Relationship Between Nutritional Risk Index and Inflammatory Markers in Metabolic Syndrome—Synergy and Clinical Significance in Geriatrics: A Systematic Review

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ABSTRACT

The increasing prevalence of metabolic syndrome (MS) in the geriatric population necessitates an in-depth understanding of its interaction with nutritional status and systemic inflammation. There is an urgent need to determine the synergistic effect and clinical significance of the Geriatric Nutritional Risk Index (GNRI) and C-reactive protein–triglyceride–glucose index (CTI) in this vulnerable category of patients. During the course of the study, a systematic review of scientific literature published over the past 5 years was conducted. For this purpose, the scientometric databases Web of Science, Scopus, PubMed, and Google Scholar were used. This review included identifying key mechanisms, patterns, and gaps in the data related to the study topic. The analysis confirmed that GNRI and CTI are independent prognostic markers reflecting interrelated pathophysiological processes with a synergistic effect that worsens outcomes in elderly patients with MS. GNRI reliably assesses nutritional status and predicts adverse events, while CTI captures metabolic dysfunction and chronic inflammation, predicting progression and cardiovascular complications. Their interaction—where inflammation worsens nutrition and poor nutrition increases inflammation—creates a vicious cycle. Both indices are simple to use and applicable in routine clinical settings. GNRI and CTI demonstrate strong prognostic value and a synergistic effect, supporting the need for an integrated risk assessment approach in elderly patients with MS. Their combined use enables more precise stratification and targeted interventions to improve nutrition and reduce inflammation. Further research is required to validate this strategy.

Keywords: Chronic inflammation, Elderly patients, Geriatric nutritional risk, Metabolic syndrome, Nutritional status, Synergistic effect

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Introduction

Metabolic syndrome (MS) is increasingly prevalent in the geriatric population, raising the risk of cardiovascular disease, diabetes, and disability. However, the interplay between nutritional status, systemic inflammation, and metabolic dysregulation remains underexplored in older adults.

Recent studies have emphasized two key biomarkers in this context: the Geriatric Nutritional Risk Index (GNRI), a measure of malnutrition, and the C-reactive protein–triglyceride–glucose index (CTI), an indicator of chronic inflammation and insulin resistance.[1,2] Data from the National Health and Nutrition Examination Survey (1999–2016) show that low GNRI significantly increases the risk of all-cause and cardiovascular mortality in elderly patients with type 2 diabetes.[3,4] Similarly, elevated CTI correlates with depressive symptoms and heightened metabolic risk, particularly among older adults.[5,6] Wang et al. demonstrated that the combination of low-level GNRI and high-level CTI predicts increased hospitalization, organ dysfunction, and cognitive decline.[7] These findings suggest a synergistic effect: inflammation worsens nutritional status, and malnutrition amplifies inflammation—together worsening clinical outcomes. Such synergy underscores the importance of dual assessment in geriatric MS management.

This synergistic effect indicates a disruption of the antioxidant defense system, activation of proinflammatory cytokines (IL-6, TNF-α), and progression of vascular dysfunction.[8–10] In addition, according to a Global Burden of Disease (GBD) study, MS is one of the factors that affects disability and mortality in people over 65 years of age. Chronic inflammation and nutritional deficiencies are unfavorable prognostic factors and can be used to simultaneously monitor early risk stratification.[11]

Thus, GNRI and CTI are not only separate predictors of clinical complications, but also have a synergistic effect in the context of the pathophysiology of MSs, especially in elderly patients. The indicators can be used for risk stratification, reduction of systemic inflammation, and individualization of nutritional support strategies.

