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ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ

Медицинские новости Грузии
საქართველოს სამედიცინო სიახლენი

GEORGIAN MEDICAL NEWS

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GMN: Georgian Medical News is peer-reviewed, published monthly journal committed to promoting the science and art of medicine and the betterment of public health, published by the GMN Editorial Board since 1994. GMN carries original scientific articles on medicine, biology and pharmacy, which are of experimental, theoretical and practical character; publishes original research, reviews, commentaries, editorials, essays, medical news, and correspondence in English and Russian.
GMN is indexed in MEDLINE, SCOPUS, PubMed and VINITI Russian Academy of Sciences. The full text content is available through EBSCO databases.

GMN: Медицинские новости Грузии - ежемесячный рецензируемый научный журнал, издаётся Редакционной коллегией с 1994 года на русском и английском языках в целях поддержки медицинской науки и улучшения здравоохранения. В журнале публикуются оригинальные научные статьи в области медицины, биологии и фармации, статьи обзорного характера, научные сообщения, новости медицины и здравоохранения. Журнал индексируется в MEDLINE, отражён в базе данных SCOPUS, PubMed и ВИНИТИ РАН. Полнотекстовые статьи журнала доступны через БД EBSCO.

GMN: Georgian Medical News – საქართველოს სამედიცინო სიახლენი – არის ყოველთვიური სამეცნიერო სამედიცინო რეცენზირებადი ჟურნალი, გამოიცემა 1994 წლიდან, წარმოადგენს სარედაქციო კოლეგიისა და აშშ-ის მეცნიერების, განათლების, ინდუსტრიის, ხელოვნებისა და ბუნებისმეტყველების საერთაშორისო აკადემიის ერთობლივ გამოცემას. GMN-ში რუსულ და ინგლისურ ენებზე ქვეყნდება ექსპერიმენტული, თეორიული და პრაქტიკული ხასიათის ორიგინალური სამეცნიერო სტატიები მედიცინის, ბიოლოგიისა და ფარმაციის სფეროში, მიმოხილვითი ხასიათის სტატიები.
ჟურნალი ინდექსირებულია MEDLINE-ის საერთაშორისო სისტემაში, ასახულია SCOPUS-ის, PubMed-ის და ВИНИТИ РАН-ის მონაცემთა ბაზებში. სტატიების სრული ტექსტი ხელმისაწვდომია EBSCO-ს მონაცემთა ბაზებიდან.

WEBSITE

www.geomednews.com

К СВЕДЕНИЮ АВТОРОВ!

При направлении статьи в редакцию необходимо соблюдать следующие правила:

1. Статья должна быть представлена в двух экземплярах, на русском или английском языках, напечатанная через **полтора интервала на одной стороне стандартного листа с шириной левого поля в три сантиметра**. Используемый компьютерный шрифт для текста на русском и английском языках - **Times New Roman** (**Кириллица**), для текста на грузинском языке следует использовать **AcadNusx.** Размер шрифта - **12**. К рукописи, напечатанной на компьютере, должен быть приложен CD со статьей.

2. Размер статьи должен быть не менее десяти и не более двадцати страниц машинописи, включая указатель литературы и резюме на английском, русском и грузинском языках.

3. В статье должны быть освещены актуальность данного материала, методы и результаты исследования и их обсуждение.

При представлении в печать научных экспериментальных работ авторы должны указывать вид и количество экспериментальных животных, применявшиеся методы обезболивания и усыпления (в ходе острых опытов).

4. К статье должны быть приложены краткое (на полстраницы) резюме на английском, русском и грузинском языках (включающее следующие разделы: цель исследования, материал и методы, результаты и заключение) и список ключевых слов (key words).

5. Таблицы необходимо представлять в печатной форме. Фотокопии не принимаются. **Все цифровые, итоговые и процентные данные в таблицах должны соответствовать таковым в тексте статьи**. Таблицы и графики должны быть озаглавлены.

6. Фотографии должны быть контрастными, фотокопии с рентгенограмм - в позитивном изображении. Рисунки, чертежи и диаграммы следует озаглавить, пронумеровать и вставить в соответствующее место текста **в tiff формате**.

В подписях к микрофотографиям следует указывать степень увеличения через окуляр или объектив и метод окраски или импрегнации срезов.

7. Фамилии отечественных авторов приводятся в оригинальной транскрипции.

8. При оформлении и направлении статей в журнал МНГ просим авторов соблюдать правила, изложенные в «Единых требованиях к рукописям, представляемым в биомедицинские журналы», принятых Международным комитетом редакторов медицинских журналов - http://www.spinesurgery.ru/files/publish.pdf и http://www.nlm.nih.gov/bsd/uniform_requirements.html
В конце каждой оригинальной статьи приводится библиографический список. В список литературы включаются все материалы, на которые имеются ссылки в тексте. Список составляется в алфавитном порядке и нумеруется. Литературный источник приводится на языке оригинала. В списке литературы сначала приводятся работы, написанные знаками грузинского алфавита, затем кириллицей и латиницей. Ссылки на цитируемые работы в тексте статьи даются в квадратных скобках в виде номера, соответствующего номеру данной работы в списке литературы. Большинство цитированных источников должны быть за последние 5-7 лет.

9. Для получения права на публикацию статья должна иметь от руководителя работы или учреждения визу и сопроводительное отношение, написанные или напечатанные на бланке и заверенные подписью и печатью.

10. В конце статьи должны быть подписи всех авторов, полностью приведены их фамилии, имена и отчества, указаны служебный и домашний номера телефонов и адреса или иные координаты. Количество авторов (соавторов) не должно превышать пяти человек.

11. Редакция оставляет за собой право сокращать и исправлять статьи. Корректура авторам не высылается, вся работа и сверка проводится по авторскому оригиналу.

12. Недопустимо направление в редакцию работ, представленных к печати в иных издательствах или опубликованных в других изданиях.

