



Original research

Mitigating the risk of musculoskeletal injury: A systematic review of the most effective injury prevention strategies for military personnel



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ABSTRACT

Objectives: To update the current injury prevention strategy evidence base for making recommendations to prevent physical training-related musculoskeletal injury.

Design: We conducted a systematic review to update the evidence base on injury prevention strategies for military personnel.

Methods: Literature was systematically searched and extracted from five databases, and reported according to PRISMA guidelines. Sixty one articles meeting the inclusion criteria and published during the period 2008–2015 were selected for systematic review.

Results: The retrieved articles were broadly categorised into six injury prevention strategies; (1) conditioning, (2) footwear modifications, (3) bracing, (4) physical activity volume, (5) physical fitness, and (6) leadership/supervision/awareness. The majority of retrieved articles ($n = 37$ (of 61)) evaluated or systematically reviewed a conditioning intervention of some nature. However, the most well-supported strategies were related to reducing physical activity volume and improving leadership/supervision/awareness of injuries and injury prevention efforts.

Conclusions: Several injury prevention strategies effectively reduce musculoskeletal injury rates in both sexes, and many show promise for utility with military personnel. However, further evaluation, ideally with prospective randomised trials, is required to establish the most effective injury prevention strategies, and to understand any sex-specific differences in the response to these strategies.

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1. Introduction

Musculoskeletal injuries (MSKI) are the primary cause of medical discharge and medical downgrade in the United Kingdom Armed Forces.¹ Given the impact of MSKI on deployability and combat effectiveness, understanding how to most effectively mitigate against this risk is crucial for achieving, maintaining and retaining a healthy, effective and operationally deployable workforce. Physical training (PT) is a primary cause of, and risk factor for, MSKI,² yet developing and maintaining physical capability is a critical aspect of military training and employment. Acquiring and maintaining a high level of physical fitness (aerobic endurance, anaerobic endurance, muscle strength and muscle endurance) is necessary for successful performance of military-specific tasks during training and operations. Optimising this cost-benefit trade-off between PT-mediated combat effectiveness and injury risk is critical for achieving and maintaining the required performance standards,

and reducing injury rates, of Service personnel. Mitigation strategies for MSKI therefore include, but are not limited to, optimising PT and injury prevention.

Women are at higher risk of MSKI than men throughout military training and employment.¹ Accordingly, female sex is often considered a major risk factor for injury.³ However, this risk may be reflective of lower aerobic fitness in women than men, rather than a fundamental sex difference in injury risk.³ Currently, it is not known whether different injury prevention strategies should be adopted for men and women to promote recovery from injury and protect against future injury. During initial military training, rates of MSKI, and particularly rates of debilitating injuries including hip and pelvic stress fractures, are higher in women and Infantry males than men undergoing Standard Entrant military training.¹ If women are to be successfully incorporated into the Combat arms, the projected increased risk of MSKI in this demographic group will require attention. Understanding the most effective strategies for injury prevention will facilitate this mitigation of risk and promote a healthier Force that is effective in combat.

We undertook a systematic review of the literature relating to prevention strategies for PT-related injuries. This review was

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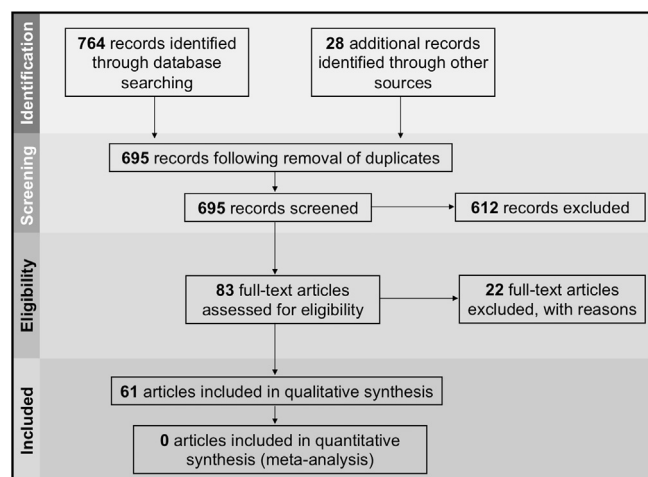


Fig. 1. PRISMA flow chart detailing article identification, screening, eligibility and inclusion (adapted from Moher et al.⁷²).

