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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.

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THE EFFECT OF TRIVALENT CHROMIUM ON METABOLIC SYNDROME: A NARRATIVE REVIEW

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Abstract.

Introduction: Trivalent chromium is an essential trace element involved in carbohydrate and lipid metabolism. The widespread global prevalence of metabolic syndrome and its close association with cardiovascular diseases and type 2 diabetes mellitus have increased scientific interest in the potential metabolic effects of chromium. However, currently available evidence regarding its clinical significance remains inconsistent.

Methods: This narrative review describes the role of trivalent chromium in the context of metabolic syndrome. A systematic literature search was conducted in the Scopus and Web of Science databases for studies published between 2015 and 2025. The review included randomized controlled trials, observational studies, experimental studies, systematic reviews, and meta-analyses that investigated chromium intake, supplementation, or the association between chromium levels and components of metabolic syndrome.

Results: The reviewed studies reported heterogeneous findings regarding the effects of trivalent chromium on components of metabolic syndrome. While some studies demonstrated improvements in glucose metabolism, insulin sensitivity, and lipid profiles, other studies reported no clear or statistically significant effects. The inconsistency of results has been attributed to differences in study design, studied populations, types and dosages of chromium supplementation, and duration of interventions.

Discussion: The lack of uniform research methodologies, limited sample sizes, and the absence of standardized protocols for chromium supplementation hinder the comparability of results. In addition, the heterogeneity of the studied populations limits the reliability of the available data.

Conclusion: Available evidence does not support the widespread clinical use of trivalent chromium. Therefore, further large-scale studies are required to determine its efficacy and safety.

Key words. Metabolic syndrome, trivalent chromium, insulin resistance, lipid metabolism, supplementation.

Introduction.

Metabolic syndrome (MS) is a common metabolic disorder that significantly increases the risk of type 2 diabetes mellitus (T2DM) and cardiovascular diseases. Its key components include impaired insulin sensitivity (IR), abdominal obesity (AO), elevated blood pressure, and dyslipidemia. The global prevalence of MS continues to rise, contributing not only to cardiovascular morbidity but also to a broad range of metabolic and endocrine complications [1].

The development of MS is multifactorial and influenced by genetic predisposition, environmental factors, lifestyle behaviors, and disturbances in micronutrient homeostasis [2]. Among micronutrients, increasing attention has been directed toward trivalent chromium, an essential trace element involved in carbohydrate and lipid metabolism [3]. Several studies suggest that alterations in chromium status may affect glucose regulation, lipid balance, and overall metabolic function, indicating a possible association with MS [4,5]. However, other investigations report inconsistent or inconclusive outcomes, leaving chromium's precise metabolic role uncertain [6,7].

These conflicting findings highlight an important gap in current scientific understanding regarding the physiological relevance of trivalent chromium and its potential involvement in the pathogenesis of MS. Therefore, the purpose of this review is to summarize and evaluate contemporary scientific evidence on the metabolic effects of Cr (III), with a focus on proposed molecular mechanisms and findings from clinical and experimental studies.

Methods.

To write this narrative review, a comprehensive search was conducted in the Scopus and Web of Science databases. This step included scientific studies published between 2015 and 2025. The following keywords were used for the search strategy: ("Metabolic syndrome" OR "Insulin resistance" OR "Abdominal obesity" OR "Dyslipidemia" OR "Arterial hypertension" OR "Lipid metabolism" OR "Glucose metabolism") AND ("Trivalent chromium" OR "Chromium (III)" OR "Cr^{3+}" OR "chromium compounds" OR "chromium picolinate"). In addition, the "All fields" option was applied in order to cover all relevant topics within the scope of the narrative review. English-language articles describing the association of Cr (III) or its compounds with MS and its individual components were included in the review. In addition, observational, experimental, randomized controlled, and review-type studies were included. Conference abstracts, editorial articles, studies not published in English, studies with inaccessible full texts, and articles lacking data describing the association between Cr (III) and MS were excluded from the review.

Results.

Biological relevance of Cr (III).

