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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 ВИНТИ 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 ВИНТИ РАН-ის მონაცემთა ბაზებში. სტატიების სრული ტექსტი ხელმისაწვდომია EBSCO-ს მონაცემთა ბაზებში.

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. Корректур авторам не высылаются, 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 computer-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 საყურადღებო!

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, შემავსებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

6. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრაფიის ფოტოსურათები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტოსურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შედეგების 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 ფხიხლებში 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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CALCULATED WHOLE BLOOD VISCOSITY IS SPECIFICALLY ASSOCIATED WITH ABDOMINAL OBESITY, BUT NOT WITH OTHER COMPONENTS OF METABOLIC SYNDROME: A CROSS-SECTIONAL STUDY IN A CENTRAL ASIAN ADULT COHORT

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Abstract.

Introduction: Metabolic syndrome (MetS) is a heterogeneous condition, and its individual components may reflect haemorheological disturbances to differing degrees. Estimated whole blood viscosity (WBV), computed from haematocrit and total protein using the de Simone formulas, is a non-invasive marker of potential microcirculatory disturbance. Existing data on the relationship between WBV and MetS in Central Asian populations remain limited and conflicting.

Aim: To evaluate the associations between estimated WBV and abdominal obesity as the leading anthropometric component of MetS, as well as its associations with the remaining components and the composite diagnosis of MetS, in an adult Central Asian population.

Material and methods: This cross-sectional study enrolled 359 adults (18–65 years) from Turkestan, Kazakhstan. WBV was calculated at two shear rates (208 s^{-1} and 0.5 s^{-1}) using the de Simone formulas. MetS components were defined according to the IDF 2006 criteria. The Mann–Whitney U test and the χ^2 test (or Fisher's exact test) were used for bivariate comparisons; multivariable logistic regression was performed with WBV quartiles as predictors; models were adjusted for age, sex, ethnicity, smoking and alcohol consumption; BMI was added to all models except the one for abdominal obesity (because of collinearity with waist circumference).

Results: Abdominal obesity showed a strong dose-dependent association with WBV: the adjusted odds ratio (aOR) for the highest vs. lowest WBV quartile was 5.03 (95% CI 1.62–15.60; $p = 0.005$) at 208 s^{-1} and 4.38 (1.45–13.22; $p = 0.009$) at 0.5 s^{-1} . The effect persisted with WBV as a continuous variable (aOR 3.04 per 1 cP at 208 s^{-1} ; $p < 0.001$). The remaining components — elevated blood pressure, hypertriglyceridemia, low HDL-C and impaired glucose metabolism — showed no significant association with WBV quartiles after adjustment. The composite MetS was likewise not significantly associated with WBV after adjustment (aOR Q4 vs. Q1 = 1.20, $p = 0.52$).

Conclusion: Estimated WBV is specifically associated with abdominal obesity, but not with the metabolic or hypertensive components of MetS after multivariable adjustment. This finding is consistent with the biological role of haemoconcentration and plasma volume as the leading determinants of the de Simone formula parameters. Estimated WBV may represent a marker of anthropometric rather than metabolic disturbance in the Central Asian population and should not be regarded as an independent predictor of composite MetS in such cohorts.

Key words. Whole blood viscosity, metabolic syndrome, abdominal obesity, de Simone formulas, haemorheology, Central Asia.

Introduction.

Metabolic syndrome (MetS) is a cluster of interrelated cardiometabolic risk factors — abdominal obesity, dyslipidaemia, elevated blood pressure and impaired glucose tolerance [1,2]. According to the 2006 International Diabetes Federation (IDF) criteria, a diagnosis of MetS requires the presence of abdominal obesity as a mandatory component in combination with any two of the four other criteria [3]. The prevalence of MetS in Central Asian populations reaches 20–25% and continues to rise against the background of urbanisation and lifestyle changes [4,5].

Whole blood viscosity (WBV) is a haemorheological parameter reflecting the internal resistance of blood to flow and determined primarily by haematocrit, plasma protein concentration and erythrocyte aggregation [6,7]. Elevated WBV is associated with microcirculatory disturbances, increased total peripheral resistance and a heightened risk of cardiovascular events [8,9]. Direct viscometric measurement of WBV is technically demanding and poorly standardised in clinical practice; for this reason, de Simone et al. [7] proposed empirical formulas for calculating WBV at two shear rates — high (208 s^{-1} , corresponding to blood flow in large arteries) and low (0.5 s^{-1} , corresponding to the microcirculatory level) — on the basis of haematocrit and total plasma protein concentration. This method is widely used in epidemiological studies owing to the availability of the required laboratory parameters [10–12].

Several previous studies have reported associations between estimated WBV and MetS components, predominantly in East Asian and European populations [13–16]. However, data on such associations in Central Asian populations remain extremely limited. Moreover, the existing literature largely focuses on the composite diagnosis of MetS, while associations with individual components and potential differences between the anthropometric and metabolic aspects of the syndrome have been insufficiently studied.

This distinction is biologically meaningful. WBV estimated by the de Simone formulas are determined by two variables — haematocrit and total plasma protein concentration — both of which reflect plasma volume and hydration status, closely linked to visceral obesity and body fluid distribution [17,18]. By contrast, lipid and carbohydrate metabolism disturbances are not part of the WBV formula and may therefore exert a less direct influence on the estimated index. Differentiating the specific associations of WBV with the anthropometric component of MetS from its associations with the metabolic components may help clarify whether estimated WBV reflects overall cardiometabolic dysregulation or predominantly anthropometric/haemoconcentration shifts.

Aim. The aim of the present study was to evaluate the associations between estimated WBV and abdominal obesity

as the leading anthropometric component of MetS (primary outcome), and to compare these associations with those for the remaining four MetS components and the composite MetS diagnosis (secondary outcomes) in a cross-sectional sample of adults from Turkestan, Kazakhstan.

Materials and Methods.

