Journal of Biosciences and Medicines, 2025, 13(5), 331-342
https://www.scirp.org/journal/jbm
ISSN Online: 2327-509X
ISSN Print: 2327-5081

The Association between CK, CK-MB, and Osteoporotic Fracture Patients

Yinjun Luo[1,2], Quanquan Zhang[1,2], Xin Zhang[1,2], Ying Li[1,2], Tao Feng[1,2], Jinting Wei[1,2], Shijing Ma[1,2], Zeding Du[1,2], Lingling Huang[2,3*], Jinhua Wang[1,2*]

[1]School of Basic Medical Sciences, Youjiang Medical University for Nationalities, Baise, China
[2]Guangxi Database Construction and Application Engineering Research Center for Intracorporal Pharmacochemistry of TCM, Youjiang Medical University for Nationalities, Baise, China
[3]Department of Histology and Embryology, School of Basic Medical Sciences, Youjiang Medical University for Nationalities, Baise, China
Email: *lingling_h@ymun.edu.cn, *wangjinhua@ymun.edu.cn

How to cite this paper: Luo, Y.J., Zhang, Q.Q., Zhang, X., Li, Y., Feng, T., Wei, J.T., Ma, S.J., Du, Z.D., Huang, L.L. and Wang, J.H. (2025) The Association between CK, CK-MB, and Osteoporotic Fracture Patients. *Journal of Biosciences and Medicines*, **13**, 331-342.
https://doi.org/10.4236/jbm.2025.135026

Received: April 12, 2025
Accepted: May 24, 2025
Published: May 27, 2025

Abstract

Objective: To investigate the association between creatine kinase (CK), creatine kinase myocardial band (CK-MB), and osteoporotic fracture. **Methods:** The clinical data of 60 patients with osteoporotic fractures and 52 patients with normal physical examinations were analyzed retrospectively. The above individuals were set as an osteoporotic fracture group and a control group. Age, body mass index, serum C-reactive protein, CK and CK-MB between the two groups were compared. Analyses of the relationship between biochemical indexes and osteoporotic fractures were employed by Pearson correlation analysis, receiver operating characteristic curve (ROC) and multiple logistic regression model. **Results:** A higher level of age was found in the osteoporotic fracture group than in the control group, and lower levels of serum CK and CK-MB of the osteoporotic fracture group than in the control group were observed ($P < 0.05$, respectively). The age of the osteoporotic fracture group was significantly negatively correlated with CK and CK-MB ($P < 0.05$). After age adjustment, the CK and CK-MB were protective factors for osteoporotic fractures ($P < 0.05$). **Conclusion:** Lower levels of serum CK and CK-MB were found in osteoporotic fracture patients and were adversely linked with age. The serum CK and CK-MB may be new diagnostic indicators of osteoporotic fracture.

Keywords

Osteoporotic Fracture, Creatine Kinase, Creatine Kinase Myocardial Band

1. Introduction

Osteoporotic fractures known as low-trauma or non-traumatic fractures or fragility fractures, predominantly affect women and the elderly, particularly postmenopausal women who are at high risk for low bone mineral density (BMD) and osteoporosis (OP) [1]. OP is a chronic bone disease characterized by low bone density and deterioration of bone microstructure, which increases the risk of bone fragility and susceptibility to osteoporotic fractures [2] [3]. Epidemiology estimates that about 22% of men and 50% of women over the age of 50 are susceptible to osteoporotic fractures [4]. The number of osteoporotic fractures in China is projected to reach 4.83 million in 2035 and 5.99 million in 2050 [5]. Osteoporotic fractures can result in limited mobility, impaired physical function, decreased quality of life, and increased mortality in elderly patients [6]. Osteoporosis has obvious clinical and public health implications, affecting an estimated 750,000 people worldwide and the number of fragility fractures that occur each year is approximately 90,000 [7]. Some studies have shown that the low quality of muscle tissue in elderly patients induced by sarcopenia is characterized by low CK levels [8]. In addition, sarcopenia was positively correlated with osteoporotic fractures [9].