Cr (III) is an important trace element involved in the regulation of complex metabolic processes [8]. In recent years, scientific interest has increasingly focused on its potential role in the pathogenesis of MS. In particular, the ability of Cr (III) to enhance insulin signalling, as well as to influence glucose and lipid metabolism through modulation of key cellular pathways such as AMP-activated protein kinase (AMPK), has been considered [9].

Although overt chromium deficiency is rare in healthy individuals, alterations in chromium status are frequently observed in conditions such as IR and T2DM. This indicates a possible association between chromium and metabolic disorders [10]. While clinical studies examining the relationship between chromium and metabolic disturbances have produced inconsistent results, recent molecular and clinical investigations highlight the important role of Cr (III) in metabolic regulatory processes in the human body [11,12].

MS and its components.

IR, AH, dyslipidemia, and AO are considered the key components of MS. These components are closely linked from a pathogenetic perspective and often potentiate each other, thereby exacerbating disease progression. Currently, established diagnostic criteria for MS are used in medical practice worldwide (Table 1) [13].

The potential role of Cr (III) has been discussed since the last century. In addition, some researchers have investigated its effects on glucose and lipid metabolism. Despite these studies, the clinical use of Cr (III) compounds remains restricted, and the available evidence is not sufficient to support their widespread application [14,15]. Thus, this part of the review provides a brief overview of the components of MS, their interrelationships, and the possible effects of Cr (III) on these components.

Insulin resistance: pathogenesis and its relationship with MS:

Insulin resistance (IR) is one of the main metabolic determinants of MS and is characterized by a reduced biological response of peripheral tissues to insulin. As a result, glucose uptake by tissues is impaired, leading to the development of compensatory hyperinsulinemia and an increased risk of T2DM. The development of IR is influenced by genetic predisposition, AO, low physical activity, chronic low-grade inflammation, and hormonal disorders [16].

In the general scientific literature, experimental and clinical studies addressing the relationship between Cr (III) and IR are reported. Some studies suggest that chromium supplements may enhance insulin signaling processes and improve glucose uptake into cells, while other studies, particularly those using chromium picolinate ($CrPic_3$), have reported reductions in HOMA-IR (Homeostasis Model Assessment of Insulin Resistance) values, improvements in glucose tolerance, and decreases in glycated hemoglobin levels (HbA1c) [17,18]. However, systematic reviews and meta-analyses published between 2022 and 2024 indicate that the results about the effects of chromium on IR are inconsistent and, in many cases, not statistically significant [19,20]. Overall, despite some positive findings, researchers do not recommend the use of Cr (III) supplements for IR. In addition, they emphasize the need for future large-scale, high-quality randomized controlled clinical trials (RCTs).

Clinical evidence on the effects of chromium supplementation:

Meta-analyses of clinical studies indicate that the effects of chromium supplementation on glycaemic outcomes are heterogeneous. Several RCTs and pooled analyses, particularly those involving CrPic3, have reported modest improvements in fasting plasma glucose (FPG), HbA1c, insulin levels, and HOMA-IR in individuals with T2DM [21,17]. Some studies also observed favourable changes in lipid profiles and anthropometric parameters, whereas no significant effects were detected on blood pressure or hepatic enzyme levels [22,23]. However, other large RCTs comparing chromium supplementation with placebo did not demonstrate statistically significant effects on FPG or HbA1c. These findings were observed in both individuals with and without diabetes [24,25]. Such inconsistencies across studies may be attributed to differences in chromium formulation, dosage, duration of supplementation, co-administration with other nutrients, and baseline metabolic characteristics of the study populations [26].