undertaken to update the existing evidence base reported by Bullock and colleagues in 2010.⁴ Evaluation of 31 PT-related injury prevention strategies by Bullock et al.⁴ resulted in identification of 6 strategies that were graded as having a strong evidence base for the working group to make implementation recommendations for the military. These 6 strategies included; (1) prevent overtraining, (2) perform multiaxial, neuromuscular, proprioceptive and agility training, (3) wear mouthguards during high-risk activities, (4) wear semi-rigid ankle braces for high-risk activities, (5) consume nutrients to restore energy balance within 1 h following high-intensity activity, and (6) wear synthetic-blend socks to prevent blisters. Within all successful injury prevention strategies, 4 components were deemed critical to their success. These critical components ('essential elements') included; (1) education of military leaders, (2) leadership support, (3) unit injury surveillance, and (4) adequate resources for injury research and programme evaluation.

Our aims were to: (1) update the current injury prevention strategy evidence base for making recommendations to prevent PT-related MSKI covering the period 2008–2015; (2) prioritise the recommendations for MSKI prevention programmes, strategies and policies, with consideration for the influence of sex, and (3) highlight areas for further research to evaluate interventions likely to reduce PT-related MSKI. The years 2008–2015 were chosen as the date parameters for our literature search to directly follow on from the papers reviewed by Bullock et al.⁴

2. Methods

Our methodological approach closely followed that outlined in the paper by Bullock et al.⁴ Literature was searched and extracted from five databases (PUBMED, COCHRANE, ATHENA, Defense Technical Information Centre Scientific and Technical Information Network, Google Scholar), with papers also identified from the reference lists of appropriate articles. Searches included the terms "injury prevention", AND "physical training" OR "physical fitness". A total of 764 articles were identified from the initial search terms with 28 articles added from the reference lists of appropriate articles. Date filters were applied for all searches, with the exception of 'related articles' to Bullock et al.⁴ searched on Google Scholar (where a date filter could not be applied). Filters relating to human studies also were applied where the search engine allowed. A flow diagram of article identification, screening, eligibility and inclusion is provided in Fig. 1. Included articles were published between 2008 and 2015, written in English, and included injury as an outcome measure. Articles were excluded if they; (1) were not written in

English ($n = 22$), (2) were a non-research paper, conference abstract, commentary or narrative review ($n = 18$), (3) did not directly assess injury prevention ($n = 346$), (4) used a patient, child or elderly participant cohort ($n = 58$), (5) covered a different or unrelated topic ($n = 126$), (6) were duplicated ($n = 97$), or (7) were published prior to 2008 ($n = 42$; only 'related articles' to Bullock et al.⁴ given the inability to apply a date filter to this search). Following full-text review of the remaining 83 articles, a further 22 articles were excluded for not meeting the review inclusion criteria due to not directly assessing PT-related injury prevention ($n = 7$) or being a narrative review, book chapter, position statement, conference abstract or commentary ($n = 15$). Thus, in total, 61 articles were selected for systematic review.

All included articles were classified according to their study type; (1) systematic reviews/meta-analyses ($n = 18$), (2) intervention studies ($n = 37$), (3) risk factor/cause studies ($n = 6$), (4) descriptive epidemiology ($n = 0$), and (5) case series ($n = 0$). For intervention studies, the median of the pre-post changes in injury occurrence and/or the difference in injury occurrence between intervention and control groups is provided in Table 1 as a representative approximation of intervention effectiveness. However, this method is not equivalent to the rigours of a meta-analysis and thus should not be considered as a pooled effect size.

Systematic reviews/meta-analyses, intervention studies and risk factor/cause studies were graded in relation to the overall effect of the intervention/risk factor on injuries. Each intervention and risk factor/cause study was qualitatively scored (Table 2) using a study quality scoring system adapted from Thacker et al.⁵ by Bullock et al.⁴ Strategies (from various studies) were graded on the overall evidence for their effectiveness of use in injury prevention. For grading of strategies, a four-colour scale was used (adapted from Bullock et al.⁴) representing strategies; with good to fair evidence to recommend or strongly recommend (green), strategies with fair evidence to recommend but where no clear recommendations could be made due to a lack of clear difference between benefits and harms and/or a benefit to only a small proportion of the population (amber), strategies with good to fair evidence to recommend against (red) or strategies with insufficient evidence to make a recommendation for, or against (grey). Prioritisation of the strategies was based on assessment of the strength of evidence, considering the amount of evidence for/against the given strategy; homogeneity of findings; and quality of evidence according to the scoring matrices. Strategies with sufficient evidence to make recommendations for injury prevention were ranked using a 5-point scale scoring matrix developed by the US Army Center for Health Promotion and Preventive Medicine and the John Hopkins Center for Injury Research and Policy, detailed by Bullock et al.⁴ The strength of evidence (scientific quality), magnitude of effect and the practicality of implementation were given a greater weighting in the scoring matrix to represent the importance of these factors. Time to implement and achieve a reduction in injury incidence, sustainability, measurable outcomes and collateral benefit were all considered of secondary importance. Overall prioritisation of strategies with average quality and priority scores are provided in Table 2.

