.0) |
| Football | 12 (7/5) | 14 | 35.7 / 35.7 / 28.6 | 1.17 | 8 (6/2) | **-** |
| Gymnastics |  |  |  |  |  |
|  Artistic | 83 (55/28) | 142 | 22.5 / 68.3 / 9.2 | 1.71 | 59 (42/17) | 71.1% (61.3 to 80.0) |
|  Rhythmic | 29 (29/0) | 41 | 7.3 / 90.2 / 2.5 | 1.41 | 20 (20/0) | 69.0% (52.1 to 85.8) |
|  Trampoline | 5 (1/4) | 6 | 16.7 / 83.3 / 0 | 1.20 | 5 (1/4) | **-** |
| Handball | 45 (17/28) | 74 | 47.3 / 45.9 / 6.8 | 1.64 | 37 (14/23) | 82.2% (71.1 to 93.4) |
| Hockey | 138\* (56/81) | 154 | 48.1 / 46.1 / 5.8 | 1.12 | 88 (37/51) | 64.2% (50.2 to 78.2) |
| Judo | 93 (32/61) | 175 | 34.9 / 54.9 / 10.2 | 1.88 | 72 (25/47) | 77.4% (68.9 to 85.9) |
| Modern pentathlon | 35 (4/31) | 40 | 30 / 55 / 15 | 1.14 | 23 (4/19) | 65.7% (50.0 to 81.4) |
| Rowing | 341\* (137/200) | 296 | 5.4 / 86.5 / 8.1 | 0.87 | 191\* (95/94) | 56.0% (50.7 to 61.3) |
| Rugby 7s | 17\* (12/4) | 27 | 51.9 / 40.7 / 7.4 | 1.59 | 10\* (7/2) | **-** |
| Sailing | 131 (53/78) | 113 | 31.9 / 56.6 / 11.5 | 0.86 | 75 (38/37) | 57.3% (48.8 to 65.7) |
| Shooting | 60 (22/38) | 37 | 5.4 / 73 / 21.6 | 0.62 | 24 (9/15) | 40.0% (27.6 to 52.4) |
| Softball | 13 (13/0) | 18 | 50 / 44.4 / 5.6 | 1.38 | 11 (11/0) | **-** |
| Table tennis | 17 (10/7) | 15 | 40 / 60 / 0 | 0.88 | 8 (6/2) | **-** |
| Taekwondo | 36 (21/15) | 50 | 36 / 50 / 14 | 1.39 | 24 (13/11) | 66.7% (51.3 to 82.1) |
| Tennis | 8 (8/0) | 10 | 20 / 60 / 20 | 1.25 | 6 (6/0) | **-** |
| Triathlon | 19 (10/9) | 35 | 14.3 / 68.6 / 17.1 | 1.84 | 16 (8/8) | **-** |
| Volleyball | 48\* (25/21) | 79 | 30.4 / 58.2 / 11.4 | 1.65 | 33\* (19/13) | 68.8% (55.6 to 81.9) |
| Water polo | 46 (13/33) | 49 | 38.8 / 49 / 12.2 | 1.07 | 26 (10/16) | 56.5% (42.2 to 70.8) |
| Weightlifting | 28 (9/19) | 41 | 34.1 / 61 / 4.9 | 1.46 | 18 (8/10) | 64.3% (46.5 to 82.0) |
| Wrestling | 26 (5/21) | 49 | 20.4 / 71.4 / 8.2 | 1.88 | 19 (4/15) | 73.1% (56.0 to 90.1) |
| Unknown/other\*\* | 49 (16/33) | 30 | 41.9 / 51.6 / 6.5 | 0.61 | 19 (9/10) | 38.8% (25.1 to 52.4) |
| Total summer sports | 2850\* (1264/1562) | 3085 | 25.6 / 64.3 / 10.1 | 1.08 | 1767\* (850/907) | 62.0% (60.2 to 63.8) |
|  |  |  |  |  |  |  |
| **Winter sports** |   |  |  |  |  |  |
| Alpine skiing | 68\* (39/28) | 128 | 42.2 / 50 / 7.8 | 1.88 | 56\* (31/24) | 82.4% (73.3 to 91.4) |
| Biathlon | 30 (15/15) | 13 | 23.1 / 76.9 / 0 | 0.43 | 12 (9/3) | 40.0% (22.5 to 57.5) |
| Bobsleigh | 76 (12/64) | 80 | 22.5 / 70 / 7.5 | 1.05 | 53 (10/43) | 69.7% (59.4 to 80.1) |
| Cross country skiing | 30 (17/13) | 27 | 11.1 / 88.9 / 0 | 0.90 | 18 (14/4) | 60.0% (42.5 to 77.5) |
| Curling | 35 (14/21) | 22 | 50 / 40.9 / 9.1 | 0.63 | 19 (7/12) | 54.3% (37.8 to 70.8) |
| Figure skating | 39 (18/21) | 47 | 19.2 / 72.3 / 8.5 | 1.21 | 26 (10/16) | 66.7% (51.9 to 81.5) |
| Freestyle skiing | 38\* (22/15) | 80 | 38.8 / 58.7 / 2.5 | 2.11 | 31 (20/11) | 81.6% (69.3 to 93.9) |
| Ice hockey | 22 (13/9) | 33 | 81.8 / 15.2 / 3 | 1.50 | 15 (7/8) | 68.2% (48.7 to 87.6) |
| Long track speed skating | 34 (17/17) | 31 | 6.5 / 77.4 / 16.1 | 0.91 | 20 (11/9) | 58.8% (42.3 to 75.4) |
| Luge | 39\* (13/25) | 58 | 22.4 / 69 / 8.6 | 1.49 | 29 (10/19) | 74.4% (60.6 to 88.1) |
| Nordic combined | 6 (0/6) | 10 | 20 / 60 / 20 | 1.67 | 4 (0/4) | - |
| Short track speed skating | 36 (17/19) | 50 | 32 / 66 / 2 | 1.39 | 27 (12/15) | 75.0% (60.9 to 89.1) |
| Skeleton | 12\* (5/6) | 19 | 21.1 / 68.4 / 10.5 | 1.58 | 10\* (4/5) | - |
| Ski jumping | 15 (4/11) | 17 | 5.9 / 82.3 / 11.8 | 1.13 | 9 (3/6) | - |
| Snowboarding | 22 (15/7) | 39 | 33.3 / 59 / 7.7 | 1.77 | 17 (13/4) | 77.3% (59.8 to 94.8) |
| Unknown | 4 (3/1) | 7 | 28.6 / 71.4 / 0 | 1.75 | 3 (3/0) | - |
| Total winter sports | 506\* (224/278) | 661 | 31.6 / 61.6 / 6.8 | 1.31 | 349\* (164/183) | 69.0% (64.9 to 73.0) |
| **Overall Total** | **3357\* (1488/1840)** | **3746** | **26.7 / 63.8 / 9.5** | **1.12** | **2116\* (1013/1090)** | **63.0%** (61.4 to 64.7) |
| (\*sex unknown; \*\*other includes – golf athlete n=1; c=competition injuries, t=training injuries, u=unknown; CI=confidence intervals; prevalence not reported for sports with <20 Olympians) |
| \*\*insert figure 1\*\* |