Study design and population: This cross-sectional observational study was conducted in Turkestan (Republic of Kazakhstan) between 2022 and 2024. Adult patients who attended the clinical base of the Khoja Akhmet Yassawi International Kazakh-Turkish University for a preventive medical examination were enrolled consecutively. Inclusion criteria were: age 18–65 years, signed informed consent and complete data on anthropometry, blood pressure, biochemical parameters (total protein, lipid profile, fasting glucose) and complete blood count (including haematocrit). Exclusion criteria were: pregnancy, active infectious diseases, haematological disorders (anaemia, erythrocytosis, haemoglobinopathies), decompensated chronic liver or kidney disease and known malignancy.

A total of 373 participants were included in the initial database. After applying the age criterion (18–65 years), 13 individuals were excluded (1 younger than 18 years, 12 older than 65 years). Of the remaining 360 participants, one was excluded owing to missing haematocrit or total plasma protein data, which precluded WBV calculation. The final analytical sample comprised $n = 359$ (Figure 1).

Anthropometry and clinical measurements: Anthropometric measurements were performed in a standardised manner. Body weight was measured to the nearest 0.1 kg using a medical scale; height to the nearest 0.5 cm using a fixed stadiometer. Body mass index (BMI) was calculated as weight (kg) / height (m)². Waist circumference was measured in the horizontal plane at the midpoint between the lower margin of the last rib and the iliac crest; hip circumference at the level of the maximal protrusion of the greater trochanter.

Blood pressure was measured by the Korotkoff method after 5 minutes of seated rest, twice at a 2-minute interval; the mean of the two measurements was used for analysis. Information on smoking status, alcohol consumption, chronic diseases and medication use (antihypertensive, antidiabetic, lipid-lowering) was collected by structured interview.

Laboratory investigations: Blood for laboratory testing was drawn in the morning after an 8–12-hour overnight fast. The complete blood count, including haematocrit and haemoglobin concentration, was performed on an automated haematology analyser. Biochemical parameters (total protein, total cholesterol, triglycerides, HDL- and LDL-cholesterol) were determined by standard enzymatic methods on an automated biochemistry analyser.

Fasting glucose was measured in capillary blood using a plasma-calibrated point-of-care glucometer (Optium Xceed, Abbott Diabetes Care Ltd., UK). The IDF criterion (fasting glucose ≥ 5.6 mmol/L) was applied to these capillary values, with the understanding that capillary and venous plasma measurements are not fully interchangeable; the potential implications of this approach are addressed in the Limitations section.

Calculation of whole blood viscosity:

Estimated WBV was computed using the empirical formulas proposed by de Simone et al. [7] at two shear rates:

$$\text{WBV (208 s}^{-1}\text{)} = 0.12 \times \text{Hct (\%)} + 0.17 \times \text{TP (g/dL)} - 2.07$$

$$\text{WBV (0.5 s}^{-1}\text{)} = 1.89 \times \text{Hct (\%)} + 3.76 \times \text{TP (g/dL)} - 78.42$$

where Hct is haematocrit in percent and TP is total plasma protein concentration in g/dL; results are expressed in centipoise (cP). WBV was calculated from the raw haematocrit values (converted from fractions to percent by multiplying by 100) and total protein (converted from g/L to g/dL by dividing by 10) for each participant individually.

Definition of metabolic syndrome and its components:

Metabolic syndrome was diagnosed according to the IDF 2006 criteria [3], which require the presence of abdominal obesity (mandatory component) in combination with any two of the four additional components. All five components were defined as follows:

(1) **Abdominal obesity** — waist circumference ≥ 80 cm in women or ≥ 94 cm in men (IDF ethnicity-specific thresholds for the European population);

(2) **Elevated blood pressure** — systolic BP ≥ 130 mmHg, or diastolic BP ≥ 85 mmHg, or use of antihypertensive medication;

(3) **Hypertriglyceridemia** — triglyceride concentration ≥ 1.7 mmol/L or use of lipid-lowering medication;

(4) **Low HDL-cholesterol** — HDL-C < 1.29 mmol/L in women or < 1.03 mmol/L in men, or use of lipid-lowering medication;

(5) **Impaired glucose metabolism** — fasting glucose ≥ 5.6 mmol/L, use of antidiabetic medication or an established diagnosis of type 2 diabetes mellitus.

Statistical analysis:

All statistical analyses were performed in R version 4.6.0 (R Foundation for Statistical Computing). The distribution of continuous variables was assessed using the Shapiro–Wilk test. WBV parameters at both shear rates deviated substantially from a normal distribution ($W = 0.979$, $p < 0.001$ at 208 s^{-1} ; $W = 0.975$, $p < 0.001$ at 0.5 s^{-1}); accordingly, continuous variables are presented as median (Q1–Q3), and the Mann–Whitney U test was used for bivariate between-group comparisons. Categorical variables are presented as n (%); the χ^2 test or Fisher's exact test (when expected cell counts were < 5) was used for their comparison.

Primary analysis:

To assess the association between WBV and abdominal obesity (primary outcome), multivariable logistic regression was performed with WBV quartiles as the main predictor (Q1 as the reference category). Covariates were selected *a priori* on the basis of established cardiometabolic risk factors that are potential confounders of the relationship between haemorheological parameters and obesity: age, sex, ethnicity, smoking status and alcohol consumption. BMI was not included in the model for abdominal obesity owing to inherent collinearity with waist circumference (the variable defining the outcome).

Secondary analysis:

For the remaining four MetS components (elevated blood pressure, hypertriglyceridemia, low HDL-C, impaired glucose

metabolism) and the composite MetS diagnosis, analogous logistic regression models were fitted with additional adjustment for BMI. The overall effect of WBV quartiles was assessed using the likelihood ratio test (LRT) comparing full models with models without the WBV variable.

Sensitivity analyses included: (i) repeating the analysis with WBV as a continuous variable (per 1 cP and per +1 SD) to test for a dose-dependent effect; (ii) repeating the abdominal obesity analysis with BMI included in the model as a pessimistic test; (iii) sex-stratified analysis.

