SMER
SOCIETY OF MEDICAL EDUCATION & RESEARCH

Society of Medical Education & Research

2024, Volume 4, Issue 1, Page No: 39-44
ISSN: 3108-4826

Journal of Medical Sciences and Interdisciplinary Research

Influence of Vibrations and Other Negative Physical Factors of Production on Protein Metabolism and Protein Dynamics in the Body

Markha Suleymanovna Umarova[1], Zalina Sergeevna Akhyadova[1], Tanzila Osmanovna Salamanova[1], Zezag Ilm-Pashaevna Dzhamaldinova[1], Zukhra Dzhamalayevna Taysumova[1], Malika Ramzesovna Bekmurzaeva[1], Madina Magamedovna Tapaeva[1], Anastasia Maksimovna Ivanushkina[2*]

[1]Department of Therapy, Medical Institute, Chechen State University named after A.A. Kadyrov, Grozny, Russia.
[2]Department of Therapy, Medical Institute, Tula State University, Tula, Russia.

***E-mail** ✉ bucky99@ya.ru

Abstract

The detrimental effect of vibration, which is considered one of the main physical factors in production, requires comprehensive scientific exploration. This study investigates how whole-body vibration influences protein metabolism using laboratory animals as a model. Two series of experiments were conducted involving a total of 30 white rats housed under uniform environmental conditions. Animals in group 1 were subjected to vibration exposure, whereas group 2 served as the control and did not experience any such exposure. The vibration parameters applied to group 1 included general vertical sinusoidal vibration at a frequency of 20 Hz and an intensity of 126 dB, administered for 4 hours per day for 8 weeks. The experimental data showed that while the total protein concentrations remained largely unaltered, a significant decrease in albumin levels was observed in the protein fraction profile. In addition, there was a significant elevation in both α-globulin and γ-globulin fractions. By the conclusion of the study, a statistically significant decline in serum concentrations of several total amino acids was detected in the vibration-exposed group, including aspartic acid ($P < 0.05$), proline ($P < 0.05$), glycine ($P < 0.01$), valine ($P < 0.05$), methionine ($P < 0.05$), and phenylalanine ($P < 0.001$). A general downward trend was also observed in the levels of hydrophobic (nonpolar) amino acids—specifically valine, proline, phenylalanine, and methionine—as well as in slightly polar uncharged and negatively charged amino acids such as aspartic acid.

Keywords: Protein metabolism, Vibrations, Proteins, Physical factors of production, Negative factors of production

Introduction

Among all organic compounds constituting living organisms, proteins hold a central role due to their intricate molecular structure and critical biological functions. They represent the primary component of body mass—comprising approximately 20%—in contrast to other substances such as fats (14.7%), inorganic salts (4.9%), nucleic acids (1.0%), and carbohydrates (1.0%) [1–3]. Given their broad functional range—spanning catalytic, structural, energetic, transport, hereditary, immune, and regulatory roles—understanding how protein metabolism responds to environmental influences is of substantial scientific interest [4, 5].

With the continuous advancement of industrialization and urban growth, a rising number of workers are routinely subjected to negative physical factors of the production environment. This trend inevitably leads to increasing exposure to harmful physical conditions at the workplace, contributing to cumulative physiological strain. As such, the scale of potential health consequences

Access this article online https://smerpub.com/

Received: 03 March 2024; **Accepted:** 01 June 2024

How to cite this article: Umarova MS, Akhyadova ZS, Salamanova TO, Dzhamaldinova ZIP, Taysumova ZD, Bekmurzaeva MR, et al. Influence of Vibrations and Other Negative Physical Factors of Production on Protein Metabolism and Protein Dynamics in the Body. J Med Sci Interdiscip Res. 2024;4(1):39-44. https://doi.org/10.51847/Jk38F1v5XH

linked to these exposures is significant, underlining the pressing societal importance of this issue [6–8].

