Musculoskeletal injury in military Special Operations Forces: a systematic review

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ABSTRACT

Introduction Special Operations Forces conduct military activities using specialised and unconventional techniques that offer a unique and complementary capability to conventional forces. These activities expose Special Operations Forces personnel to different injury risks in comparison with personnel in the conventional forces. Consequently, different injury patterns are expected in this population. The purpose of this research is to establish high-level evidence informing what is known about musculoskeletal injury epidemiology in Special Operations Forces.

Methods A systematic review was conducted using three online databases to identify original studies reporting musculoskeletal injury data in Special Operations Forces. A critical appraisal tool was applied to all included studies. Descriptive data were extracted for demographics, study design details and injuries (eg, injury frequency, injury type, body part injured, activity, mechanism, severity). Results were narratively synthesised.

Results Twenty-one studies were included. Trainees conducting qualification training had the highest injury frequency, up to 68% injured in a training period. The ankle, knee and lumbar spine were the most common body parts affected. Parachuting caused the most severe injuries. Physical training was the most common activity causing injury, accounting for up to 80% of injuries. Running and lifting were common injury mechanisms. Injury causation information was frequently not reported. Partially validated surveillance methods limited many studies.

Conclusions Injuries are prevalent in Special Operation Forces. Future research should prioritise identifying injury causation information that supports prevention. Focus on improving surveillance methods to enhance the accuracy and comparison of results across cohorts is also recommended.

Key messages

- ► Musculoskeletal injuries are prevalent across all Special Operations Forces (SOF) populations.
- ► SOF trainees are a priority for injury prevention measures.
- ► Physical training is the most commonly known injury cause.
- ► Static-line parachuting causes the most severe injuries.
- ► Current injury surveillance methods are inconsistent, are likely to underestimate the burden of injury and lack sufficient detail to direct prevention planning.

INTRODUCTION

Special Operations Forces (SOF) are military units which are specially designated and equipped to conduct military activities using unconventional techniques and employment modes.[1] Special Operations Forces perform strategic tasks in high-risk environments using clandestine techniques, such as special reconnaissance and precision strike operations.[1] In doing so, SOF provides a unique capability that is complementary to the capabilities of conventional forces. The activities undertaken by SOF are often physically arduous, such as open water swimming, airborne operations, small squad raids and prolonged exposure to load carriage.[2] Subsequently, due to the nature of these activities, SOF personnel are exposed to different injury risks in comparison with conventional forces personnel. Consequently, different musculoskeletal injury patterns and different requirements to prevent injury in this population are expected.

Understanding injury epidemiology is essential in working towards strategic injury reduction to preserve military capability.[3 4] While there is a growing body of epidemiological evidence drawing attention to the existing injury problems in conventional forces, by comparison, far less is known about injury epidemiology in SOF.[5–9] It is important to distinguish the epidemiology of injuries in SOF to identify the aetiological risks that are representative of this population. With epidemiology evidence, prevention programmes can be prioritised, and interventions can be explicitly designed to protect the health of SOF personnel.[3 4]

Currently, there is no high-level evidence analysing injury epidemiology in SOF populations. The purpose of this study is to establish high-level evidence informing what is currently known about musculoskeletal injury epidemiology in SOF populations. The findings are important to monitor health problems and to generate information for prevention planning.[10]

METHODS

Protocol and registration

This systematic review is reported following the Preferred Reporting Items for Systematic reviews and Meta-Analyses (PRISMA).[11] The PRISMA flowchart is depicted in Figure 1.[11] The systematic review was registered on the international prospective register of systematic reviews (CRD42020159639).[12]

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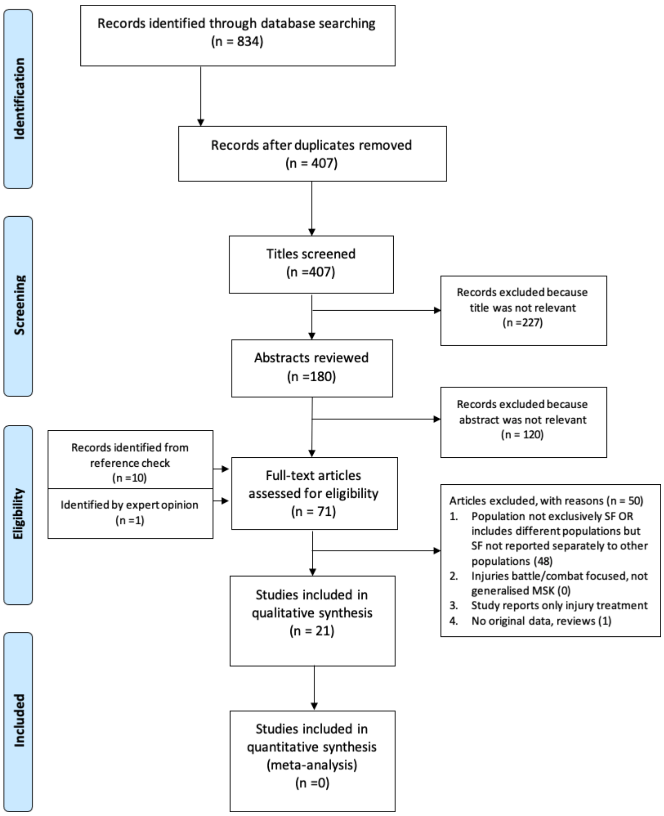

Figure 1 PRISMA protocol flowchart demonstrating the flow of information through each phase of the systematic review.

Search strategy

The search for peer-reviewed publications was conducted in December 2019 through online databases PubMed, Medline and Cumulative Index of Nursing and Allied Health Literature (CINAHL). A predefined search strategy was developed using musculoskeletal injury and SOF military-related keywords (online supplemental appendix A).

Study selection

Following the removal of duplicates, all articles from the initial search strategy were screened for suitability according to the pre-established eligibility criteria (Table 1). Two reviewers independently screened all articles' titles and abstracts. Where the reviewers disagreed, the article was retained for full-text review. One reviewer screened the references of all remaining articles, and if a reference was considered relevant, the study was included for further screening. The full texts of all remaining articles were reviewed, and those eligible were retained for analysis.