При нарушении указанных правил статьи не рассматриваются.

REQUIREMENTS

Please note, materials submitted to the Editorial Office Staff are supposed to meet the following requirements:

1. Articles must be provided with a double copy, in English or Russian languages and typed or compu-ter-printed on a single side of standard typing paper, with the left margin of **3** centimeters width, and **1.5** spacing between the lines, typeface - **Times New Roman** (**Cyrillic**), print size - **12** (referring to Georgian and Russian materials). With computer-printed texts please enclose a CD carrying the same file titled with Latin symbols.

2. Size of the article, including index and resume in English, Russian and Georgian languages must be at least 10 pages and not exceed the limit of 20 pages of typed or computer-printed text.

3. Submitted material must include a coverage of a topical subject, research methods, results, and review.

Authors of the scientific-research works must indicate the number of experimental biological species drawn in, list the employed methods of anesthetization and soporific means used during acute tests.

4. Articles must have a short (half page) abstract in English, Russian and Georgian (including the following sections: aim of study, material and methods, results and conclusions) and a list of key words.

5. Tables must be presented in an original typed or computer-printed form, instead of a photocopied version. **Numbers, totals, percentile data on the tables must coincide with those in the texts of the articles.** Tables and graphs must be headed.

6. Photographs are required to be contrasted and must be submitted with doubles. Please number each photograph with a pencil on its back, indicate author's name, title of the article (short version), and mark out its top and bottom parts. Drawings must be accurate, drafts and diagrams drawn in Indian ink (or black ink). Photocopies of the X-ray photographs must be presented in a positive image in **tiff format**.

Accurately numbered subtitles for each illustration must be listed on a separate sheet of paper. In the subtitles for the microphotographs please indicate the ocular and objective lens magnification power, method of coloring or impregnation of the microscopic sections (preparations).

7. Please indicate last names, first and middle initials of the native authors, present names and initials of the foreign authors in the transcription of the original language, enclose in parenthesis corresponding number under which the author is listed in the reference materials.

8. Please follow guidance offered to authors by The International Committee of Medical Journal Editors guidance in its Uniform Requirements for Manuscripts Submitted to Biomedical Journals publication available online at: http://www.nlm.nih.gov/bsd/uniform_requirements.html
http://www.icmje.org/urm_full.pdf
In GMN style for each work cited in the text, a bibliographic reference is given, and this is located at the end of the article under the title "References". All references cited in the text must be listed. The list of references should be arranged alphabetically and then numbered. References are numbered in the text [numbers in square brackets] and in the reference list and numbers are repeated throughout the text as needed. The bibliographic description is given in the language of publication (citations in Georgian script are followed by Cyrillic and Latin).

9. To obtain the rights of publication articles must be accompanied by a visa from the project instructor or the establishment, where the work has been performed, and a reference letter, both written or typed on a special signed form, certified by a stamp or a seal.

10. Articles must be signed by all of the authors at the end, and they must be provided with a list of full names, office and home phone numbers and addresses or other non-office locations where the authors could be reached. The number of the authors (co-authors) must not exceed the limit of 5 people.

11. Editorial Staff reserves the rights to cut down in size and correct the articles. Proof-sheets are not sent out to the authors. The entire editorial and collation work is performed according to the author's original text.

12. Sending in the works that have already been assigned to the press by other Editorial Staffs or have been printed by other publishers is not permissible.

Articles that Fail to Meet the Aforementioned Requirements are not Assigned to be Reviewed.

ავტორთა საყურადღებოდ!

რედაქციაში სტატიის წარმოდგენისას საჭიროა დავიცვათ შემდეგი წესები:

1. სტატია უნდა წარმოადგინოთ 2 ცალად, რუსულ ან ინგლისურ ენებზე,დაბეჭდილი სტანდარტული ფურცლის 1 გვერდზე, 3 სმ სიგანის მარცხენა ველისა და სტრიქონებს შორის 1,5 ინტერვალის დაცვით. გამოყენებული კომპიუტერული შრიფტი რუსულ და ინგლისურენოვან ტექსტებში - **Times New Roman (Кириллица)**, ხოლო ქართულენოვან ტექსტში საჭიროა გამოვიყენოთ **AcadNusx.** შრიფტის ზომა – 12. სტატიას თან უნდა ახლდეს CD სტატიით.

2. სტატიის მოცულობა არ უნდა შეადგენდეს 10 გვერდზე ნაკლებს და 20 გვერდზე მეტს ლიტერატურის სიის და რეზიუმეების (ინგლისურ,რუსულ და ქართულ ენებზე) ჩათვლით.

3. სტატიაში საჭიროა გაშუქდეს: საკითხის აქტუალობა; კვლევის მიზანი; საკვლევი მასალა და გამოყენებული მეთოდები; მიღებული შედეგები და მათი განსჯა. ექსპერიმენტული ხასიათის სტატიების წარმოდგენისას ავტორებმა უნდა მიუთითონ საექსპერიმენტო ცხოველების სახეობა და რაოდენობა; გაუტკივარებისა და დაძინების მეთოდები (მწვავე ცდების პირობებში).

4. სტატიას თან უნდა ახლდეს რეზიუმე ინგლისურ, რუსულ და ქართულ ენებზე არანაკლებ ნახევარი გვერდის მოცულობისა (სათაურის, ავტორების, დაწესებულების მითითებით და უნდა შეიცავდეს შემდეგ განყოფილებებს: მიზანი, მასალა და მეთოდები, შედეგები და დასკვნები; ტექსტუალური ნაწილი არ უნდა იყოს 15 სტრიქონზე ნაკლები) და საკვანძო სიტყვების ჩამონათვალი (key words).

