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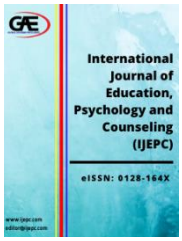

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SYSTEMATIC REVIEW OF RISK FACTORS CONTRIBUTING TO MUSCULOSKELETAL DISORDERS (MSDs) AND INJURIES IN MILITARY PERSONNEL

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Abstract:

This systematic literature review studies the occurrence and contributing factors of musculoskeletal disorders (MSDs) and injuries among military personnel. Musculoskeletal injuries (MSKIs) are a significant concern within military populations caused by the physically demanding nature of their respective duties, which often leads to high rates of disability and medical discharge. A comprehensive methodology was employed, involving systematic searches of electronic databases, including PubMed and Scopus, to identify peer-reviewed articles published between 2020-2024 that examined the occurrence of MSDs along with the psychological and physical risk factors contributing to these conditions, and the effectiveness of injury prevention and management strategies. Our findings reveal that the occurence of MSDs in military personnel is alarmingly high, with key risk factors identified across three themes: first, the prevalence and risk factors associated with MSDs indicate a strong correlation with the demands of military training and operational activities; second, psychological factors, including stress and

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mental health issues, along with physical risk factors like inadequate conditioning and repetitive movements, significantly contribute to the likelihood of injury; finally, effective injury prevention and management strategies, such as training programs and ergonomic assessments, holds a vital function in reducing the frequency and impact of MSDs. This review underscores the need for comprehensive interventions addressing both physical and psychological factors to mitigate the risks of MSKIs in military settings, ultimately enhancing the health and operational readiness of military personnel.

Keywords:

Risk Factor, Musculoskeletal Disorders, Musculoskeletal Injuries, Military

Introduction

Musculoskeletal disorders (MSDs) are a notable issue in various occupational settings, including the military and manufacturing industries. These disorders comprise a variety of conditions affecting the bones, muscles, as well as joints, often resulting from repetitive strain, awkward postures, and other ergonomic risk factors. The occurrence and influence of MSDs are well-documented, with numerous studies highlighting the substantial burden they place on workers' health and productivity. For example, the World Health Organization (WHO) as well as the International Labour Organization (ILO) have jointly formulated estimates to assess the work-related effects of these diseases, emphasizing the need for effective interventions to mitigate these risks (Hulshof, et al., 2021; Sundstrom et al., 2021). In the military, the physical demands placed on personnel are particularly high, leading to a significant incidence of musculoskeletal injuries (MSKIs). Key risk factors for these injuries consist of age, physical fitness, as well as prior injuries. A systematic review as well as meta-analysis found that older age, obesity or excess weight, and poor performance in physical fitness tests were related to a higher risk regarding MSKIs among military personnel (Bunn et al., 2021). Consequently, these results highlight the significance of targeted strategies to address these risk factors and minimize injury incidence within this population. MSDs remain a major concern for military personnel because of the physical demands of their duties. Identifying the ergonomic risk factors that contribute to these disorders is crucial for developing preventive measures (Rhon et al., 2021). The primary ergonomic risk factors with regard to MSDs in military personnel include high BMI, previous injuries, poor physical performance, and gender. Additionally, poor ergonomic conditions in administrative roles and specific occupational exposures significantly contribute to the risk. Addressing these factors through targeted interventions can help mitigate the risk of MSDs in military settings (Salma et al., 2021; Pourtaghi et al., 2015). Ergonomic interventions, including engineering and organizational changes, have been shown to reduce these risks. For example, a study in a truck manufacturing plant demonstrated that a combination of ergonomic measures could effectively decrease physical workloads and musculoskeletal symptoms among workers (Zare et al., 2020; Hoe et al., 2012). These interventions underscore the possibility of improving workplace ergonomics to improve worker health as well as productivity.

Literature Review

The prevalence of MSKIs within military populations has gained significant attention due to the high physical demands and unique occupational risks faced by service members (Vu et al., 2024) observed that female service members experience higher rates of MSKIs, such as hip

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fractures, than their male counterparts, pointing to gender disparities possibly driven by differing physical requirements and body compositions. Roach, et al., (2023) emphasized that self-reported MSKI assessments are valuable for identifying at-risk personnel, underscoring the importance of early detection in injury prevention. On the other hand, Nikolaidis & Havenetidis, (2023) highlighted that basic combat training (BCT) leads to a significant incidence of soft tissue injuries, suggesting that certain injuries are inherent to the physical rigor of training. Their study found that factors like sex, nationality, and body fat were not predictive of MSKI risk, questioning previous assumptions about these variables. Apart from that, (Suikkanen et al., 2023) identified smoking and low education as consistent MSKI predictors, especially for back pain among conscripts, suggesting that specific risk factors remain underexplored. Suikkanen et al., (2023) also presented a longitudinal perspective, revealing a stable 20% back pain incidence among Finnish male conscripts over nearly two decades, with factors such as smoking remaining consistent predictors.