Table 1 Article inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Conducted in Special Operations Forces military populations	Studies where data included other military services, for example, support staff
Musculoskeletal injuries reported	Traumatic battle-related injuries
Report injury data with an epidemiological focus, such as the no of injuries and types of injuries	Studies that only report treatment of injuries
Peer-reviewed publications with original data collected	Study designs without original data collection
Published in English	Written in languages other than English

Risk of bias in individual studies

In the absence of a gold standard appraisal tool for injury epidemiology research, three tools recommended by the Cochrane Collaboration were trialled against similar, but not included, studies.[13–16] From this exercise, the 'Risk of Bias' (RoB) tool was deemed most applicable.[14] Minor tool modifications were made to improve the suitability to a military context (online supplemental appendix B). The modified RoB tool was applied to all studies independently by two reviewers, with deliberation on the results. A third independent reviewer moderated for selected articles when there was a discrepancy.

Data extraction

One reviewer independently extracted data from the included studies based on predetermined variables. A second reviewer confirmed all data output. Descriptive data were extracted for demographics, study design details and injuries (injury frequency, injury type, body part injured, activity, mechanism, severity). In the instances where many results were reported, such as injury classification by body part, injury type and the activity causing injury, the top three results by percentage were extracted. Results were summarised as a narrative synthesis.

RESULTS

Study selection

The initial search yielded 834 articles, from which 60 titles/abstracts were considered relevant, as seen in the PRISMA flow chart (Figure 1). A further 10 titles were identified from reference screening these 60 articles. One additional text was identified by a content expert.[17] Following a full-text review, 21 studies were retained for analysis.[17–37] The main reason for study exclusion was due to other occupation types in the sample population, and the results were not reported separately to provide data exclusive to a SOF population.

Risk of bias

Table 2 presents the critical appraisal of the studies. A third reviewer was required to appraise seven articles due to unclear reporting of study methods. Many studies had sampling bias, used partially validated surveillance methods and had incomplete reporting.

Study and demographic data

Fourteen studies were descriptive epidemiological designs, and seven were analytical study designs (Table 3). Most of the studies were Army affiliated (n=11, 52.4%) followed by Navy (n=5, 23.8%), Marine (n=2, 9.5%) and Airforce (n=1, 4.8%). Two studies did not specify a name to identify a SOF component or an associated military service other than being SOF.[27 32] Eighteen of the 21 studies were from the USA. The remaining studies were from Belgium, the Netherlands and Australia.[17 18 26]

Table 4 identifies the demographic data extracted from individual studies. Seventeen studies included fully qualified personnel and four studies involved trainees completing qualification training. Seven studies reported on sex within the sample population of which all were male-only. Two studies analysed musculoskeletal injuries in military conflicts and one during a pre-deployment phase.[21 25 28] The remaining studies were conducted with participants in garrison.

Injury occurrence

Table 5 presents all musculoskeletal injury information. Between 20% and 50% of qualified personnel sustained at least one injury

Table 2 Risk of bias assessment of individual studies (n=21)

Article	1. Was the purpose of the study clearly defined in the abstract and introduction?*	2. Was the sampling frame a true or close representation of the target population?	3. Was some form of random selection used to select the sample, OR was a census undertaken?	4. Was the likelihood of non-response bias minimal?	5. Were data collected directly from the subjects?	6. Was an acceptable case definition used in the study?	7. Was the study instrument that measured valid and reliable?	8. Was the same mode of data collection used for all subjects?	9. Was the length of the shortest prevalence period for the parameter of interest appropriate?	10. Were the numerator(s) and denominator(s) for the parameter of interest appropriate?
Pirson and Pirlot (1990)[18]	Yes	No	No	Yes	Partially	No	Partially	Partially	Yes	Yes
Linenger *et al* (1993)[19]	Partially	No	No	No	Partially	Yes	Partially	Yes	Yes	Yes
Shwayhat *et al* (1994)[20]	Yes	Yes	Partially	Yes	Partially	Yes	Partially	Yes	Yes	Yes
Kragh *et al* (1996)[22]	Yes	No	Partially	No	No	Yes	No	No	Yes	Yes
Miser *et al* (1995)[21]	Yes	No	No	No	Yes	Partially	No	No	Yes	No
Ensign *et al* (2000)[24]	Partially	No	No	No	Yes	No	No	Yes	No	Yes
Schumacher *et al* (2000)[23]	Yes	No	No	No	No	Yes	Partially	Yes	Yes	Yes
Kotwal *et al* (2004)[25]	Partially	No	No	No	Partially	Yes	No	Partially	Yes	Partially
Hughes and Weinrauch (2008)[26]	Yes	No	No	No	No	No	No	Partially	Yes	Partially
Lynch and Pallis (2008)[37]	Yes	Partially	No	No	No	No	Partially	Yes	Yes	No
Hollingsworth (2009)[28]	Yes	Yes	No	Yes	Yes	Partially	No	Yes	No	No
Reynolds *et al* (2009)[27]	Yes	No	No	No	Partially	Yes	No	Yes	Yes	Yes
Abt *et al* (2014)[29]	Yes	Partially	No	Yes	Yes	Yes	No	Yes	Yes	Partially
Teyhen *et al* (2015)[30]	Yes	Yes	Partially	No	Partially	Yes	Partially	Yes	Yes	No
Lovalekar *et al* (2016)[31]	Yes	No	No	No	No	Yes	No	Partially	Yes	No
Heebner *et al* (2017)[34]	Yes	No	No	No	No	Yes	Partially	Yes	Yes	Partially
Lovalekar *et al* (2017)[32]	Yes	Yes	No	No	Yes	Yes	Partially	Partially	No	No
Lovalekar *et al* (2017)[33]	Yes	No	No	No	Partially	Yes	Partially	Partially	Yes	Partially
Lovalekar *et al* (2018)[35]	Yes	No	No	No	No	Yes	No	Partially	Yes	Partially
Teyhen *et al* (2018)[36]	Yes	Yes	Partially	No	Partially	Partially	Partially	Partially	Yes	Yes
Dijksma *et al* (2020)[17]	Yes	Partially	Partially	Yes	Partially	Yes	Partially	Partially	Yes	Partially

Table 3 Study designs and the data collection methods of individual studies (n=21)