Literature Review

In geriatric practice, MS is complicated by age-related changes and comorbidities such as sarcopenia and nutrient deficiencies. Researchers Ruan et al.[12] and Zhu et al.[3] point to the importance of GNRI biomarkers of the CTI inflammation index for patients with MS, and GNRI is an indicator of the risk of malnutrition in older adults. Qin et al.[13] and Kim et al.[5] found that low GNRI levels are associated with increased hospitalization rates, risk of frailty, functional limitations, and overall mortality. Zhao et al.[2] and Zhu et al.[3] identified GNRI as an independent predictor of cardiovascular complications. In geriatric patients, nutritional deficiencies are often hidden, making regular GNRI assessment necessary to prevent serious complications. This is especially true for patients with abdominal obesity and sarcopenia, who are at increased risk of MS.[8]

Recent studies show that a low GNRI is significantly associated with an increased risk of mortality, and its predictive ability underscores its usefulness as a general prognostic indicator.[2,5,14,15]

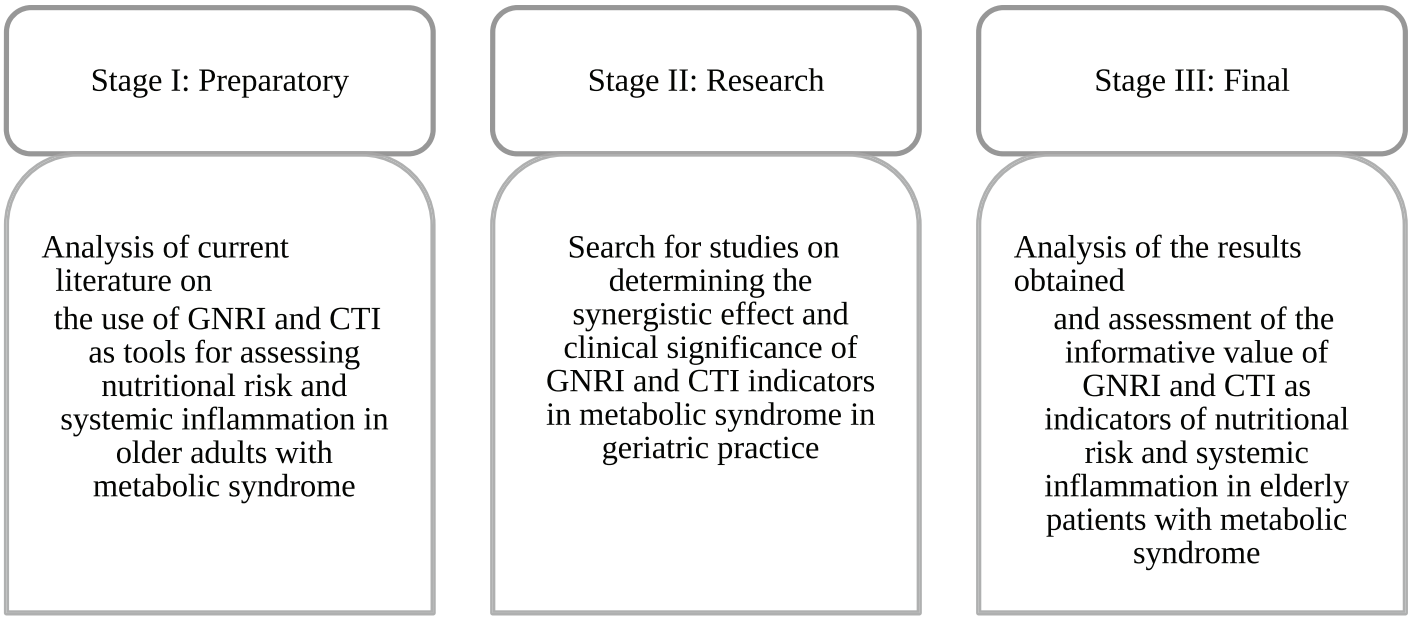

Fig 1 | Research design
Source: Created by the author

Low GNRI levels indicate impaired ability to adapt and recover from acute illness, surgical stress, or progression of chronic disease.

CTI combines the triglyceride–glucose index (hereinafter referred to as TyG) and C-reactive protein (hereinafter referred to as CRP), thereby providing combined information on metabolic dysfunction and chronic inflammation.[16,17] A study by Guo et al.[18] established a link between the TyG index and the prevalence of MS among geriatric patients, indicating the importance of the metabolic parameters included in the CTI. Tang et al.[16] and Ruan et al.[12] identified CTI as a risk marker in patients with hypertension or cardiovascular disease.