Research on ergonomic risk factors and MSDs within military populations has identified significant occupational risks tied to the psychological as well as physical demands on military personnel. Hayhurst et al., (2024) conducted a retrospective study of UK military specialists, reporting high injury rates—26.8 and 27.7 per 100 person-years in 2018 and 2019—primarily in the lower extremities (40%), trunk (36%), and upper extremities (24%). Military activities, particularly weightlifting and running, were found to elevate MSD risk, emphasizing the need for adjustments in training and ergonomic practices. Exploring footwear, Fraser et al. (2024) examined U.S. Coast Guard recruits, revealing that allowing footwear choice did not significantly affect injury rates, though comfort varied, highlighting the complexity of MSD prevention. Sundaramurthy et al., (2023) demonstrated that stride length modification among military personnel could reduce tibial stress fractures by up to 96%, advocating for tailored training interventions. Beyond physical factors, Mowery et al., (2024) studied psychological influences, finding that fear avoidance pain catastrophizing, anxiety, and depression substantially delayed recovery, underscoring the importance of psychological as well as physical interventions. These studies collectively suggest a multidimensional approach, incorporating ergonomic adjustments, personalized training, and psychological support to mitigate MSD risks and enhance military readiness.

Research on MSDs and injuries among military personnel underscores the critical need for targeted, multi-faceted preventive strategies. Dupuis et al., (2022) examined the efficacy of group-based exercise programs for MSD management in the Canadian Armed Forces, finding them potentially resource-efficient compared to traditional one-on-one physiotherapy; however, further research is needed to confirm effectiveness in diverse settings. Hall et al., (2023) identified intrinsic risk factors among New Zealand Army recruits, including low aerobic fitness, lim asymmetry, and prior injuries, along with modifiable lifestyle factors such as smoking and alcohol use, suggesting baseline assessments could identify high-risk individuals for targeted interventions. Similarly, Pedro et al., (2024) found that Leopard 2 A6 tank crew members are prone to MSDs due to repetitive tasks and awkward postures, highlighting a need for ergonomic adaptations. Saleby et al., (2024) reported that nearly half of the medical visits by Swedish military personnel were for non-combat MSDs, exacerbated by environmental conditions, while Leugers et al., (2024) noted the benefits of tailored running protocols to address running-related injuries. Studies by Nesterovica-Petrikova et al., (2023) indicated that barefoot stride variability could help predict overuse injuries, a factor obscured by standard military footwear. Advanced predictive models, as shown by (Rhon et al., 2022)

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and Coppack et al., (2023), could improv injury prevention, though (Saleby et al., 2024) pointed out the need for longitudinal health data to enable effective injury monitoring. Other studies by (Johnson et al., 2024) and Gun et al., (2022) identified common injury risks like bone stress injuries and lower back pain in U.S. personnel, influenced by prior injuries, fitness, age, and gender. Lastly, Berglund et al., (2024) noted that low cardiorespiratory fitness and heavy workloads contribute to disability pensions among Swedish conscripts.

Research Question (RQ)

Research Questions (RQs) are crucial in a systematic literature review (SLR) as they lay the groundwork and set the course for the whole process. They determine the scope and focus of the review, steering the selection of studies for inclusion or exclusion to ensure relevance and specificity to the area of concern. A clearly formulated RQ allows a thorough and systematic literature search, capturing all relevant studies that address key aspects of the subject while minimizing bias and ensuring comprehensive coverage of existing evidence. Additionally, RQs provide a structured framework for organizing and categorizing data from the included studies, facilitating thorough analysis and synthesis of findings to derive important conclusions. Moreover, they enhance the focus and clarity of the review by eliminating ambiguity and ensuring that the findings remain actionable and relevant to the issues examined. In addition, precise RQs improve the reproducibility and transparency with regard to the review. This enables other researchers to repeat the process, assess the results, or expand the review to associated areas. As a result, they align the review with its core objectives, whether in examining gaps in the literature, determining the interventions' efficiency, or examining trends within a particular field. As such, RQs form the basis of a focused, rigorous, as well as impactful SLR.