Currently, the clinical diagnosis of osteoporosis is mainly founded on bone mineral density (BMD) examination [10]. BMD was considered a predictor of osteoporotic fractures [11]. Moreover, bone transition markers (BTM), the World Health Organization (WHO) fracture risk assessment instrument (FRAX), quantitative computed tomography (CT), and quantitative ultrasound (QUS) 2 are recommended as predictors of osteoporotic fractures [11]. In economically underdeveloped regions, however, these detection methods are costly for hospitals and patients and require specialized equipment. Previous studies reported that clinical bone biochemical markers show high sensitivity and significance for predicting fracture healing, diagnosing, and determining the efficacy of treatment [12]. For instance, indicators of bone formation, bone resorption, calcium and phosphorus metabolism regulation, etc. However, the above methods also require specific biochemical detection instruments. Therefore, the development of a convenient and economical biochemical marker associated with osteoporotic fractures could help identify at-risk populations and design personalized fracture prevention strategies [13].

In human anatomy, skeletal muscles are attached to bones by tendons, the damage to bone tissue may also cause damage to skeletal muscle [14] [15]. Studies indicate that osteocalcin, sclerostin, and fibroblast growth factor-23, which are factors secreted by osteoblasts or osteocytes, may have a regulatory effect on skeletal muscle [16]. Nevertheless, the interaction between bone and skeletal muscle following fracture is still unknown. Both creatine kinase (CK) and creatine kinase myocardial band (CK-MB), are involved in the muscle contraction process and are crucial in assessing myocardial injury in patients [17]. Studies have found that skeletal muscle damage is detrimental to bone formation [18]. CK is a cytoplasmic

and mitochondrial enzyme capable of catalyzing the reversible reaction of creatine or phosphocreatine with adenosine diphosphate [19]. CK-MB is an isoenzyme of CK that catalyzes the same chemical reaction as CK [20]. Both CK and CK-MB are considered to be important indicators of myocardial injury, but their role in skeletal muscle injury is unclear. Therefore, we hypothesized that the serum CK and CK-MB were associated with osteoporotic fractures. In pathological conditions, osteoporotic fractures often lead to a localized inflammation response and cause the release of inflammatory factors into the circulation. The serum level of C-reactive protein (CRP) accurately reflects the systemic inflammatory response, regulation of bone metabolism, and degree of fracture repair [21]. In addition, age and body mass index (BMI) are also considered influential factors in osteoporotic fractures.

Consequently, the purpose of this study is to investigate the relationship between serum biochemical indicators, especially serum CK, CK-MB, and osteoporotic fractures, to discover affordable and readily available clinical biomarkers for osteoporotic fractures.

2. Materials and Methods

2.1. Clinical Data

From January 2018 to January 2022, the clinical data of sixty patients with osteoporotic fractures and fifty-two normal subjects admitted to the Affiliated Hospital of Youjiang Medical University for Nationalities were retrospectively analyzed. To evaluate the sample size of this study, the GPower 3.1 program was used. The formula for calculating the effect size was: Effect size = [(Mean 1 − Mean 2)]/SD 1. The effect size was computed using peripheral blood osteocalcin data (15.1 ± 5.6 ng/mL vs 18.9 ± 7.7 ng/mL) from a previous study, and the difference between the non-osteoporosis group and osteoporosis group was statistically significant [22]. As a result, the effect size is equal to [(15.1 − 18.9)]/5.6 = 0.7. When the acceptable α error in a two-tailed test was less than 0.05 and the study's power (1-β) was adjusted at 0.95, the final calculated sample size via GPower 3.1 software was 45 for each group. Finally, 52 healthy individuals and 60 patients with osteoporotic fractures were included in this study. Clinical data were collected on all patients with primary osteoporotic fractures (including patients with senile fractures, postmenopausal fractures, and idiopathic fractures). The control group consists of individuals who have undergone normal physical examinations. No other invasive treatment was performed other than blood collection. In this retrospective study, approximately equal numbers of male and female participants are represented. All participants consented to the investigation and signed an informed consent form. The protocol of the study was reviewed by the Ethics Committee of Youjiang Medical University for Nationalities, the ethical approval number is 20230601001.