Vibrational impacts stand out among the most critical physical production stressors, which informed the decision to focus this research specifically on vibration as the primary variable [9, 10]. While a wide body of research has addressed the broader health implications of workplace vibration exposure [11–18], including disruptions to multiple physiological systems observed both in at-risk professionals and in experimental animal models [19–22], detailed insight into its effects on protein metabolism remains sparse [23].

This study aims to fill that gap by examining how general vibration—one of the key physical factors of production—affects protein metabolism, using laboratory animals as a model to explore these changes in a controlled setting.

Materials and Methods

To evaluate the adverse impact of vibration as a physical production factor, two experimental series were carried out using thirty white laboratory rats. The study utilized sexually mature Wistar rats, each weighing between 220–250 grams. All subjects were maintained under identical conditions regarding housing, diet, environmental hygiene, and sleep-wake cycles. The animals were divided into two distinct cohorts:

- Group 1: rats subjected to vibration exposure;
- Group 2: control rats that weren't exposed to vibration.

The rats in group 1 experienced general vertical sinusoidal vibration at a frequency of 20 Hz and a vibration velocity of 126 dB, applied using a VSV-240-445 vibration stand (produced by Rostech, Russia). The cumulative vibration exposure was evaluated using total vibration dose metrics, aligning in physical interpretation with exposure criteria outlined in international ISO standards for noise and vibration [24].

Key markers of protein metabolism assessed in this study included total plasma protein levels, its fractionation, and serum amino acid profiles—the latter being the foundational constituents of protein structures [25]. Total protein concentrations were measured using an IRF-464 refractometer (Agroservice, Russia), while electrophoresis on paper was employed for analyzing protein fractions [26]. Quantification of amino acids in serum was performed with an automatic AAA-500 amino acid analyzer (INGOS, Czech Republic).

All experimental data were analyzed using conventional statistical methods, including the calculation of the arithmetic mean (M) and standard error (m). The significance of differences between data sets was determined through coefficient calculation and Student's t-test to establish the level of statistical confidence.

Results and Discussion

Effectively addressing the mechanisms through which general vibration impacts the body requires an in-depth examination of alterations in metabolic pathways, particularly those involving protein and amino acid metabolism [27]. Proteins, serving as the structural foundation of cells, represent the most quantitatively dominant organic compounds across living organisms, especially in more complex species [28, 29]. In light of this, a targeted investigation was conducted to determine how protein metabolism responds under conditions of experimental vibration exposure.

Findings from this study revealed that subjecting animals to vibration with a frequency of 35 Hz and a vibration velocity of 126 dB for 4 hours daily over 8 weeks—resulting in a cumulative exposure of 150 dB—did not lead to statistically significant alterations in total protein levels **(Table 1)**. The mean total protein value recorded in the vibration-exposed group was 6.18 ± 0.11%, compared to 6.35 ± 0.1% in the control group. Nevertheless, a marked decline in the proportion of albumin within the protein fractions was observed, decreasing from 55.18% to 49.20%. Concurrently, there was a noticeable elevation in both α-globulin and γ-globulin fractions **(Table 1)**, indicating that although total protein remained relatively stable, the distribution among protein subtypes was notably affected.

Table 1. Indicators of protein metabolism under the influence of vibration with parameters f = 35 Hz, Lv = 126 dB, time t = 4 hours, cumulative dose of vibration 150 dB

Groups, statistical indicators	Total protein (%)	Protein fractions	
		Albumins (%)	Globulins (%)

			α	β	γ
	M ± m				
Control	6.35 ± 0.13	55.18 ± 2.4	12.56 ± 0.21	20.71 ± 0.4	13.13 ± 0.70
Experience	6.18 ± 0.11	49.20 ± 1.10	14.20 ± 0.63	19.1 ± 1.20	16.9 ± 0.44
P	> 0.05	< 0.05	< 0.05	> 0.05	> 0.05

The observed reduction in albumin levels may be closely linked to alterations in amino acid metabolism, particularly tryptophan, which is essential for the production of nicotinic acid (PP), serum proteins, and hemoglobin synthesis [30, 31]. Additionally, tryptophan acts as a growth factor, and its demand is higher in younger organisms, which may explain the impaired weight gain in developing rats subjected to prolonged vibration exposure [20, 32, 33].