Article	Study design			Case definition	Injury data collection method	Injury classification
Pirson and Pirlot (1990)[18]	Descriptive	Prospective	Case series*	–	–	–
Linenger *et al* (1993)[19]	Descriptive	Prospective	Case series*	Medical attention	Primary data, medical consults	ICD-9, reported codes used
Shwayhat *et al* (1994)[20]	Analytical	Prospective	Case–control*	Medical attention, overuse injuries only	Primary data, medical consults and survey	ICD-9†
Kragh *et al* (1996)[22]	Descriptive	Prospective	Case series*	Time loss, ankle injuries only	Primary data, medical consults	–
Miser *et al* (1995)[21]	Descriptive	Retrospective	Case series*	All complaints‡	Primary data, face-to-face interview	–
Ensign *et al* (2000)[24]	Descriptive	–	Cross-sectional*	All complaints‡	Primary data, survey	–
Schumacher *et al* (2000)[23]	Analytical	Retrospective	Cohort*	Time loss	Secondary data, sick call and ED	–
Kotwal *et al* (2004)[25]	Descriptive	Prospective	Case series*	Medical attention, parachuting injuries only	Primary data, medical consults	–
Hughes and Weinrauch (2008)[26]	Analytical	Retrospective	Case–control*	Medical attention‡	Secondary data, medical documents	–
Lynch and Pallis (2008)[37]	Descriptive	Retrospective	Case series*	Medical attention	Secondary data, EHS	ICD-9-CM†
Hollingsworth (2009)[28]	Descriptive	–	Cross-sectional*	All complaints‡	Primary data, survey	–
Reynolds *et al* (2009)[27]	Analytical	Prospective	Cohort*	Medical attention	Secondary data, medical documents	–
Abt *et al* (2014)[29]	Descriptive	–	Cross-sectional*	Time loss	Primary data, survey	–
Teyhen *et al* (2015)[30]	Analytical	Prospective	Prognostic	All complaints	Primary data, survey and secondary from EHS	ICD-9†
Lovalekar *et al* (2016)[31]	Descriptive	Retrospective	Case series	Medical attention	Secondary data, medical documents	–
Heebner *et al* (2017)[34]	Analytical	Prospective	Cohort*	Medical attention	Secondary data, medical documents	ICD-9-CM†
Lovalekar *et al* (2017)[32]	Descriptive	–	Cross-sectional	All complaints	Primary data, survey and secondary data, medical documents	–
Lovalekar *et al* (2017)[33]	Descriptive	–	Cross-sectional	Medical attention	Secondary data, medical documents	–
Lovalekar *et al* (2018)[35]	Descriptive	–	Cross-sectional	Medical attention	Secondary data, EHS	–
Teyhen *et al* (2018)[36]	Analytical	Prospective	Cohort	All complaints	Primary data, survey and secondary, EHS	ICD-9 (700–900 codes)
Dijksma *et al* (2020)[17]	Descriptive	Retrospective	Case series*	Medical attention	Secondary data, EHS	ICPC-2 L codes

*Specific study design not reported, implied by manuscript.
†Codes not reported; (–) data were not reported.
‡Definition not explicitly reported, implied from the manuscript.
EHS, electronic health system; ICD, International Classification of Disease; ICPC, International Classification of Primary Care.

Table 4 Demographic data from individual studies (n=21)

Author (year) (reference)	Geographical setting	SOF population	Sample size	Age (years)*	Sex	Military experience (years)*	Rank
Pirson and Pirlot (1990)[18]	Belgium	ParaCommando Regiment	1880	18–27	Male only	Trainees	Trainees
Linenger *et al* (1993)[19]	USA	NSW SEAL trainees	–	18–31	Male only	Trainees	Trainees
Shwayhat *et al* (1994)[20]	USA	NSW SEAL trainees	224	22.3±2.6	Male only	Trainees	Trainees
Kragh *et al* (1996)[22]	USA	USASOC Army Rangers	556	24 (18–43)	–†	4.4	E-5, PTE-LTCOL
Miser *et al* (1995)[21]	USA	USASOC Army Rangers	471	22.7±4.2	–†	3.1±2.9	E-4 (mean)
Ensign *et al* (2000)[24]	USA	NSW SWCC	154	32.0±5.9	–†	12.0±5.5	–
Schumacher *et al* (2000)[23]	USA	USASOC Army Rangers	–	–	–†	–	–
Kotwal *et al* (2004)[25]	USA	USASOC Army Rangers	634	18–48	–†	–	PTE-COL
Hughes and Weinrauch (2008)[26]	Australia	ADF 4RAR	254	–	–	–	–
Lynch and Pallis (2008)[37]	USA	USASOC 5th SFG	–	–	–†	–	–
Hollingsworth (2009)[28]	USA	MARSOC 1st MRB	87	26.8±4.3	–†	7.6±3.9	–
Reynolds *et al* (2009)‡[27]	USA	–	162	30.5±6.0	–†	–	–
Abt *et al* (2014)[29]	USA	USASOC 3rd SFG	106	31.7±5.3	–†	11.0±5.5	–
Teyhen *et al* (2015)[30]	USA	USASOC Army Rangers	188	23.3±3.7	Male only	1–10	–
Lovalekar *et al* (2016)[31]	USA	NSW SEAL	210	28.1±6.0	Male only	–	–
Heebner *et al* (2017)[34]	USA	USASOC SOF	95	32.7±5.1	–†	–	–
Lovalekar *et al* (2017)[32]	USA	–	101	28.5±5.6	Male only	–	–
Lovalekar *et al* (2017)[33]	USA	NSW SEAL, SWCC, SQT, CQT	920	–	–†	–	–
Lovalekar *et al* (2018)[35]	USA	AFSOC 24th SOW	130	29.1±5.2	–†	–	–
Teyhen *et al* (2018)*[36]	USA	USASOC Army Rangers	207	–	–†	–	–
Dijksma *et al* (2020)[17]	Netherlands	RNLMC Trainees	482	20.6±2.3	Male only	Trainees	Trainees

(–) data not reported.
*Values are presented as reported by individual studies using either range, mean with SD, or a mean with a range in brackets.
†Special Operations Forces positions only open to females in the USA in January 2016.[38]
‡Data extracted on Special Operations Forces population cohort.
ADF, Australian Defence Force; AFSOC, Airforce Special Operations Command; COL, Colonel; CQT, Crewman Qualification Training; LTCOL, Lieutenant Colonel; MARSOC, Marine Special Operations Command; MRB, Marine Raider Battalion; NSW, Naval Special Warfare; PTE, Private; 4RAR, 4th Royal Australian Regiment; RNLMC, Royal Netherlands Marine Corps; SEAL, Sea Air and Land; SFG, Special Forces Group; SOF, Special Operations Forces; SOW, Special Operations Wing; SQT, SEAL Qualification Training; SWCC, Special Warfare Combatant Crewman; USASOC, United States Army Special Operations Command.

within a 12-month period.[29 33 34 36] Among trainees, between 17% and 68% sustained an injury during a training period.[17 33] The Royal Netherlands Marine Corps identified that 23% of trainees did not complete qualification training due to injury.[17] Trainees conducting Sea, Air and Land (SEAL) qualification training were reported to have the highest overall injury rate of 29.7 injuries per 100 trainee months.[19] Airforce-affiliated SOF had the highest injury frequency overall among qualified personnel with 84.6 injuries per 100 persons per year.[35] Parachuting-related injuries were reported to be between 0.3 and 2.2 cases per 100 jumps.[22 23]

Body part injured

Seventeen studies reported injury anatomical locations. Three studies grouped their analysis by body regions of which the lower extremity and spine were the most common regions affected.[25 32 34] Fourteen studies analysed by specific body parts of which the ankle, knee and lumbar region were the most frequently affected sublocations.