The inclusion criteria of the participants were: (1) the patient was diagnosed with an osteoporotic fracture, according to the Guidelines for Primary Osteopo-

rosis Diagnosis and Treatment (2022) of the Chinese Society of Osteoporosis and Bone Mineral Research, an osteoporotic fracture can be diagnosed if one of the following conditions is met: ① a fragility fracture of the hip or vertebral body; ② the bone mineral density of the axial bone or the bone mineral density of 1/3 of the distal radius was measured by DXA with T-value ≤ −2.5; ③ bone mineral density measurements were consistent with bone loss (−2.5 < T-value < −1.0) and proximal humerus, pelvis or a fragility fracture of the distal forearm [23]; (2) patients with no history of related fractures in the physical examination centre; (3) patients who voluntarily participate in this study and sign informed consent.

The exclusion criteria of the participants were: (1) patients who had previously taken drugs that could affect biochemical markers of bone metabolism; (2) patients with chronic diseases such as diabetes, chronic liver and kidney disease, and long-term treatment with hormone drugs; (3) patients with severe cardiovascular and cerebrovascular diseases; (4) patients with malignant tumours; (5) patients with incomplete basic information; (6) Patients with traumatic fractures or other soft tissue injuries were excluded.

In addition, the inclusion criteria of the control group were patients who did not meet the standard of osteoporosis, patients without fractures, and patients who voluntarily participated in this study and signed informed consent. Exclusion criteria are consistent with the exclusion criteria of the osteoporosis group. In the experimental group, the first pain assessment of the patient was carried out by the doctor in charge and the responsible nurse within 8 hours after admission, and the comprehensive assessment was carried out within 24 hours after admission to ensure that the pain management was consistent.

2.2. Method

The baseline characteristics (age, sex, height, weight, and BMI) of the participants were obtained from the clinical record. Fracture patients are asked to take blood samples within twenty-four hours of admission, which have undergone evaluation by clinical doctors and standardized procedures by nurses. Each patient was required to draw venous blood after fasting for 12 hours. Subsequently, the blood was centrifuged at 3000 r/min for 10 minutes to separate the serum. Biochemical indexes including CRP, CK, and CK-MB were detected by using a Roche 702 automatic biochemical analyzer for data analysis.

2.3. Statistical Analysis

Statistical analysis is conducted by using professional statistical software. The measurement data were expressed as mean ± standard deviation, and a two-independent sample t-test was used to compare the difference in clinical data between the two groups. The chi-square test was used to compare the differences in categorized data between the two groups. The correlations between clinical parameters were evaluated by using Pearson correlation analysis and multiple logistic regression analysis. The receiver operating characteristic (ROC) curve was con-

structed to determine the diagnostic accuracy of the biochemical indexes in the osteoporotic fracture. The area under the curve (AUCs) range 0.6 to 0.7 was categorized as poor, the range 0.7 to 0.8 was categorized as fair, the range 0.8 to 0.9 was categorized as good, and the range 0.9 to 1.0 was categorized as excellent [24]. $P < 0.05$ was considered statistically significant.

3. Results

Comparison of clinical data and biochemical indexes between osteoporotic fracture patients and normal subjects.

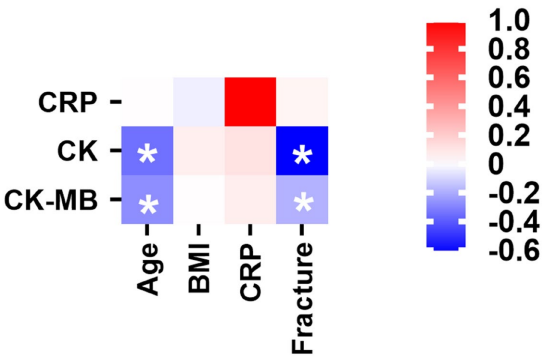
When compared to the control group, patients with osteoporotic fractures were observed to be older ($P < 0.001$). Lower levels of serum CK and CK-MB were found in the osteoporotic fracture group than those in the control group ($P < 0.001$). However, the serum CRP level and BMI were not different between the two groups (Table 1).

Table1. Comparison of general data and biochemical indexes between the two groups.

