EFFECTIVENESS OF A RISK-STRATIFIED MULTICOMPONENT PREVENTION PROGRAM FOR STRESS INJURIES AMONG MILITARY PERSONNEL IN THE ARAL SEA REGION

ЭФФЕКТИВНОСТЬ ДИФФЕРЕНЦИРОВАННОЙ МНОГОКОМПОНЕНТНОЙ СИСТЕМЫ ПРОФИЛАКТИКИ СТРЕССОВЫХ ПОВРЕЖДЕНИЙ У ВОЕННОСЛУЖАЩИХ ПРИАРАЛЬЯ

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Abstract. A 12-month prospective study evaluated the effectiveness of a risk-stratified, multicomponent prevention program for stress and low-energy injuries among military personnel stationed in the Aral Sea region. The study included 150 service members, of whom 77 received the comprehensive preventive intervention and 73 underwent standard preventive measures. The intervention increased serum vitamin D levels from 20.1±0.8 to 33.0±0.8 ng/mL, reduced C-terminal telopeptide of type I collagen (CTX) levels from 0.61±0.02 to 0.43±0.02 ng/mL, and decreased the composite risk index by 3.00 points, compared with 0.94 points under standard preventive care ($p<0.001$). A shift to a lower risk category was observed in 78.4% of the intervention group and 30.0% of the comparison group. The developed prevention program demonstrated effectiveness in improving bone metabolic parameters and functional outcomes and reducing estimated stress injury risk.

Keywords: military personnel, stress fractures, low-energy injuries, prevention, vitamin D, bone metabolism, composite risk index, Aral Sea region.

Аннотация. В 12-месячном проспективном исследовании оценена эффективность дифференцированной многокомпонентной профилактики стрессовых и низкоэнергетических повреждений у военнослужащих Приаралья. В исследование включены 150 военнослужащих, из которых 77 получали комплекс профилактических мероприятий, а 73 — стандартную профилактику. Применение разработанной системы обеспечило повышение уровня витамина D с 20,1±0,8 до 33,0±0,8 нг/мл, снижение С-концевого телопептида с 0,61±0,02 до 0,43±0,02 нг/мл и уменьшение интегрального индекса риска на 3,00 балла по сравнению с 0,94 балла при стандартном подходе ($p<0,001$). В категорию более низкого риска перешли 78,4% военнослужащих основной группы и 30,0% группы сравнения.

Ключевые слова: военнослужащие, стрессовые переломы, низкоэнергетические повреждения, профилактика, витамин D, костный метаболизм, интегральный индекс риска, Приаралье.

Relevance. Prevention of stress injuries among military personnel has traditionally relied on general physical training recommendations and uniform vitamin D supplementation without consideration of baseline vitamin D status, body weight, or individual risk. This approach fails to correct vitamin D deficiency in a substantial proportion of service members stationed in arid regions and does not adequately address the mechanical loading component of injury risk.

Objective. To develop a risk-stratified, multicomponent prevention program for stress and low-energy injuries and evaluate its effectiveness during a 12-month prospective follow-up.

Materials and Methods. The study included 150 contract military personnel stationed in the Aral Sea region, comprising 76 individuals with a history of stress or low-energy injury and 74 individuals

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classified as being at increased risk. In military units assigned to the intervention group (n=77), a five-component prevention program was implemented. The first component involved load management, limiting weekly increases in training load to no more than 10% and introducing a graded return to physical training. The second component consisted of nutritional optimization, with protein intake calculated at 1.4–1.6 g/kg of body weight and calcium intake adjusted to 1,000–1,200 mg/day. The third component involved individualized pharmacological correction based on serum 25-hydroxyvitamin D concentrations. Cholecalciferol was administered at 50,000 IU weekly for 6–8 weeks in cases of vitamin D deficiency, 2,000 IU daily in cases of insufficiency, and 1,000–2,000 IU daily for maintenance. For individuals weighing more than 90 kg, the prescribed daily dose was 3,000–4,000 IU. Vitamin K2 was included when reduced bone mineral density was accompanied by increased bone resorption. The fourth component focused on modifications to daily routines aimed at increasing time spent outdoors. The fifth component consisted of regular monitoring based on measurable clinical, laboratory, and functional indicators. In military units assigned to the comparison group (n=73), standard preventive measures were applied, including general recommendations and cholecalciferol supplementation at 1,000 IU/day. The 12-month follow-up was completed by 74 participants in the intervention group and 70 in the comparison group. Effectiveness was assessed through changes in the composite risk index, bone metabolic parameters, functional outcomes, and clinical provocation test results at 3 and 12 months.

Results. The groups were comparable at baseline in terms of age, duration of military service, body mass index, bone mineral density Z-score, vitamin D concentration, CTX level, and composite risk index ($p=0.236–0.867$). Over the 12-month follow-up, serum vitamin D concentrations in the intervention group increased from 20.1±0.8 to 33.0±0.8 ng/mL, compared with a change from 18.5±1.0 to 20.4±1.2 ng/mL in the comparison group ($p<0.001$). The prevalence of vitamin D deficiency decreased from 50.0% to 2.7% in the intervention group, compared with a reduction from 57.1% to 51.4% under standard preventive measures. Serum CTX levels decreased from 0.61±0.02 to 0.43±0.02 ng/mL in the intervention group, compared with 0.63±0.03 to 0.60±0.03 ng/mL in the comparison group ($p<0.001$). The bone mineral density Z-score improved from −1.54 to −1.20 ($p<0.001$ in paired analysis). The Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) score decreased from 15.4 to 8.0 points, compared with 15.2 to 13.9 points in the comparison group. Calf muscle endurance increased from 19.6 to 24.8 repetitions, whereas no meaningful improvement was observed in the comparison group ($p<0.001$). The composite risk index decreased from 7.07±0.32 to 4.07±0.22 points in the intervention group, compared with a reduction from 6.80±0.31 to 5.86±0.33 points in the comparison group. The corresponding absolute reductions were 3.00 and 0.94 points, respectively ($p<0.001$). A shift to a lower risk category was recorded in 78.4% of the intervention group and 30.0% of the comparison group. Among participants initially classified as high risk, 79.5% in the intervention group and 35.1% in the comparison group moved out of this category. After 12 months, the proportion of high-risk personnel was 10.8% in the intervention group and 34.3% in the comparison group ($p=0.001$). Positive clinical provocation tests persisted in 12.2% of the intervention group, compared with 38.6% of the comparison group ($p<0.001$). Adherence rates (83.8% and 82.9%, respectively) and adverse event rates (8.1% and 7.1%) did not differ significantly between groups. Compliance with the prescribed gradual training load progression was achieved in 90.5% of the intervention group, compared with 51.4% of the comparison group ($p<0.001$).

Conclusions. The risk-stratified, multicomponent prevention program substantially reduced vitamin D deficiency, improved markers of bone resorption, alleviated functional impairment, and decreased the composite risk index by 3.00 points over 12 months. Approximately four out of five high-risk service members were reclassified into lower risk categories. The intervention demonstrated adherence and tolerability comparable to standard preventive measures. Three of the five program components could be implemented at the military unit level without laboratory equipment, supporting the feasibility of this approach within military primary healthcare services.

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