Injury type

Thirteen studies reported injury type. Seven studies used a recognised injury classification tool to categorise by pathology.[17 19 20 30 34 36 37] The remaining six studies did not describe their injury type categorisation methods. Injury type was categorised inconsistently between studies, resulting in 19 different injury types identified in the data extraction process. The most common injury types were 'sprains and strains', followed by fractures and injuries categorised as 'pain and spasm'.

Activity causing injury

Twelve studies reported activities when injured. Seven studies investigated injuries resulting from specific tactical activities.[18 21–26] One study analysed the prevalence of injuries concerning operations conducted by Special Boat Operators in the Naval Special Warfare.[24] In this study, 66% of injury events were attributed to mission-related causes; however, the study did not specify further detail on the type of mission activities.[24]

Six studies exclusively analysed injuries sustained from military parachuting, of which five reported on static-line parachuting, and one did not specify a parachuting type.[18 21–23 25 26] All parachuting studies reported their injury outcomes differently. One study identified lower injury rates in paratroopers who used a parachuting ankle brace in comparison with those who did not, 1.31 and 1.67 injuries per 100 jumps, respectively.[23] Landing terrain also influenced injury rates with dirt strips being more hazardous than water, fields or airports.[22 26] Two studies demonstrated increased injuries associated with increased paratrooper weight.[18 26] One study identified that almost 90% of injuries sustained in a combat mission resulted from a static-line parachuting insertion.[21]

Four studies analysed activities more broadly.[29 31 33 35] These studies used secondary data collected from medical documents or electronic health systems, which were limited by missing or insufficiently detailed information. One study reported

Table 5 Musculoskeletal injury epidemiological data extracted from individual studies (n=21)

Author Year (ref)	Injury numbers/rate	Anatomical location	Injury type	Activity causing injury	Mechanism of injury	Severity
Pirson and Pirlot (1990)[18]	Total not reported Injuries/1000 jumps by weight: ▶ (82–87 kg) 6.22 ▶ (76–81 kg) 4.38 ▶ (70–75 kg) 3.33	–	–	Static-line parachuting	Landing	–
Linenger *et al* (1993)[19]	143 total injuries 29.7 cases/100 trainee months	Per 100 trainee months: ▶ Knee 10.2 ▶ Ankle/foot 6.0 ▶ Lower leg 3.3 ▶ Upper limb 3.3	Per 100 trainee months ▶ Iliotibial band syndrome 4.4 ▶ Patellofemoral syndrome 3.3 ▶ Lower leg stress fracture 2.3	–	–	–
Shwayhat *et al* (1994)[20]	232 total injuries 94 injured soldiers 3.4 injuries per 1000 trainee days	–	Per 1000 trainee days ▶ Stress fractures 0.54 ▶ Sprains/strains 0.47 ▶ Iliotibial band syndrome 0.47	–	–	–
Kragh *et al* (1996) (prospective data only)[22]	163 injured soldiers 2.2% injured per 100 jumps	▶ Ankle 19% ▶ Foot 15% ▶ Lumbosacral 14%	▶ Thoracolumbar strain or sprain 17% ▶ 'Other minor injury' 17% ▶ Ankle sprain 13%	Static-line parachuting Time ▶ Day 1.4% (46/3211) ▶ Night 2.7% (117/4358) ▶ Drop zone ▶ Landing strips (4.7%) ▶ Airports (2.3%) ▶ Fields (1.6%)	–	Mild, <72 hours of restrictions 24% Moderate, >72 hours of restrictions 57% Severe, complete loss of work 19%
Miser *et al* (1995)[21]	281 total injuries 217 injured soldiers	▶ Ankle 19.6% (n=55) ▶ Knee 11.7% (n=33) ▶ Back 10.3% (n=29)	▶ Sprain/strain 37.0% (n=104) ▶ Contusion 29.2% (n=82) ▶ Closed fracture 10.3% (n=29)	▶ Parachuting 89.7%	–	No limitations 56.9% (n=160) Limited performance 22.1 (n=62) Out of combat 21.0% (n=59)
Ensign *et al* (2000)[24]	121 injury events 153 total injuries 100 injured soldiers	Reported as a proportion of injuries Low back 33.6% (n=50) Knee 21.5% (n=32) Shoulder 14.1% (n=21)	Reported as a proportion of injuries Sprain/strain 49.3% (n=69) Disc problems 7.9% (n=11) Trauma 7.9% (n=11)	Reported as a proportion of injuries Special boat operations ▶ Mission related 66.1% (n=76) ▶ During unusual sea states or weather 18.3% (n=21) ▶ Physical training 10.4% (n=12)	–	145 days of hospitalisation 4223 days of limited duty
Schumacher *et al* (2000)[23]	210 total injuries Without PAB: ▶ 132 total injuries ▶ 16.78 per 1000 jumps With PAB: ▶ 78 total injuries ▶ 13.16 per 1000 jumps RR for sustaining an ankle injury without PAB 2.93:1	Injury rate per 1000 jumps Without PAB: ▶ Ankle 4.45 ▶ Back 3.56 ▶ Knee 3.31 ▶ With PAB: ▶ Back 2.87 ▶ Foot 2.70 ▶ Knee 2.02	Only fractures reported: ▶ Without PAB: 1.1/1000 (n=9) ▶ With PAB: 0.5/1000 (n=3)	Static-line parachuting	–	Limited duty: ▶ 71 days without PAB ▶ 47 days with PAB