3. Results

The eligible full-text reviewed intervention studies were broadly categorised into 6 types of injury prevention intervention. These intervention categories included; (1) conditioning ($n = 26^{6-31}$), (2) footwear modification ($n = 6^{32-37}$), (3) bracing ($n = 2^{18,38}$), (4) physical activity volume ($n = 5^{39-43}$), (5) physical fitness ($n = 3^{44-46}$) and, (6) leadership/supervision/awareness ($n = 3^{14,47,48}$). Eighteen systematic reviews/meta-analyses

Table 1
Effectiveness of injury prevention strategies.

	Positive effect of intervention (n)	Negative effect of intervention (n)	No effect of intervention (n)	Change in intervention injury rates from control/pre-intervention (%)
Conditioning				
Military studies	2	0	3	9
Non-military studies	8 ^a	0	13 ^b	–22
All studies	10	0	16	–12
Footwear modifications				
Military studies	1	0	5	4
Non-military studies	0	0	0	–
All studies	1	0	5	4
Bracing				
Military studies	1	0	0	–13
Non-military studies	1	0	0	–44
All studies	2	0	0	–29
Reducing physical activity volume				
Military studies	4	0	1	–36
Non-military studies	1	0	1	2
All studies	5	0	2	–34
Leadership/supervision/awareness				
Military studies	2	0	0	–49
Non-military studies	1	0	0	–20
All studies	3	0	0	–35

The number of studies showing a positive effect of the intervention, negative effect of the intervention, or no effect of the intervention are demonstrated for all studies, military only studies and non-military studies. The median % change of the pre-post changes in injury occurrence or the difference in injury occurrence between intervention and control groups are provided in the final column as an indication of intervention effectiveness.

^a In one study there was only a statistical trend ($p = 0.06$) for overall injury incidence but all other measures, e.g. first-time injuries, acute injuries *etc.* were significantly improved.

^b Some studies demonstrated no effect of the intervention on overall injuries but a positive effect on specific injuries, e.g., muscle injuries and lumbar spine.

Table 2
Recommendation of injury prevention strategies.

Injury prevention strategy	Number of studies (number of participants)	Average score (intervention study)	Average score (risk factor / cause study)	Average priority score	Priority classification
Improving physical fitness	3 (10,823)	-	7.8	72	Recommended
Conditioning	26 (19,196)	7.8	-	70	Insufficient evidence to recommend
Leadership / supervision / awareness	3 (43,658) ^a	6.5	-	70	Recommended
Bracing	2 (103,124) ^b	9.0	-	68	Potential to recommend for some populations
Reducing physical activity volume	5 (4,933)	9.0	7.1	66	Recommended
Footwear modification	6 (7976)	8.7	-	46	Not recommended

The total number of studies with participant numbers are presented for each injury prevention strategy category. Average scores (range 0–10) for intervention and risk factor/cause studies are presented alongside average priority scores (range 0–100). Studies were scored using a study quality scoring system adapted from Thacker et al.⁵ by Bullock et al.⁴ Prioritisation of strategies was based on assessment of the strength of evidence, considering the amount of evidence for/against the given strategy; homogeneity of findings; and quality of evidence according to the scoring matrices. Colour codings represent strategies with; good to fair evidence to recommend or strongly recommend (green ('recommended')), strategies with fair evidence to recommend but where no clear recommendations could be made due to a lack of clear difference between benefits and harms and/or a benefit to only a small proportion of the population (amber ('potential to recommend for some populations')), strategies with good to fair evidence to recommend against (red ('not recommended')) or strategies with insufficient evidence to make a recommendation for, or against (grey ('insufficient evidence to recommend')).