**Injuries by location, type and cause**

Injuries most frequently affected the knee (20.6% of all injuries, median severity 120 days (mean 197 days)), lumbar spine (13.1%, 100 days (mean 227 days)), and shoulder/ clavicle (12.9%, 92 days (mean 180 days)). The most common injury types were fracture (12.0%, 60 days (mean 111 days)), strain/muscle rupture/tear (11.9%, 70 days (mean 158 days)) and ligament rupture (10.4%, 180 days (mean 186 days)). By specific diagnosis knee lesion of meniscus/cartilage (24.6% of all knee injuries, 100 days (mean 199 days)), knee ligament rupture (19.6%, 180 days (mean 194 days)), lumbar spine nerve/spinal cord (16.2% of all lumbar spine, 150 days (mean 231 days)), shoulder dislocation/subluxation (15.1% of all shoulder, 100 days (median 184 days)), and thigh muscle strain/rupture/tear (49.3% of all thigh, 60 days (mean 126 days)) were predominant. These patterns were similar for both summer and winter Olympians. Of all lumbar spine injuries 65.6% were reported to be recurrent in nature, shoulder/clavicle injuries 52.7% and knee injuries 46.6%.

The majority of injuries were acute in nature accounting for 75.8% and 82.3% of all injuries for summer and winter Olympians (respectively), with overuse reported as the cause of injury for the remainder. The most common reported injury mechanisms were overuse gradual onset (41.4%), overuse sudden onset (23.5%) and non-contact trauma (14.5%) for summer Olympians, and contact: stagnant object (29.8%), overuse gradual onset (26.5%) and overuse sudden onset (19.8%) for winter Olympians.