Multicollinearity was assessed using generalised variance inflation factors (GVIF); values < 5 were considered acceptable and > 10 critical. Statistical significance was defined as $p < 0.05$ (two-sided test).

Ethical aspects:

The study was conducted in accordance with the principles of the Declaration of Helsinki and approved by the local ethics committee of the Khoja Akhmet Yassawi International Kazakh-Turkish University. All participants provided written informed consent to participate in the study and to the use of their personal data in anonymised form.

Results.

Sample characteristics:

The final analytical sample included 359 participants. The prevalence of MetS was 35.1% ($n = 126$); 233 participants (64.9%) did not have MetS. The median age in the overall sample was 48.0 years (Q1–Q3: 38.0–55.0); women comprised 76.9% ($n = 276$) and men 23.1% ($n = 83$). The vast majority of participants (89.4%, $n = 321$) identified as ethnic Kazakhs.

The full sample characteristics, stratified by MetS status, are presented in Table 1. Participants with MetS were significantly older (median 53.5 vs. 44.0 years; $p < 0.001$), had higher BMI (31.7 vs. 27.1 kg/m²; $p < 0.001$), waist circumference (104.0 vs. 94.0 cm; $p < 0.001$), and higher systolic (135.0 vs. 113.0 mmHg) and diastolic (90.0 vs. 76.0 mmHg) blood pressure. All biochemical parameters — glucose, total cholesterol, triglycerides, LDL-C — were significantly elevated in the MetS group, while HDL-C was reduced (all $p \leq 0.016$). No significant differences were observed for haematocrit (median 0.422 vs. 0.414; $p = 0.121$) or total protein (70.0 vs. 70.0 g/L; $p = 0.828$) between groups.

Estimated WBV: distribution:

Mean estimated WBV values were 4.08 ± 0.60 cP at 208 s⁻¹ (range 2.28–5.45) and 25.90 ± 9.75 cP at 0.5 s⁻¹ (range -2.55–47.54). The Shapiro–Wilk test confirmed deviation from a normal distribution for both variables ($p < 0.001$). The differences in median WBV between the MetS and non-MetS groups in the bivariate analysis did not reach statistical significance (4.16 vs. 4.06 cP at 208 s⁻¹, $p = 0.160$; 27.23 vs. 25.74 cP at 0.5 s⁻¹, $p = 0.201$).

Bivariate associations of WBV with MetS components:

Table 2 presents median WBV according to the presence/absence of each of the five MetS components. Significant associations in the bivariate analysis were observed for two components: abdominal obesity (WBV at 208 s⁻¹: 4.13 vs. 3.94 cP, $p = 0.037$; WBV at 0.5 s⁻¹: 26.69 vs. 23.92 cP, $p = 0.047$) and

elevated blood pressure (4.19 vs. 4.00 cP, $p = 0.015$; 27.76 vs. 24.87 cP, $p = 0.021$). For hypertriglyceridemia, low HDL-C and impaired glucose metabolism, no significant associations with WBV were found in the bivariate analysis (all $p > 0.45$). These shifts are visualised in Figure 2.

Multivariable analysis: primary outcome — abdominal obesity:

In the multivariable logistic regression adjusted for age, sex, ethnicity, smoking and alcohol consumption, a strong dose-dependent association between WBV quartiles and abdominal obesity was identified. At the high shear rate (208 s⁻¹): aOR for Q2 vs. Q1 = 2.59 (95% CI 1.00–6.72; $p = 0.050$); Q3 vs. Q1 = 2.95 (1.13–7.71; $p = 0.027$); Q4 vs. Q1 = 5.03 (1.62–15.60; $p = 0.005$); overall effect (LRT) $p = 0.014$. A similar pattern was observed at the low shear rate (0.5 s⁻¹): Q4 vs. Q1 = 4.38 (1.45–13.22; $p = 0.009$); overall LRT $p = 0.018$.

With WBV as a continuous variable (without quartile splitting), the association remained highly significant: aOR per 1 cP WBV at 208 s⁻¹ = 3.04 (95% CI 1.67–5.51; $p < 0.001$); per +1 SD (0.60 cP) = 1.95 (1.36–2.79; $p < 0.001$). At 0.5 s⁻¹, the corresponding values were 1.07 per 1 cP (1.03–1.11; $p < 0.001$) and 1.88 per +1 SD (1.32–2.66; $p < 0.001$).

Multicollinearity analysis (GVIF) confirmed the absence of collinearity problems in the main model (all $GVIF^{(1/(2-Df))} < 1.58$).

Multivariable analysis: secondary outcomes:

Results for all five MetS components and the composite MetS diagnosis are presented in Figure 3. In contrast to abdominal obesity, none of the remaining MetS components showed a significant association with WBV quartiles after multivariable adjustment:

— Elevated blood pressure: Q4 vs. Q1 aOR 1.00 (0.42–2.36; LRT $p = 0.443$) at 208 s⁻¹; 0.94 (0.40–2.21; LRT $p = 0.309$) at 0.5 s⁻¹;

— Hypertriglyceridemia: Q4 vs. Q1 aOR 0.62 (0.25–1.52; LRT $p = 0.322$) at 208 s⁻¹; 0.65 (0.27–1.57; LRT $p = 0.185$) at 0.5 s⁻¹;

— Low HDL-C: Q4 vs. Q1 aOR 0.64 (0.24–1.75; LRT $p = 0.306$) at 208 s⁻¹; 0.46 (0.17–1.28; LRT $p = 0.349$) at 0.5 s⁻¹;

— Impaired glucose metabolism: Q4 vs. Q1 aOR 0.47 (0.22–1.04; LRT $p = 0.150$) at 208 s⁻¹; 0.44 (0.20–0.96; LRT $p = 0.150$) at 0.5 s⁻¹.

The composite MetS diagnosis was likewise not significantly associated with WBV quartiles after adjustment: Q4 vs. Q1 aOR 1.20 (0.55–2.65; LRT $p = 0.522$) at 208 s⁻¹ and 1.05 (0.48–2.29; LRT $p = 0.341$) at 0.5 s⁻¹. Age was the leading predictor of composite MetS in all models (OR per 1 year = 1.10; $p < 10^{-10}$).