Continued

Table 5 Continued

Author Year (ref)	Injury numbers/rate	Anatomical location	Injury type	Activity causing injury	Mechanism of injury	Severity
Kotwal *et al* (2004)[25]	83 total injuries 76 injured soldiers 12% injury proportion	▶ Lower extremities 68.7% (n=57) ▶ Foot>ankle, (n/% not reported)	–	Static-line parachuting	–	Attrition 4.3% (n=27) Surgical intervention 1.7% (n=11)
Hughes and Weinrauch (2008)[26]	31 total injuries 28 injured soldiers 5.05% injury proportion	▶ Coccyx 19.4% (n=6) ▶ Shoulder 16.1% (n=5) ▶ Lumbar 12.9% (n=4) ▶ Ankle 12.9% (n=4)	▶ Contusion/soft tissue (n=16) ▶ Fracture (n=8)	Static-line parachuting ▶ Land descents 7.8% (24/307) ▶ Water descents 1.6% (4/247) By weight (kg): ▶ 91–100 5.4% ▶ >100 12.5% By time: ▶ Night descents (2.2%, 1 of 46) ▶ Daytime descents (5.3%, 27 of 508)	–	Hospitalisation 1.8% (n=10)
Lynch and Pallis (2008)[37]	1005 total injuries	▶ Back/neck (31%) ▶ Ankle (10%) ▶ Shoulder (10%) ▶ Knee (10%)	–	–	–	–
Hollingsworth (2009)[28]	41 total injuries 28 injured soldiers 32% injury proportion	Reported as a count ▶ Knee (n=10) ▶ Low back (n=7) ▶ Ankle (n=6)	–	–	–	Training days lost 6.03 average (0–60 days)
Reynolds *et al* (2009)[27]	297 total injuries 86 injured soldiers 3.5 injuries/100 soldier-months	–	▶ Tear/rupture 21.9% (n=65) ▶ Fracture 20.5% (n=61) ▶ Dislocation 2% (n=6) ▶ (note—blister 15%, not MSK)	No raw data presented Narrative reports >80% physical training and sport related	–	Limited duty days Total 3179.0
Abt *et al* (2014)[29]	26 total injuries 24.5 injuries/100 subjects/year 20.8 injured soldiers/100 subjects/year	▶ Knee 23.1% (n=6) ▶ Shoulder 23.1% (n=6) ▶ Ankle 11.5% (n=3)	▶ Sprain 23.1% (n=6) ▶ Fracture 11.5% (n=3) ▶ Strain 11.5% (n=3)	▶ Physical training 46.2% (n=12) ▶ Tactical training 15.4% (n=4) ▶ Recreational activity/sport 11.5% (n=3)	▶ Running 23.1% (n=6) ▶ Lifting 19.2% (n=5) ▶ Cutting 11.5%(n=3) ▶ Direct trauma 11.5% (n=3) ▶ Unknown 11.5% (n=3)	–
Teyhen *et al* (2015)[30]	85 injured soldiers	–	–	–	–	–
Lovalekar *et al* (2016)[31]	63 total injuries 44 injured soldiers 0.025 injuries/operator/month	▶ Shoulder 23.8% (n=15) ▶ Lumbopelvic region 12.7% (n=8) ▶ Ankle 9.5% (n=6)	▶ Strain 20.6% (n=13) ▶ Pain/spasm 19.0% (n=12) ▶ Fracture 11.1% (n=7) ▶ Sprain 11.1% (n=7)	▶ Unknown 22.2% ▶ Other 22.2% ▶ Physical training 19.0% ▶ Recreational activities/sport 12.7%	▶ Unknown 60.3% (n=38) ▶ Other 9.5% (n=6) ▶ Lifting 7.9% (n=5) ▶ Direct trauma 6.3% (n=4) ▶ Falls 6.3% (n=4)	–
Heebner *et al* (2017)[34]	48 injured soldiers 50.5% injury proportion (narrative reports 47 injured)	▶ Lower extremity 39.4% (n=26) ▶ Spine 34.8% (n=23) ▶ Upper extremity 25.8% (n=17)	–	–	–	–

Continued

Table 5 Continued

Author Year (ref)	Injury numbers/rate	Anatomical location	Injury type	Activity causing injury	Mechanism of injury	Severity
Lovalekar *et al* (2017)[32]	374 total injuries in EHS 294 total self-reported injuries	EHS ▶ Lower extremity 54.5% (n=204) ▶ Upper extremity 25.9% (n=97) ▶ Spine 15.5% (n=58) Survey ▶ Lower extremity 40.1% (n=118) ▶ Upper extremity 39.1% (n=115) ▶ Spine 10.9% (n=32)	EHS ▶ Strain 16.6% (n=62) ▶ Sprain 13.4% (n=50) ▶ Pain 10.4% (n=39) Survey ▶ Traumatic fracture 27.2% (n=80) ▶ Sprain 11.2% (n=33) ▶ Strain 8.5% (n=25)	–	–	–
Lovalekar *et al* (2017)[33]	267 total injuries Injuries/100 persons/year: ▶ SEAL: 23.1 ▶ SQT: 46.5 ▶ SWCC: 31.6 ▶ CQT: 17.0	SEAL ▶ Shoulder 21.6% (n=16) ▶ Lumbopelvic 14.9 (n=11) ▶ Ankle 13.5% (n=10) SQT ▶ Foot and toes 17% (n=17) ▶ Ankle 13% (n=13) ▶ Hip 12% (n=12) SWCC ▶ Lumbopelvic 21.7% (n=13) ▶ Shoulder 20.0% (n=12) ▶ Knee 15% (n=9) CQT ▶ Knee 30.3% (n=10) ▶ Hand & Fingers 15.2% (n=5) ▶ Ankle 12.1% (n=4)	SEAL ▶ Pain/spasm 29.7% (n=22) ▶ Tendinopathy 13.5% (n=10) ▶ Sprain 12.2% (n=9) SQT ▶ Tendinopathy 21.0% (n=21) ▶ Pain 17.0% (n=17) ▶ Strain 14.0% (n=14) ▶ SWCC ▶ Pain 21.7% (n=13) ▶ Sprain 20.0% (n=12) ▶ Strain 16.7% (n=10) CQT ▶ Fracture 15.2% (n=5) ▶ Tendinopathy 15.2% (n=5) ▶ Sprain 12.1% (n=4)	Physical training ▶ SEAL: 28.4% ▶ SQT: 68.0% ▶ SWCC: 35.0% ▶ CQT: 39.4% Tactical training: ▶ SEAL: 10.8% ▶ SQT: 10.0% ▶ SWCC: 16.7% ▶ CQT: 12.1% Unknown ▶ SEAL: 24.3% ▶ SQT: 17.0% ▶ SWCC: 25.0% ▶ CQT: 42.4%	SEAL ▶ Unknown 36.5% (n=27) ▶ Other 21.6% (n=16) ▶ Lifting 13.5% (n=10) SQT ▶ Unknown 36.0% (n=36) ▶ Other 27% (n=27) ▶ Running 17.0% (n=17) SWCC ▶ Unknown 31.7% (n=19) ▶ Lifting 16.7% (n=10) ▶ Other 15% (n=9) CQT ▶ Unknown 48.5% (n=16) ▶ Direct Trauma 15.2% (n=5) ▶ Running 12.1% (n=4)	–
Lovalekar *et al* (2018)[35]	110 total injuries 84.6 injuries/100 soldiers/year 49.2 injured soldiers/100 operators/year	▶ Shoulder 20.9% (n=23) ▶ Lumbopelvic spine 15.5% (n=17) ▶ Knee 14.5% (n=16)	▶ Pain/spasm/ache 44.5% (n=49) ▶ Sprain 11.8% (n=13) ▶ Strain 11.8% (n=13) ▶ Tendinopathy 11.8% (n=13)	▶ Physical training 38.2% (n=42) ▶ Unknown 24.5% (n=27) ▶ Tactical training 17.3% (n=19) ▶ Recreation activity/sport 8.2% (n=9)	▶ Lifting 21.8% (n=24) ▶ Direct trauma 8.2% (n=9) ▶ Landing 8.2% (n=9)	–
Teyhen *et al* (2018)[36]	141 total injuries 104 injured soldiers 50.2% injury proportion Injury incidence: ▶ 45.2% Cumulative ▶ 31.8% Overuse ▶ 13.4% Acute	▶ Foot and ankle 24.1% (n=34) ▶ Knee 19.1% (n=27) ▶ Upper back, head, neck 17.0% (n=24)	–	–	–	Time loss injury index 18.9% lost workdays/1000 person-days
Dijksma *et al* (2020)[17]	68% injury proportion	Incidence rate per 100 person-years ▶ Foot 64.7 ▶ Knee 62.2 ▶ Leg/thigh 46.3	–	–	–	Dropout rate due to injury 23% Restricted duty 47%