^a Scott et al.⁴⁷ had a mean of 42,002 participants over a 4–5 year period.

^b Knapik et al.³⁸ analysed 102,784 descents rather than participants.

were identified covering all injury prevention intervention categories.^{49–66} Of the intervention studies, 84% were randomised controlled trials, representing the highest quality of evidence.

Given that the majority of retrieved studies either were not conducted in women, or if women were included, they were part of a larger training group that was treated as a whole group at the time of analysis, we have been unable to discuss the following results in the context of sex differences.

Conditioning: Twenty-six intervention studies (19,196 participants; Table 2) investigated the influence of undertaking a

conditioning programme on injury outcomes in both athletic and military mixed-sex populations. Conditioning programmes included, but were not limited to, neuromuscular exercises, balance and agility training, core stability training and functional stretching and strengthening exercises. Five of these studies were conducted in military cohorts.^{6,9,11,20,21} The balance of evidence across all studies was mixed with no conclusive evidence for the beneficial effect of conditioning programmes, although, importantly, no negative effects of conditioning interventions on injury prevalence were observed.

In military cohorts, the median effect of the intervention was a 9% higher injury rate in the intervention *versus* control groups. Two studies reported a significant positive effect of the intervention, compared to 3 studies showing no significant effect. In non-military cohorts, the median effect of the intervention was an injury reduction of 22%. Conditioning interventions in 8 of the 21 studies were beneficial for reducing injury rates, with the remaining 13 studies showing no effect of the intervention. The median effect of conditioning-type interventions across all studies was an injury reduction of 12%. In total, 10 of 26 studies demonstrated a significant positive effect of the intervention, with the remaining 16 studies showing no effect of the intervention.

Eleven systematic reviews were retrieved covering the topic of conditioning programmes for injury prevention. In general, all reviews indicated a beneficial effect of some aspect of conditioning exercise programmes for injury prevention. However, the most effective elements of these programmes, particularly when multifactorial in nature, were difficult to tease out from these existing studies.

We graded conditioning exercises as a joint-second priority (Table 2). However, given the inconsistency in the results across all retrieved studies and apparent lack of effect in military cohorts, we gave conditioning exercises a colour grading of *grey* (not enough evidence for, or against, to make a recommendation).

Footwear modification: Six studies (7976 participants; Table 2) investigated the influence of modifying footwear on outcome injury incidence. Three of these studies investigated the effectiveness of prescribing running shoes based on plantar shape of the foot, whereas three studies investigated the utility of orthotics for reducing injury risk. All included studies used a military trainee cohort; the population in four studies was mixed-sex, but male only in two of the studies. The balance of evidence across all studies was a lack of significant effect of footwear modification on outcome injury prevalence.

There was a 4% difference between the median effect of footwear modification interventions on injury rates in intervention *versus* control groups (higher in intervention group). Systematic reviews/meta-analyses relating to footwear modification provided somewhat mixed findings. Shock-absorbing insoles seemed to be of benefit for reducing stress fracture-type overuse injuries^{51,58,63} but not all injuries. There were some limitations with the studies included for review in these systematic reviews, including heterogeneity and inconclusive confidence levels/risk values.

We graded footwear modifications as the lowest priority for implementation (Table 2). Although the quality of these studies was good, there was no clear indication of the effectiveness of footwear modifications, leading to the *red* colour rating (fair evidence that the intervention is ineffective).

Bracing: Two studies (103,124 cases; Table 2) investigated the use of ankle braces for preventing ankle sprains and other ankle injuries.^{18,38} Although the study populations and injury status of participants were different between studies, both offered data in support of the use of ankle braces for preventing ankle injuries.

The median effect of bracing across both studies was a 29% lower injury rate in intervention *versus* control groups. Both studies were conducted in mixed-sex cohorts but no sex-stratification was performed.

Five systematic reviews designed to analyse the impact of bracing on injury risk provided mixed findings, particularly in non-military cohorts. The only systematic review of solely military literature, conducted by Knapik et al.⁶⁶ concluded that the parachute ankle brace is a cost-effective intervention for reducing ankle sprain, fracture and injury incidence during military parachuting. Wearing an ankle brace or using prophylactic ankle taping appeared to be beneficial for previously injured recreational

and elite adolescent and adult athletes from various sports, but not effective for non-injured players.⁶⁴

We graded bracing as the third priority for implementation (Table 2). Although the balance of evidence was favourable, this evidence was from only 2 studies and the intervention appeared effective for only a proportion of the population (*i.e.*, those engaging in high-risk activities or who have suffered a previous injury). For this reason, bracing received a colour grading of *amber* (benefit to only a small proportion of the population).

