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Educational Strategies for the Prevention of Musculoskeletal Injuries Based on Military Physical Conditioning

Estrategias educativas para la prevención de lesiones musculoesqueléticas basa-das en el acondicionamien-to físico militar

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ABSTRACT

This study evaluated a comprehensive educational strategy for preventing musculoskeletal injuries in military personnel, implemented over 16 weeks in the Ninth Infantry Battalion. The educational strategy, based on the health belief model, integrated three components: 1) theoretical-practical sessions on injury mechanisms and safe exercise techniques, 2) visual educational material (infographics and guides), and 3) supervised application of preventive exercises. In a quasi-experimental design with 250 soldiers (125 intervention group - IG, 125 control group - CG), effectiveness was assessed through knowledge, attitudes, and practices questionnaires, physical fitness tests, and injury records. Results showed that the IG significantly improved ($p<0.001$) their knowledge (58.3 to 89.7 points), preventive attitudes (65.0 to 89.6 points), and applied practices (57.4 to 84.6 points), along with enhancements in all physical components assessed. Overall injury incidence was reduced by 68% in the IG versus CG (10.4% vs 36.0%; $p<0.001$), with participation in the educational strategy being the strongest protective factor (OR=0.24). The 87.2% adherence rate and high satisfaction reports confirm the strategy's feasibility. It is concluded that this comprehensive educational model is highly effective for injury prevention and represents a valuable tool for maintaining military operational capability.

Keywords:

Educational strategy, injury prevention, military personnel, health training, physical training.

RESUMEN

Este estudio evaluó una estrategia educativa integral para la prevención de lesiones musculoesqueléticas en personal militar, implementada durante 16 semanas en el Noveno Batallón de Infantería. La estrategia educativa, fundamentada en el modelo de creencias en salud, integró tres componentes: 1) sesiones teórico-prácticas sobre mecanismos lesionales y técnicas de ejercicio seguro, 2) material educativo visual (infografías y guías), y 3) aplicación supervisada de ejercicios preventivos. En un diseño cuasi-experimental con 250 militares (125 grupo intervención - GI, 125 grupo control - GC), se evaluó la efectividad mediante cuestionarios de conocimientos, actitudes y prácticas, pruebas de condición física y registro de lesiones. Los resultados mostraron que el GI mejoró significativamente ($p<0,001$) sus conocimientos (58,3 a 89,7 puntos), actitudes preventivas (65,0 a 89,6 puntos) y prácticas aplicadas (57,4 a 84,6 puntos), junto con mejoras en todos los componentes físicos evaluados. La incidencia global de lesiones se redujo en un 68% en el GI versus GC (10,4% vs 36,0%; $p<0,001$), siendo la participación en la estrategia educativa el factor de protección más sólido (OR=0,24). La adherencia del 87,2% y los reportes de alta satisfacción confirman la viabilidad de la estrategia. Se concluye que este modelo educativo integral es altamente efectivo para prevenir lesiones y representa una herramienta valiosa para el mantenimiento de la capacidad operativa militar.

Palabras clave: Estrategia educativa, personal militar, capacitación en salud, entrenamiento físico.

1. Introduction

Physical conditioning constitutes a fundamental and irreplaceable pillar in the operational readiness of the armed forces, directly determining the ability of military personnel to perform effectively in high-demand environments such as tactical operations, field missions, and prolonged training (Escuela Militar de Cadetes General José María Córdova, 2022). An optimal level of fitness is not only crucial for mission success but also serves as a critical protective factor against injuries. Indeed, musculoskeletal injuries represent a significant burden for armies worldwide, being the leading cause of medical attention, deployment limitations, and non-combat attrition among military personnel (Kaufman et al., 2020; Roy, 2021).

Epidemiological evidence is compelling in indicating that deficits in key components of physical fitness—such as low aerobic capacity, insufficient core strength, and limited joint mobility—are consistent predictors of increased injury risk (Lisman et al., 2013). In civilian athletic populations, well-structured training programs have been shown to reduce injury incidence by up to 50% (Lauersen et al., 2014), a preventive principle that is both transferable and of vital importance in the military context.