Identification

In this research, key steps with regard to the SLR were implemented to collect a substantial body of relevant literature. Here, the process began with keyword selection, followed by identifying related terms via dictionaries, encyclopedias, thesauri, as well as prior research. Correspondingly, relevant terms were determined, and search strings were constructed for the Scopus as well as PubMed databases, as outlined in Table 1. Note that this initial phase concerning the systematic review resulted in 418 publications associated with the study topic retrieved from both databases.

Table 1
The Search String.

Scopus	TITLE-ABS-KEY (risk AND factor AND " musculoskeletal disorders " OR " musculoskeletal injuries " AND military) AND PUBYEAR > 2019 AND PUBYEAR < 2025 AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (LANGUAGE , "English")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (SRCTYPE , "j")) Date of Access: November 2024
PubMed	risk AND factor AND " musculoskeletal disorders " OR " musculoskeletal injuries " AND military Date of Access: November 2024

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Screening

Potentially pertinent research items are assessed in the screening step to make sure they support the predetermined RQ or questions. During this stage, choosing research topics is frequently done using risk factors and musculoskeletal disorders " OR " musculoskeletal injuries " AND " military. At this point, duplicate documents are eliminated. After 292 publications were initially discarded, 124 papers were left for additional analysis in accordance with particular inclusion and exclusion standards (refer to Table 2). Here, the literature was the primary criterion, as it remains the leading source concerning valuable insights. It included conference proceedings, meta-analyses, meta-syntheses, book reviews, book series, as well as chapters excluded from the latest study. Correspondingly, only English-language publications from 2022 to 2024 were included in the review. Due to duplication, a total of two publications were rejected.

Table 2
The Selection Criterion Is Searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2022 – 2024	< 2022
Literature type	Journal (Article)	Book, Review, Conference
Publication Stage	Final	In Press

Eligibility

During the third step, referred to as the eligibility phase, 124 articles were selected for review. At this stage, the titles as well as the main content of all articles, were thoroughly assessed to ensure their compliance with the inclusion criteria and alignment with the research objectives. Here, 92 articles were removed for various reasons, such as lack of relevance to the field, irrelevant titles, abstracts irrelevant to the research's objective, or the unavailability of full-text access based on empirical evidence. Ultimately, 31 articles were maintained for the next review stage.

Data Abstraction and Analysis

An integrative analysis was utilized as one of the evaluation strategies in this research to assess and synthesize various research designs, with a particular focus on quantitative methods. The study's primary objective was to assess key topics as well as subtopics. Note that the data collection phase is the initial step in the theme development process. As depicted in Figure 2, the authors thoroughly examined a set of 31 publications to evaluate statements or content relevant to the study's themes. They then assessed the most significant existing studies on risk factors and musculoskeletal disorders "OR" musculoskeletal injuries "AND" the military. The methodologies and research findings of all studies were thoroughly reviewed. Collaborating with co-authors, the author identified and refined themes referring to the study's context. Consequently, a log was recorded throughout the data analysis to document analyses, perspectives, questions, as well as other relevant insights for interpreting the data. Finally, the authors make a comparison of their results to determine inconsistencies with regard to theme

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development. Subsequently, disagreements regarding the concepts were resolved through discussions among the authors.

Quality of Appraisal

As outlined in the framework by Kitchenham and Charters (Kitchenham, 2007), after choosing the primary studies, it is crucial to assess the research quality they present as well as conduct a quantitative comparison. In this context, primary studies are the original research documents, papers, or articles that are directly incorporated into the systematic review after the initial selection process. Other than that, these studies act as the main sources of evidence, undergoing analysis, quality assessment (QA), and quantitative or qualitative comparison to address the RQs outlined in the review. This research employs the QA framework proposed by (Abouzahra et al., 2020), which incorporates six QA criteria with regard to the SLR. Subsequently, each criterion is evaluated utilising a scoring system with three possible ratings: "Yes" (Y), assigned a score of 1 when the criterion is fully met; "Partly" (P), assigned a score of 0.5 when the criterion is partially satisfied. However, it contains some gaps or limitations. Meanwhile, "No" (N) is assigned a score of 0 when the criterion is not met.

• QA1. Is the research objective explicitly articulated?
• QA2. Is the significance and practical applicability of the study effectively conveyed?
• QA3. Is the research methodology comprehensively delineated?
• QA4. Are the theoretical constructs and methodological approaches distinctly defined?
• QA5. Is the study systematically compared and benchmarked against analogous research?
• QA6. Are the study's constraints and limitations transparently acknowledged?