5. ცხრილები საჭიროა წარმოადგინოთ ნაბეჭდი სახით. ყველა ციფრული, შემაჯამებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

6. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრამების ფოტოასლები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტოსურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შეღებვის ან იმპრეგნაციის მეთოდი და აღნიშნოთ სურათის ზედა და ქვედა ნაწილები.

7. სამამულო ავტორების გვარები სტატიაში აღინიშნება ინიციალების თანდართვით, უცხოურისა – უცხოური ტრანსკრიპციით.

8. სტატიას თან უნდა ახლდეს ავტორის მიერ გამოყენებული სამამულო და უცხოური შრომების ბიბლიოგრაფიული სია (ბოლო 5-8 წლის სიღრმით). ანბანური წყობით წარმოდგენილ ბიბლიოგრაფიულ სიაში მიუთითეთ ჯერ სამამულო, შემდეგ უცხოელი ავტორები (გვარი, ინიციალები, სტატიის სათაური, ჟურნალის დასახელება, გამოცემის ადგილი, წელი, ჟურნალის №, პირველი და ბოლო გვერდები). მონოგრაფიის შემთხვევაში მიუთითეთ გამოცემის წელი, ადგილი და გვერდების საერთო რაოდენობა. ტექსტში კვადრატულ ფჩხილებში უნდა მიუთითოთ ავტორის შესაბამისი N ლიტერატურის სიის მიხედვით. მიზანშეწონილია, რომ ციტირებული წყაროების უმეტესი ნაწილი იყოს 5-6 წლის სიღრმის.

9. სტატიას თან უნდა ახლდეს: ა) დაწესებულების ან სამეცნიერო ხელმძღვანელის წარდგინება, დამოწმებული ხელმოწერითა და ბეჭდით; ბ) დარგის სპეციალისტის დამოწმებული რეცენზია, რომელშიც მითითებული იქნება საკითხის აქტუალობა, მასალის საკმაობა, მეთოდის სანდოობა, შედეგების სამეცნიერო-პრაქტიკული მნიშვნელობა.

10. სტატიის ბოლოს საჭიროა ყველა ავტორის ხელმოწერა, რომელთა რაოდენობა არ უნდა აღემატებოდეს 5-ს.

11. რედაქცია იტოვებს უფლებას შეასწოროს სტატია. ტექსტზე მუშაობა და შეჯერება ხდება საავტორო ორიგინალის მიხედვით.

12. დაუშვებელია რედაქციაში ისეთი სტატიის წარდგენა, რომელიც დასაბეჭდად წარდგენილი იყო სხვა რედაქციაში ან გამოქვეყნებული იყო სხვა გამოცემებში.

აღნიშნული წესების დარღვევის შემთხვევაში სტატიები არ განიხილება.

Содержание:

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COMPARATIVE ANALYSIS OF MEMORY AND BEHAVIORAL CHANGES AFTER RADON-CONTAINED MINERAL WATER INHALATION THERAPY IN AGED RATS

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Abstract.

Aim: This research article elucidates the pivotal role of radiopharmacy in the contemporary landscape, underscoring its potential therapeutic efficacy in addressing symptoms associated with aged-related neurocognitive processes. Clinical trials, characterized by the judicious application of modest radiation doses, exemplified by low-dose radon, have yielded affirmative outcomes in the amelioration of aged, related symptoms.

Materials and methods: The study was conducted on an animal model. The effect of low doses of radon on cognitive processes is being studied by inhalation of randomized mineral water.

Changes in the clinical picture were studied using behavioral tests, namely the Barnes maze tests.

At the cellular level, radon-contained water inhalation causes different changes: in the fraction of synaptic membranes (determined by Na, K-ATPase activity), aged, related changes by telomerase activity and oxidative stress level changes.

Results: Our studies show that age-related changes in brain tissue are less noticeable after radon inhalation, namely, the concentration of amyloid plaques decreases in a group of aged rats after radon therapy. A significant improvement in cognitive function was observed after radon inhalation in aged rats.

Conclusion: The results show that exposure to radon-containing mineral water leads to improved spatial perception, potentially improving age-related cognitive functions not only at the level of neurocognitive tests, but also changes at the level of cellular functioning.

Key words. Aging, radon, barney maze, behavior.

Introduction.

As individuals age, corresponding physiological aging processes manifest across various systems in the body. One of the formidable challenges in contemporary medicine is the deceleration of these age-related physiological changes, which are both irreversible and widespread [1-20].

Notably, the brain and cognitive functions experience specific alterations, heightening the risk of developing various neurocognitive disorders such as Alzheimer's and Parkinson's disease as age advances [7,12,16].

Oxidative stress plays a pivotal role in the physiology of cellular aging, influencing the aging process through both oxidative and non-oxidative mechanisms. Abnormalities in telomere dynamics, such as excessive shortening or unwarranted lengthening, may not only signify pathological conditions but also precipitate further pathological processes [10].

The primary objective of our study was to investigate the modifications in the rate of natural aging processes through radon therapy. Specifically, the study focused on the changes in oxidative and antioxidant reactions within the brain in instances of clinically evident cognitive dysfunction [11,14,18].

Materials and Methods.

We conducted research on an animal model, in particular we used wild white rats.

Experiment design: Our study was structured around two distinct groups of rats. The first group, designated as the control group, comprised 10 rats aged 12 months. The second group consisted of 20 rats aged 28 months, referred to here as the aged rats group. These were selected based on their performance in the passive deviation test; out of 150 candidates, the 20 rats making the most errors were chosen.

We further subdivided the aged rats into two subgroups: control aged rats (10 rats) and experimental aged rats (10 rats). Following radon inhalation procedures, we conducted the Barney maze test on the experimental aged group.

Parallel tests were carried out on the control group, which included younger rats aged 12 months. This group was also split into two: sham control and control groups. The rats in the sham control group were subjected to the same radon - therapy procedures as those in the experimental aged group].