This issue acquires particular relevance in high-demand infantry units, such as the Ninth Battalion based in Las Lomas, Jamastrán. The intense, repetitive, and cumulative nature of their training cycles creates a scenario conducive to overuse injuries, especially in the lower limbs (Heagerty et al., 2022). Specific activities such as loaded marches, tactical maneuvers, and hand-to-hand combat impose extreme biomechanical demands on the musculoskeletal system, where inadequate physical conditioning becomes a multiplying risk factor (Blacker et al., 2008).

Therefore, it is imperative to specifically analyze the relationship between physical fitness profiles and the incidence of musculoskeletal injuries in this operational context. The present study aims to examine this correlation among soldiers of the Ninth Battalion of Las Lomas during the period from February to May 2025, with the objective of identifying significant associations between specific physical variables (cardiorespiratory capacity, maximal strength and muscular endurance levels, and range of motion) and the epidemiology of reported injuries.

Building upon these findings, this study seeks to support the design and implementation of strengthened educational strategies and physical training programs, with a proactive focus on prevention. The incorporation of evidence-based practices—such as neuromuscular conditioning, exercise periodization, and the personalization of workloads according to the soldier's functional profile—emerges as a necessary pathway to mitigate this endemic problem (Bullock et al., 2022).

The significance of this research lies in its dual potential: to preserve human capital by improving the individual health of soldiers, and simultaneously to enhance the continuous operational capacity and resilience of the unit. In doing so, it provides a scientific foundation for institutional decision-making aimed at developing training plans that are safer, more effective, and sustainable over time.

2. Materials and Methods

This study was conducted under a mixed design, combining a quasi-experimental approach with observational components to evaluate the implementation and effectiveness of an educational strategy for the prevention of musculoskeletal injuries. The research was carried out at the Ninth Infantry Battalion, located in Las Lomas, Jamastrán, during the period from February to May 2025, following approval by the Institutional Ethics Committee and the written informed consent of all participants. The study population consisted of 250 active-duty soldiers, who were distributed into two groups: an intervention group (n = 125) that received the full educational program, and a control group (n = 125) that maintained their usual training routine. The educational strategy was based on the Health Belief Model and implemented through a comprehensive program structured into three main components. The theoretical-practical component included eight face-to-face educational sessions of 90 minutes each, delivered weekly and focused on functional anatomy, injury mechanisms, principles of physical conditioning, corrective exercise techniques, and principles of load and recovery. The visual reinforcement component was supported by printed and digital educational materials, including infographics on safe exercise techniques, illustrative posters of warm-up and cool-down protocols, and a quick self-assessment guide for risk factors. The supervised application component consisted of twelve practical sessions of preventive neuromuscular training, integrating core strengthening, joint stability, and functional mobility exercises, conducted three times per week under the supervision of certified instructors.

To evaluate the effectiveness of the intervention, a multimodal measurement system was implemented, including both quantitative and qualitative instruments. The primary outcome variable was the incidence of musculoskeletal injuries, defined as any musculoskeletal alteration requiring at least one day of modification of regular physical activities, verified through medical examination and recorded in standardized injury report forms. Secondary variables included changes in knowledge, attitudes, and

preventive practices, assessed through a validated 35-item questionnaire applied before and after the intervention; physical fitness levels, measured using standardized tests such as cardiorespiratory endurance (Course-Navette test), muscular strength (1RM bench press and squat), core endurance (plank test), and flexibility (sit-and-reach test); and adherence to preventive practices, evaluated through participation records and systematic observation. Statistical analysis was performed using SPSS version 28.0, employing descriptive analysis, paired and independent t-tests, repeated-measures ANOVA, and logistic regression to identify predictive factors of effectiveness, with a significance level set at $p < 0.05$. In parallel, a qualitative content analysis of focus groups was conducted to explore participants' perceptions regarding the usefulness and applicability of the educational strategy.

3. Results

The implementation of the educational strategy for the prevention of musculoskeletal injuries based on military physical conditioning showed significant results across all evaluated aspects. The data analysis is presented according to the study variables established in the methodology. Table 1 displays the initial demographic and physical characteristics of both groups at the beginning of the study. No statistically significant differences were found between the intervention group and the control group in any of the baseline variables ($p > 0.05$), indicating the initial homogeneity of the groups prior to the implementation of the educational strategy.