Physical activity volume and the influence of physical fitness: Eight studies (15,756 participants; Table 2) were retrieved relating to reducing physical activity volume and the influence of physical fitness. Many of these studies were analysed to evaluate associations between physical activity/fitness and injuries rather than differences in injury rates following an intervention or between control and intervention groups, meaning that the median effect was only from 3 studies of mixed-sex^{39,42} or male only⁴⁰ populations.

The median difference in injury rates with lower physical activity volume or adapted PT between intervention and control groups was 34% (lower in intervention group). There were no systematic reviews directly assessing the influence of physical fitness on injury risk.

We graded a reduction in physical activity volume and the influence of physical fitness as the number one priority for implementation (Table 2). Although there were few studies to evaluate, the quality of these studies was good, and when combined with the recommendation of Bullock et al.,⁴ we believe that sufficient evidence exists to have confidence in its effects. Therefore, we gave reducing physical activity volume and the influence of physical fitness a colour rating of *green* (fair evidence that the strategy reduces injuries).

Leadership/supervision/awareness: Three studies (43,658 participants; Table 2) investigated the influence of leadership/supervision/awareness on injury incidence in military populations^{47,48} and physical education trainee teachers.¹⁴ All studies were conducted with mixed-sex populations, however either no statistical comparisons between sexes were performed^{47,48} or there were no differences between sexes.¹⁴ The median reduction in outcome injury prevalence was 35%.

Two articles detailing a systematic review of the influence of injury education revealed no influence of injury prevention videos⁵¹ but a positive influence of neuromuscular and educational interventions⁶² on injury incidence. The unknown independent role of the neuromuscular interventions within the pooled estimate in the study of Gagnier et al.,⁶² like many studies of this nature, precludes our ability to specifically evaluate the role of education in preventing injuries.

We graded leadership/supervision/awareness as our joint second priority for implementation (Table 2). The effect sizes of these studies were large, however there were only 3 studies reviewed. Despite the low number of studies, in combination with the evidence base from Bullock et al.,⁴ we gave leadership/supervision/awareness a colour grading of *green* (fair evidence that the strategy reduces injuries).

4. Discussion

We provide an updated position to the injury prevention evidence base detailed by Bullock et al.⁴ Combined findings support a reduction in physical activity volume, and bracing for high-risk activities, to reduce injury rates, particularly in military cohorts. However, using multiaxial, neuromuscular, proprioceptive and agility training to reduce injury rates was not supported by the additional studies in our review. Although no negative effects of

these types of conditioning programmes were observed, their effectiveness was unclear, most likely due to inconsistencies in the nature, duration and frequency of these programmes. Modifications to footwear with orthotics or use of footwear specifically designed for proper plantar shape fit did not decrease injury rates in military cohorts. A high level of pre-accession physical fitness and proper leadership/supervision, and awareness of injury prevention strategies, were deemed protective for injury. We therefore support the recommendation by Bullock et al.⁴ that leadership/supervision/awareness are best considered 'essential elements' of all injury prevention efforts.

Initial military training is typically a busy programme of physical activities such as marching, field/exercise craft, formal physical training sessions, and drill practise. Often, there is little time for the body to recover from the constant and often new, physical demands of training which can lead to overtraining, a risk factor for MSKI.⁶⁷ In support of the findings from Bullock et al.⁴ we provide further data from three studies in military cohorts to show that reducing physical activity volume, including distance on foot, is effective for reducing injury rates during initial military training. One strategy, utilised by Roos et al.,⁴⁰ to reduce distance on foot involved vehicle transportation to training grounds and a progressive increase in weekly mileage during the first 4 weeks of training. This strategy appeared particularly effective for reducing overuse injuries, likely due to the more gradual, progressive increase in training load and volume. Moreover, two studies demonstrated a positive association between PT volume (including ambulatory activity) and injury incidence during initial military training. However, the cost of reducing ambulatory activity or other physical activities to performance is unknown and must be carefully monitored to ensure the optimal balance between reducing injury risk and achieving exercise overload, essential for musculoskeletal adaptation, is achieved.