Amino acids are integral to the formation of proteins and other biologically active compounds in the body [34], but they also serve as a source of energy [35]. The body of higher animals metabolizes both exogenous amino acids, obtained from food proteins, and endogenous amino acids, which are produced through the body's metabolic renewal processes [36]. The findings from the study indicated a significant reduction in the overall concentration of amino acids in the blood serum of the rats by the end of the exposure period **(Figure 1)**.

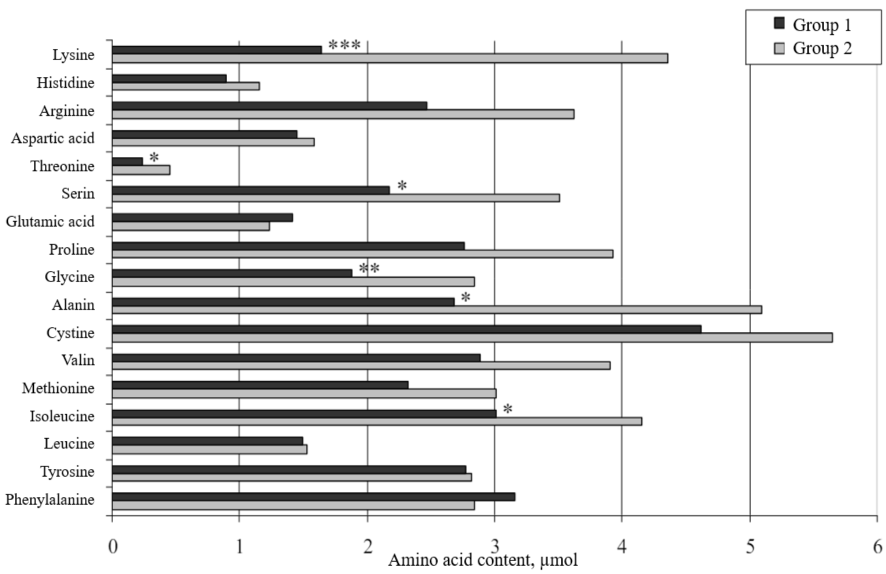

Figure 1. Dynamics of changes in amino acid content under the influence of vibration with a cumulative dose of 150 dB (confidence (P): * 0.05; ** 0.01; *** 0.001)

Amid the overall reduction in amino acids, a significant decline was noted in the levels of aspartic acid ($P < 0.05$), proline ($P < 0.05$), glycine ($P < 0.01$), valine ($P < 0.05$), methionine ($P < 0.05$), and phenylalanine ($P < 0.001$). Specifically, there was a decrease in the hydrophobic (nonpolar) amino acids, such as valine, proline, phenylalanine, and methionine, as well as slightly polar uncharged amino acids and negatively charged ones like aspartic acid. The reduction in methionine is particularly significant, given its role in fat metabolism by influencing fat-phospholipid processes and being a key lipotropic agent that helps prevent the development of fatty liver [37, 38]. Furthermore, methionine plays an essential role in donating methyl groups for choline synthesis, which acts as an anti-atherosclerotic agent [39]. Additionally, vibration exposure resulted in decreased lysine levels, which is vital for hematopoiesis. A deficiency in lysine is associated with a reduction in red blood cell production and hemoglobin levels [40], as well as disruptions in bone calcification and muscle wasting [41].

These disturbances in protein and amino acid metabolism could be connected to alterations in nitrogen metabolism, which have been reported by other studies examining the effects of vibration exposure [42-44].