Sensitivity analyses:

When BMI was included in the abdominal obesity model (a pessimistic analysis given the collinearity of BMI with waist circumference), the effect of WBV quartiles weakened and was no longer significant (Q4 vs. Q1 aOR 3.50, 95% CI 0.33–37.30; $p = 0.300$), whereas BMI itself became the dominant predictor (aOR per 1 kg/m² = 3.46; $p < 10^{-8}$). This finding is consistent with the biological interpretation that the contribution of WBV to the risk of abdominal obesity is partly mediated by overall anthropometric status.

Table 1. Baseline characteristics of the study population, stratified by metabolic syndrome status.

Characteristic	Total (n = 359)	With MetS (n = 126)	Without MetS (n = 233)	p-value
Demographics				
Age, years, median (Q1–Q3)	48.0 (38.0–55.0)	53.5 (48.0–59.0)	44.0 (35.0–52.0)	<0.001
Female, n (%)	276 (76.9%)	102 (81.0%)	174 (74.7%)	0.224
Ethnicity — Kazakh, n (%)	321 (89.4%)	112 (88.9%)	209 (89.7%)	0.953
Anthropometry & vital signs				
BMI, kg/m ² , median (Q1–Q3)	29.0 (25.5–33.3)	31.7 (28.7–35.3)	27.1 (23.9–31.6)	<0.001
Waist circumference, cm, median (Q1–Q3)	98.0 (87.3–106.0)	104.0 (97.1–110.0)	94.0 (84.0–102.0)	<0.001
Hip circumference, cm, median (Q1–Q3)	107.0 (101.0–114.5)	111.5 (104.0–120.0)	106.0 (100.0–111.0)	<0.001
Systolic BP, mmHg, median (Q1–Q3)	120.0 (108.0–135.5)	135.0 (125.0–147.0)	113.0 (104.0–124.0)	<0.001
Diastolic BP, mmHg, median (Q1–Q3)	80.0 (73.0–90.0)	90.0 (81.0–96.0)	76.0 (70.0–83.0)	<0.001
Behavioural factors				
Current smoking, n (%)	55 (15.3%)	13 (10.3%)	42 (18.0%)	0.075
Alcohol consumption, n (%)	65 (18.1%)	20 (15.9%)	45 (19.3%)	0.506
Medication use				
Antihypertensive medication, n (%)	98 (27.3%)	68 (54.0%)	30 (12.9%)	<0.001
Antidiabetic medication, n (%)	23 (6.4%)	20 (15.9%)	3 (1.3%)	<0.001
Lipid-lowering medication, n (%)	6 (1.7%)	6 (4.8%)	0 (0.0%)	0.002
Laboratory parameters				
Hematocrit, median (Q1–Q3)	0.416 (0.386–0.448)	0.422 (0.394–0.450)	0.414 (0.381–0.445)	0.121
Hemoglobin, g/L, median (Q1–Q3)	132.0 (121.0–143.0)	132.0 (124.3–145.0)	131.0 (118.0–141.0)	0.057
Total protein, g/L, median (Q1–Q3)	70.0 (67.1–72.1)	70.0 (67.1–72.0)	70.0 (67.0–72.2)	0.828
Fasting glucose*, mmol/L, median (Q1–Q3)	5.40 (5.00–5.80)	5.90 (5.60–6.60)	5.20 (4.80–5.40)	<0.001
Total cholesterol, mmol/L, median (Q1–Q3)	4.88 (4.28–5.49)	5.12 (4.49–6.13)	4.70 (4.25–5.18)	<0.001
Triglycerides, mmol/L, median (Q1–Q3)	1.35 (1.23–1.54)	1.46 (1.31–1.75)	1.30 (1.18–1.42)	<0.001
HDL-C, mmol/L, median (Q1–Q3)	1.41 (1.33–1.69)	1.40 (1.23–1.64)	1.42 (1.37–1.69)	0.016
LDL-C, mmol/L, median (Q1–Q3)	2.74 (2.21–3.29)	2.91 (2.32–3.96)	2.62 (2.18–3.14)	<0.001
Estimated whole blood viscosity				
WBV at 208 s ⁻¹ , cP, median (Q1–Q3)	4.10 (3.74–4.48)	4.16 (3.84–4.51)	4.06 (3.68–4.46)	0.160
WBV at 0.5 s ⁻¹ , cP, median (Q1–Q3)	26.41 (20.71–32.28)	27.23 (22.19–33.01)	25.74 (19.74–31.78)	0.201
MetS components, n (%)				
Abdominal obesity	304 (84.7%)	126 (100.0%)	178 (76.4%)	<0.001
Elevated blood pressure	184 (51.3%)	117 (92.9%)	67 (28.8%)	<0.001
Hypertriglyceridemia	67 (18.7%)	49 (38.9%)	18 (7.7%)	<0.001
Low HDL-C	52 (14.5%)	40 (31.7%)	12 (5.2%)	<0.001
Impaired glucose metabolism	140 (39.0%)	101 (80.2%)	39 (16.7%)	<0.001

Note: Continuous variables are presented as median (Q1–Q3). Between-group comparisons used the Mann–Whitney U test for continuous variables and the χ^2 test (or Fisher's exact test when any expected cell count was < 5) for categorical variables. * Fasting glucose was measured in capillary blood using a plasma-calibrated point-of-care glucometer (Optium Xceed, Abbott Diabetes Care Ltd., UK); the implications are addressed in the Discussion.