Table 1. *Classification of MS.*

Year / Author	Obesity	Fasting glucose	TG	HDL-C	Blood Pressure	Diagnostic criteria
AHA/NHLBI (2009)	Men >102 cm; Women >88 cm	≥5.6 mmol/L	≥1.7 mmol/L	Men <1.0 mmol/L; Women <1.3 mmol/L	Systolic ≥130 mmHg; Diastolic ≥85 mmHg	≥3 criteria
IDF (2005)	Men >94 cm; Women >80 cm; BMI >30 kg/m²	≥5.6 mmol/L	≥1.7 mmol/L	Men <1.0 mmol/L; Women <1.3 mmol/L	Systolic ≥130 mmHg; Diastolic ≥85 mmHg	≥3 criteria (one must be obesity)
ATP III (2001)	Men >102 cm; Women >88 cm	≥6.1 mmol/L	≥1.7 mmol/L	Men <1.0 mmol/L; Women <1.3 mmol/L	Systolic ≥130 mmHg; Diastolic ≥85 mmHg	≥3 criteria
EGIR (1999)	Men >102 cm; Women >88 cm	IFG	–	<1.0 mmol/L (both sexes)	Systolic ≥140 mmHg; Diastolic ≥90 mmHg	≥3 criteria (one must be IR)
WHO (1998)	WHR: Men >0.9; Women >0.85; BMI >30	IFG	–	Men <0.9 mmol/L; Women <1.0 mmol/L	Systolic ≥140 mmHg; Diastolic ≥90 mmHg	≥3 criteria (one must be IR)

Abbreviations: *AHA – American Heart Association; NHLBI – National Heart, Lung, and Blood Institute; IDF – International Diabetes Federation; ATP III – Adult Treatment Panel III; EGIR – European Group for the Study of Insulin Resistance; WHO – World Health Organization; BMI – body mass index; TG – triglycerides; HDL-C – high-density lipoprotein cholesterol; IFG – impaired fasting glucose; IR – insulin resistance; WHR – waist-to-hip ratio; mmol/L – millimoles per liter; mmHg – millimeters of mercury.*

Abdominal obesity: diagnostic criteria, pathogenesis and its association with Cr (III):

Abdominal obesity (AO) is a main component of MS and makes a significant contribution to its development. AO is characterized by an increased waist circumference (≥94 cm in men and ≥80 cm in women). In addition, it is closely associated with the development of IR and other metabolic disorders and is distinguished by excessive accumulation of metabolically active visceral adipose tissue [27].

In a number of studies, the relationship between the use of Cr(III) supplementation and AO have been examined. However, the obtained results are not consistent. In some clinical studies, particularly in individuals with metabolic disorders, a slight reduction in waist circumference was observed as a result of Cr(III) supplementation [28-30]. In other studies, however, no significant effect on anthropometric parameters was detected [31,32]. These contradictory results may be related to differences in the form and dose of chromium used, the duration of the intervention, as well as the baseline metabolic status of the studied populations [26].

Dyslipidemia: Pathogenesis and its relationship with MS:

Dyslipidemia is an integral part of MS and one of its clinically significant components. It is typified by diminution of High-Density Lipoprotein Cholesterol (HDL-C) and escalation of the level of Triglycerides (TG) and low-density and very low-density lipoprotein (LDL-C, VLDL-C). These changes form an atherogenic lipid profile, significantly increasing the risk of cardiovascular diseases, particularly myocardial infarction and stroke [33].

IR, AO, and impaired hepatic lipid metabolism are the risk factors for the development of dyslipidemia. Free fatty acids released from visceral adipocytes can be the reason for excess TG production and increased LDL-C levels in the liver. At the same time, levels of HDL-C, which protect the cardiovascular system against atherosclerosis, decrease. Insulin deficiency suppresses lipoprotein lipase activity, further increasing TG accumulation in the plasma [34].

Cr (III) and dyslipidemia: proposed mechanisms and clinical evidence:

Experimental studies suggest that Cr (III) may influence lipid metabolism primarily at the hepatic level. Chromium appears to regulate lipid homeostasis by reducing fatty acid uptake and lipogenesis, enhancing cholesterol transport, and attenuating inflammatory and oxidative stress (OS) processes in hepatocytes. In addition, observational data indicate that low circulating chromium levels are associated with increased hepatic fat accumulation, whereas higher chromium status may be linked to a reduced risk of hepatic steatosis [35].