The table showcases a QA approach for evaluating a study against predefined criteria. Three experts review the study using these criteria, assigning one of three possible scores: "Yes" (Y), "Partly" (P), or "No" (N). Below is a detailed description of the process:

1. **Is the purpose of the study clearly stated?**
    - This criterion evaluates whether the objectives of the study are clearly articulated and explicitly defined. A well-defined purpose enhances clarity and provides a clear direction as well as scope for the research.
2. **Is the interest and usefulness of the work clearly presented?**
    - This criterion assesses whether the study's importance as well as potential contributions, are clearly articulated. It considers the research's relevance and potential impact.
3. **Is the study methodology clearly established?**
    - This evaluates whether the research methodology is clearly articulated and suitable for accomplishing the study's objectives. A well-defined methodology is essential for ensuring the study's reproducibility as well as validity.
4. **Are the concepts of the approach clearly defined?**
    - This criterion evaluates the clarity of the theoretical framework as well as key concepts. Precise definitions are crucial for apprehending the research's methodology and approach.
5. **Is the work compared and measured with other similar work?**
    - This assesses whether the research has been compared to existing research, as such comparisons help situate the work within the broader academic landscape as well as emphasize its contributions.
6. **Are the limitations of the work clearly mentioned?**

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Note that each expert independently assesses the research based on the established criteria, as well as their scores are aggregated to establish the overall score. In order to advance to the next stage, the total score—obtained from the combined evaluations of all three experts—must exceed 3.0. This criterion guarantees that only research studies adhering to the requisite quality benchmarks progress to subsequent stages.