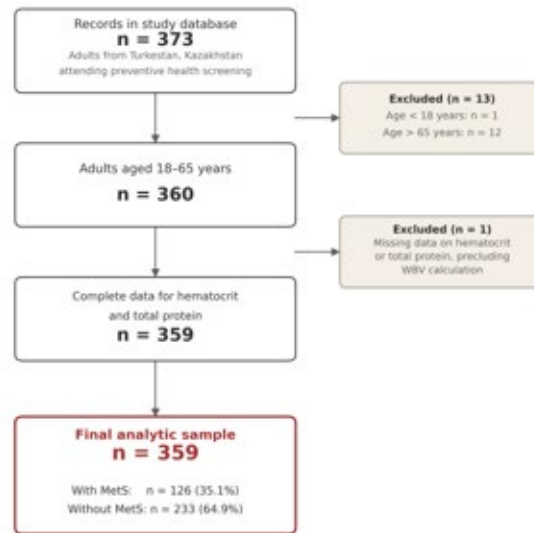
Abbreviations: BMI — body mass index; BP — blood pressure; cP — centipoise; HDL-C — high-density lipoprotein cholesterol; LDL-C — low-density lipoprotein cholesterol; MetS — metabolic syndrome; Q1, Q3 — first and third quartiles; WBV — whole blood viscosity.

Table 2. Estimated whole blood viscosity according to individual components of metabolic syndrome.

MetS component	Status	n	High shear · 208 s ⁻¹		Low shear · 0.5 s ⁻¹	
			WBV, cP, median (Q1–Q3)	p	WBV, cP, median (Q1–Q3)	p
Abdominal obesity	No	55	3.94 (3.27–4.49)	0.037 *	23.92 (12.59–32.96)	0.047 *
	Yes	304	4.13 (3.80–4.47)		26.69 (21.50–32.23)	
Elevated blood pressure	No	171	4.00 (3.62–4.42)	0.015 *	24.87 (18.62–31.27)	0.021 *
	Yes	184	4.19 (3.82–4.53)		27.76 (21.97–33.15)	
Hypertriglyceridemia	No	292	4.13 (3.76–4.49)	0.508	26.75 (20.85–32.31)	0.556
	Yes	67	3.98 (3.72–4.47)		24.41 (20.21–32.16)	
Low HDL-C	No	306	4.12 (3.75–4.48)	0.474	26.61 (20.79–32.71)	0.453
	Yes	52	4.00 (3.74–4.40)		24.88 (20.21–30.93)	
Impaired glucose metabolism	No	213	4.13 (3.74–4.54)	0.783	26.47 (20.74–33.25)	0.663
	Yes	140	4.10 (3.77–4.42)		26.20 (21.00–31.27)	

Note: Data are presented as median (Q1–Q3). Between-group comparisons were performed using the Mann–Whitney U test. Rows shaded in light pink and p-values marked with an asterisk (*) indicate statistically significant between-group differences (p < 0.05).

Flow diagram of participant selection
Cross-sectional study of estimated whole blood viscosity and metabolic syndrome components

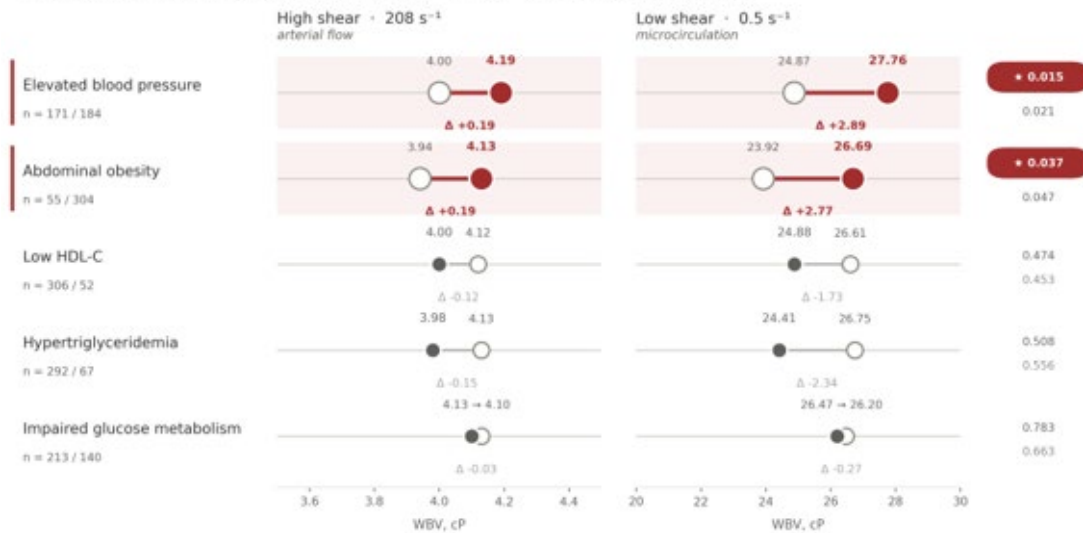


MetS, metabolic syndrome (IDF 2009 criteria); WBV, whole blood viscosity (de Simone formulas).

Figure 1. Flow diagram of participant selection. Of the initial database of 373 participants, 13 were excluded by the age criterion and 1 owing to missing laboratory data required for WBV calculation; the final analytical sample comprised $n = 359$ (126 with MetS, 233 without MetS). MetS—metabolic syndrome (IDF 2006 criteria); WBV—whole blood viscosity (de Simone formulas).

Effect of MetS components on estimated whole blood viscosity

Median WBV shift from absent (○) to present (●) component - $n = 359$ - ranked by statistical significance



* $p < 0.05$ (Mann-Whitney U test). Significant bivariate associations (red) seen for elevated BP and abdominal obesity at both shear rates.

Figure 2. Shift plot: estimated whole blood viscosity by MetS components (bivariate analysis). Median WBV values in the subgroups without (○) and with (●) each MetS component, shown separately at high (208 s⁻¹) and low (0.5 s⁻¹) shear rates. Components are ordered by statistical significance. Asterisks (*) denote statistically significant differences ($p < 0.05$; Mann-Whitney U test).