**Returning from injury**

During injury, 23.6% [21.3-25.8] of Olympians reported continuing all training/competition activities with performance decline. A fifth (21.6% [19.4-23.8]) of Olympians reported that they stopped all training/competition and performed rehabilitation exercises, and allowed the injury to fully heal (19.1% [17.0-21.2]) (Table 3).

Table 3. Olympian behaviours during injury.

|  |  |  |
| --- | --- | --- |
|  | athletes(n) | % of all athletes (95% CI) |
| Continued all training/competition with injury (with performance decline) | 791 | 23.6 (21.3 to 25.8) |
| Continued training but avoided some activities to off-load injured area | 775 | 23.1 (20.9 to 25.3) |
| Continued training but changed mode of training to off-load injured area | 610 | 18.2 (16.1 to 20.2) |
| Continued all training/competition with injury (without performance decline) | 505 | 15.0 (13.2 to 16.9) |
| Stopped all training/competition but did rehabilitation exercises for injury | 725 | 21.6 (19.4 to 23.8) |
| Stopped all training/competition completely to allow injury to fully heal | 641 | 19.1 (17.0 to 21.2) |

(multiple option selection, per injury and per athlete across different injuries, permitted)

One third (29.3% [27.8-30.9]) of Olympians reported that they continued to compete and/or train using painkillers and 40.7% [39.0-42.3] reported that they competed/trained using non-steroidal anti-inflammatory drugs (NSAID). 11.1% competed/trained using a steroid injection and 11.5% a local pain killing injection, for their injury.

When experiencing an injury 75.5% of Olympians indicated they put pressure on themselves to return to sport as quickly as possible. This was followed by pressure felt from coaches (33.6%), sport governing body (15.5%) and teammates (13.6%) (Figure 2).

\*\*insert figure 2\*\*

**Olympic career health, and residual symptoms**

The prevalence of depression reported by Olympians during their career was 6.6%, and this increased to 9.5% on retirement. Of those reporting depression during their career, 83.7% also reported sustaining a significant injury (88.3% women, 77.8% men), compared with 16.4% reporting no injury. Asthma prevalence was 8.3% (triathlon 26.3%; cross country skiing 20.0%, long track speed skating 17.6%), and regular painkiller and NSAID use during an Olympians career 16.7% and 29.8%, respectively. Overall, the prevalence of health issues e.g. depression during Olympic career (PR=2.09 [1.96-2.23]; p=<0.001), asthma (PR=2.10 [1.98-2.22]; p=<0.001), and painkiller use (PR=1.31 [1.23-1.39]; p=<0.001) were significantly higher in women compared with men (Table 4). A third of Olympians reported current, ongoing pain (32.4% [30.8-34.0]) and functional limitation (35.9% [34.2-37.5]) attributed to significant injuries sustained during their Olympic career, with the prevalence of pain higher for women compared with men (PR=1.33 [1.28-1.38]; p=<0.05). Injuries to the knee, lumbar spine, shoulder/clavicle and ankle were most commonly associated with ongoing symptoms.

Table 4. Health during Olympic career, and residual symptoms.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | women (n) | Prevalence % (95% CI) | men (n) | Prevalence % (95% CI) | all (n) | Overall prevalence % (95% CI) |
| Depression during Olympic career | 137 | 9.2 (7.7 to 10.7) | 81 | 4.4 (3.5 to 5.3) † |  221\* | 6.6 (5.7 to 7.4) |
| Depression on retirement from Olympic career | 190 | 12.8 (11.1 to 14.5) | 127 | 6.9 (5.7 to 8.1) † | 317 | 9.5 (8.5 to 10.4) |
| Asthma | 175 | 11.8 (10.1 to 13.4) | 103 | 5.6 (4.5 to 6.6) † |  280\* | 8.3 (7.4 to 9.3) |
| Other heart problems e.g. arrhythmia | 33 | 2.2 (1.5 to 3.0) | 23 | 1.3 (0.7 to 1.8) |  57\* | 1.7 (1.3 to 2.1) |
| Regular painkiller use during career | 286 | 19.2 (17.2 to 21.2) | 269 | 14.6 (13.0 to 16.2) † |  561\* | 16.7 (15.4 to 18.0) |
| Regular NSAIDS use during career | 513 | 34.5 (32.1 to 36.9) | 488 | 26.5 (24.5 to 28.5) † |  1001\* | 29.8 (28.3 to 31.4) |
| Current pain from Olympic-career injuries | 560 | 37.6 (35.2 to 40.1) | 520 | 28.3 (26.2 to 30.3) † |  1087\* | 32.4 (30.8 to 34.0) |
| Current functional limitation from Olympic-career injuries | 595 | 40.0 (37.5 to 42.5) | 603 | 32.7 (30.6 to 34.9) |  1204\* | 35.9 (34.2 to 37.5) |
| (\*some sex data unknown; p=<0.05 †men to women) |  |  |  |  |  |  |