Clinical evidence regarding the effects of chromium supplementation on lipid profiles remains inconsistent. Meta-analyses and RCTs, particularly those involving $CrPic_3$, have reported modest reductions in total cholesterol and TG, while effects on LDL-C and HDL-C are variable or statistically non-significant [36]. These discrepancies are likely attributable to differences in chromium formulation, dosage, intervention duration, and baseline metabolic status of study populations. Overall, although Cr (III) may exert favourable effects on lipid metabolism through multiple mechanisms, current clinical evidence is insufficient to support its routine use for dyslipidemia management in MS [27].

Arterial hypertension: diagnostic criteria, pathogenesis, and proposed mechanisms:

Arterial hypertension (AH) is one of the most frequent and clinically significant components of MS. In addition, it plays a crucial role in the development of cardiovascular diseases. AH is defined by persistently elevated systolic and diastolic blood pressure levels (≥130/85 mmHg according to IDF and ATP III criteria). In the context of MS, the pathogenesis of AH differs from that of primary hypertension and is associated with IR, AO, and chronic low-grade inflammation [37].

In MS, the development of AH is influenced by several interrelated mechanisms. These include endothelial dysfunction, activation of the renin–angiotensin–aldosterone system, and increased activity of the sympathetic nervous system. Free fatty acids and pro-inflammatory cytokines released from visceral adipose tissue impair vascular function, enhance renal sodium and water reabsorption, and increase vascular tone. As a result, a sustained elevation of arterial blood pressure develops [38].

Cr (III) and arterial hypertension: clinical evidence:

The association between chromium status and arterial hypertension have been investigated in observational studies, RCTs, and meta-analyses. However, the results remain inconsistent. Although lower chromium levels have frequently been reported in individuals with MS, a consistent and clear association between chromium status and arterial blood pressure has not been established [30,39,40]. Meta-analyses of RCTs generally indicate that chromium supplementation does not have a statistically significant effect on systolic or diastolic blood pressure [41,42]. Nevertheless, modest beneficial effects have been observed in certain subgroups, particularly among patients with diabetes or heart failure [43,44].

Insulin-dependent and insulin-independent mechanisms of Cr (III) in glucose metabolism.

Mechanisms by which Cr (III) regulates glucose metabolism via insulin signalling:

Cr (III) is considered a biologically active trace element involved in the regulation of glucose homeostasis, and its effects on glucose metabolism through insulin signalling are illustrated in Figure 1 [45]. Under hyperglycaemic conditions, insulin secretion from pancreatic β-cells is stimulated, followed by insulin binding to its receptor and activation of downstream insulin receptor substrates (IRS). This process initiates PI3K/Akt (phosphatidylinositol-3-kinase/protein kinase B) signalling, which plays a central role in insulin-mediated glucose metabolism by promoting GLUT4 (glucose transporter type 4) translocation to the plasma membrane and enhancing cellular glucose uptake and glycogen storage. In addition to glucose transport, Akt (protein kinase B) signalling also contributes to the regulation of lipid and protein metabolism, as well as cellular growth and survival. Collectively, modulation of insulin signalling by Cr (III) provides a biological rationale for its potential metabolic effects observed in experimental and clinical studies [45].