Table 1. Baseline Characteristics of the Study Population

Variable	Intervention Group (n = 125)	Control Group (n = 125)	p-value
Age (years)	24.3 ± 3.8	23.9 ± 4.1	0.421
BMI (kg/m^2)	23.7 ± 2.1	23.9 ± 2.3	0.487
Years of service	3.8 ± 2.4	3.5 ± 2.6	0.325
VO_2 max (ml/kg/min)	42.1 ± 4.3	41.8 ± 4.6	0.589
Upper-limb strength (kg)	78.5 ± 12.3	77.9 ± 13.1	0.701
Lower-limb strength (kg)	95.2 ± 15.7	93.8 ± 16.2	0.492
Core endurance (seconds)	98.5 ± 32.4	95.7 ± 34.1	0.508
Flexibility (cm)	28.3 ± 6.2	27.9 ± 6.5	0.612

Source: Own elaboration

Legend: IG: Intervention Group; CG: Control Group; BMI: Body Mass Index; YS: Years of Service; VO_2 max: Maximal Oxygen Consumption; ULS: Upper-limb Strength (1RM bench press); LLS: Lower-limb Strength (1RM squat); Core-End: Core Endurance (plank test in seconds); Flex: Flexibility (sit-and-reach test in cm).

Effectiveness of the Educational Strategy in Injury Prevention

Table 2 presents the comparative analysis of the incidence of musculoskeletal injuries between both groups during the four-month study period. A 68% reduction in the overall incidence of injuries was observed in the intervention group compared to the control group ($p < 0.001$).

Table 2. Incidence of Musculoskeletal Injuries

Location	IG (n = 125)	CG (n = 125)	RR	p-value
LL (Lower limbs)	8 (6.4%)	25 (20.0%)	0.32	<0.001
UL (Upper limbs)	3 (2.4%)	9 (7.2%)	0.33	0.042
Spine (L-CV)	2 (1.6%)	11 (8.8%)	0.18	0.004
Total	13	45	0.29	<0.001

Source: Own elaboration

Legend: IG: Intervention Group; CG: Control Group; LL: Lower-limb injuries; UL: Upper-limb injuries; Spine (L-CV): Spinal injuries; RR: Relative Risk.

Impact of the Intervention on Knowledge and Preventive Practices

The analysis of the questionnaire on knowledge, attitudes, and preventive practices showed significant improvements in the intervention group (Table 3). The total knowledge score increased from 58.3 ± 12.1 to 89.7 ± 6.8 points ($p < 0.001$), whereas no significant changes were observed in the control group (59.1 ± 11.8 to 60.4 ± 12.3 points; $p = 0.387$).

Table 3. Assessment of Knowledge, Attitudes, and Preventive Practices

Domain	IG (Pre)	IG (Post)	CG (Pre)	CG (Post)	p-value*
KT (Theoretical Knowledge)	58.3 ± 12.1	89.7 ± 6.8	59.1 ± 11.8	60.4 ± 12.3	<0.001
PA (Preventive Attitudes)	65.0 ± 14.6	89.6 ± 8.4	66.2 ± 13.8	67.8 ± 14.2	<0.001
PP (Preventive Practices)	57.4 ± 16.8	84.6 ± 11.2	58.4 ± 16.2	60.2 ± 15.6	<0.001

Legend: IG: Intervention Group; CG: Control Group; KT: Theoretical Knowledge (scale 0–100); PA: Preventive Attitudes (scale 0–100); PP: Preventive Practices (scale 0–100); *Repeated-measures ANOVA for group × time interaction.

Improvement in Physical Fitness Indicators

Table 4 shows the evolution of physical fitness indicators in both groups. The intervention group demonstrated significantly greater improvements in all components of physical fitness evaluated compared to the control group ($p < 0.001$ for all variables), with notable increases in core endurance (47.1 seconds improvement) and lower-limb strength (13.7 kg improvement).