Current scientific research increasingly points to a possible synergistic effect between GNRI and CTI. For example, Li et al.[6] found that patients with low-level GNRI and high-level CTI have a higher risk of cardiometabolic complications than patients with only one of these factors.[8,10,19]

For elderly patients with comorbidities, GNRI and CTI are proposed as prognostic tools for identifying individuals at increased risk of complications. Their use can be the basis for clinical decisions regarding both nutritional correction and the prescription of anti-inflammatory and metabolically active therapies. In addition, GNRI and CTI assessments do not require expensive or invasive procedures, making them accessible even in resource-limited settings.

Thus, in the context of MS in geriatric practice, the combined use of GNRI and CTI is recommended for risk assessment and an individualized treatment approach. Determining these indicators at an early stage can reduce the likelihood of disability and improve quality of life.

Research Objectives and Aims

The aim of the study was to determine the synergistic effect and clinical significance of GNRI and CTI in MS in geriatric practice.

Materials and Methods

The literature was analyzed using a qualitative approach. Current data on the pathophysiological role of GNRI and CTI in patients with MS were analyzed and systematized, the informativeness of GNRI and CTI was assessed, the possible systemic interaction between GNRI and CTI was established, and their mutual influence on the main clinical parameters was determined. The qualitative approach included identifying themes and patterns in the data, as well as analyzing empirical data regarding the research objectives.

Research Design

This study was conducted in several stages, following the design presented in Figure 1 and adopting a case study approach, which includes bibliometric and documentary analysis of "Systemic interaction of GNRI and CTI indicators in MS: synergistic effect and clinical significance in geriatric practice." This approach allows for an in-depth analysis of the problem, taking into account the individual characteristics of patients.

The first stage of the work involved analyzing contemporary scientific literature by Ukrainian and foreign authors, setting the research objectives, determining methodological approaches, and establishing the scope of the research. The data obtained were analyzed and systematized to determine the clinical and pathophysiological role of GNRI and CTI in geriatric patients with MS, as well as to assess the informative value of GNRI and CTI as indicators of nutritional risk and systemic inflammation in elderly patients with MS. In addition, possible associations and systemic

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interactions between GNRI and CTI were established, and their mutual influence on key clinical indicators was determined.

This systematic review was conducted in accordance with the PRISMA 2020 guidelines for transparent reporting.[20] This review included original articles, meta-analyses, and systematic reviews published between 2019 and 2025 that investigated the relationship between GNRI and CTI in patients with MS. Only full-text studies conducted on human subjects and published in English, with a clearly described methodology, were considered. The literature search was conducted using the following databases: PubMed, Scopus, Web of Science, Google Scholar, and ScienceDirect. Works that did not contain an analysis of GNRI or CTI, animal studies, non-peer-reviewed materials, and publications devoted exclusively to nongeriatric populations were excluded. The following keywords were used during the literature search: "Geriatric Nutritional Risk Index," "GNRI," "CTI," "TyG index," "metabolic syndrome," "inflammation," "insulin resistance," "nutritional status," "older adults," "frailty," and "sarcopenia." These terms were combined using Boolean operators AND and OR. The search was limited to studies published between 2019 and 2025, available in English or Ukrainian, and conducted on human subjects.

A total of approximately 560 records were retrieved via database searches (PubMed, Scopus, Web of Science, ScienceDirect, Google Scholar). After removing 160 duplicates, 400 unique titles/abstracts were screened, resulting in 120 full-text articles assessed for eligibility. Of these, 87 were excluded for reasons including missing GNRI or CTI measures, nongeriatric subjects, non-peer-reviewed or animal studies, or lack of methodological clarity. Ultimately, 33 studies were included in the qualitative review, and 6 cohort studies provided sufficient data for analysis of GNRI's association with all-cause or cardiovascular mortality. A standard PRISMA 2020 flow diagram (Figure 2) illustrates this process.

Inclusion and Exclusion Criteria

The inclusion criteria were original studies, systematic reviews, and meta-analyses published between 2019 and 2025 that investigated the relationship between GNRI and CTI in the context of MS in older adults. Only studies conducted on humans, published in English, and with clearly described methodology were considered.

Exclusion criteria included animal studies, case reports, editorial articles, papers without data on GNRI or CTI, and studies.