Index (mean ± SD)	Control group (n = 52)	Fracture group (n = 60)	F value	P value
Age (years)	33.538 ± 4.570	70.733 ± 10.462	12.925	<0.001*
BMI (kg/m^2)	22.429 ± 4.925	21.653 ± 3.078	0.871	0.353
CRP (mg/L)	21.769 ± 31.738	28.657 ± 66.858	1.341	0.249
CK (U/L)	531.000 ± 837.593	78.105 ± 148.356	35.320	<0.001*
CK-MB (U/L)	24.931 ± 23.290	15.551 ± 4.811	18.019	<0.001*

Data are reported as mean ± standard deviation. Two-tailed Student's t-test or chi-square test was used for the comparisons between two groups, and a one-way analysis of variance (ANOVA) was used for the comparisons between multiple groups. * $p < 0.05$. BMI: body mass index; CRP: C-reactive protein; CK: creatine kinase; CK-MB: creatine kinase myocardial band.

3.1. Correlation Analysis among Different Indicators of the Participants



Data are analyzed by using Spearman's rank correlation analysis. Red indicates a positive correlation and blue indicates a negative correlation. *$p < 0.05$. CRP: C-reactive protein; CK: creatine kinase; CK-MB: creatine kinase myocardial band; BMI: body mass index.

Figure 1. Correlation analysis among different indicators.

Age was significantly negatively correlated with the serum CK and CK-MB levels, respectively ($P < 0.05$). The fracture condition was found to be negatively correlated with the serum CK and CK-MB levels, respectively ($P < 0.05$). However, there was no correlation between CRP, BMI, and serum CK, CK-MB levels (Figure 1).

3.2. Multivariate Logistic Regression Analysis

According to the results of univariate analysis, adjusted for age, variables with statistical differences were included in the logistic regression analysis (backward method). Primarily, the occurrence of osteoporotic fractures was set as the dependent variable. In model 1, the serum CK level and the age were set as the independent variables. The result showed that a lower level of serum CK was a risk factor for osteoporotic fractures (OR: 0.991; 95% CI: 0.985 - 0.996). In model 2, the serum CK-MB level and age were set as the independent variables. The result indicated that the lower level of serum CK-MB was a risk factor for osteoporotic fractures (OR: 0.731; 95% CI: 0.637 - 0.839). In model 3, the serum levels of CK, CK-MB, and age were set as the independent variables, the lower levels of serum CK and CK-MB were both risk factors for osteoporotic fractures, and the effect of the serum CK-MB level (OR: 0.744; 95% CI: 0.633 - 0.874) was more significant than that of the serum CK level (OR: 0.999; 95% CI: 0.994 - 1.004). Since the CRP and BMI did not differ significantly between the two groups ($P > 0.05$), they were omitted from the model analysis (Table 2).

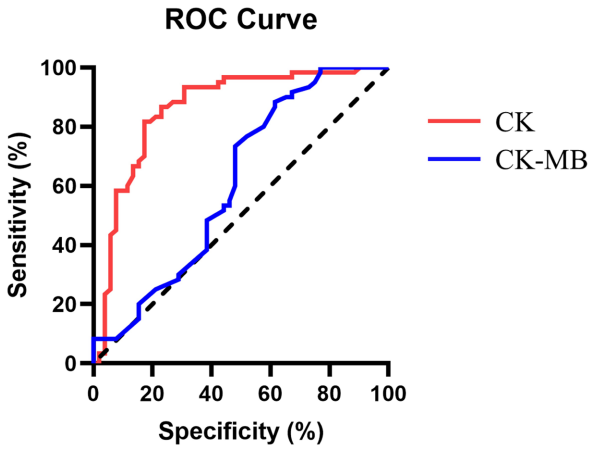
Table 2. Multivariate logistic regression analysis.

Model	Index	β value	SE value	Wald χ^2 value	P value	Adjusted OR	Estimated 95% CI
1	Age	0.035	0.007	28.020	<0.001*	1.035	1.022 - 1.049
	CK	−0.009	0.003	11.541	0.001*	0.991	0.985 - 0.996
2	Age	0.112	0.023	23.188	<0.001*	1.119	1.069 - 1.171
	CK-MB	−0.031	0.070	20.030	<0.001*	0.731	0.637 - 0.839
3	Age	0.109	0.025	19.149	<0.001*	1.115	1.062 – 1.170
	CK	−0.001	0.003	0.131	0.718	0.999	0.994 - 1.004
	CK-MB	−0.296	0.082	12.992	<0.001*	0.744	0.633 - 0.874

Data are reported as mean ± standard deviation. Two-tailed Student's t-test or chi-square test was used for the comparisons between two groups, and a one-way analysis of variance (ANOVA) was used for the comparisons between multiple groups. *$P < 0.05$. CK: creatine kinase; CK-MB: creatine kinase myocardial band.