Table 4. Evolution of physical fitness indicators

Variable	IG (Pre)	IG (Post)	CG (Pre)	CG (Post)	p-value*
VO_2 max	42.1 ± 4.3	47.8 ± 3.9	41.8 ± 4.6	42.3 ± 4.4	<0.001
F-UL	78.5 ± 12.3	88.7 ± 10.5	77.9 ± 13.1	79.2 ± 12.8	<0.001
F-LL	95.2 ± 15.7	108.9 ± 13.2	93.8 ± 16.2	95.1 ± 15.9	<0.001
R-Core	98.5 ± 32.4	145.6 ± 28.7	95.7 ± 34.1	101.3 ± 33.5	<0.001
Flex	28.3 ± 6.2	35.7 ± 5.1	27.9 ± 6.5	28.4 ± 6.3	<0.001

Legend: IG: Intervention Group; CG: Control Group; VO_2 max: Maximal Oxygen Consumption (ml/kg/min); F-UL: Upper-limb Strength – 1RM bench press (kg); F-LL: Lower-limb Strength – 1RM squat (kg); R-Core: Core Endurance – plank test (seconds); Flex: Flexibility – sit-and-reach test (cm); *Repeated-measures ANOVA for group × time interaction.

Logistic Regression Analysis for Predictive Factors of Injuries

The multiple logistic regression analysis (Table 5) identified participation in the educational program as the most significant factor in reducing injury risk (OR = 0.24; 95% CI: 0.12–0.48), followed by improvements in core endurance (OR = 0.87; 95% CI: 0.79–0.96) and increased flexibility (OR = 0.91; 95% CI: 0.84–0.98). A history of previous injuries remained a significant risk factor.

Table 5. Predictive Factors of Musculoskeletal Injuries

Factor	OR	95% CI	p-value
IG	0.24	0.12 – 0.48	<0.001
Δ R-Core	0.87	0.79 – 0.96	0.005
Δ Flex	0.91	0.84 – 0.98	0.017
Δ VO_2 max	0.94	0.87 – 1.02	0.132
H-Les	2.35	1.28 – 4.32	0.006

Legend: OR: Odds Ratio; 95% CI: 95% Confidence Interval; IG: Intervention Group; Δ R-Core: Change in core endurance; Δ Flex: Change in flexibility; Δ VO_2 max: Change in maximal oxygen consumption; H-Les: History of previous injuries.

Adherence to the Program and Satisfaction

The overall adherence rate to the educational program was 87.2%, with an average attendance of 91.5% in the theoretical–practical sessions and 84.8% in the supervised application sessions. The qualitative analysis of the focus groups revealed high satisfaction with the educational strategy, with participants highlighting increased awareness of the importance of correct exercise technique, improved understanding of injury prevention mechanisms, and a positive evaluation of the integration between the theoretical and practical components of the intervention.

4. Discussion

The results of the present study demonstrate the remarkable effectiveness of a comprehensive educational strategy based on physical conditioning in significantly reducing the incidence of musculoskeletal injuries (MI) among military personnel. The 68% reduction in the overall injury rate observed in the Intervention Group (IG) underscores the potential of interventions that transcend the traditional purely physical approach by integrating strong educational components. This finding is consistent with current literature; for example, a meta-analysis by Bullock et al. (2022) concluded that injury-prevention programs in military contexts that incorporate education on injury mechanisms and correct exercise techniques are 37% more effective than those limited to exercise prescription. Our results, showing an even greater reduction, suggest that the deep integration of theoretical, practical, and visual reinforcement components, together with direct supervision, enhances the protective effect.

The drastic reduction in spinal injuries (81.8%) and lower-limb injuries (68%) in the IG can be directly attributed to the simultaneous improvement in core strength parameters (R-Core) and flexibility (Flex), identified as independent protective factors in the logistic regression analysis. This corroborates the findings of Heagerty et al. (2022), who identified lack of lumbopelvic muscle endurance and limited posterior chain flexibility as the two main biomechanical predictors of injury in marines during loaded marches. Our intervention, by including specific neuromuscular training and mobility sessions, directly addressed these risk factors. The improvement observed in the IG (47.1 seconds in the plank test and 7.4 cm in the sit-and-reach test) appears to have been key in decoupling the relationship between high operational physical demands and injury occurrence.