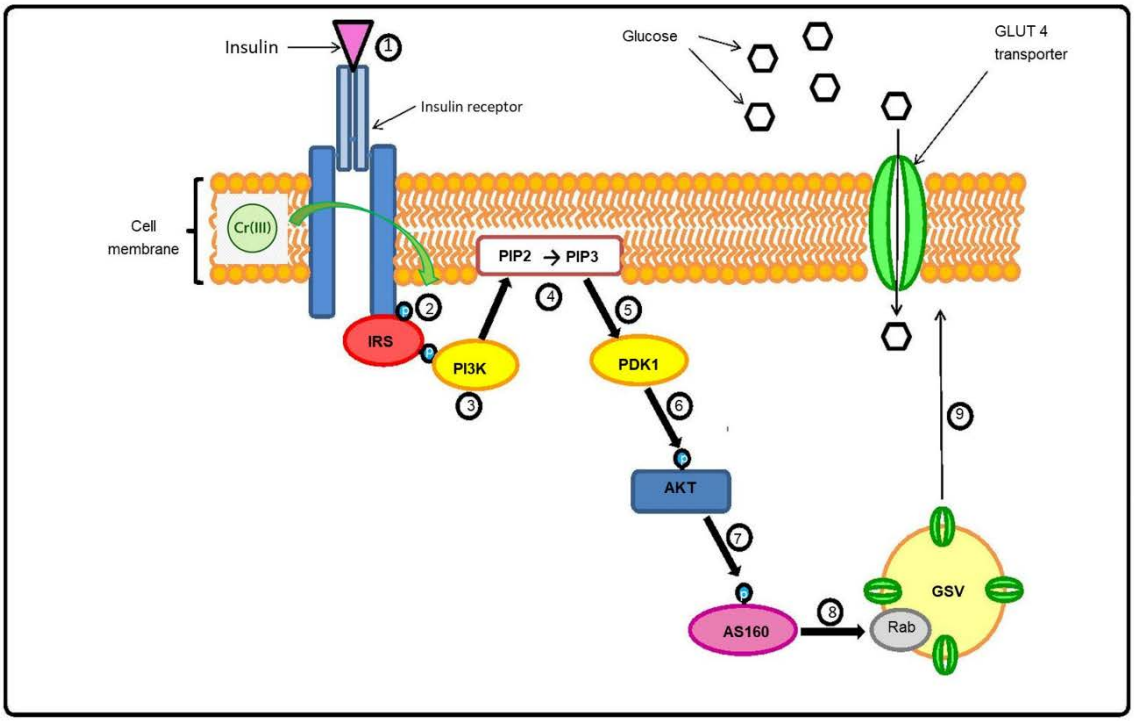

Figure 1. *Proposed mechanisms of Cr III action in insulin signaling and GLUT4 translocation. Adapted and modified by the authors. AMPK – AMP-activated protein kinase, AKT (PKB) – protein kinase B, AS160 – Akt substrate of 160 kDa, Cr – trivalent chromium, GSV – GLUT4 storage vesicles, GLUT4 – glucose transporter type 4, IR – insulin receptor, IRS – insulin receptor substrate, PDK1 – phosphoinositide-dependent kinase-1, PI3K – phosphoinositide-3-kinase, PIP2 – phosphatidylinositol-4,5-bisphosphate, PIP3 – phosphatidylinositol-3,4,5-trisphosphate, Rab – Rab GTPase.*

Regulation of glucose levels via the 5'-AMP-activated protein kinase pathway:

In addition to insulin-dependent mechanisms, chromium has been reported to regulate glucose metabolism through activation of the 5 AMPK pathway, an insulin-independent energy-sensing system. AMPK is activated under conditions of cellular energy deficiency, characterized by an increased AMP/ATP ratio, and plays a central role in coordinating glucose and lipid metabolism.

Activation of AMPK enhances cellular glucose uptake and promotes glucose utilization as an energy source, while simultaneously stimulating fatty acid oxidation and suppressing energy-consuming metabolic processes. Through concurrent modulation of PI3K/Akt- and AMPK-mediated pathways, Cr (III) may contribute to improved glycaemic regulation under conditions of metabolic stress. This insulin-independent mechanism provides an additional biological rationale for the potential effects of chromium on glucose homeostasis [46,47].

Regulation of glycaemia by Cr (III) via suppression of hepatic gluconeogenesis:

Gluconeogenesis is a physiological process that plays an essential role in maintaining blood glucose homeostasis. However, its excessive activation contributes to the development of hyperglycaemia in diabetes and IR. Recent experimental studies suggest that Cr (III) may influence glycaemic regulation by attenuating hepatic gluconeogenesis [48].

Chromium has been shown to downregulate the gene expression of key gluconeogenic enzymes, including glucose-6-phosphatase (G6Pase) and phosphoenolpyruvate carboxykinase (PEPCK), leading to reduced hepatic glucose output and lower circulating glucose levels [49]. Overall, suppression of gluconeogenesis represents one of the potential mechanisms through which Cr (III) may contribute to glucose homeostasis.