3.3. ROC Curves Analysis

A sensitivity of 81.67%, specificity of 82.69%, and likelihood ratio of 4.719 was obtained for serum CK level at the cut-off point of 73 U/L (AUC = 0.861, $P < 0.001$). A sensitivity of 71.67%, specificity of 51.92%, and likelihood ratio of 1.491 was obtained for serum CK-MB level at the cut-off point of 16.46 U/L (AUC = 0.610, $P < 0.001$) (Figure 2).



Receiver operating characteristic (ROC) curve and area under the ROC curve (AUC) of serum CK and CK-MB to detect osteoporotic fracture. *p < 0.05. CK: creatine kinase; CK-MB: creatine kinase myocardial band.

Figure 2. ROC curves analysis.

4. Discussion

As the global population ages, senile fractures, particularly osteoporotic fractures, are becoming increasingly prevalent in clinical settings [25]. During the aging process, an osteoporotic fracture is more common and often accompanied by sarcopenia [26]. Osteoporosis combined with sarcopenia is prone to weakness, which increases the risk of fractures [27]. Muscle damage often occurs after a fracture [28]. This study aims to explore the correlation between bone fracture metabolic injury and muscle metabolic injury, providing new evidence for clinical indicators of osteoporotic fractures. Our results demonstrated that the levels of CK and CK-MB are lower in patients with osteoporotic fractures. This confirms that the severity of trauma in patients with fractures is closely related to their serological indicators.

In a study of different surgical approaches to treat intertrochanteric fractures in elderly patients, the serum CK-MB was found to decrease in the proximal femoral nail anti-rotation treatment groups [29]. However, the author focuses on the possibility of myocardial infarction in elderly patients with intertrochanteric fractures. In an overview study of musculoskeletal laboratory parameters in competitive athletes, serum CK was considered an indicator of muscle load and potential injury in competitive athletes [30]. In our study, the serum CK and CK-MB were found to be reduced in patients with osteoporotic fractures. The first reason may be that the degree of osteoporotic fractures varies significantly between studies [31], and some patients may not have significant myocardial cell damage. The second reason may be that the detection time of CK or CK-MB may influence the statistical difference between groups [32]. The blood samples from patients with osteoporotic fractures were collected within 24 hours of admission in our study, and clinicians analyzed this blood biochemical index together with clinical symptoms and other examinations before providing patients with personalized treat-

ment, which included surgery or conservative treatment. Since blood samples were collected before treatment, we believe that treatment will not affect patients' CK and CK-MB levels. However, the interval between feeling ill and being admitted to the hospital may influence the CK and CK-MB levels in the blood.

Contrary to our results, Xinye Li *et al.* reported that serum CK levels increased and were related to osteoclasts [33]. The study showed that the number of osteoclasts decreased when CK release was increased to 2.6 times the basal value [34]. Consequently, we conjecture that serum CK and CK-MB will decrease to varying degrees when osteoporotic fractures occur, particularly in the elderly population. This is consistent with our findings. The activation of osteoblasts is typically normal, whereas the transformation of osteoclasts is abnormal, thus increasing the number of osteoclasts and bone resorption [34]. A decrease in CK may indicate an increase in osteoclast activity, thus increasing the incidence of osteoporotic fractures. In addition, an animal study from Hong Kong, China, found that impaired fracture healing in sarcopenic SAMP8 mice was attributed to increased expression of myostatin in callus and muscle, which was negatively correlated with callus formation [7]. In patients with osteoporotic fractures, our investigation also revealed a decrease in serum CK levels. According to multivariable logistic regression analysis, lower levels of CK and CK-MB were risk factors for osteoporotic fractures.

5. Conclusion

The serum levels of CK and CK-MB in patients with osteoporotic fractures were lower and negatively correlated with age. Decreased serum CK and CK-MB were risk factors for osteoporotic fractures. This may provide a novel concept for the clinical indicator of osteoporotic fractures and certain clinical significance.