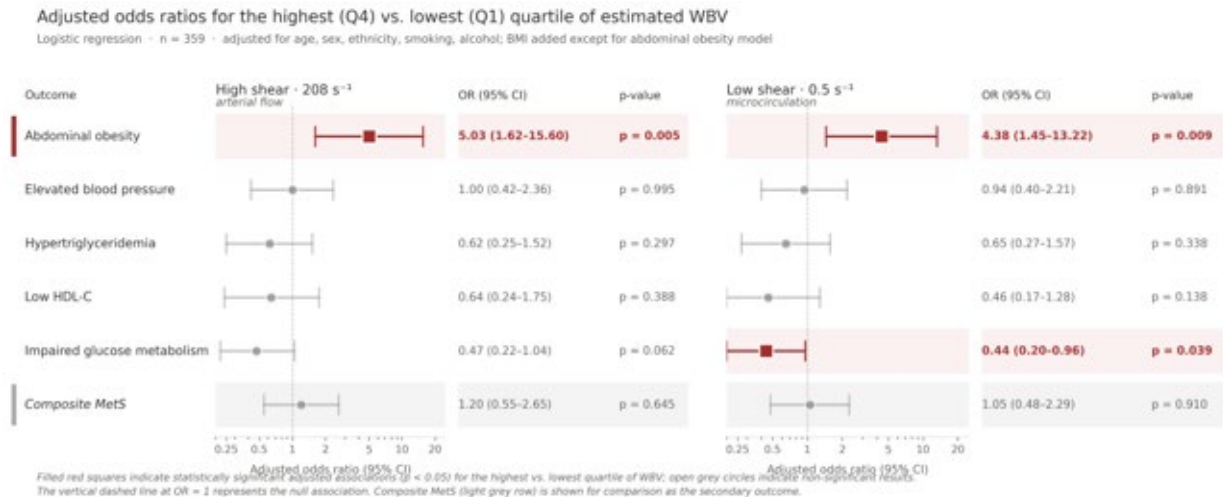


Figure 3. Forest plot of adjusted odds ratios for the highest (Q4) vs. lowest (Q1) quartile of estimated WBV. Logistic regression ($n = 359$); models adjusted for age, sex, ethnicity, smoking and alcohol consumption; BMI added to all models except the abdominal obesity model (because of collinearity with waist circumference). Red squares — statistically significant associations ($p < 0.05$); grey circles — non-significant associations. Composite MetS is shown as a secondary outcome for comparison (light-grey row).

The sex-stratified analysis showed that the effect of WBV on abdominal obesity was expressed predominantly in women (Q4 vs. Q1 aOR 12.23, 95% CI 1.39–107.88; $p = 0.024$). In men the association was not significant (Q4 vs. Q1 aOR 1.08; $p = 0.92$); however, this result should be interpreted with caution given the small size of the male subsample ($n = 83$) and the associated limited statistical power.

Discussion.

In this cross-sectional study of 359 adults from Turkestan (Kazakhstan), estimated WBV showed a strong dose-dependent association with abdominal obesity, but not with the remaining components of metabolic syndrome or with the composite MetS diagnosis after multivariable adjustment. The adjusted odds ratio for the highest vs. lowest WBV quartile was 5.03 at the high shear rate (208 s^{-1}) and 4.38 at the low shear rate (0.5 s^{-1}), with a clear monotonic gradient across quartiles. This specificity of the association — a pronounced link with the anthropometric component and the absence of significant links with the metabolic, lipid and hypertensive components — represents the main conceptual contribution of the present work.

Biological interpretation:

The specificity of the WBV association with abdominal obesity (rather than with MetS overall) has a clear biological rationale. The de Simone formulas calculate WBV exclusively from two parameters — haematocrit and total plasma protein concentration [7]. Both parameters are closely linked to plasma volume and haemoconcentration status, which in turn are disturbed in visceral obesity: visceral adipose tissue increases renin–angiotensin–aldosterone system activity, promotes sodium retention and reduces relative plasma volume, leading to relative haemoconcentration [17–19]. In addition, obesity is associated with chronic subclinical inflammation and increased acute-phase protein concentrations [18], which may also be reflected in changes in total protein concentration.

By contrast, carbohydrate and lipid metabolism disturbances do not directly affect the parameters of the de Simone formula.

Glucose, triglycerides and HDL-C are not part of the calculation, and these parameters have no direct influence on haematocrit or total protein. Arterial hypertension may theoretically affect haemodynamics and plasma volume status, but these effects are indirect and are not reflected in estimated WBV as directly as abdominal adiposity.

This allows an important conclusion: WBV estimated by de Simone reflects predominantly anthropometric/haemoconcentration disturbances rather than metabolic risk per se. This interpretation is consistent with the known biological limitations of the formula and helps explain why previous studies using the composite MetS diagnosis as the outcome may have produced conflicting results.

Comparison with previous work:

Previous studies in East Asian and European populations reported increased estimated WBV in patients with MetS [13–16]. However, most of these studies did not perform a breakdown by individual components of the syndrome and did not use the full range of adjustments for age and anthropometric parameters. Our results underscore the importance of such a breakdown: the association observed for MetS overall may to a large extent reflect the correlation of WBV with one specific component — abdominal obesity — and may not be an indicator of an independent contribution of metabolic dysregulation.

Age proved to be the dominant predictor of MetS in all our models (OR per 1 year ≈ 1.10 ; $p < 10^{-10}$), consistent with abundant epidemiological evidence of an increasing prevalence of MetS with age [1,4]. The fact that WBV did not add independent information to age in the modelling of composite MetS may partly reflect shared age-related changes in both cardiometabolic status and haemorheology.

Sex differences:

The stratified analysis showed that the association between WBV and abdominal obesity was expressed predominantly in women (Q4 vs. Q1 aOR 12.23) and did not reach significance in men (aOR 1.08). Although the small size of the male subsample

($n = 83$) limits statistical inference, this pattern is consistent with known sex differences in haemorheology: in women, WBV is closely linked to menopausal status and fat distribution [12]. A large part of our sample comprised women of reproductive and perimenopausal age, which may have amplified the observed effect. Larger samples with equal gender representation are needed to clarify these differences.