Conclusion

When subjected to a cumulative vibration dose of 150 dB, experimental animals show a notable decrease in albumin levels ($P < 0.05$) and an increase in the α- and γ-globulin fractions in their blood plasma, indicating a significant shift in amino acid metabolism. Along with these protein metabolism alterations, vertical sinusoidal vibration disrupts amino acid balance, leading to a decrease in overall amino acids. Specifically, there is a substantial reduction in aspartic acid ($P < 0.05$), proline ($P < 0.05$), glycine ($P < 0.01$), valine ($P < 0.05$), methionine ($P < 0.05$), and phenylalanine ($P < 0.001$). The primary impact of this vibration exposure is a decrease in hydrophobic (nonpolar) amino acids such as valine, phenylalanine, proline, and methionine, in addition to aspartic acid, which is negatively charged. Furthermore, significant reductions in methionine and lysine levels are observed, both of which are crucial for fat metabolism and blood cell production.

Acknowledgments: None

Conflict of Interest: None

Financial Support: None

Ethics Statement: The protocol used for laboratory animal experiments adhered to the European Convention for the Protection of Vertebrate Animals used for experimental and other scientific purposes.

References

1. Tur JA, Bibiloni MDM. Anthropometry, body composition and resting energy expenditure in human. Nutrients. 2019;11(8):1891. doi:10.3390/nu11081891
2. Karpińska E, Moskwa J, Puścion-Jakubik A, Naliwajko SK, Soroczyńska J, Markiewicz-Żukowska R, et al. Body composition of young women and the consumption of selected nutrients. Nutrients. 2022;15(1):129. doi:10.3390/nu15010129
3. Yang B, Tang C, Shi Z, Gao L. Association of macronutrients intake with body composition and sarcopenic obesity in children and adolescents: a population-based analysis of the National Health and Nutrition Examination Survey (NHANES) 2011-2018. Nutrients. 2023;15(10):2307. doi:10.3390/nu15102307
4. Fischer NH, Oliveira MT, Diness F. Chemical modification of proteins - challenges and trends at the start of the 2020s. Biomater Sci. 2023;11(3):719-48. doi:10.1039/d2bm01237e
5. Gurevich VV. Protein multi-functionality: introduction. Cell Mol Life Sci. 2019;76(22):4405-6. doi:10.1007/s00018-019-03271-6
6. Siegrist J. Psychosocial stress at work and disease risks: scientific evidence and implications for practice. Internist (Berl). 2021;62(9):893-8. [In German]. doi:10.1007/s00108-021-01105-x
7. Dutta S, Gorain B, Choudhury H, Roychoudhury S, Sengupta P. Environmental and occupational exposure of metals and female reproductive health. Environ Sci Pollut Res Int. 2022;29(41):62067-92. doi:10.1007/s11356-021-16581-9
8. GBD 2019 Risk Factors Collaborators. Global burden of 87 risk factors in 204 countries and territories, 1990-2019: a systematic analysis for the global burden of disease study 2019. Lancet. 2020;396(10258):1223-49. doi:10.1016/S0140-6736(20)30752-2
9. Wang Z, Jiang Y, Shao X, Liu C. On-site measurement and environmental impact of vibration caused by construction of double-shield TBM tunnel in urban subway. Sci Rep. 2023;13(1):17689. doi:10.1038/s41598-023-45089-0
10. Beben D, Maleska T, Bobra P, Duda J, Anigacz W. Influence of traffic-induced vibrations on humans and residential building-A case study. Int J Environ Res Public Health. 2022;19(9):5441. doi:10.3390/ijerph19095441
11. Park I, Kim S, Kim Y, Yun B, Yoon JH. Association between physical risk factors and sleep disturbance among workers in Korea: the 5th Korean working conditions survey. Sleep Med. 2022;100:157-64. doi:10.1016/j.sleep.2022.08.011
12. Debenedictis TA, Billing D, Milanese S, Furnell A, Tomkinson G, Thewlis D. The impact of the mechanical whole-body vibration experienced during military land transit on the physical attributes underpinning dismounted combatant physical performance: a randomized controlled trial. J Sci