**DISCUSSION**

This is the first worldwide study reporting injury epidemiology spanning the entire sporting career of Olympians. The aims were to describe the prevalence and nature of sport related significant injuries, including residual symptoms and general health, across the career of Olympic athletes. The main findings were 1) 63% of retired Olympians reported having had at least one Olympic-career injury which equated to a mean 1.1 injuries per Olympian over 10.4 years participation; 2) the knee, lumbar spine and shoulder/clavicle were the most frequently injured, 3) career-depression prevalence was higher in those with injury compared to those without, and 4) one-third of Olympians reported current, ongoing pain and functional limitation attributed to injuries sustained during their Olympic career.

**Olympic career injury**

To date there is only one other cross-sectional study available on whole-career injuries in Olympians. Compared with Great Britain Olympians (D. Cooper Doctoral thesis, 2016, unpublished data) the prevalence of injury within the present study (63%) was higher than that found by Cooper (52%), where a similar injury definition was used. The difference in rate of injury may reflect regional variations, differences in the length and level of exposure to high-level sport and the length of recall. [29] In the present study Olympians reported on average 10.4 years of Olympic/International level competition, compared with 9.2 years of Olympic/International and National level competition in the GB study. Also, Olympians were retired 18.3 years versus 30.5 years (respectively) meaning a longer period from which to remember (or forget) significant injuries during their sporting career in the GB study. In contrast, the number of injuries *per Olympian* in the present study (1.1 injuries) was lower compared with the latter study whereby they reported 2.0 injuries per athlete. In agreement with the GB study female Olympians had a higher prevalence of injury than male Olympians.

There was no evidence in the present study to explain why female Olympian injury rates were higher overall, and there were no differences observed across Olympic sports between male and female athletes other than in rowing and sailing. In Rio 2016 and PyeongChang 2018 there were no differences observed in the rates of injury between men and women, with significant differences observed in only a handful of sports e.g. sailing, shooting and mountain biking and luge and ice hockey. [26, 14] The present study findings may simply represent self-report bias whereby more females with injury completed the survey, however, in the event true differences exist for example by sport, further investigation may also be warranted.

The prevalence of injury was highest for handball, badminton, judo and wrestling for summer Olympians and alpine skiing, freestyle skiing and snowboarding for winter Olympians. Conversely, the lowest injury rates were recorded for shooting and swimming for summer Olympians and biathlon and curling for winter Olympians. These findings are similar to previous prospective Olympic surveillance studies. In London 2012 handball and badminton were among the sports with the highest injury rates. [5] Although in Rio 2016 rates were seen to decrease for these sports they remained in the top half for injury incidence. [26] Badminton, handball [5] and wrestling [26] also presented the highest rates of more severe injuries (>7 days absence), in London and Rio. Consistently, shooting and swimming presented the lowest prevalence during both studies. In Sochi 2014 and PyeongChang 2018 alpine skiing, freestyle skiing disciplines and snowboarding disciplines presented the highest winter sport injury rates while again biathlon and curling were amongst the lowest. [6, 14] Snowboard cross, ski cross and snowboard slopestyle also presented the most number of severe injuries (>7 days absence) of all sports. [6, 14] The risk of injury across different sports is understood to be influenced by a number of factors, and frequent events such as player to player contact (i.e. during handball, judo, and wrestling), [30, 26] or a combination of factors such as speed and jumps leading to falls and crashes (i.e. during alpine and freestyle skiing and snowboarding) [31, 32, 33, 34, 14] have been reported to increase the rate and severity of athlete injury. These high speeds, jumps and contact events characterised in a large proportion of winter sport disciplines may explain the higher prevalence of injury reported by winter compared with summer Olympians. It is important to remain cognisant of the effect that differences in both recording methodology and injury definitions may have when comparing results. For example, a broad medical attention definition in the Olympic surveillance studies permits recording of more frequent, minor injuries compared with the present study significant injury definition. Hence, sports with more frequent, but less severe injuries such as abrasions, contusions and lacerations may present with a higher injury prevalence in the latter studies. Additionally, Olympian numbers in some sports in the current study were too low to provide a reasonable measure of prevalence in previously reported higher risk sports e.g. BMX.