Clinical relevance:

These findings have two practical implications. First, estimated WBV should not be interpreted as an indicator of cardiometabolic risk in general; it specifically reflects the anthropometric component. The use of estimated WBV in screening programmes should take this limitation into account. Second, in Central Asian populations — a region with a high prevalence of abdominal obesity and limited haemorheological data [4] — estimated WBV may represent a simple and inexpensive supplementary anthropometric indicator, derived from standard laboratory data, without the need for specialised haemorheological equipment.

Strengths and Limitations.

Strengths: The present study include: (i) careful analytical planning with pre-specified covariates; (ii) comprehensive analysis of all five MetS components separately, which made it possible to reveal the specificity of the association; (iii) consistent use of non-parametric methods in accordance with the distribution of the variables; (iv) performance of sensitivity analyses (continuous WBV, BMI adjustment, sex stratification); (v) presentation of study findings from an under-studied Central Asian region.

Limitations: First, the study has a cross-sectional design, which precludes conclusions about causality or the temporal sequence between WBV and abdominal obesity. Second, estimated WBV is a calculated index based on empirical formulas and does not replace direct viscometric measurement; the original de Simone formulas were validated in European populations, and their accuracy in Central Asian cohorts requires additional confirmation. Third, *fasting glucose was measured in capillary blood using a plasma-calibrated glucometer rather than in venous plasma by laboratory methods*. Despite calibration, point-of-care measurements may show systematic differences from the reference venous method [20], which could have affected classification of the “impaired glucose metabolism” component and potentially weakened the observed associations for this component. Fourth, female sex predominated substantially in the sample (76.9%), which limits the generalisability of the results to the male population. Fifth, potentially relevant covariates such as physical activity (in detail), dietary patterns, menopausal status in women and the use of certain medications that may influence haemorheology were not assessed.

Future research directions.

Promising directions include: (i) prospective cohort studies with repeated WBV measurements to assess its prognostic value for cardiometabolic outcomes; (ii) comparison of estimated WBV with direct viscometric measurement in a Central Asian population to validate the de Simone formulas; (iii) investigation

of possible effect modification by age and menopausal status in larger samples; (iv) integrated studies with biomarkers of haemoconcentration (natriuretic peptide, plasma osmolality, volaemia markers).

Conclusion.

In a cross-sectional study of 359 adults from a Central Asian population, whole blood viscosity estimated by the de Simone formulas was specifically and strongly associated with abdominal obesity (adjusted OR 5.03 at 208 s^{-1} and 4.38 at 0.5 s^{-1} for the highest vs. lowest quartile). At the same time, no significant associations were found between estimated WBV and the other components of metabolic syndrome (elevated blood pressure, hypertriglyceridemia, low HDL-C, impaired glucose metabolism) or with the composite MetS diagnosis after multivariable adjustment. This pattern is consistent with the biological interpretation of the de Simone formulas as reflecting predominantly the anthropometric and haemoconcentration component rather than the metabolic component of cardiometabolic risk. Estimated WBV should not be regarded as an independent predictor of composite MetS in such populations, but may represent a useful supplementary anthropometric biomarker, particularly for the assessment of visceral obesity in women.

Conflicts of interest.

The authors declare no conflicts of interest.

Funding.

No.

Ethics statement.

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Local Ethics Committee of Khoja Akhmet Yassawi International Kazakh-Turkish University (protocol No.9, dated 15.12.2022). Written informed consent was obtained from all participants prior to enrolment.

Authors' contributions (CRediT taxonomy).

- E.K.E. (Eibov): Conceptualization, Investigation, Data curation, Formal analysis, Writing — original draft.
- S.K. (Khavaskhonova): Investigation, Data curation, Writing — original draft.
- K.S.T. (Taubay): Investigation, Data curation, Writing — original draft.
- K.Zh.S. (Sadykova): Project administration, Scientific Supervision, Conceptualization, Methodology, Writing — review & editing.

All authors have read and approved the final version of the manuscript and agree to be accountable for all aspects of the work.

Data availability statement.

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

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- ქართული
- შესავალი: მეტაბოლური სინდრომი (მსს) ჰეტეროგენული მდგომარეობაა და მისი ცალკეული კომპონენტები სისხლის რეოლოგიურ დარღვევებს სხვადასხვა ხარისხით შეიძლება ასახავდეს. სრული სისხლის სიბლანტის (სსსს) სავარაუდო მაჩვენებელი, რომელიც ჰემატოკრიტისა და მთლიანი ცილის საფუძველზე დე სიმონეს ფორმულებით გამოითვლება, წარმოადგენს მიკროცირკულაციური დარღვევის პოტენციური არაინვაზიური მარკერს. სსსს-სა და მსს-ს შორის კავშირის შესახებ არსებული მონაცემები ცენტრალური აზიის პოპულაციებში შეზღუდულია და წინააღმდეგობრივი ხასიათისაა.
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- მასალა და მეთოდები: ამ განივი კვლევით ჩაირიცხა 359 ზრდასრული (18–65 წელი) ყაზახეთის ქ. თურქესტანიდან. სსსს გამოითვლა ორ სხვადასხვა გრადიენტის სიჩქარეზე (208 წმ^{-1} და $0,5 \text{ წმ}^{-1}$) დე სიმონეს ფორმულებით. მსს-ს კომპონენტები განისაზღვრა IDF 2006 წლის კრიტერიუმების შესაბამისად. ბივარიანტული შედარებისათვის გამოყენებულ იქნა მან-უიტნის U-კრიტერიუმი და χ^2 -კრიტერიუმი (ან ფიშერის ზუსტი კრიტერიუმი); მრავლობითი ლოჯისტიკური რეგრესია ჩატარდა სსსს-ის კვარტილებით, როგორც პრედიქტორებით; მოდელები კორექტირდა ასაკის, სქესის, ეთნიკური კუთვნილების, მოწევისა და ალკოჰოლის მოხმარების მიხედვით; სხეულის მასის ინდექსი (სმი) ჩართული იქნა ყველა მოდელში, გარდა მუცლის სიმსუქნის მოდელისა (წელის გარშემოწერილობასთან კოლინეარობის გამო).
- შედეგები: მუცლის სიმსუქნემ გამოავლინა სსსს-თან გამოხატული დოზადამოკიდებული ასოციაცია: კორექტირებული შანსების შეფარდება (კშშ) ყველაზე მაღალი კვარტილის ყველაზე დაბალთან შეპირისპირებისას შეადგინა $5,03$ (95% სი $1,62$ – $15,60$; $p = 0,005$) — 208 წმ^{-1} -ზე და $4,38$ ($1,45$ – $13,22$; $p = 0,009$) — $0,5 \text{ წმ}^{-1}$ -ზე. ეფექტი შენარჩუნდა სსსს-ის, როგორც უწყვეტი ცვლადის, გამოყენებისასაც (კშშ $3,04$ 1 cP -ზე 208 წმ^{-1} -ზე; $p < 0,001$). დარჩენილმა კომპონენტებმა — არტერიული წნევის მომატება, ჰიპერტრიგლიცერიდემია, დაბალი მაღალი სიმკვრივის ლიპოპროტეინების ქოლესტეროლი (მსლ-ქ) და გლუკოზის მეტაბოლიზმის დარღვევა — კორექტირების შემდეგ სსსს-ის კვარტილებთან სტატისტიკურად მნიშვნელოვანი ასოციაცია არ გამოავლინა. კომპოზიტური მსს ასევე კორექტირების