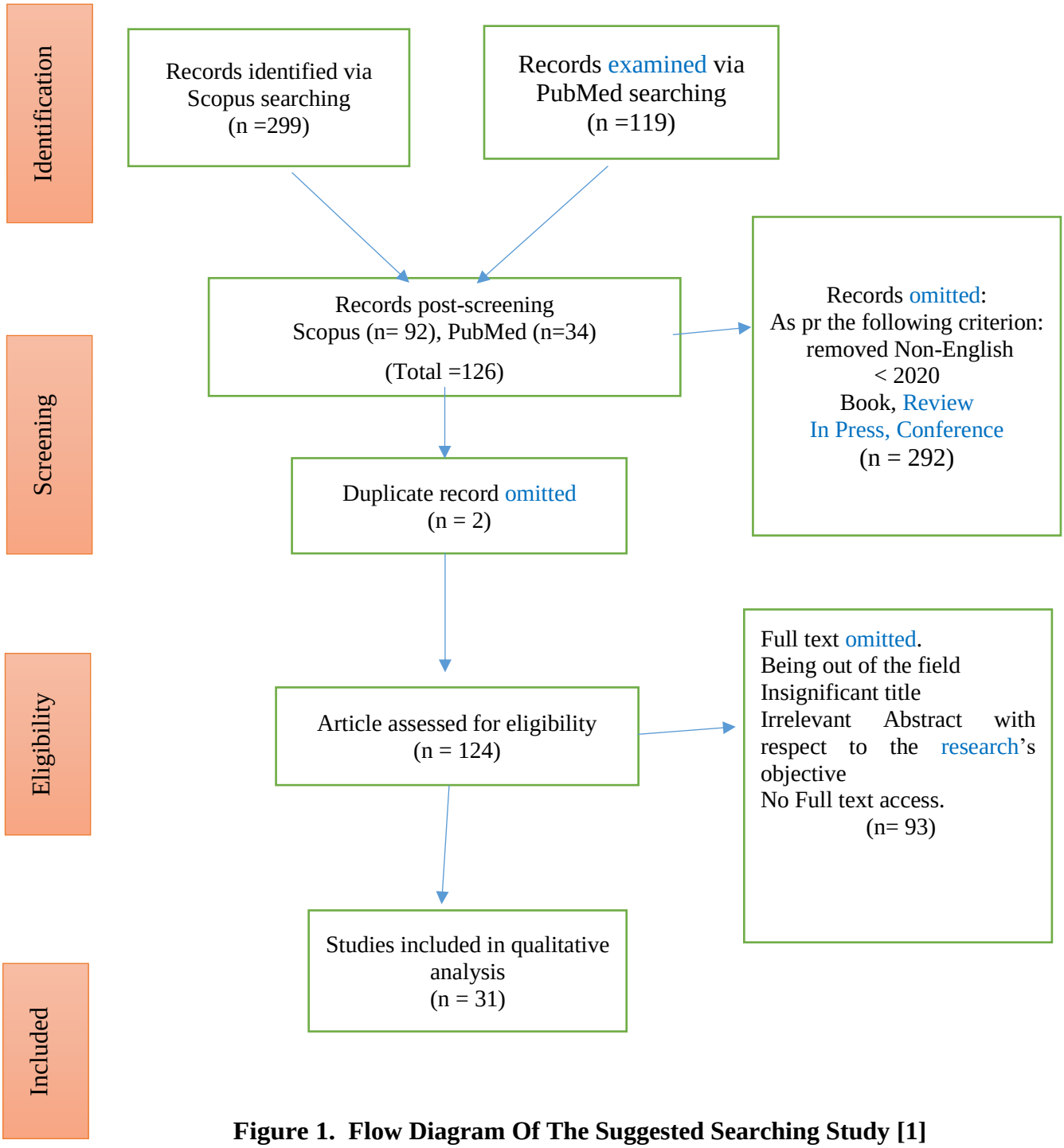

Figure 1. Flow Diagram Of The Suggested Searching Study [1]

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Result

For the background of the selected study, Table 3 depicts the assessment performance results with regard to the selected primary studies based on the QA. Below is the QA table for the selected papers.

Summary:

In the QA, several studies achieved a full score of 100%, demonstrating clear articulation of purpose, relevance, rigorous methodology, well-defined concepts, effective comparisons with existing research, as well as an acknowledgment of restriction. The papers by (Vu et al., 2024), (Hayhurst et al., 2024), (Mowery et al., 2024), (Tegern et al., 2020), (Lovalekar et al., 2024), (Sundaramurthy et al., 2023), (Molloy et al., 2020), (Bird et al., 2023), (Hearn et al., 2021) and (Steinberg et al., 2021) met all the specified criteria, achieving the highest score due to their comprehensive approach and thoroughness in addressing the required elements.

Conversely, (Hiebert et al., 2020) and (Mauntel et al., 2022) received the lowest score of 58.33%. These papers partially fulfilled the criteria for the concepts of approach and comparative analysis with other work. Additionally, they lacked mention of limitations, which contributed to the lower evaluation score in the systematic QA.

Table 3: Quality Assessment Result

No.	Author	Total Mark	%
1.	(Yang et al., 2023)	5.5	91.67
2.	(Smith et al., 2023)	5.5	91.67
3.	(Vu et al., 2024)	6	100
4.	(Roach, Bird, et al., 2023)	5.5	91.67
5.	(Suikkanen et al., 2023)	5.5	91.67
6.	(Nikolaidis & Havenetidis, 2023)	4.5	75
7.	(Roach, Aderman, et al., 2023)	5.5	91.67
8.	(Hayhurst et al., 2024)	6	100
9.	(Mowery et al., 2024)	6	100
10.	(Leugers et al., 2024)	5.5	91.67
11.	(Tegern et al., 2020)	6.0	100
12.	(Pedro et al., 2024)	4.5	75
13.	(Lovalekar et al., 2024)	6.0	100
14.	(D. I. Rhon et al., 2022)	5.5	91.67
15.	(Yang et al., 2022)	5.5	91.67
16.	(Sundstrom et al., 2021)	6.0	100
17.	(Campbell et al., 2022)	5.5	91.67
18.	(Molloy et al., 2020)	6.0	100
19.	(Gołuchowska & Sobieszek, 2024)	5.5	91.67
20.	(Bird et al., 2023)	6.0	100
21.	(Hearn et al., 2024)	5	83.33
22.	(Wooldridge et al., 2022)	4.5	75
23.	(Hearn et al., 2024)	6	100

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24.	(Sidiq et al., 2021)	4.5	75
25.	(Steinberg et al., 2021)	6	100
26.	(Whittle, 2020)	5	83.33
27.	(Butowicz et al., 2022)	5	83.33
28.	(Johnson et al., 2024)	5	83.33
29.	(Gun et al., 2022)	6	100
30.	(Mauntel et al., 2022)	3.5	58.33
31.	(Hiebert et al., 2020)	3.5	58.33

Prevalence and Risk Factors of Musculoskeletal Disorders

MSDs have become a significant health concern among military personnel, impacting both operational efficiency and overall quality of life. Various studies have documented the prevalence and risk factors associated with MSDs in different military contexts, particularly focusing on low back pain (LBP) as well as neck pain (NP). The prevalence of LBP among military pilots, as reported by (Yang et al., 2022), was found to be 37.8%, with a notable variation among different pilot categories. In contrast, Suikkanen et al., (2023) indicated a steady incidence of back pain among Finnish conscripts ranging from 18% to 21% over nearly two decades, highlighting a persistent challenge in addressing back-related issues within military ranks. The findings suggest that occupational demands and specific physical strains are critical in understanding the prevalence of MSDs among military personnel, necessitating targeted interventions. Factors contributing to the onset of MSDs in military settings are multifaceted and often linked to lifestyle, occupational demands, and pre-existing conditions. Yang et al., (2023) identified significant associations between NP and variables such as shoulder pain, continuous flight training, as well as pre-existing LBP among Chinese fighter pilots. Similarly, Sidiq et al., (2021) observed that chronic LBP prevalence among Saudi soldiers was significantly correlated with age, smoking habits, and quality of sleep. These studies highlights the significance of demographic as well as lifestyle factors in developing effective preventive strategies against MSDs in military populations. Furthermore, Tegern et al., (2020) emphasized the higher prevalence of MSDs among Swedish Air Force personnel in comparison to army soldiers, revealing that not only occupational exposure but also personal health perceptions play a role in MSD development.