(–) indicates that data were not reported.
CQT, Crewman Qualification Training; EHS, electronic health system; MSK, musculoskeletal; PAB, parachuting ankle brace; RR, risk ratio; SEAL, Sea Air Land; SQT, SEAL Qualification Training; SWCC, Special Warfare Combatant Crewman.

'unknown' and 'other' as the two most common injury causes, collectively accounting for 44% of injuries.[31] Physical training was the most commonly known activity reported to cause injury, causing between 19% and 80% of injuries sustained.[27 31] Physical training–related injuries were the highest in SEAL qualification trainees, accounting for 68% of injuries.[33]

Two studies investigated the association of musculoskeletal injury risk and certain intrinsic factors, such as movement patterns or lifestyle factors.[30 34] Teyhen *et al* identified that previous history of injury, smoking, prior surgery and asymmetry of ankle mobility were associated with increased risk of acute and overuse injuries.[30] Heebner *et al* demonstrated a weak increased injury risk associated with reduced strength of knee extension and shoulder retraction.[34] Neither study recorded activity exposure information, such as military or physical training activities, to provide insight into other confounding variables.

Mechanism of injury

Very few studies (n=5) reported injury mechanisms to identify the specific events or mechanics involved in the injury event.[18 29 31 33–35] Information on injury mechanism was often missing and instead categorised as 'unknown'.[29 31 33] Of the studies that reported known injury mechanisms, running was the most common, followed by lifting and direct trauma. Running-related injuries were reported to be between 12% and 23%.[29 33] Special Forces Group had the most running-related injuries accounting for 23% of injuries, followed by SEAL trainees with 17%.[29 33] Lifting accounted for 8%–21% of injury mechanisms.[31 35] Lifting-related injuries occurred most commonly in Airforce Special Operations Command Operators in which almost all were attributed to weight lifting.[35] One study assessing parachute landing injuries identified increased injury with the increasing weight of paratroopers.[18] Two studies discussed that parachuting-related injuries could occur at any stage between exiting the plane, mid-air or on landing; however, neither included an injury mechanism analysis in their study.[25 26]

Severity of injury

Ten studies reported various metrics to indicate injury severity (Table 5). Eight studies reported severity by time loss, such as restricted duty days.[17 21–24 27 28] Studies investigating parachuting-related injuries used reporting metrics that indicated greater injury severity than other studies, such as rates of hospitalisation and surgical intervention.[25 26] Hospitalisation and surgical intervention resulted from 1.8% and 1.7% of parachute-related injuries, respectively.[25 26] One study assessing static-line parachuting reported an average of 71 limited duty days per ankle injury.[23] Another study identified that 57% of parachute-related injuries resulted in greater than 72 hours of restricted duty, and 19% caused a total loss of work.[22] Significant loss of soldier availability was also identified in another study investigating a parachute insertion into a combat environment, of which 21% of parachute-related injuries resulted in soldiers deemed no longer fit for combat.[21]

Special Warfare Combat Crewman in the Naval Special Warfare recorded the highest cumulative time loss of 4223 restricted duty days for 121 injury events; however, it is not clear over which timeframe this was.[24] Another study by Reynolds *et al* identified that within 12 months, a total of 3170 injury-related restricted duty days occurred in a SOF cohort of just 162 individuals.[27] In this study, the average limited duty days was three times greater in SOF in comparison with other combatant military cohorts. No studies assessed injury severity concerning physical training or assessed medical discharge rates in qualified personnel.

DISCUSSION

Injuries appear to be prevalent across all SOF populations. There were considerable variances of injury frequency between SOF populations which indicate some demographic subgroups, such as trainees, may be at more risk of injury than others. The lower extremities and spine were the most commonly affected anatomical locations. The majority of injuries were physical training related. There was a growing number of studies published within the last 5 years, which likely reflects the increasing recognition and the need to understand injuries better to sustain a capable workforce.