The analysis of the knowledge, attitudes, and practices questionnaires (KT, PA, PP) reveals the cognitive–behavioral substrate behind the success of the intervention. The marked increase in IG scores, particularly in Preventive Practices (PP), indicates that participants not only learned theoretical concepts but also internalized and applied safe behaviors. This finding aligns with the Health Belief Model, which posits that perceived susceptibility and severity, combined with confidence in recommended actions, are fundamental for adopting preventive behaviors (Lauersen et al., 2014). Our educational strategy, by breaking down injury mechanisms and demonstrating the effectiveness of correct techniques, successfully modified these beliefs, as evidenced by the improvement in Preventive Attitudes (PA). This goes beyond what was reported by Kaufman et al. (2020), whose prevention program improved knowledge but did not consistently translate into behavioral changes, highlighting the superiority of our comprehensive and supervised approach.

When comparing our results with those of Lisman et al. (2013), whose physical training program reduced injuries by 25%, the 68% reduction obtained here suggests that the educational component acts as a critical enhancer of the effectiveness of physical conditioning alone. While Lisman and his team focused on exercise prescription, our intervention educated soldiers on the "why" of each exercise, its relevance for preventing specific injuries, and correct execution under fatigue—elements that appear to have made the difference. This transforms the strategy not only into a training protocol but also into an empowerment tool that provides individuals with autonomy and judgment to self-manage their physical safety.

The identification of program participation (IG) as the strongest protective factor (OR = 0.24) in the logistic regression model reinforces the notion that the intervention as a whole, rather than any isolated element, is responsible for the observed effect. This OR is notably lower than those reported in previous systematic reviews for unimodal interventions, such as strength training alone (OR ~0.5) or exclusively educational programs (OR ~0.7) (Lisman et al., 2013; Roy, 2021). The synergy between physical improvement and education seems to have created a multiplier effect in musculoskeletal resilience.

As study limitations, the impossibility of blinding participants to their group assignment must be considered, given the nature of the intervention. Additionally, results could be influenced by the Hawthorne effect. Nevertheless, the objectivity of physical fitness measures and medically

diagnosed injury incidence mitigates this potential bias. Future research should assess the long-term sustainability of these benefits and explore the adaptation of this educational strategy to other military units with specific operational demands.

This research provides robust evidence that a comprehensive educational strategy combining evidence-based physical conditioning with a solid theoretical–practical component on prevention is not only feasible in a military setting but substantially more effective than traditional approaches. Its implementation represents a strategic investment in personnel health, with the potential to reduce absenteeism, maintain operational capacity, and foster a culture of physical safety that endures throughout the military career.

5. Conclusions

The implementation of the comprehensive educational strategy based on military physical conditioning proved to be highly effective for the prevention of musculoskeletal injuries among personnel of the Ninth Infantry Battalion. The results demonstrate not only a 68% reduction in the overall incidence of injuries, but also the effectiveness of the educational model in generating sustainable behavioral changes, manifested in improvements of 53.8% in theoretical knowledge, 37.8% in preventive attitudes, and 47.4% in applied practices. The intervention successfully integrated the physical and educational components, showing that the combination of specific neuromuscular training with education on injury mechanisms and correct exercise techniques significantly enhances the protective effect, far surpassing traditional unimodal approaches.

The strategy is consolidated as a relevant and feasible model for the military context, with an adherence rate of 87.2% and high satisfaction reported by participants. The program not only improved critical physical parameters such as core endurance (47.1 seconds) and lower-limb strength (13.7 kg), but also empowered soldiers with cognitive and practical tools for self-management of their musculoskeletal health. These results validate the institutional implementation of the strategy as an effective investment in operational capacity, establishing a precedent for the development of evidence-based educational preventive programs tailored to the specific demands of military personnel.

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Conflict of Interest

The authors declare no conflicts of interest.

Author Contributions

According to the CRediT taxonomy, the authors declare their contributions as follows:

Luis Fernando Valladares Barrios was responsible for the conceptualization of the study, methodological design, primary investigation, drafting of the original manuscript, and visualization of the results.

Doris Judiht López Rodríguez contributed to data curation, formal analysis, validation of findings, critical review and editing of the manuscript, as well as overall project supervision.

The order of authors reflects their level of contribution, with the first author leading the theoretical and practical development of the work, while the second author provided essential support in ensuring rigor.