The musculoskeletal health of military personnel is significantly impacted by rigorous physical training and operational duties, with studies highlighting various risk factors and prevalence trends. (Gołuchowska & Sobieszek, 2024) reported a high occurrence of MSKIs among Polish Territorial Defence Forces soldiers, notably knee injuries, primarily due to challenging terrains and excessive training loads. This aligns with prior findings that intensive training and inadequate conditioning contribute to MSDs in military personnel (Tegern et al., 2020; Yang et al., 2022). Comprehensive training programs and regular health assessments are essential to mitigate these risks. Additionally, Steinberg et

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al., (2021) emphasized the predictive value of tendon structure, such as the patellar tendon (PT) and Achilles tendon (AT) in assessing injury risks, showing that soldiers with certain tendon fiber types are more prone to injuries during high-intensity training. This insight points to tendon health as a critical area for injury prevention in military training (Steinberg et al., 2021; Hiebert et al., 2020). Meanwhile, (Whittle, 2020) explored the connection between travel distance during basic training and lower limb overuse injuries, finding that while weekly distance was not directly correlated with injuries, the accumulated distance could indirectly raise injury risk. Hiebert et al., (2020) further noted a high incidence of MSDs, especially lower back injuries, among U.S. Navy personnel on aircraft carriers, often resulting from sports and exercise activities. These findings highlight the critical role of safety measures in physical and recreational activities. Furthermore, Gun et al., (2022) reported a high burden of LBP in the U.S. Army, particularly among older, obese, female, and enlisted personnel, highlighting the need for policies that encourage a healthy lifestyle as well as body mass index (BMI). Together, these studies suggest a multi-faceted approach to MSD prevention, emphasizing tailored training protocols, physical conditioning, and proactive health assessments to effectively decrease the occurrence of MSIs and improve musculoskeletal health within military populations.

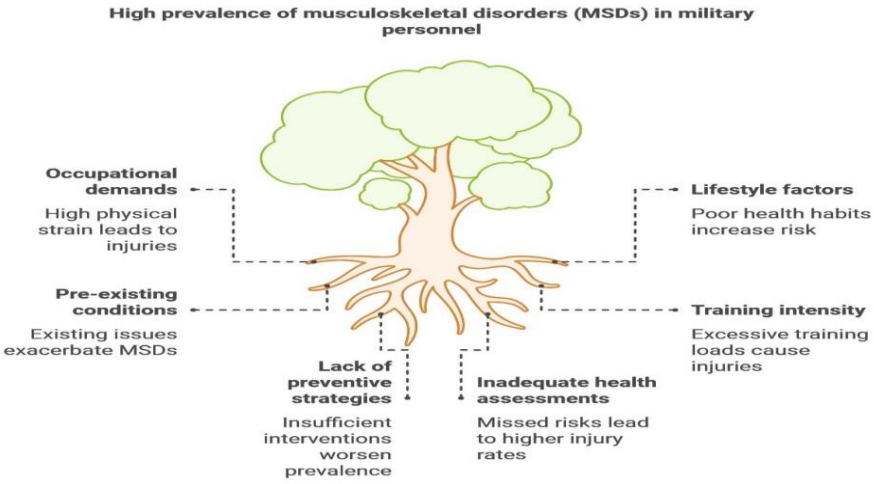

Figure 1: High Prevalence Of Musculoskeletal Disorders (MSDs) In Military Personnel

Psychological and Physical Risk Factors Associated with Injuries

MSIs are a significant challenge within military settings, often resulting in adverse outcomes such as service separation and prolonged recovery times. The studies reviewed underscore the complex interplay of risk factors affecting the incidence and severity of MSIs among military personnel. Notably, psychological responses—particularly fear avoidance behaviors and maladaptive thought patterns—play a vital role in shaping recovery trajectories. (Mowery et al., 2024) found that a substantial proportion of active-duty service members exhibited elevated yellow flag scores, indicative of delayed recovery risks like anxiety and fear of physical activity. Identifying these psychological indicators facilitates early intervention, improving treatment outcomes and enhancing deployment readiness. Additionally, physical training environments significantly influence injury rates, particularly during basic combat training (BCT), which carries inherent risks for soft tissue and MSKIs. For example, (Nikolaidis & Havenetidis, 2023) reported a 24.1% injury