Animal Care and Handling: Male rats, weighing between 300 and 350 g, were domiciled under standard laboratory conditions characterized by a "12-hour light - 12-hour dark" cycle. The environment was meticulously controlled, maintaining a constant temperature of 22°C ± 2°C. Rats enjoyed ad libitum access to both food and water. All procedures pertaining to animal care and handling strictly adhered to the guidelines delineated by the European Community Council Directive of 24 November 1986 (86/609/EEC). Additionally, these procedures conformed to the officially adopted regulations governing the use and care of animals in biological laboratories [12].

Post-experimentation, the neurological processes of the rats in all four groups were assessed. This evaluation involved analyzing the Brain Synaptic Membrane Fraction and conducting morphological analyses of the brain. Additionally, oxidative stress levels were measured through specific laboratory tests [11,17].

- **Age related processes in the brain:** Morphological confirmation was achieved using a polaroid microscope, specifically the Leica 2500p with a 160x magnification, to examine brain tissue. Additionally, telomerase activity was assessed through immunoenzymatic analysis using the Rat Telomerase ELISA Kit, Catalog No. MBS 261517.
- **Brain Synaptic Membrane Fraction**: In particular, the activity of Na, K-ATPase was determined using established protocols by De Robert and Whittaker. The assay was conducted

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in a total ATPase incubation medium composed of 140 mM NaCl, 5 mM KCl, and 50 mM Tris-HCl buffer at a pH of 7.7. Control conditions were defined using 1 mM ouabain, 145 mM KCl, and 50 mM Tris-HCl buffer also at a pH of 7.7. The measurement of Na, K-ATPase activity was calculated based on the differences between these two assays. The incubation was performed at a temperature of 37°C for a period of 15 minutes. ATPase activity was subsequently quantified by measuring the production of inorganic phosphorus (Pi), which results from the hydrolysis of ATP induced by the enzyme [8].

- **Radon therapy:** Radon therapy was administered through inhalation at the spa center pool in Tskaltubo, which features mineral waters containing radon at small, therapeutic, and non-hazardous concentrations of 37 becquerels (Bq) per cubic meter (37 Bq/m³). The experiment was conducted in a small laboratory established nearby [13,14]. Here, natural radonized water surfaces from the ground, and approximately 50 cm from the pool's edge, a cage was positioned on the floor housing rats from the 10 experimental age groups. The rats inhaled the radonized steam emanating from the spa. This inhalation procedure was carried out over a duration of three hours daily, spanning a period of 10 days [10,13,14].
- **Barney maze (BM):** This test is employed to assess short-term memory. Barney's tank consists of a circular arena, 122 cm in diameter, featuring 18 peripheral holes each 9.5 cm in diameter. One of these holes leads to a shelter constructed from black plastic, while the others are sealed with plastic plugs of the same color for the duration of the experiment. The arena, positioned 113 cm above the floor, is uniformly illuminated at a brightness of 500 lux [4,5].

During the familiarization phase, an animal is placed in the center of the arena under an opaque plastic container for 15 seconds, which randomizes its initial orientation relative to the shelter and distant visual stimuli. Upon removal of the container, the rat freely explores the environment. Should the experimental animal fail to locate or enter the shelter within 3 minutes, it is gently guided there by the experimenter and remains for 1 minute. Over five days, two training sessions are conducted daily, each not exceeding 2 minutes, with 2–3-minute intervals between sessions. On the fifth day, the exploration time is reduced to 1 minute. Following each attempt, the arena is cleansed with 70% ethanol to remove odor cues and other potential stimuli. Observational data are captured via video recording, analyzing parameters such as latency period (LP) to find the shelter, time spent in each sector, and visits to target zones. A learning curve is constructed by averaging LP values from two attempts during each session.

Barney's test was administered to all research groups, and the task completion was analyzed across six flawless attempts [5]. The efficacy of memory retention was evaluated three months post-experiment, following the completion of the radon inhalation procedures in both the aged radon therapy group and the sham-control group, as well as in the control and aged control groups [11].

Results.

Age-related alterations in brain structure are depicted in Figures 1 and 2. Figure 1 illustrates the brain structure of sham-control rats, as observed under polar microscopy, highlighting the presence of amyloid plaques typical of physiological aging. Subsequent to radon therapy, a notable reduction in the number of amyloid plaques was observed in the brains of the experimental aged group rats These changes are detailed in Figure 2.

Figure 1. *Brain tissue under a polaroid microscope (with 10X magnification objective, Congo red staining), where A-β plaques are marked with green arrows in aged-control group rats (non-radon inhalation group).*

Figure 2. *Depicts brain tissue as viewed under a Polaroid microscope (10 X magnification objective, Congo red staining), A-β plaques are marked with red arrows observable after radon therapy (inhalation) in experimental aged group rats (radon inhalation group).*

As evidenced by Figures 1 and 2, the concentration of amyloid plaques is reduced in the aged rat group following radon therapy.

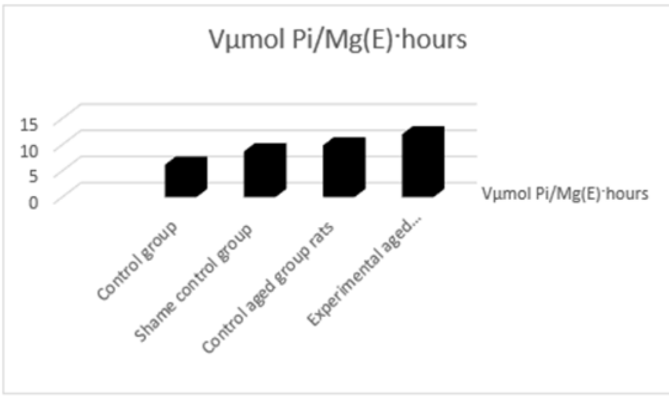

Figure 3. *Na+/K+-ATPase changes in young and aged rats groups.*

Regarding Na+, K+-ATPase activity, the results are detailed in Table 1 and Figure 3. For the aged -control and the experimental aged group following radon therapy, the drug