შემდეგ სსსს-თან მნიშვნელოვნად არ იყო ასოცირებული (კშშ Q4 vs. Q1 = 1,20, p = 0,52).

დასკვნა: სავარაუდო სსსს სპეციფიკურად ასოცირებულია მუცლის სიმსუქნესთან, მაგრამ არა მსს-ს მეტაბოლურ ან ჰიპერტენზიულ კომპონენტებთან მრავლობითი კორექტირების შემდეგ. ეს მონაცემები შეესაბამება ჰემოკონცენტრაციისა და სისხლის პლაზმის მოცულობის, როგორც დე სიმონეს ფორმულის პარამეტრების წამყვანი დეტერმინანტების, ბიოლოგიურ როლს. სავარაუდო სსსს შეიძლება წარმოადგენდეს ცენტრალური აზიის პოპულაციაში მეტაბოლური და არა ანთროპომეტრული დარღვევის მარკერს, და არ უნდა განიხილებოდეს, როგორც ასეთ კოჰორტებში კომპოზიტური მსს-ს დამოუკიდებელი პრედიქტორი.

საკვანძო სიტყვები: სრული სისხლის სიბლანტე, მეტაბოლური სინდრომი, მუცლის სიმსუქნე, დე სიმონეს ფორმულები, ჰემორეოლოგია, ცენტრალური აზია.

Расчётная вязкость цельной крови специфически ассоциирована с абдоминальным ожирением, но не с другими компонентами метаболического синдрома: поперечное исследование в когорте взрослых Центральной Азии

Введение:

Метаболический синдром (МС) является гетерогенным состоянием, и его отдельные компоненты могут в разной степени отражать гемореологические нарушения. Расчётная вязкость цельной крови (ВЦК), вычисляемая по гематокриту и общему белку по формулам де Симоне, представляет собой неинвазивный маркер потенциальных микроциркуляторных расстройств. Имеющиеся данные о взаимосвязи ВЦК и МС в центральноазиатских популяциях остаются ограниченными и противоречивыми.

Цель: Оценить ассоциации расчётной ВЦК с абдоминальным ожирением как ведущим антропометрическим компонентом МС, а также её ассоциации с остальными компонентами и суммарным диагнозом МС во взрослой центральноазиатской популяции.

Материал и методы: В данное поперечное исследование включены 359 взрослых (18–65 лет) из г. Туркестан,

Казахстан. ВЦК рассчитывалась при двух скоростях сдвига (208 с^{-1} и $0,5 \text{ с}^{-1}$) по формулам де Симоне. Компоненты МС определялись в соответствии с критериями МФД 2006 года. Для бивариантных сравнений использовались критерий Манна–Уитни и критерий χ^2 (или точный критерий Фишера); многофакторная логистическая регрессия выполнялась с квартилями ВЦК в качестве предикторов; модели корректировались по возрасту, полу, этнической принадлежности, курению и употреблению алкоголя; ИМТ включался во все модели, за исключением модели для абдоминального ожирения (в связи с коллинеарностью с окружностью талии).

Результаты: Абдоминальное ожирение продемонстрировало выраженную дозозависимую ассоциацию с ВЦК: скорректированное отношение шансов (аОШ) для наибольшего квартиля в сравнении с наименьшим составило 5,03 (95% ДИ 1,62–15,60; p = 0,005) при 208 с^{-1} и 4,38 (1,45–13,22; p = 0,009) при $0,5 \text{ с}^{-1}$. Эффект сохранялся при использовании ВЦК как непрерывной переменной (аОШ 3,04 на 1 сП при 208 с^{-1} ; p < 0,001). Остальные компоненты — повышенное артериальное давление, гипертриглицеридемия, низкий ХС-ЛПВП и нарушение метаболизма глюкозы — не проявляли значимой ассоциации с квартилями ВЦК после поправки. Суммарный МС также не был значимо связан с ВЦК после корректировки (аОШ Q4 vs. Q1 = 1,20, p = 0,52).

Заключение: Расчётная ВЦК специфически ассоциирована с абдоминальным ожирением, но не с метаболическими или гипертензивными компонентами МС после многофакторной поправки. Полученные данные согласуются с биологической ролью гемоконцентрации и объёма плазмы как ведущих детерминант параметров формулы де Симоне. Расчётная ВЦК может служить маркером антропометрических, а не метаболических нарушений в центральноазиатской популяции и не должна рассматриваться как независимый предиктор суммарного МС в подобных когортах.

Ключевые слова: вязкость цельной крови, метаболический синдром, абдоминальное ожирение, формулы де Симоне, гемореология, Центральная Азия.