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rate among cadets in BCT, highlighting a high incidence of soft tissue injuries comparable to MSIs. Although traditional risk factors like sex and body composition were not strong predictors of injury occurrence, the overall physical demands of military training were apparent, emphasizing the need for customized training programs that account for individual capabilities and aim to reduce injury risks during high-stress physical activities. The integration of predictive modeling provides valuable insights into injury risk factors among military cadets. Hearn et al., (2024) developed a multivariable risk model incorporating factors, for example, sex, injury history, BMI, and aerobic fitness, underscoring the need for comprehensive assessment methods to predict lower extremity injuries. This perspective is further reinforced by Rhon et al., (2022), who showed that statistical methodologies substantially impact the effectiveness of injury prediction models, underscoring the need for advancements in predictive techniques. Additionally, Johnson et al., (2024) found that trainees lacking high-impact sports experience and with lower fitness scores face a higher risk of bone stress injuries (BSIs), suggesting that prior training and conditioning should be prioritized in pre-training assessments. Together, these studies emphasize the importance of holistic injury prevention strategies addressing both psychological and physical factors to mitigate musculoskeletal injuries (MSIs) in military personnel, which affect operational readiness and health. Campbell et al., (2022) identified lifestyle factors, such as smoking and functional limitations, as predictors of upper quadrant injuries, highlighting the importance of addressing these in prevention.

Injury Prevention and Management Strategies

MSKI in military settings have garnered significant attention because of their influence on service members' health and operational readiness. Research such as that Bird et al., (2023) highlights the predictive constraints of commercial technologies in evaluating MSKI risk, noting that while composite scores correlate somewhat with injury risk, their accuracy remains inadequate. Mauntel et al., (2022) underscored the endemic nature of MSKI in military personnel and advocated for systems like the Military Orthopedics Tracking Injuries and Outcomes Network (MOTION) to enhance injury management through systematic data collection. Similarly, Butowicz et al., (2022) proposed a phased approach to pinpoint both psychosocial as well as physical factors that contribute to MSKI, stressing that a multifaceted strategy is crucial for effective risk assessment. Bird et al., (2023) identified common risk factors—including age, gender, and running performance—among Marine Officer candidates but emphasized the need for occupation-specific screenings given the limited accuracy of commercial predictive models. Wooldridge et al., (2022) revealed substantial knowledge gaps among U.S. Army ROTC cadets in injury prevention strategies, underscoring the need for educational interventions. Integrating educational resources into military training programs could improve service members' understanding of injury prevention, thereby reducing the incidence of MSKI. This educational approach aligns with the data-driven strategies proposed by (Mauntel et al., 2022) and (Butowicz et al., 2022), suggesting that a comprehensive strategy that combines education, data collection, and personalized assessments may lead to better outcomes in managing these injuries. Overall, managing MSKIs in military settings necessitates a multifaceted approach that leverages advanced technology, thorough data analysis, and strong educational programs. The findings from the reviewed studies indicate that while some predictive models and data systems show promise, further research is urgently needed to optimize these tools for practical military application. Emphasizing personalized risk

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assessments alongside enhanced education on injury prevention could significantly boost the medical readiness of military personnel and mitigate the impact of MSKIs.

MSKIs pose significant challenges for military populations, resulting from a combination of physical demands, training regimens, and demographic factors. Research indicates that military personnel face an increased risk of experiencing MSKIs, particularly those returning to activity after concussions or in specialized roles. For example, Roach,et al., (2023) discovered that individuals with concussions are 1.84 times more prone to experiencing upper extremity injuries than their non-concussed peers. This risk persists even after adjusting for prior injuries and sports levels. Similarly, (Hayhurst et al., 2024) highlighted high incidences of MSKIs among military specialists, emphasizing the need for targeted injury prevention strategies tailored to their unique training environments. The analysis of injury causation reveals a complex interplay of environmental and behavioral factors, with military training being the primary source of injuries, particularly from weight training, running, and military exercises. Additionally, (Vu et al., 2024) found that younger female recruits in combat roles experience disproportionately high rates of stress fractures, indicating the need for revised training and policy frameworks. Innovative approaches to injury risk mitigation are being investigated, for instance, (Smith et al., 2023) showed that a personalized training program could effectively reduce injury risk among army personnel while improving performance metrics. (Campbell et al., 2022) established that movement-based assessments could predict upper quadrant MSKIs, enabling early identification of at-risk individuals. Overall, the literature underscores the multifactorial nature of MSKIs in military personnel, highlighting the necessity for tailored training programs, effective risk assessment tools, and proactive management strategies to lower injury rates and improve the physical readiness and health of military personnel. Molloy et al., (2020) concluded that uniform exercise programs have lowered the incidence of MSKI among trainees.