Limitation and Further Study

Indeed, this cross-sectional observation study is regional and only focuses on patients from southwest China. If the dynamic changes of CK and CK-MB can be monitored, it will be more conducive to the connection between bone and muscle, and their role in the prognosis and prediction of osteoporotic fractures will be more conducive to research. In addition, the muscle strength of the patients was not measured and there was no body composition data in this study, so we cannot assess whether sarcopenia is a risk factor for osteoporotic fractures, and these data should be included in subsequent studies.

Although AUC = 0.61, it is greater than 0.5 can still indicate that CK-MB has predictive value for osteoporotic fractures. In addition, due to its regional limitations, the AUC may increase further if the sample size is expanded.

Acknowledgements

This work was supported by the 2023 Innovation Project of Youjiang Medical University for Nationalities Graduate Education (YXCXJH2023023). This work

was also supported by the Guangxi Zhuang Autonomous Region University student innovation and entrepreneurship training program under Grant numbers S202210599048 and S202210599057.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Author Contributions

Y.L.: Design of the work, Acquisition, Analysis, Interpretation of data, Draft the manuscript; Q.Z.: Design of the work, Acquisition, Analysis; X.Z.: Acquisition, Experimental technical guidance, Analysis; Y.L.: Acquisition, Experimental technical guidance, Analysis; T.F.: Acquisition, Analysis; J.W.: Acquisition, Analysis; S.M.: Acquisition, Analysis; Z.D.: Conception, Funding Acquisition; L.H.: Conception, Design of the work, Interpretation of data, Revise the manuscript, Final approval of the manuscript to be published; J.W.: Conception, Design of the work, Interpretation of data, Revise the manuscript, Final approval of the manuscript to be published, Funding Acquisition.

Conflicts of Interest

The authors declared that there is no conflict of interest.

References

[1] Ding, J., Zhang, C. and Guo, Y. (2021) The Association of OPG Polymorphisms with Risk of Osteoporotic Fractures: A Systematic Review and Meta-Analysis. *Medicine*, **100**, e26716. https://doi.org/10.1097/md.0000000000026716

[2] Akkawi, I. and Zmerly, H. (2018) Osteoporosis: Current Concepts. *Joints*, **6**, 122-127. https://doi.org/10.1055/s-0038-1660790

[3] Wang, P., Liu, L. and Lei, S. (2021) Causal Effects of Homocysteine Levels on the Changes of Bone Mineral Density and Risk for Bone Fracture: A Two-Sample Mendelian Randomization Study. *Clinical Nutrition*, **40**, 1588-1595. https://doi.org/10.1016/j.clnu.2021.02.045

[4] Shi, L., Min, N., Wang, F. and Xue, Q. (2019) Bisphosphonates for Secondary Prevention of Osteoporotic Fractures: A Bayesian Network Meta-Analysis of Randomized Controlled Trials. *BioMed Research International*, **2019**, Article ID: 2594149. https://doi.org/10.1155/2019/2594149

[5] Zhang, H., Hu, Y., Chen, X., Wang, S., Cao, L., Dong, S., *et al.* (2022) Expert Consensus on the Bone Repair Strategy for Osteoporotic Fractures in China. *Frontiers in Endocrinology*, **13**, Article 989648. https://doi.org/10.3389/fendo.2022.989648

[6] Dai, C., Liang, G., Zhang, Y., Dong, Y. and Zhou, X. (2022) Risk Factors of Vertebral Re-Fracture after PVP or PKP for Osteoporotic Vertebral Compression Fractures, Especially in Eastern Asia: A Systematic Review and Meta-analysis. *Journal of Orthopaedic Surgery and Research*, **17**, Article No. 161. https://doi.org/10.1186/s13018-022-03038-z

[7] Yang, Z., Zhang, W., Ren, X., Tu, C. and Li, Z. (2021) Exosomes: A Friend or Foe for

Osteoporotic Fracture? *Frontiers in Endocrinology*, **12**, Article 679914. https://doi.org/10.3389/fendo.2021.679914

[8] Bermejo, I., Carnicero, J.A., Garcia, F.J., Pérez-Baos, S., Mateos, M., Medina, J.P., *et al.* (2022) POS1446 Creatine Kinase Could Be a Marker of Chronic Inflammation-Induced Sarcopenia in FRAIL Patients. *Annals of the Rheumatic Diseases*, **81**, 1067-1068. https://doi.org/10.1136/annrheumdis-2022-eular.4571