***Table 1.** The Na/K-ATPase activity in the brain synaptic membranes of the control, sham control, control aged group, and experimental group rats is presented.*

Research group	**Vµmol Pi/Mg(E)·hours**	**%, vs control**	**%, vs Shame control group rats**
Control group	6,18 ± 0,12	100%	71% (↓ 29%)
Shame control group (after radon therapy)	8,73 ± 0,60	141% (↑ 41%)	100%
Control aged group rats	9,87± 0,64	139% (↑ 41%)	110%
Experimental aged group rats after radon therapy	11,99 ± 0,70	194% (↑ 94%)	137% (↑ 37%)

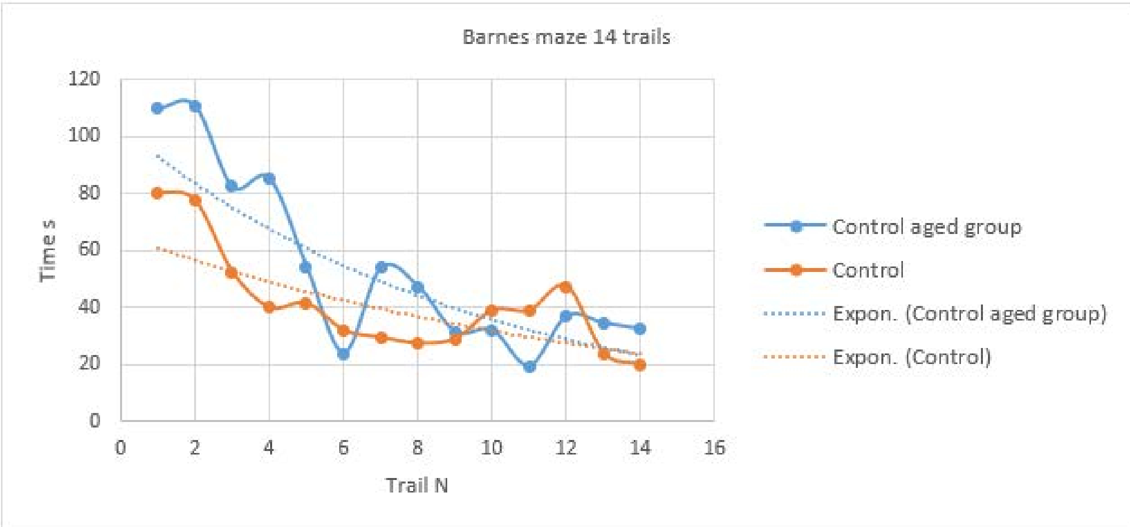

***Figure 4.** Illustrates the results of short and long-term learning in the Barnes Maze for control, shame control, aged-control and experimental group rats. Specifically, it displays the outcomes of 14 learning trials.*

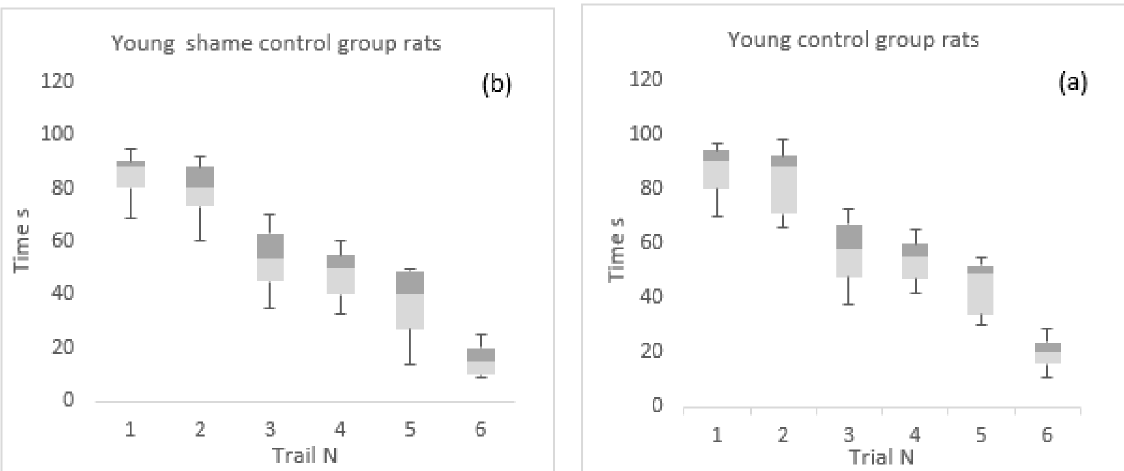

***Figure 5.** Radon-induced changes in young rats, namely control and sham-control (after radon inhalation in this group) in Barnes maze.*

P2Wp concentrations (1.2M – 0.8M) correspond to the same fraction of synaptic membranes. The concentrations are detailed as follows: [ATPf] (fraction of synaptic membranes) = 0.32 mM; [MgATP] = 1.68 mM.

Barnes (Barney) maze: We first conducted experiments to determine the minimum number of trials required to obtain a clear picture of learning in the Barnes maze. From Figure 4 it can be seen that a stable level is achieved after 5 tests. The graph also shows that older rats spend more time solving a problem. The graph illustrates a comparison between the performance and memory-related metrics of the two groups, highlighting the significant disparity between them.

The subsequent experiment was designed to scrutinize potential distinctions between young and aged rats, specifically those aged 28 months.

This investigation likely involved a comparative analysis of characteristics, behaviors, or performance between young rats (3 months old) and elderly (28 months) rats. The overarching aim was to discern whether age exerted an influence on the progression or severity of age in rats. The research extended to six trials for both groups of animals.