The knee, followed by the lumbar spine and then shoulder/clavicle were the three most common injury locations and fracture, strain/muscle rupture/tear and ligament rupture the most frequent injury types. These findings are consistent with those of previous studies showing the knee, lumbar spine and shoulder most commonly injured in current [35] and retired (D. Cooper Doctoral thesis, 2016, unpublished data) Great Britain athletes, and similar to Olympic Games surveillance studies where knee, and sprain/ligament rupture injuries were most prevalent. [26, 14]

Focussing evidence informed prevention initiatives on sports that pose a higher risk for injury, the mechanisms involved and/or around targeted injury locations and types may help to lower the short-term risk for injury in both current and future Olympians.

**Olympic-career health**

In addition to injury, Olympians answered questions on key health indicators during their Olympic career. Overall, 6.6% reported experiencing depression at some point during their Olympic-career and this increased to 9.5% on retirement from their sport. The prevalence of depression in Olympians in the present study is not directly comparable to other studies due to the time period of measurement (10.4 years), however the rate overall is low when compared with the 15%-21% previously reported over one season in college athletes, [36, 37] and compared with one year (6.7%) within the general population. [38, 39] Depression may present as a post-injury sequela in athletes [40, 41] and the present results confirm this finding where 83.7% of those reporting depression also reported injury during their career. Similar to other athlete studies [42, 36] and that found within the general population, [38] female Olympians reported higher rates of depression compared with male Olympians. This was consistent during their career, perhaps mediated by a higher injury prevalence, and on retirement. Retirement from sport marks a period of major life transition for elite athletes. Findings in this study agree with previous research on career termination and depression whereby retirement may precipitate behavioural and emotional difficulties in some athletes, and an increase in occurrence of depression and anxiety. [43, 44, 45] In a study by Wippert and Wippert (2010), the authors concluded that the manner in which retirement occurred (e.g. planned versus involuntary retirement) may also influence the magnitude of depression symptomatology. [45]

Olympians report regularly using non-steroidal anti-inflammatories (NSAIDs, 29.8%) and painkillers (opiods) (16.7%) during their Olympic careers with the use of NSAIDs most predominant. This supports previous findings of their widespread use in elite athletes from football, [46] triathlon, [47] American collegiate sports [48] and during major games events. [49] The use of painkillers by athletes has the potential to worsen injury due to the inhibition of the pain response and/or inflammatory process, [50] and NSAID use in athletes has been linked to a five times higher incidence of adverse events e.g. gastrointestinal cramps and bleeding, haematuria and cardiovascular events, such as arrhythmia and palpitations. [51] Additionally, longer term use has been shown to decrease protein synthesis in muscle after exercise, and increase the risk for small intestine mucosal injury. [52, 53] Hence, their continued use and reliance by athletes remains of concern.

Athletes in the present study reported feeling pressure to return to sport and continuing to train and compete whilst injured. Continuing to train and compete with underlying health problems is not new in elite sport, [54] and it is often associated with painkiller and NSAID use, disregard of medical advice and hiding symptoms from others. [55, 56] Athletes who perceive more social pressure to compete hurt are likely to be more rest-averse. [54] An athletes behaviour during injury and the concept of ‘playing hurt’ [56, 55] has an impact on recovery, where short term symptoms and outcomes for injury may be exacerbated, and longer term consequences of injury such as irreversible tissue damage, and the development of recurrent and chronic injury more frequently occur. [15]