Med Sport. 2021;24(4):380-5. doi:10.1016/j.jsams.2020.09.020
13. Thaper R, Sesek R, Garnett R, Acosta-Sojo Y, Purdy GT. The combined impact of hand-arm vibration and noise exposure on hearing sensitivity of agricultural/forestry workers-a systematic literature review. Int J Environ Res Public Health. 2023;20(5):4276. doi:10.3390/ijerph20054276
14. Grossmann T, Steffan B, Kirsch A, Grill M, Gerstenberger C, Gugatschka M. Exploring the pathophysiology of Reinke's Edema: the cellular impact of cigarette smoke and vibration. Laryngoscope. 2021;131(2):E547-54. doi:10.1002/lary.28855
15. Bhuiyan MHU, Fard M, Robinson SR. Effects of whole-body vibration on driver drowsiness: a review. J Safety Res. 2022;81:175-89. doi:10.1016/j.jsr.2022.02.009
16. Viellehner J, Potthast W. The effect of cycling-specific vibration on neuromuscular performance. Med Sci Sports Exerc. 2021;53(5):936-44. doi:10.1249/MSS.0000000000002565
17. Kia K, Fitch SM, Newsom SA, Kim JH. Effect of whole-body vibration exposures on physiological stresses: mining heavy equipment applications. Appl Ergon. 2020;85:103065. doi:10.1016/j.apergo.2020.103065
18. Bartel L, Mosabbir A. Possible mechanisms for the effects of sound vibration on human health. Healthcare (Basel). 2021;9(5):597. doi:10.3390/healthcare9050597
19. Lawrence-Sidebottom D, Schmidt MA, Harvey DO, Van Dongen HPA, Davis CJ. Floor vibrations for motivation and feedback in the rat vibration actuating search task. PLoS One. 2021;16(9):e0257980. doi:10.1371/journal.pone.0257980
20. Minematsu A, Nishii Y. Effects of whole body vibration on bone properties in growing rats. Int Biomech. 2022;9(1):19-26. doi:10.1080/23335432.2022.2142666
21. Koh ES, Lim JY. Impacts of whole-body vibration on denervated skeletal-muscle atrophy in rats. J Orthop Res. 2023;41(12):2579-87. doi:10.1002/jor.25589
22. Krajnak K, Waugh S, Welcome D, Xu XS, Warren C, McKinney W, et al. Effects of whole-body vibration on reproductive physiology in a rat model of whole-body vibration. J Toxicol Environ Health A. 2022;85(23):953-71. doi:10.1080/15287394.2022.2128954
23. Chen D, Kim S, Lee S, Lee JM, Choi YJ, Shin SJ, et al. The effect of mechanical vibration on osteogenesis of periodontal ligament stem cells. J Endod. 2021;47(11):1767-74. doi:10.1016/j.joen.2021.08.014
24. ISO 9612-2016 Acoustics. Noise measurement for the purpose of evaluating human exposure to noise. Method of measurements at workplaces. Available from: https://docs.cntd.ru/document/1200140579 (Accessed on 15 Jun 2024)
25. Verevkina M, Goncharov V, Nesmeyanov E, Kamalova O, Baklanov I, Pokhilko A, et al. Application of the Se NPs-Chitosan molecular complex for the correction of selenium deficiency in rats model. Potr S J Food Sci. 2023;17(1):455-66. doi:10.5219/1871
26. Belyaev NG, Rzhepakovsky IV, Timchenko LD, Areshidze DA, Simonov AN, Nagdalian AA, et al. Effect of training on femur mineral density of rats. Biochem Cell Arch. 2019;19(2):3549-52.
27. Wu P, Lin S, Cao G, Wu J, Jin H, Wang C, et al. Absorption, distribution, metabolism, excretion and toxicity of microplastics in the human body and health implications. J Hazard Mater. 2022;437:129361. doi:10.1016/j.jhazmat.2022.129361
28. Bigman LS, Levy Y. Proteins: molecules defined by their trade-offs. Curr Opin Struct Biol. 2020;60:50-6. doi:10.1016/j.sbi.2019.11.005
29. Mesquita FS, Abrami L, Linder ME, Bamji SX, Dickinson BC, van der Goot FG. Mechanisms and functions of protein S-acylation. Nat Rev Mol Cell Biol. 2024;25(6):488-509. doi:10.1038/s41580-024-00700-8
30. Xue C, Li G, Zheng Q, Gu X, Shi Q, Su Y, et al. Tryptophan metabolism in health and disease. Cell Metab. 2023;35(8):1304-26. doi:10.1016/j.cmet.2023.06.004
31. Comai S, Bertazzo A, Brughera M, Crotti S. Tryptophan in health and disease. Adv Clin Chem. 2020;95:165-218. doi:10.1016/bs.acc.2019.08.005
32. Pirami H, Khavanin A, Nadri F, Tajpoor A, Mehrifar Y, Tirani ZM. The combined effects of noise and vibration stress on sex hormone levels, fertility capacity, and the protective role of cinnamon extract in rats: an experimental study. Arch Environ Occup