Low aerobic fitness is an independent risk factor for MSKI.³ Lower levels of aerobic fitness, rather than sex *per se*, have been attributed to the increased risk of injury in women in training.³ Three studies^{44–46} investigating the influence of physical fitness on occupational injury risk demonstrated a greater MSKI risk for individuals with low physical fitness (failure of a pre-accession step test) or low VO_2max ($<43\text{ mL kg}^{-1}\text{ min}^{-1}$) compared to 'acceptable' physical fitness (successful completion of a pre-accession step test) or higher VO_2max ($>48\text{ mL kg}^{-1}\text{ min}^{-1}$). Together, these data suggest that strategies designed to increase baseline physical (particularly aerobic) fitness may be beneficial for reducing MSKI incidence in physically demanding occupations like the military, and may reduce the rates of MSKI in women. Consideration may be given to pre-accession training programmes for potential recruits, as well as effectively balancing exercise overload with overtraining to reduce the risk of MSKI in military trainee cohorts.

Building physical robustness and resistance to injury may be achieved through regular adherence to a conditioning programme. Bullock et al.⁴ recommended the addition of multi-axial, neuromuscular, proprioceptive and agility training exercises into military training for injury prevention. Despite the largest number of reports retrieved from our literature search concerning conditioning programmes of some nature, the available evidence was very mixed across both military and athletic cohorts. The most common conditioning programme in the non-military literature was a FIFA-developed programme with specific exercises designed to be incorporated into the warm up of football activity to improve movement quality. However, despite this specificity, the resultant effect of these exercises on football-related injuries was mixed with some included studies showing beneficial effects^{13,15} and others showing no effect.^{10,12} Conditioning exercises incorporated into military training included neuromuscular exercises, core stability, balance and agility, and functional stretching and strengthening exercises, but again showed mixed responses. The lack of consistency in

the nature, duration, frequency of, and adherence to, the trialled conditioning programmes precludes our ability to effectively compare across studies. Moreover, several systematic reviews have highlighted certain aspects of conditioning as more beneficial to injury prevention over others (e.g.⁵⁴). These differences need to be explored further, and methodologies standardised, before appropriate conclusions regarding the utility of conditioning exercises can be drawn.

External ergonomic aids, including braces and orthotics, have been used as a means to reduce MSKI risk. Bullock et al.⁴ recommended the use of semi-rigid ankle braces for high-risk activities based on their evidence base. Although only an additional two studies were retrieved from our search, these two studies also supported the use of bracing for reducing new and recurrent ankle injuries. One concern that bracing may refer injuries to other body regions was countered by findings from Knapik et al.³⁸ who demonstrated a reduction in ankle injuries with no difference in the injury rates of any other lower limb region when wearing ankle braces for military parachute jumps compared to not wearing any ankle protection. Janssen et al.¹⁸ studied male and female athletes who had suffered a recent lateral ankle sprain and found bracing to be more effective than neuromuscular conditioning exercises for preventing recurrent ankle injuries. Together, these data suggest that employing ankle braces for high-risk activities such as parachuting and/or following ankle injury can protect against sustaining new or recurrent ankle injuries, without concern for a referral of injuries to other body regions. Given that previous injury is a recognised risk factor for MSKI,³ bracing and/or other external supports may be useful for rehabilitation efforts. Improving rehabilitation can reduce lost training days and improve pass-out from training.

The evidence base for orthotic/insole use and/or footwear modification was deemed insufficient at the time of review by Bullock et al.⁴ for recommendations to be made for, or against, their effectiveness. Six studies relating to footwear modification were retrieved from our search with little evidence for the benefits of orthotic use or assigning trainers based on plantar shape. All of these studies were conducted in military cohorts and despite some preliminary evidence for the use of orthotics to reduce lower limb overuse injuries in male and female Naval Officers,³⁷ the remaining evidence did not support a recommendation for such modifications. In particular, assigning trainers based on individual plantar shape was ineffective in US Army, Marine Corps and Air Force cohorts,⁶⁵ suggesting that this practise may not be an optimal use of resource for reducing total injury rates.