**Residual symptoms**

A third of retired Olympians attributed current, ongoing pain and functional limitation to injuries they sustained during their Olympic career. This suggests that there may be longer-term musculoskeletal consequences related to some sport-related injuries and the knee, lumbar spine, shoulder/clavicle and ankle were the most common locations for both past injury and for ongoing current symptoms. It is known that significant joint injury is a risk factor for the development of osteoarthritis (OA), and there is an emerging body of evidence in retired athletes from football, [57, 58, 59] Rugby Union, [60] and most recently Olympic sports [25] reporting an association between joint injury and ongoing pain, and the development and progression of OA. During acute injury direct joint tissue damage may result in initial injury related pain. If damage to the joint structures is sufficient e.g. damage to cartilage and/or subchondral bone, this may result in degenerative changes. In addition to direct joint damage, damage to the surrounding structures may also lead to changes in biomechanics, resulting in uneven or altered distribution of load. [18] It is this resulting, repeated abnormal loading, mal-alignment and instability which is thought to lead to asymmetrical joint wear patterns, ongoing/increasing dysfunction and pain and the development of osteoarthritis.[18, 20] Poor musculoskeletal health in retired elite athletes may impact on their future general health and their ability to continue to pursue an active lifestyle in later life. Hence, if it is possible to improve treatment guidelines and recommendations, and provide evidence-based interventions during the very early, dynamic post injury phase there is potential to limit the degree of acute joint damage and to delay the onset and/or reduce the severity of ongoing symptoms and OA.[61, 62]

Alongside injury, age, sex and obesity [63, 64, 65] are additional well known risk factors for the development of OA. Going forwards it may be important to understand how changes in body composition (e.g. increasing BMI) in retired elite athletes may also influence longer-term musculoskeletal health outcomes.

**Strengths and limitations**

This is the first Worldwide large-scale study surveying injuries in retired Olympians including retired athletes from 131 countries, 57 summer and winter Olympic sports and a range of elite sport eras spanning 36 summer and winter Olympic Games from London 1948 to PyeongChang 2018. The study also includes indices related to behaviours during recovery from injury e.g. what athletes did, and what pressures they felt which is unique compared to previous regional surveys. In addition, measures of health status provide information on Olympian general health during their Olympic-career, and early information on the consequences with respect to Olympic-career injury such as residual symptoms of pain and functional limitations.

It is recognised that this cross-sectional study may be limited by recall bias, given the range of ages and number of years retired, particularly regarding injury history for older Olympians (the oldest Olympian was 97 years). To mitigate some recall bias a significant, a one-month, injury definition was used whereby Olympians were asked to recall only significant injuries they had sustained i.e. injuries they were more likely to remember. Because minor injuries were not recorded due to the definition used, a consequence is an inflation of the reported mean severity of injuries, meaning the present study may not reflect the true severity rate related to certain sports and/or body locations. Overall, it is important to consider this injury definition when both reporting and comparing injury rates and severity with other studies. There is an inherent self-selection bias in the study cohort, whereby Olympians who have a significant injury history may have had a greater propensity to participate and complete the survey. A prize draw was included as part of the study in an effort to incentivise those less inclined to participate, to provide a broader demographic. Finally, the present descriptive study does not provide direct causal association, and some inferences should be made with caution. Further detailed risk factor analyses are recommended.

**CONCLUSION**

In summary, 63% of retired Olympians reported experiencing a significant injury during their Olympic career, although overall the rate per Olympian was low (1.1 Olympic-career injuries). Career-injury prevalence varied by sport, and overall the knee, lumbar spine and shoulder/clavicle were the most commonly affected locations. Olympians reporting injury also reported a higher prevalence of depression during their Olympic careers. Finally, a third of retired Olympians attributed ongoing pain and functional limitation as a direct result of injuries sustained, and hence it is clear there are some long-term consequences with respect to Olympic-career injuries.

Injury reduction initiatives during an elite athlete’s career should be tailored with attention paid to high risk sports, and specific injuries and their mechanisms. Further investigation on the magnitude of and risk factors associated with long-term musculoskeletal and general health outcomes for Olympians, and how these compare with the general population, are also needed.

What are the new findings?

* Overall, 63% of retired Olympians reported at least one Olympic-career related significant injury, equating 1.1 injuries per 10.4 years participation
* Three quarters of Olympians put pressure on themselves to return to sport and a quarter continued train/compete, while injured
* A third of Olympians experience current, ongoing pain and functional limitation attributed to an Olympic-career injury

How might it impact on clinical practice in the future?

* New knowledge on Olympic-career injury prevalence and nature by sport may help to inform targeted acute injury prevention initiatives for current Olympians
* Identification of the magnitude of and risk factors associated with longer-term consequences of Olympic-career injury are needed in order to help mitigate risk and protect the mobility and health of Olympians in later life

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