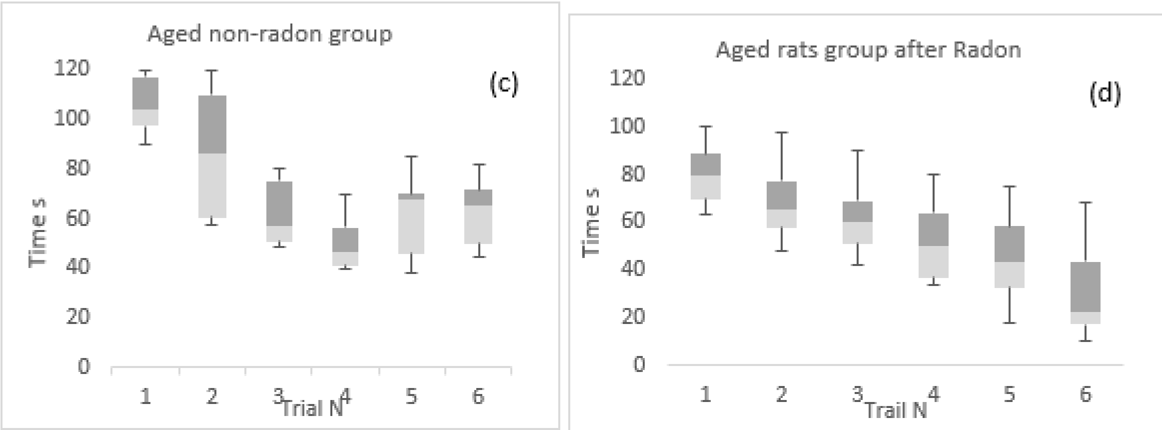

Figure 6. *Barnes maze training in control- aged and experimental aged (radon inhalation) group (after radon inhalation).*

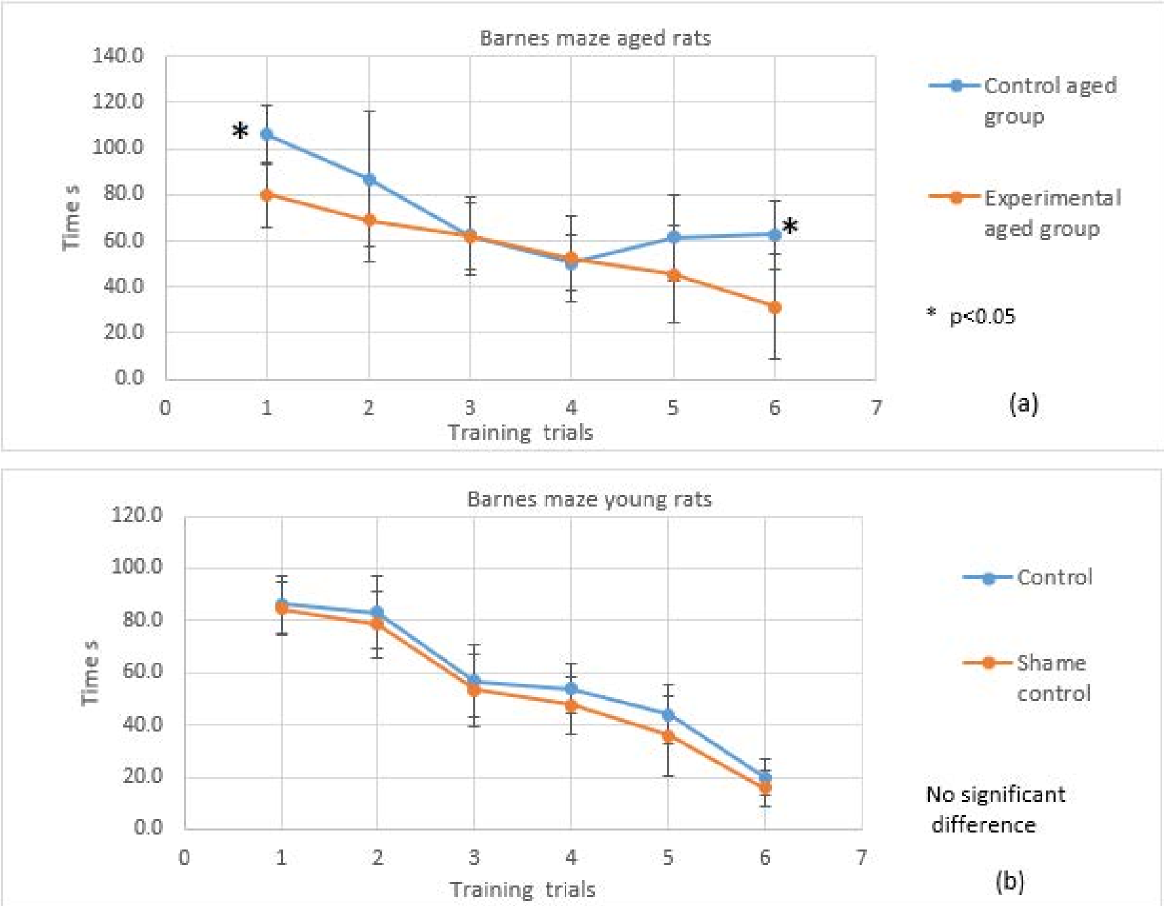

Figure 7. *(a) Aged rats - radon inhalation improved learning time at Barnes maze compared to non-inhalation aged group rats. (Initial and final stages are statistically significant p<0.05), however in young rats (b) there was no statistical difference between two groups.*

In young animals (in control and shame control groups) a congruent pattern was observed, as illustrated in Figure 5. No significant differences were discerned in this group, neither in the duration of learning nor in the dynamics of training.

Within the group of aged rats, noteworthy alterations were evident between the aged- control and experimental (radon-exposed) cohorts, vividly portrayed in Figure 6.