Study Limitations

There is a notable lack of direct, large-scale population-based empirical data from the National Health and Nutrition Examination Survey (NHANES) or GBD that would help assess the synergistic effect of GNRI and CTI on the development of MS in geriatric practice.

In addition, a targeted selection of cohort studies was conducted that included hazard ratio (HR) estimates for GNRI and CTI in relation to all-cause or cardiovascular mortality. The selected studies included the HR data with 95% confidence intervals and *p*-values. The results were summarized in a comparative evidence table (Table 4).

Results

A review of the literature, particularly based on data from the NHANES, shows the high predictive potential of GNRI and the CTI inflammation index in elderly patients with MS and comorbidities. Scientific articles have found a link between GNRI and CTI and cardiovascular risks.[2,21]

Kim et al.[5] showed that geriatric patients with diabetes with low GNRI have a higher risk of overall mortality and cardiovascular complications (Table 1). Similar data were obtained by Min et al.,[14] who also found a prognostic effect of CTI-related parameters on overall and cardiovascular mortality in adults. According to the China Health and Retirement Longitudinal Study (CHARLS) cohort study, each one-unit increase in CTI is associated with a 21% increase in stroke risk, and the highest quartile of CTI was associated with a 66% higher risk of stroke compared to the lowest.[15,22,23]

The studies by Kim et al.,[5] Qin et al.,[13] and Zhao et al.[2] demonstrate the consistency of the results, which increases the level of reliability of the empirical findings. It is important to note that the GNRI, as a tool for clinical assessment of nutritional risks, is simple to calculate, does not require sophisticated laboratory equipment, and can be used in a wide range of healthcare facilities, including primary care.

Researchers emphasize that GNRI is an independent marker of poor prognosis, regardless of HbA1c levels, body mass index, and other components of MS.[2,3] Qin et al.[13] found an association between decreased GNRI and increased risk of frailty among older adults.

Also, a study conducted by Zhao et al.[2] among individuals with hyperlipidemia showed that lower GNRI values statistically significantly correlated with increased mortality from all causes, including cardiovascular complications. This fact allows us to consider GNRI as a universal risk marker in patients with different metabolic phenotypes.

In elderly patients undergoing emergency surgery, the GNRI is a powerful predictor of adverse outcomes. As the severity of malnutrition according to the GNRI worsens from mild to very severe, there is a progressive and statistically significant increase in the risk of 30-day mortality, 30-day morbidity (including infectious and noninfectious complications), and total length of hospital stay.[24] Specifically, patients with very severe malnutrition (GNRI < 73) have at least a twofold increased risk of mortality (odds ratio 2.79), deep vein thrombosis (odds ratio 2.07), and respiratory failure (odds ratio 1.95).[24]

For critically ill older adults, especially those in the intensive care unit (ICU), significant nutritional risk (GNRI < 82) is strongly associated with a higher risk of