Health. 2022;77(9):764-73. doi:10.1080/19338244.2021.2011085

33. Minematsu A, Nishii Y, Imagita H, Sakata S. Possible effects of whole body vibration on bone properties in growing rats. Osteoporos Sarcopenia. 2019;5(3):78-83. doi:10.1016/j.afos.2019.07.001
34. Nagdalian AA, Oboturova NP, Krivenko DV, Povetkin SN, Blinov AV, Verevkina MN, et al. Why does the protein turn black while extracting it from insect biomass? J Hyg Eng Des. 2019;29:145-50.
35. Ansori AN, Widyananda MH, Antonius Y, Murtadlo AA, Kharisma VD, Wiradana PA, et al. A review of cancer-related hypercalcemia: pathophysiology, current treatments, and future directions. J Med Pharm Chem Res. 2024;6(7):944-52. doi:10.48309/jmpcr.2024.435280.1088
36. Thalacker-Mercer A, Riddle E, Barre L. Protein and amino acids for skeletal muscle health in aging. Adv Food Nutr Res. 2020;91:29-64. doi:10.1016/bs.afnr.2019.08.002
37. Hoshi T, Heinemann S. Regulation of cell function by methionine oxidation and reduction. J Physiol. 2001;531(Pt 1):1-11. doi:10.1111/j.1469-7793.2001.0001j.x
38. Wei F, Locasale JW. Methionine restriction and antitumor immunity. Trends Cancer. 2023;9(9):705-6. doi:10.1016/j.trecan.2023.07.008
39. Newberne PM, Suphiphat V, Locniskar M, de Camargo JL. Inhibition of hepatocarcinogenesis in mice by dietary methyl donors methionine and choline. Nutr Cancer. 1990;14(3-4):175-81. doi:10.1080/01635589009514092
40. Wan J, Liu H, Chu J, Zhang H. Functions and mechanisms of lysine crotonylation. J Cell Mol Med. 2019;23(11):7163-9. doi:10.1111/jcmm.14650
41. Azevedo C, Saiardi A. Why always lysine? The ongoing tale of one of the most modified amino acids. Adv Biol Regul. 2016;60:144-50. doi:10.1016/j.jbior.2015.09.008
42. Kodama M, Nakayama KI. A second Warburg-like effect in cancer metabolism: the metabolic shift of glutamine-derived nitrogen: a shift in glutamine-derived nitrogen metabolism from glutaminolysis to de novo nucleotide biosynthesis contributes to malignant evolution of cancer. Bioessays. 2020;42(12):e2000169. doi:10.1002/bies.202000169
43. Santoso KH, Wahyu S, Maulydia M. Neutrophil gelatinase associated lipocalin as biomarker in predicting acute renal tubular injury following general anesthesia with sevoflurane on low-flow anesthesia. J Med Pharm Chem Res. 2024;6(10):1567-82. doi:10.48309/jmpcr.2024.449596.1151
44. Setyawati AN. The role of oxidative stress in hypoalbuminemia nephropathy related to Nephrotic syndrome: a critical review. J Med Pharm Chem Res. 2024;6(1):32-49. doi:10.48309/jmpcr.2024.182755