The graph distinctly showcases an enhancement in the learning dynamics of the task within the Barnes maze. Additionally, post-radon inhalation in aged rats, the learning process exhibited heightened stability. This graphical representation effectively captures the positive impact of radon inhalation on spatial perception ability, leading to a concurrent decrease in the latency period for finding the shelter and an increased inclination to enter the shelter.

The figure 7 illustrates a comparison of the movement patterns between aged rats (28 months rats) and young rats (6 month) in the Bernese Maze, providing insights into the differences in their behavior and highlighting the memory impairment observed in the elderly (old 28 months rats). From the figure, it

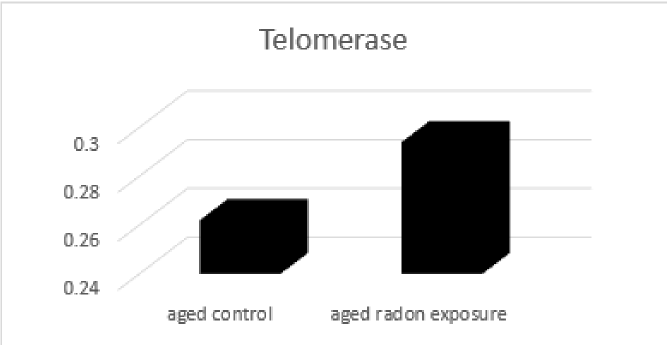

Figure 8. *Displays the telomerase activity in aged rats, specifically comparing the aged control group and the radon inhalation group three months after 6 month the radon inhalation procedure.*

is evident that the movement of the old (28 months rats) appears to be more erratic and disorganized compared to the movement of young rats.

The regulatory influence of radon inhalation extends to processes outlined above, as corroborated by the data presented. Additionally, a compelling facet of this study involves the investigation of telomerase length before and after radon exposure. We observed a statistically significant increase in telomerase length from 0.262 ± 0.0002 before radon exposure to 0.294 ± 0.0002 after radon exposure ($P < 0.001$). This noteworthy difference between the two measurements provides further robust support for the hermetic effect of radon, underscoring its role in the reduction and normalization of oxidative stress.

Discussion.

The results of our study show several changes caused by inhalation of low doses of radon. Since the purpose of the study was to study the effect of radon on age-related physiological processes, we focused our attention on this area.

Our studies show that age-related changes in brain tissue are less noticeable after radon inhalation, namely, the concentration of amyloid plaques decreases in a group of aged rats after radon therapy.

Amyloid accumulation in the brain has been shown to impair glucose transport in neurons in the hippocampus and cerebral cortex, leading to membrane lipid peroxidation [2, 6]. This peroxidation process may contribute to the reduction in Na+, K+-ATPase activity.

Amyloid-induced oxidative stress and mitochondrial dysfunction further disrupt the activity of Na+, K+-ATPase in hippocampal neurons. Inhibition of Na+, K+-ATPase activity not only causes edema and cell death within the central nervous system but also impairs learning and memory.

Our experiments have revealed that inhalation of radon can decrease lipid peroxidation, reduce oxidative stress [1], and improve memory. This memory improvement is observed in the restoration of memory in aged rats (28 month).

Radon acts as a protective agent by enhancing long-term learning and memory in the aged brain. Evidence suggests that radon inhalation increases the basal electrical impulse rate, Na+, K+-ATPase activity, and PKC activity in the CA1 and CA3 regions of the hippocampus, which are critical sites for initial learning and memory processes.

Na+, K+-ATPase, also known as the sodium pump, is crucial for normal brain function and is concentrated in synaptic membranes where it participates in important reactions associated with neurotransmission. Fine-tuning the activity of this enzyme is essential, as its inhibition by Ouabain can impair various biochemical and physicochemical activities [19]. These findings highlight the significance of proper Na+, K+-ATPase functioning. Malfunctioning of this enzyme can lead to diverse changes in neuronal behavior. It has been suggested that impairment of Na+, K+-ATPase activity is associated with increased neuronal excitability. Infra-low minute post-hyperpolarization, observed after locomotor episodes, is mediated by enhanced Na+/K+ electrogenic pumping function, which is dependent on activity and sodium release. This infra-low hyperpolarization appears to be linked to short-term memory of neural network function through activity-dependent potentiation of Na+/K+ pumping function [20].

Specifically, it is believed that radon exposure could impact the activity of Na+, K+-ATPase, an enzyme involved in maintaining the balance of sodium and potassium ions within neurons. Disruption in the function of Na+, K+-ATPase has been associated with increased neuronal excitability. However, in this study, radon exposure seemed to decrease neuronal excitability, leading to the normalization of behavior in aged rats.

These observed changes collectively suggest a reduction in oxidative stress among the elderly rats, a facet meticulously assessed in our study. Furthermore, the reduction in oxidative stress observed in the rats supports the hypothesis that radon inhalation has antioxidant properties.

The reduction in the latency period of finding shelter in aged rats 28 month aged suggests that radon exposure may have influenced the excitability of neurons.

A significant improvement in cognitive function was observed after radon inhalation in aged rats.

The findings suggest that exposure to radon leads to improvements in spatial perception, potentially enhancing cognitive function. The decreased latency period and increased tendency to enter the shelter indicate enhanced memory and learning capabilities.

The employment of radon-containing waters, characterized by very low radon levels at 37 Bq (1 nc), has shown potential benefits in reducing amyloid-beta (Aβ) formation, as referenced in studies. These waters also exhibit antioxidant and anti-inflammatory properties and modulate cholinergic activity. Such findings are promising for the prevention and treatment of Alzheimer's disease [15].

The hormetic effects of radon, as discussed in this article, demonstrate promising outcomes on symptoms related to AD [3]. Further preclinical studies are warranted to investigate the therapeutic potential of radon hormesis not only for AD but also for other neurodegenerative diseases [17].

Radon inhalation orchestrates the aforementioned processes, concurrently eliciting a discernible reduction in oxidative stress.