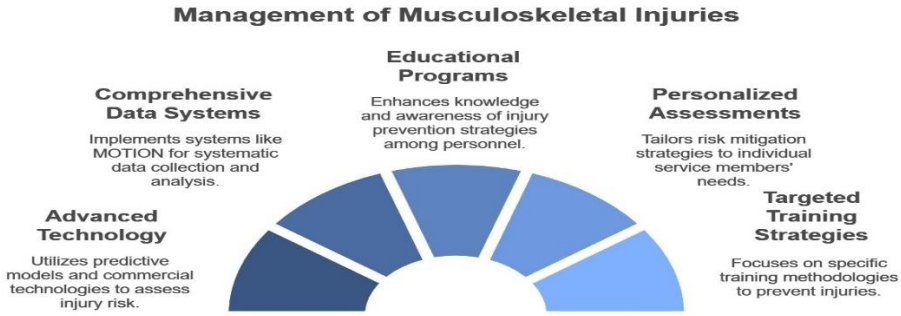

Figure 2 Management of Musculoskeletal Injuries

Discussion and Conclusion

MSDs in military personnel pose a significant health challenge, adversely affecting operational effectiveness and overall quality of life. The prevalence of these disorders, particularly NP and LBP, varies among different military roles and populations. For instance, LBP is notably common among military pilots, with its occurrence fluctuating based on pilot categories. At the same time, a consistent incidence of back pain has been observed among conscripts over several years, reflecting persistent management challenges. The contributing factors to MSDs in military settings are multifaceted,

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encompassing lifestyle choices, occupational demands, and pre-existing health conditions. Notably, significant associations have been identified between NP and factors such as flight training intensity and shoulder discomfort, alongside correlations between chronic LBP and demographic variables like age, smoking, and sleep quality. These insights underscore the need to address both individual and occupational factors to develop effective preventive strategies for MSDs in military personnel.

Additionally, rigorous physical training and operational tasks further exacerbate musculoskeletal health concerns, with specific injuries, particularly to the knees, being prevalent among soldiers facing challenging terrains and high training loads. This highlights the necessity for comprehensive training programs and routine health evaluations to mitigate risks associated with intense physical demands. A thorough examination of factors influencing MSDs, including tendon structure and training distances, can provide valuable insights into injury risks in military settings. This suggests that understanding tendon characteristics may enhance pre-training assessments, while managing training distances could help reduce overuse injuries among recruits.

MSIs pose a significant challenge in military settings, impacting both operational effectiveness and individual health. The reviewed studies indicate that the occurrence and severity of these injuries result from a complex interplay of psychological and physical risk factors. Psychological elements, such as fear avoidance behaviors and maladaptive coping strategies, are crucial for understanding recovery, with elevated anxiety and fear of physical activity linked to delayed healing among service members. This highlights the necessity for early identification and intervention focused on these psychological aspects. Additionally, the physical training environment significantly influences injury rates, particularly during basic combat training, where high-intensity activities increase the risk of injuries. Implementing tailored training programs that consider individual physical capabilities could help mitigate these risks.

Conclusion

The findings underscore the urgent need with regard to systematic prevention and intervention strategies designed for the unique demands of military environments. A multifaceted approach is essential for managing MSKIs among military personnel, emphasizing educational efforts regarding physical conditioning, modifications to training protocols, and enhanced safety measures to significantly reduce the incidence of MSDs. Recognizing the interplay between lifestyle factors and occupational challenges is crucial for improving musculoskeletal health. At the same time, strategies that integrate psychological support with physical rehabilitation are vital for enhancing recovery outcomes and maintaining operational readiness. By acknowledging the complex nature of risk factors associated with MSIs, military healthcare providers can develop more effective prevention and treatment protocols that promote both mental and physical well-being. Additionally, incorporating advanced technology for data collection and analysis, robust educational initiatives, and personalized risk assessments can help focus on modifiable risk factors. Ultimately, these comprehensive management strategies will enhance the physical readiness and health outcomes of military personnel, leading to a reduction in the incidence of MSKIs.

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Conflicts of Interest
The authors affirm the absence of any conflicts of interest relevant to the present study.

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