Regulation of glucose metabolism via chromodulin by chromium:

Experimental studies indicate that Cr (III) may enhance insulin action through chromodulin. In insulin-responsive cells, intracellular apochromodulin binds Cr (III) under conditions of elevated glucose and insulin levels, forming an active chromodulin complex. There is evidence that this complex increases insulin receptor tyrosine kinase activity, thereby enhancing downstream insulin signalling.

Enhanced insulin signalling via chromodulin facilitates the translocation of the GLUT4 transporter to the plasma membrane, increasing glucose uptake into cells and leading to improved glycaemic control. According to scientific evidence, enhancement of insulin signalling through chromodulin may represent an additional mechanism by which Cr (III) influences glucose metabolism [50,51].

Proposed mechanisms of Cr (III) in lipid metabolism.

Mechanisms of Cr (III) - mediated regulation of lipid metabolism:

Lipid metabolism comprises a coordinated set of processes involved in the transport, synthesis, oxidation, and utilization of fatty acids, TG, and cholesterol, and plays a crucial role in maintaining energy balance and cellular homeostasis [52]. Experimental studies indicate that metabolic conditions such as obesity and IR are characterized by elevated circulating non-esterified fatty acids (NEFA), reduced activity of the PI3K/Akt signalling pathway in hepatocytes, impaired fatty acid oxidation, and increased hepatic lipid accumulation. These alterations are accompanied by decreased levels of lipid oxidation and transport regulators, including PPARα and VLDL, along with activation of lipogenic transcription factors such as SREBP-1c and key enzymes involved in lipid synthesis and gluconeogenesis [53].

Activation of the PI3K/Akt pathway by Cr (III) may enhance fatty acid oxidation, promote VLDL-mediated lipid transport, and suppress hepatic lipogenesis, thereby reducing lipid accumulation in hepatocytes and stabilizing lipid homeostasis [54]. This process provides a biological basis for the potential regulatory effects of Cr (III) on lipid metabolism through modulation of insulin signalling.

Regulation of AMPK pathways of lipid metabolism by Cr (III):

In a review article published in 2024, Gencoglu and colleagues described mechanisms by which chromium may directly interact with the β-subunit of mitochondrial ATP synthase, leading to displacement of magnesium ions and subsequent activation of AMPK. Activated AMPK regulates lipid metabolism through multiple pathways by inhibiting lipogenesis, enhancing fatty acid oxidation and lipolysis, and promoting the transport and utilization of glucose and fatty acids.

In addition, Cr (III) has been reported to increase the expression of key components involved in insulin signalling and lipid metabolism, including peroxisome proliferator-activated receptor γ (PPARγ), insulin receptor substrate-1 (IRS-1), and the Akt/mTOR pathway. Through these interconnected mechanisms, chromium may reduce the accumulation of fatty acids and TG in hepatocytes and myocytes, improve lipid profiles, and attenuate IR in adipose tissue [55].

Regulation of hepatic lipid metabolism by Cr (III):

Current scientific evidence suggests that Cr (III) may be directly involved in the regulation of lipid homeostasis in hepatocytes. These effects appear to be mediated through modulation of processes related to lipid transport, synthesis, and accumulation, as well as through regulation of key metabolic signalling pathways such as PI3K/Akt and AMPK [56].

Recent epidemiological studies indicate an association between chromium status and hepatic lipid accumulation. In a large population-based study conducted by Xiang Y and colleagues (2024) using National Health and Nutrition Examination Survey (NHANES) 2017–2020 data, individuals with low circulating chromium levels exhibited increased fat accumulation in hepatocytes. Conversely, higher chromium levels were associated with a reduced risk of developing hepatic steatosis [35,57].