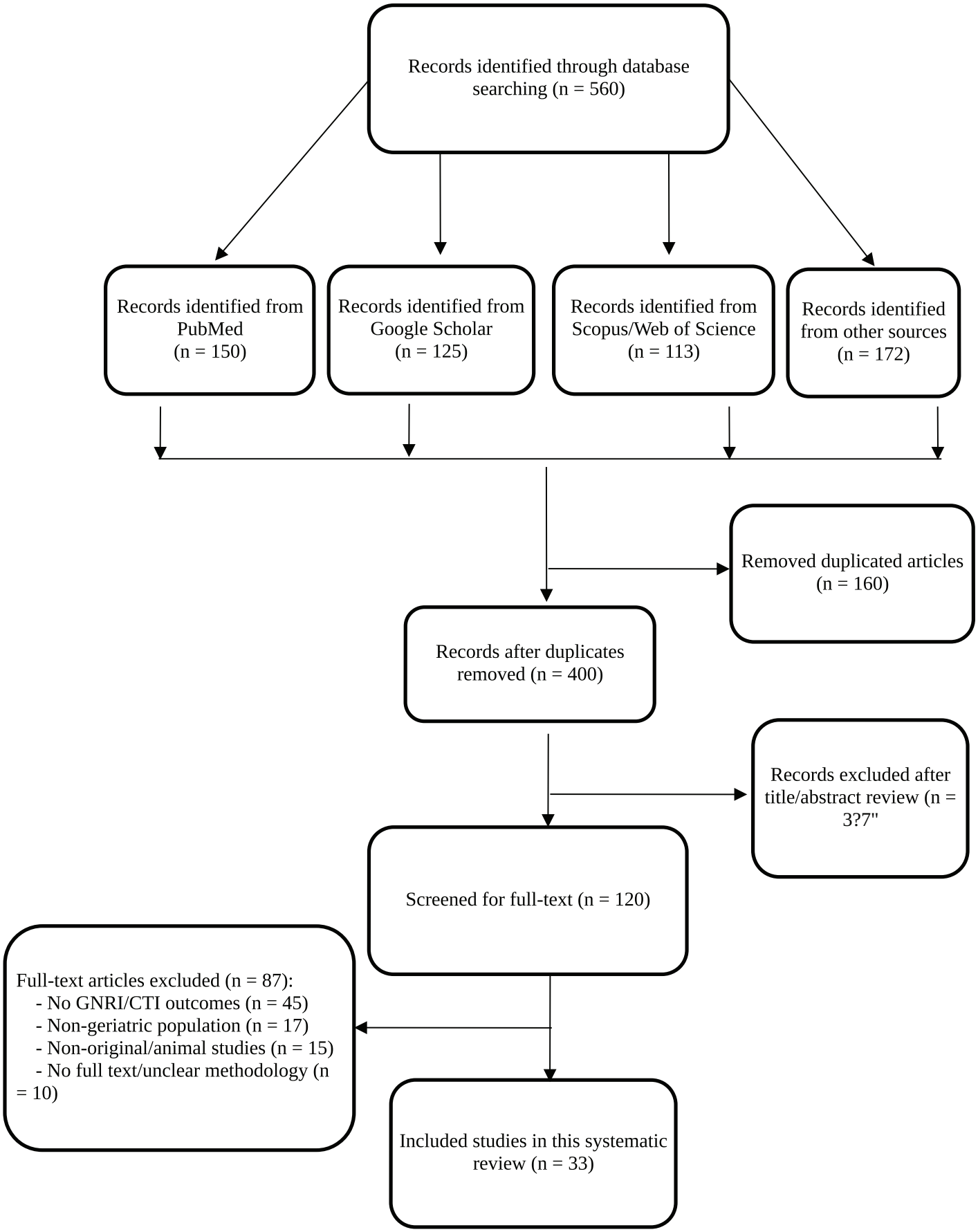

Fig 2 | Flow chart of study selection process

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Table 1 | Impact of GNRI on MS and mortality (NHANES data)

Research	Sample	Main Results
Kim et al.[5]	Older Americans with diabetes	Low GNRI is associated with an increased risk of cardiovascular and overall mortality
Qin et al.[13]	Elderly patients	Decreased GNRI is associated with increased risk of frailty and mortality
Min et al.[14]	Elderly patients with hyperlipidemia	Low GNRI is associated with higher overall and cardiovascular mortality

Source: Created by the author based on Kim et al.;[5] Qin et al.;[13] and Min et al.[14]

Table 2 | Impact of CTI on MS and related diseases (NHANES data)

Research	Sample	Main Results
Ruan et al.[12]	Elderly patients with hypertension	One-unit increase in CTI is associated with a 21% higher risk of stroke
Kim et al.[5]	The total population of elderly patients in the United States with MS	Higher CTI is associated with an increased risk of MS

Source: Created by the author based on Ruan et al.;[12] Kim et al.[5]

adverse outcomes after extubation. These include increased mortality within 30 days of extubation, higher incidence of pneumonia within 30 days, increased likelihood of reintubation within 72 hours, and a greater risk of dysphagia after extubation. In addition, a lower GNRI value consistently correlates with an increased length of stay both in the ICU and in the hospital in general.[3]

In patients with heart failure, a high to moderate GNRI risk (GNRI < 92) is associated with an increased risk of all-cause mortality (HR 1.59). Even a low GNRI risk (GNRI < 98) predicts all-cause mortality (HR 1.56) compared to the group with a high GNRI value, indicating a gradation of risk.[4]

For patients with urologic risks, a low GNRI is significantly associated with poor overall survival (HR 2.6), cancer-specific survival (HR 2.65), recurrence-free survival (HR 1.47), and progression-free survival (HR 1.86).[22] This positions GNRI as a valuable prognostic tool in oncology.