Trainees appear to be particularly vulnerable to injury, as indicated by higher injury occurrence and attrition rates.[17 33] The Air Force Special Operations Command Special Operations Wing recorded the highest injury incidence in qualified operators.[35] It remains unknown if other demographic variables, such as age, years of military experience, rank or sex, can influence injury patterns in SOF populations. Women gained the equal opportunity for SOF employment in the USA in 2016, which is likely why sex is not reported in earlier studies.[38] Research in the regular Army has indicated that women have higher risks of injury than men.[39] Future research should report injuries in relation to sex, age and rank as subgroup analyses to understand how these may influence injuries in these populations. Such research will inform whether additional injury precautions are required for specific personnel.

The majority of injuries affected the lower extremity and spine, specifically the ankle, knee and lumbar region. These anatomical locations are consistent with research in other military services which also report a high proportion of lower limb and spine injuries.[5 36 40] The most common injury types were sprains and strains, fractures and 'pain or spasm' which are more consistent with acute-onset injuries. These greater acute injury patterns are different from those of conventional forces in which overuse injuries are more prevalent than acute-type injuries.[27 41 42]

Injury causation was often not assessed or was limited by insufficient data. Without this information, prevention opportunities cannot be prioritised as the activities leading to injury remain unknown. As such, future research should prioritise improving the recording of injury causation information. Static-line parachuting appears to result in more severe injuries than other activities. It is interesting to note that no other specific tactical skills were investigated, such as High-Altitude Low Opening parachuting, assault diving or close quarter combat fighting. It is unknown if this is because these activities are not considered to be a significant injury risk and therefore not a research priority. Of the available information, physical training was consistently the most common activity associated with an injury. These results are similar to the literature in conventional military services.[6] Running, lifting and direct trauma were common injury mechanisms. Future research should prioritise these mechanisms to provide more evidence to inform injury prevention strategies.

Improving recording and reporting of injury in SOF

The risk-of-bias assessment identified consistent difficulties across the studies, which may influence conclusions on injury patterns.[10] It was often not clear if the injury pattern variance was due to the research methods or the population within the individual studies. In addition, the inconsistent methods between studies made comparisons between studies difficult. Many studies were subjected to sampling bias which may result in the underestimation of injury prevalence. For example, some studies only recruited healthy participants from concurrent human performance studies.[29 31 33–35] The majority of the studies used secondary data. Consequently, important epidemiology information was often missing. All studies used partially validated surveillance methods to collect injury epidemiological data, which may introduce misclassification bias and uncertainty on the validity of the results.[10] This reiterates a currently established problem on the lack of taxonomy of musculoskeletal injury in a military context.[5 41 43 44]

Many studies did not record essential injury surveillance variables, such as injury causation.[45] Subsequently, studies lacked sufficient evidence to inform injury prevention recommendations.[3] Future research should consider improving the recording and reporting of essential injury surveillance variables and standardising methods to support and strengthen future research in a military context. In addition, it is recommended that future research use the Strengthening The Reporting Of Observational Studies In Epidemiology (STROBE) checklist of items to prevent inadequate or incomplete reporting of methods.[46]

Limitations of the systematic review

There were some limitations identified in our search strategy. It was noted that 10 studies were not identified by the search strategy terms but instead by screening the references of the full-text articles. We attribute this to the lack of consistent keywords applied to the manuscripts and that there are no available entry terms directly linking SOF to military-related Medical Subject Headings (MeSH). Subsequently, it is recognised that the search strategy was potentially not sensitive to detect all available literature. In future, research should allocate consistent keywords that can identify and delineate SOF populations.

Another limitation is that the critical appraisal tool used to evaluate the quality of individual studies is not formally validated. Subsequently, there are potential biases in the interpretation of study quality. To mitigate bias, the appraisal was conducted independently and collaboratively, and in some instances, a third reviewer was used to resolve discrepancies.

CONCLUSION

Musculoskeletal injuries are prevalent across all SOF populations. The available evidence indicates that physical training is the most common activity causing injury and that these injuries are most likely to occur from running or lifting. Parachute-related injuries appear to be the most severe, resulting in extended restricted duty and hospitalisation; however, the exact mechanism causing this is unknown. Overall, the epidemiological evidence suggests trainees are a priority subgroup for injury prevention and that further knowledge needs to be obtained as to why physical training and parachute-related injuries occur. Further research is essential to direct targeted injury prevention strategies and the allocation of resources, such as sport and exercise professionals, or improved parachuting equipment and training. Finally, it is recommended that future research should investigate the application of surveillance methods to a military context to improve the accuracy and consistency of future injury epidemiology research.

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REFERENCES

1 Moon M. *NATO Special Operation Forces in the modern security environment, Sub-Committee on Future Security and Defence Capabilities*. NATO Parliamentary Assembly, 2018.
2 Barringer ND, Pasiakos SM, McClung HL, *et al*. Prediction equation for estimating total daily energy requirements of special operations personnel. *J Int Soc Sports Nutr* 2018;15:15.
3 Finch C. A new framework for research leading to sports injury prevention. *J Sci Med Sport* 2006;9:3–9.
4 Jones BH, Canham-Chervak M, Sleet DA. An evidence-based public health approach to injury priorities and prevention. *Am J Prev Med* 2010;38:1–10.
5 Hauret K, Jones B, Bullock S, *et al*. Musculoskeletal injuries description of an under-recognized injury problem among military personnel. *Am J Prev Med* 2010;38:61–70.
6 Cameron KL, Owens BD. The burden and management of sports-related musculoskeletal injuries and conditions within the US military. *Clin Sports Med* 2014;33:573–89.
7 Nye NS, Pawlak MT, Webber BJ, *et al*. Description and rate of musculoskeletal injuries in air force basic military trainees, 2012–2014. *J Athl Train* 2016;51:858–65.
8 Sefton JM, Lohse KR, McAdam JS. Prediction of injuries and injury types in army basic training, infantry, armor, and cavalry trainees using a common fitness screen. *J Athl Train* 2016;51:849–57.
9 Jones BH, Hauret KG, Dye SK, *et al*. Impact of physical fitness and body composition on injury risk among active young adults: a study of army trainees. *J Sci Med Sport* 2017;20:S17–22.
10 Gordis L. *Epidemiology*. Saint Louis, USA: Elsevier, 2013.
11 Moher D, Shamseer L, Clarke M, *et al*. Preferred reporting items for systematic review and meta-analysis protocols (PRISMA-P) 2015 statement. *Syst Rev* 2015;4.
12 Booth A. PROSPERO's progress and activities 2012/13. *Syst Rev* 2013;2:1–3.
13 Wells G, Shea B, O'connell D, *et al*. *Newcastle-Ottawa quality assessment scale: case control studies*, 2019. http://www.ohri.ca/programs/clinical_epidemiology/oxford.htm
14 Hoy D, Brooks P, Woolf A, *et al*. Assessing risk of bias in prevalence studies: modification of an existing tool and evidence of interrater agreement. *J Clin Epidemiol* 2012;65:934–9.
15 Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health* 1998;52:377–84.
16 Higgins J, Green S. *Cochrane handbook for systematic reviews of interventions. Cochrane Book Series*. The Cochrane Collaboration, 2008.
17 Dijksma I, Zimmermann WO, Hertenberg E-J, *et al*. One out of four recruits drops out from elite military training due to musculoskeletal injuries in the Netherlands Armed Forces. *BMJ Mil Health* 2020. doi:10.1136/bmjmilitary-2020-001420. [Epub ahead of print: 05 Mar 2020].
18 Pirson J, Pirlot M. A study of the influence of body weight and height on military parachute landing injuries. *Mil Med* 1990;155:383–5.
19 Linenger JM, Flinn S, Thomas B, *et al*. Musculoskeletal and medical morbidity associated with rigorous physical training. *Clin J Sport Med* 1993;3:229–34.
20 Shwayhat AF, Linenger JM, Hofherr LK, *et al*. Profiles of exercise history and overuse injuries among United States Navy Sea, Air, and Land (SEAL) recruits. *Am J Sports Med* 1994;22:835–40.
21 Miser WF, Lillegard WA, Doukas WC. Injuries and illnesses incurred by an army ranger unit during Operation Just Cause. *Mil Med* 1995;160:373–80.