At the molecular level, Cr (III) may regulate hepatic lipid metabolism through several interconnected mechanisms. First, it may downregulate the expression of proteins involved in fatty acid uptake and intracellular transport, such as cluster of differentiation 36 (CD36) and liver fatty acid–binding protein (L-FABP), thereby limiting excessive fatty acid accumulation in hepatocytes [58]. In parallel, chromium may suppress hepatic lipogenesis by reducing the expression of key transcription factors and enzymes involved in lipid and TG synthesis, including sterol regulatory element-binding protein 1 (SREBP-1), fatty acid synthase (FASN), diacylglycerol acyltransferase 1 and 2 (DGAT-1 and DGAT-2), and perilipin 2 (PLIN2) [59]. In addition, Cr (III) may enhance cholesterol metabolism by upregulating the expression of apolipoprotein E (ApoE), the LDL receptor, and cholesterol 7α-hydroxylase, thereby promoting cholesterol efflux from the liver and contributing to improved lipid profiles. Beyond these direct metabolic effects, chromium may also influence inflammatory and OS pathways. Specifically, inhibition of hepatic nuclear factor kappa B (NF-κB) signalling and enhancement of antioxidant enzyme activity may attenuate inflammatory responses and oxidative stress, indirectly contributing to improved lipid metabolism [60].

Discussion.

This narrative review critically evaluates the role of Cr(III) in MS from experimental and clinical perspectives. The main focus was placed on the molecular mechanisms of action of chromium and its effects on individual components of MS. Although the reviewed data indicate the presence of biologically plausible mechanisms for Cr(III), they show that its clinical significance currently remains unclear.

Experimental studies demonstrate that Cr(III) can influence key metabolic pathways involved in the pathophysiology of MS. In particular, activation of the insulin-dependent PI3K/Akt signaling pathway, stimulation of the AMPK system, inhibition of hepatic gluconeogenesis, and increased activity of insulin receptors via chromodulin constitute a possible molecular basis for the regulation of glucose and lipid metabolism. However, evidence obtained from clinical studies is markedly heterogeneous. A number of RCTs and meta-analyses, especially with the use of CrPic3, show slight improvements in glycemic indicators, insulin sensitivity, or lipid parameters, whereas other studies have not identified statistically significant effects compared with placebo. Such differences are observed both in populations with and without diabetes and may depend on the form of chromium, dose, duration of intake, baseline metabolic status, and study design.

The association of Cr(III) with individual components of MS is also inconsistent. Positive results for body mass index (BMI), waist circumference, and dyslipidemia are modest and are not reproduced in all studies, while the effect on arterial blood pressure is in most cases not significant. In addition, data on the safety of long-term use of chromium supplements are limited, and optimal dosing regimens have not been clearly defined.

In conclusion, despite the ability of Cr(III) to affect important molecular mechanisms associated with the pathogenesis of MS, current clinical data do not support its widespread use for

the prevention or treatment of MS. In the future, large, high-quality randomized clinical trials conducted using standardized protocols are needed to determine the specific clinical role of chromium, identify patient groups that may derive potential benefit, and assess its long-term safety.

Conclusion.

Current evidence on the role of Cr III in the management of MS remains inconclusive. Experimental and limited clinical data suggest that Cr (III) may improve glycaemic control, lipid metabolism, and insulin sensitivity through several molecular mechanisms, but variability in study design and outcomes calls for caution in its clinical use. This review is limited by heterogeneity in the available studies and the predominance of short-term trials. Therefore, the potential benefits of chromium supplementation should be confirmed in large-scale, well-designed RCTs to clarify its efficacy, define optimal dosing, and assess long-term safety.

Author Contributions.

A.K.K. contributed to writing – original draft, conceptualization, formal analysis, methodology, and visualization; R.A.A. contributed to writing – review and editing, formal analysis, and methodology; M.K.J. contributed to writing – review and editing, formal analysis, and methodology; A.H. contributed to writing – review and editing, formal analysis, methodology, and validation; M.N.S. contributed to writing – review and editing and formal analysis.

Statement of Ethics.

This narrative review did not involve any original studies with human participants or animals. All data were derived from previously published literature. Therefore, ethical approval was not required. The study was conducted in accordance with generally accepted ethical standards.

Ethical Approval.

Not applicable.

Informed Consent Statement.

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Conflict of Interest.

The authors declare no conflict of interest.

Data Availability Statement.

All data analyzed in this study are included in this published article and its reference list.

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