[9] Hong, C., Choi, S., Park, M., Park, S.M. and Lee, G. (2021) Body Composition and Osteoporotic Fracture Using Anthropometric Prediction Equations to Assess Muscle and Fat Masses. *Journal of Cachexia, Sarcopenia and Muscle*, **12**, 2247-2258. https://doi.org/10.1002/jcsm.12850

[10] Imamudeen, N., Basheer, A., Iqbal, A.M., Manjila, N., Haroon, N.N. and Manjila, S. (2022) Management of Osteoporosis and Spinal Fractures: Contemporary Guidelines and Evolving Paradigms. *Clinical Medicine & Research*, **20**, 95-106. https://doi.org/10.3121/cmr.2021.1612

[11] El-Hajj Fuleihan, G., Chakhtoura, M., Cauley, J.A. and Chamoun, N. (2017) Worldwide Fracture Prediction. *Journal of Clinical Densitometry*, **20**, 397-424. https://doi.org/10.1016/j.jocd.2017.06.008

[12] Mick, P. and Fischer, C. (2022) Delayed Fracture Healing. *Seminars in Musculoskeletal Radiology*, **26**, 329-337. https://doi.org/10.1055/s-0041-1740380

[13] Kanis, J.A., Harvey, N.C., McCloskey, E., *et al.* (2019) Algorithm for the Management of Patients at Low, High and Very High Risk of Osteoporotic Fractures. *Osteoporosis International*, **31**, 1-12.

[14] Qin, H. and Jiao, W. (2022) Correlation of Muscle Mass and Bone Mineral Density in the NHANES US General Population, 2017-2018. *Medicine*, **101**, e30735. https://doi.org/10.1097/md.0000000000030735

[15] Valerio, M.S., Janakiram, N.B., Goldman, S.M. and Dearth, C.L. (2020) Pleiotropic Actions of Vitamin D in Composite Musculoskeletal Trauma. *Injury*, **51**, 2099-2109. https://doi.org/10.1016/j.injury.2020.06.023

[16] Lara-Castillo, N. and Johnson, M.L. (2020) Bone-muscle Mutual Interactions. *Current Osteoporosis Reports*, **18**, 408-421. https://doi.org/10.1007/s11914-020-00602-6

[17] Lu, S., Chen, X., Chen, Q., Cahilog, Z., Hu, L., Chen, Y., *et al.* (2021) Effects of Dexmedetomidine on the Function of Distal Organs and Oxidative Stress after Lower Limb Ischaemia-Reperfusion in Elderly Patients Undergoing Unilateral Knee Arthroplasty. *British Journal of Clinical Pharmacology*, **87**, 4212-4220. https://doi.org/10.1111/bcp.14830

[18] Huang, T., Nosaka, K. and Chen, T.C. (2022) Changes in Blood Bone Markers after the First and Second Bouts of Whole-Body Eccentric Exercises. *Scandinavian Journal of Medicine & Science in Sports*, **32**, 521-532. https://doi.org/10.1111/sms.14118

[19] Keceli, G., Gupta, A., Sourdon, J., Gabr, R., Schär, M., Dey, S., *et al.* (2022) Mitochondrial Creatine Kinase Attenuates Pathologic Remodeling in Heart Failure. *Circulation Research*, **130**, 741-759. https://doi.org/10.1161/circresaha.121.319648

[20] Zwirner, J., Anders, S., Bohnert, S., Burkhardt, R., Da Broi, U., Hammer, N., *et al.* (2021) Screening for Fatal Traumatic Brain Injuries in Cerebrospinal Fluid Using Blood-Validated CK and CK-MB Immunoassays. *Biomolecules*, **11**, Article 1061. https://doi.org/10.3390/biom11071061

[21] Si, S., Li, J., Tewara, M.A. and Xue, F. (2021) Genetically Determined Chronic Low-

Grade Inflammation and Hundreds of Health Outcomes in the UK Biobank and the FinnGen Population: A Phenome-Wide Mendelian Randomization Study. *Frontiers in Immunology*, **12**, Article 720876. https://doi.org/10.3389/fimmu.2021.720876

[22] Jiang, C., Zhu, S., Zhan, W., Lou, L., Li, A. and Cai, J. (2024) Comparative Analysis of Bone Turnover Markers in Bone Marrow and Peripheral Blood: Implications for Osteoporosis. *Journal of Orthopaedic Surgery and Research*, **19**, Article No. 163. https://doi.org/10.1186/s13018-024-04634-x

[23] Zhang, Z. (2022) Chinese Society of Osteoporosis and Bone Mineral Research. Chinese General Practice.