A noteworthy facet of our investigation pertains to the examination of telomerase length in aged group post-radon exposure.

Augmentation in telomerase length, transitioning from 0.262 + 0.0002 to 0.294 + 0.0002 post-radon exposure, prove the hormetic influence of radon and its pivotal role in mitigating and normalizing aged related oxidative stress [9].

Conclusion.

The hormetic effectiveness of radon is manifested in its antioxidant, anti-inflammatory and anti-neurotoxic properties. It skillfully limits the formation of Aβ and simultaneously enhances cholinergic excitability, thereby opening up favorable opportunities for prevention and therapeutic intervention in age-related neurocognitive disorders.

Following this, further preclinical research becomes imperative to systematically explore the therapeutic potential of radon hormesis, expanding its scope beyond age-related pathologies and covering the spectrum of neurodegenerative diseases.

Author contributions.

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Data availability.

All data can be provided upon request to the corresponding author.

Declarations.

The authors declare no competing and no conflict of interest.

Author contributions.

NMI, AGT, GTT, DKN and TAA performed experiments and data analysis. Laboratory tests are performed by DKN and TAA, neurocognitive tests by AGT, GTT. NMI and DKN wrote the manuscript.

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Сравнительный анализ изменений памяти и поведения после ингаляционной терапии радонсодержащей минеральной водой у старых крыс

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Резюме

Цель: эта исследовательская статья поясняет ключевую роль радиофармацевтики в современной ситуации, подчеркивая ее потенциальную терапевтическую эффективность в устранении симптомов, связанных с возрастными нейрокогнитивными процессами. Клинические испытания, характеризующиеся разумным применением умеренных доз радиации, примером которых являются низкие дозы радона, дали положительные результаты в улучшении симптомов, связанных со старением.

Материалы и методы: Исследование проведено на животной модели. Влияние малых доз радона на когнитивные процессы изучается путем вдыхания радонизированной минеральной воды.

Изменения клинической картины изучали с помощью поведенческих тестов, а именно тестов лабиринта Барнса.

На клеточном уровне вдыхание радонсодержащей воды вызывает различные изменения: во фракции синаптических мембран (определяется активностью Na, K-АТФазы), возрастные изменения по активности теломеразы и изменению уровня окислительного стресса.

Результаты: Наши исследования показывают, что возрастные изменения в ткани головного мозга менее заметны после ингаляции радона, а именно, в группе старых крыс после радонотерапии снижается концентрация амилоидных бляшек. Значительное улучшение когнитивных функций наблюдалось после ингаляции радона у старых крыс.

Заключение: Результаты показывают, что воздействие радонсодержащей минеральной воды приводит к улучшению пространственного восприятия, потенциально улучшая возрастные когнитивные функции не только на уровне нейрокогнитивных тестов, но и изменяя на уровне клеточного функционирования.

Ключевые слова: Старение, Радон, лабиринт Банри, Поведение.

მეხსიერების და ქცევის ცვლილებების შედარებითი ანალიზი რადონის შემცველი მინერალური წყლით ინჰალაციის თერაპიის შემდეგ ასაკოვან ვირთხებში

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[4]საქართველოს ტექნიკური უნივერსიტეტი, თბილისი, საქართველო.

რეზიუმე

მიზანი: ეს კვლევითი სტატია ეხება რადიოფარმაცევტული საშუალებების პოტენციურ თერაპიულ ეფექტურობას და როლს ასაკთან დაკავშირებულ ნეიროკოგნიტური პროცესების სიმპტომების შემსუბუქებაში. კლინიკურმა კვლევებმა აჩვენა, რომ რადიაციის, კერძოდ რადონის, ზომიერი დოზებით გონივრული გამოყენებისას, ადგილი აქვს დაბერებასთან დაკავშირებული სიმპტომების შემსუბუქებას.

მასალები და მეთოდები: კვლევა ჩატარდა ცხოველურ მოდელზე. რადონიზებული მინერალური წყლის მიწოდება მოხდა ინჰალაციის გზით. შესწავლილია რადონის დაბალი დოზების გავლენა კოგნიტურ პროცესებზე, კერძოდ კლინიკურ სურათში ცვლილებების შესასწავლად ჩავატარეთ ქცევითი ტესტი - კერძოდ ბარნის ტესტი.

უჯრედულ დონეზე, რადონის შემცველი წყლის ინჰალაციით გამოწვეული ცვლილებების შესასწავლად სინაფსური მემბრანების ფრაქციაში განვსაზღვრეთ Na, K-ATPase აქტივობა; ტელომერაზას აქტივობა და ოქსიდაციური სტრესის დონის ცვლილებები შესწავლილია ასაკთან მიმართებაში.

შედეგები: ჩვენმა კვლევებმა აჩვენა, რომ ასაკთან დაკავშირებული ცვლილებები ტვინის ქსოვილში ნაკლებად შესამჩნევია რადონის ინჰალაციის შემდეგ, კერძოდ, რადონის თერაპიის შემდეგ ასაკოვანი ვირთხების ჯგუფში მცირდება ამილოიდური დაფების კონცენტრაცია. კოგნიტური ფუნქციის მნიშვნელოვანი გაუმჯობესება დაფიქსირდა ასაკოვან ვირთხებში რადონის ინჰალაციის შემდეგ.

დასკვნა: შედეგები მიუთითებს, რომ რადონის შემცველი მინერალური წყლის ზემოქმედება იწვევს სივრცითი აღქმის გაუმჯობესებას, პოტენციურად აუმჯობესებს ასაკთან დაკავშირებულ კოგნიტურ ფუნქციას არა მხოლოდ ნეიროკოგნიტური ტესტების დონეზე, არამედ უჯრედული ფუნქციონირების დონეზეც.

საკვანძო სიტყვები: დაბერება, რადონი, ბანრის ტესტი, ქცევა.