22 Kragh JF, Jones BH, Amaroso PJ, *et al*. Parachuting injuries among Army Rangers: a prospective survey of an elite airborne battalion. *Mil Med* 1996;161:416–9.
23 Schumacher JT, Creedon JF, Pope RW. The effectiveness of the parachutist ankle brace in reducing ankle injuries in an airborne ranger battalion. *Mil Med* 2000;165:944–8.
24 Ensign W, Hodgon J, Prusaczyk W. *A survey of self-reported injuries among special boat operators, Naval Health Research Centre*, 2000.
25 Kotwal R, Meyer D, O'Connor K, *et al*. Army ranger casualty, attrition, and surgery rates for airborne operations in Afghanistan and Iraq. *Aviat Space Environ Med* 2004;75:833–40.
26 Hughes CD, Weinrauch PCL. Military static line parachute injuries in an Australian Commando battalion. *ANZ J Surg* 2008;78:848–52.
27 Reynolds K, Cosio-Lima L, Bovill M, *et al*. A comparison of injuries, limited-duty days, and injury risk factors in infantry, artillery, construction engineers, and special forces soldiers. *Mil Med* 2009;174:702–8.
28 Hollingsworth D. The prevalence and impact of musculoskeletal injuries during a pre-deployment workup cycle: survey of a Marine Corps special operations company. *J Spec Oper Med* 2009;9:11–15.
29 Abt JP, Sell TC, Lovalekar MT, *et al*. Injury epidemiology of U.S. Army Special Operations Forces. *Mil Med* 2014;179:1106–12.
30 Teyhen DS, Shaffer SW, Butler RJ, *et al*. What risk factors are associated with musculoskeletal injury in US Army Rangers? A prospective prognostic study. *Clin Orthop Relat Res* 2015;473:2948–58.
31 Lovalekar M, Abt JP, Sell TC, *et al*. Descriptive epidemiology of musculoskeletal injuries in naval special warfare sea, air, and land operators. *Mil Med* 2016;181:64–9.
32 Lovalekar M, Abt JP, Sell TC, *et al*. Accuracy of recall of musculoskeletal injuries in elite military personnel: a cross-sectional study. *BMJ Open* 2017;7:e017434.
33 Lovalekar M, Perlsweig KA, Keenan KA, *et al*. Epidemiology of musculoskeletal injuries sustained by naval special forces operators and students. *J Sci Med Sport* 2017;20:S51–6.
34 Heebner NR, Abt JP, Lovalekar M, *et al*. Physical and performance characteristics related to unintentional musculoskeletal injury in Special Forces operators: a prospective analysis. *J Athl Train* 2017;52:1153–60.
35 Lovalekar M, Johnson CD, Eagle S, *et al*. Epidemiology of musculoskeletal injuries among US Air Force Special Tactics Operators: an economic cost perspective. *BMJ Open Sport Exerc Med* 2018;4:e000471.
36 Teyhen DS, Goffar SL, Shaffer SW, *et al*. Incidence of musculoskeletal injury in US Army unit types: a prospective cohort study. *J Orthop Sports Phys Ther* 2018;48:749–57.
37 Lynch J, Pallis M. Clinical diagnoses in a special forces group: the musculoskeletal burden. *J Spec Oper Med* 2008;8:76–80.
38 Turnley JG. Funhouse mirrors: reflections of females in special operations forces. *J Spec Oper* 2019;5:25–41.
39 Nindl BC, Jones BH, Van Arsdale SJ, *et al*. Operational physical performance and fitness in military women: physiological, musculoskeletal injury, and optimized physical training considerations for successfully integrating women into combat-centric military occupations. *Mil Med* 2016;181:50–62.
40 Roy TC, Piva SR, Christiansen BC, *et al*. Description of musculoskeletal injuries occurring in female soldiers deployed to Afghanistan. *Mil Med* 2015;180:269–75.
41 Hauschild V, Hauret K, Richardson M, *et al*. *A taxonomy of injuries for public health monitoring and reporting, Injury Prevention Division*. United States of America: Army Public Health Command, 2017.
42 Hauschild VD, Schuh-Renner A, Lee T, *et al*. Using causal energy categories to report the distribution of injuries in an active population: an approach used by the U.S. Army. *J Sci Med Sport* 2019;22:997–1003.
43 Schuh-Renner A, Canham-Chervak M, Grier TL, *et al*. Expanding the injury definition: evidence for the need to include musculoskeletal conditions. *Public Health* 2019;169:69–75.
44 Hauschild V, Steelman R, Grier T, *et al*. *Injuries among military paratroopers—current evidence and data gaps*. US Army Public Health Centre APG-EA United States, 2019.
45 Holder Y, Peden M, Krug E, *et al*. *Injury surveillance guidelines*. Geneva: World Health Organisation, 2001.
46 von Elm E, Altman DG, Egger M, *et al*. The strengthening the reporting of observational studies in epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol* 2008;61:344–9.