[24] Mobasseri, M., Tarverdizadeh, N., Mirghafourvand, M., Salehi-Pourmehr, H., Ostadrahimi, A. and Farshbaf-Khalili, A. (2023) The Role of Bone Turnover Markers in Screening Low Bone Mineral Density and Their Relationship with Fracture Risk in the Postmenopausal Period. *Journal of Research in Medical Sciences*, **28**, Article 54. https://doi.org/10.4103/jrms.jrms_612_22

[25] Haarhaus, M., Aaltonen, L., Cejka, D., Cozzolino, M., de Jong, R.T., D'Haese, P., *et al.* (2022) Management of Fracture Risk in CKD—Traditional and Novel Approaches. *Clinical Kidney Journal*, **16**, 456-472. https://doi.org/10.1093/ckj/sfac230

[26] Ciancia, S., van Rijn, R.R., Högler, W., Appelman-Dijkstra, N.M., Boot, A.M., Sas, T.C.J., *et al.* (2022) Osteoporosis in Children and Adolescents: When to Suspect and How to Diagnose It. *European Journal of Pediatrics*, **181**, 2549-2561. https://doi.org/10.1007/s00431-022-04455-2

[27] Wood, C.L. and Straub, V. (2018) Bones and Muscular Dystrophies: What Do We Know? *Current Opinion in Neurology*, **31**, 583-591. https://doi.org/10.1097/wco.0000000000000603

[28] Rahmati, M., Haffner, M., Lee, M.A., Leach, J.K. and Saiz, A.M. (2023) The Critical Impact of Traumatic Muscle Loss on Fracture Healing: Basic Science and Clinical Aspects. *Journal of Orthopaedic Research*, **42**, 249-258. https://doi.org/10.1002/jor.25746

[29] Wang, B., Liu, Q., Liu, Y. and Jiang, R. (2019) Comparison of Proximal Femoral Nail Antirotation and Dynamic Hip Screw Internal Fixation on Serum Markers in Elderly Patients with Intertrochanteric Fractures. *Journal of the College of Physicians and Surgeons Pakistan*, **29**, 644-648. https://doi.org/10.29271/jcpsp.2019.07.644

[30] Delsmann, M.M., Stürznickel, J., Amling, M., Ueblacker, P. and Rolvien, T. (2021) Muskuloskelettale Labordiagnostik im Leistungssport. *Der Orthopäde*, **50**, 700-712. https://doi.org/10.1007/s00132-021-04072-1

[31] Ji, S., Jiang, X., Han, H., Wang, C., Wang, C. and Yang, D. (2022) Prediabetes and Osteoporotic Fracture Risk: A Meta-Analysis of Prospective Cohort Studies. *Diabetes/Metabolism Research and Reviews*, **38**, e3568. https://doi.org/10.1002/dmrr.3568

[32] Zhang, Y., Zheng, P., Shi, J., Ma, Y., Chen, Z., Wang, T., *et al.* (2023) Associations of Ambient Temperature with Creatine Kinase MB and Creatine Kinase: A Large Sample Time Series Study of the Chinese Male Population. *Science of the Total Environment*, **880**, Article ID: 163250. https://doi.org/10.1016/j.scitotenv.2023.163250

[33] Li, X., Pan, X., Li, Y., An, N., Xing, Y., Yang, F., *et al.* (2020) Cardiac Injury Associated with Severe Disease or ICU Admission and Death in Hospitalized Patients with COVID-19: A Meta-Analysis and Systematic Review. *Critical Care*, **24**, Article No. 468. https://doi.org/10.1186/s13054-020-03183-z

[34] Tanaka, M., Mori, H., Kayasuga, R. and Kawabata, K. (2015) Induction of Creatine Kinase Release from Cultured Osteoclasts via the Pharmacological Action of Aminobisphosphonates. *SpringerPlus*, **4**, Article No. 59. https://doi.org/10.1186/s40064-015-0848-3