The effectiveness of any intervention is influenced by both its content and delivery. Although the independent influence of leadership/supervision/awareness is often difficult to separate from the overall influence of the implemented strategy, evidence from both our review and the review by Bullock et al.⁴ indicates the value of these aspects. Improving overall awareness of injuries and their causes, and management of injury prevention efforts, within the chain of command is recommended to enhance the effectiveness of any implemented strategy. However, further work would benefit from identifying the most critical aspects of leadership and behaviour education to allow for these aspects to be prioritised in injury prevention efforts.

Given the inherent physiological and anatomical differences between men and women, it is not surprising that differences in injury rates between sexes are routinely observed.^{68,69} However, less is known about whether men and women respond differently to injury prevention interventions or require different injury prevention strategies. Although several of the studies retrieved during our literature search did use mixed-sex cohorts, rarely were results statistically analysed by sex. In cases where results were stratified and analysed by sex, the general outcome tended to reflect higher injury rates in women but with comparable injury reduction rates

between men and women.^{32,33,42} However, one study by Franklyn-Miller et al.³⁷ investigating orthotic use in Naval Officers did reveal different risk-reduction values between men and women, and indicated that orthotic use may be more effective for women over men. Some of the observed discrepancies in study outcomes may reflect the lack of sex stratification or use of single-sex cohorts. Original research studies designed to specifically address sex differences in the response to injury prevention interventions would facilitate more specific targeting of injury prevention for both men and women.

One strategy for optimising training gains and injury prevention for men and women may be single-sex training. Although we did not retrieve any studies relating to single-sex training in the current review, previous studies have shown benefits for single-sex training based on the premise that women are often working harder than men in mixed-sex cohorts, as evidenced by a 9% greater cardiovascular strain throughout initial military training in women compared to men.⁷⁰ Given our evidence suggesting that physical activity volume should be limited only to the most effective overload, training in single-sex platoons may allow women to train at the same relative intensity, and achieve the same relative fitness gains, as men, while experiencing fewer overuse injuries.⁷¹ Other strategies such as standardising total exercise time rather than total distance may be useful for reducing physical activity volume and reducing injury risk of mixed ability groups, while still allowing each individual (from the least to most fit) to effectively adapt and improve performance.⁴

5. Limitations of the review

The systematic literature search was limited to a few, specific search terms. Although we feel that these search terms enabled us to retrieve the most appropriate articles, we can not be sure that equally relevant articles were not missed. The searches were performed by only one author (SW). However, the strategy for searching, identifying and screening articles was agreed by both authors and discussed with our wider research group to ensure consistency of approach. Some of the evaluated articles had poor compliance to the interventions which may have confounded our evaluation of the evidence base. Moreover, despite the majority of studies attempting to randomise cohorts, the allocation was not always truly random, with bias possible in several studies. Many studies did not provide full data on all participants or attrition, meaning that the effect sizes of studies are difficult to calculate consistently. The absence of this information precludes our ability to make more accurate assessments on the strategies discussed, although high participant numbers across all categories of injury prevention reviewed aided evaluation of the strategies. Finally, we have tried to apply our findings to a military environment despite not all retrieved articles being directly related to military training and employment. Any retrieved articles relating to physical training and injury prevention were screened to allow us to evaluate the wider evidence base and then make an informed judgement on which strategies would be most applicable to the military environment. Taken together, we provide an updated evidence base to the findings of Bullock et al.⁴ which we hope will inform policy makers and reduce rates of MSKI in military personnel.

6. Conclusion

Prevention strategies can be implemented effectively to reduce MSKI rates in both sexes, even in military training environments where competing demands and the requirement to achieve desired output standards are high. Appropriate leadership, improving physical fitness in the absence of high physical activity volumes,

and bracing for high-risk activities/rehabilitation appear beneficial for reducing PT-related MSKI, whereas modification of footwear and conditioning exercises would not be recommended at this time. There is no evidence suggesting men and women should adopt different injury prevention strategies, although more research is required to confirm this stance. Long-term monitoring of injury rates following implementation of any strategies is necessary for understanding the through-career impact of these strategies.

Practical implications

- Appropriate leadership, and awareness of injury prevention strategies by individuals in leadership positions, are important contributors to the effectiveness of injury prevention strategies.
- Improving physical fitness, in the absence of excessive time on foot, is an effective strategy to reduce musculoskeletal rates and may reduce female injury rates.
- There is no existing evidence to suggest that different injury prevention strategies should be adopted by men and women separately, although appropriately designed studies are required to verify this stance.

Conflict of interest statement

No conflict of interest declared.

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