It has been established that elderly patients with MS are more likely to suffer from low-intensity inflammation, diastolic dysfunction, sarcopenia, and reduced functional endurance.[8] In this context, there is a need for a comprehensive assessment of both nutritional status and systemic inflammation and insulin resistance.

The CTI score reflects a combination of metabolic dysfunction and chronic systemic inflammation, two key pathogenic factors in the development and progression of MS. Researchers Ruan et al.,[12] Tang et al.,[25] and Qu et al.[23] found a high prognostic value of CTI in assessing the risk of vascular diseases such as stroke in older adults with metabolic disorders. The most convincing results regarding the prognostic value of CTI were presented in a prospective cohort study by Ruan et al.[12] This study, based on the CHARLS, found that being in the highest quartile of CTI was associated with a 66% increase in stroke risk (HR = 1.66; 95% CI: 1.23–2.25) compared to the lowest quartile in individuals with high metabolic risk. These data confirm the role of CTI as a powerful predictor of cardiovascular disease in vulnerable groups (Table 2).

Another study by Shan et al.,[17] based on data from the US NHANES, confirmed the correlation of high-level CTI values with an increased prevalence of MS and its main components—hypertension, insulin resistance, obesity, and hypertriglyceridemia. This indicates the universality of CTI as a risk marker in the general population, regardless of the presence of comorbidities.[17]

It is worth noting that the CTI score is highly clinically convenient: all of its biochemical components (glucose, triglycerides, CRP) are determined in standard biochemical packages, which makes it easy to implement this index in clinical practice without additional resources. In summary, the empirical results presented in Table 2 demonstrate a close relationship between systemic inflammation and metabolic destabilization as reflected by the CTI.[26]

In this regard, CTI can be used not only as a diagnostic but also as a prognostic criterion to identify elderly patients at high risk of developing MS.

The sequential and mutually reinforcing mechanism of the synergistic effect worsens the prognosis and increases the risk of complications (Figure 3).

If the authors describe the pathomechanism of synergistic action in detail, at the initial stage, there is a metabolic disorder and systemic inflammation, which is reflected in the CTI indicator. MetS is characterized by a combination of interrelated metabolic disorders, such as central obesity, insulin resistance, dyslipidemia (including hypertriglyceridemia), and hypertension. These disorders are closely associated with the activation of low-grade chronic systemic inflammation.[10] Visceral obesity is a key predictor of these metabolic disorders and often accompanies gastrointestinal pathologies.[27] High-level CTI values reflect the severity of both metabolic dysfunction (insulin resistance, hypertriglyceridemia, hyperglycemia)[6,18] and the presence of systemic inflammation.[15,21,25]

Chronic systemic inflammation induced by metabolic dysregulation has a catabolic effect on the body. Proinflammatory cytokines can lead to anorexia, decreased protein synthesis, increased muscle breakdown, and impaired nutrient absorption. This, in turn, leads to a deterioration in nutritional status, which is reflected in a decrease in the GNRI score.[3,22]

Thus, high CTI indirectly contributes to a decrease in GNRI through the mechanisms of inflammatory catabolism and impaired protein metabolism, forming an inflammation-induced nutritional deficiency. There is a further risk escalation: the synergistic effect of GNRI and CTI on cardiometabolic and other complications.

The simultaneous presence of severe metabolic inflammation and insulin resistance (high-level CTI) in combination with nutritional deficiencies (low-level GNRI) creates a vicious circle, significantly exacerbating pathological processes.

While a reduced GNRI (a marker of malnutrition and sarcopenia) is associated with decreased muscle mass and strength, which worsens metabolic control and increases insulin resistance,[3,8] weakening of the immune response, which makes the body more vulnerable to infections and increases inflammation,[4] and decreased

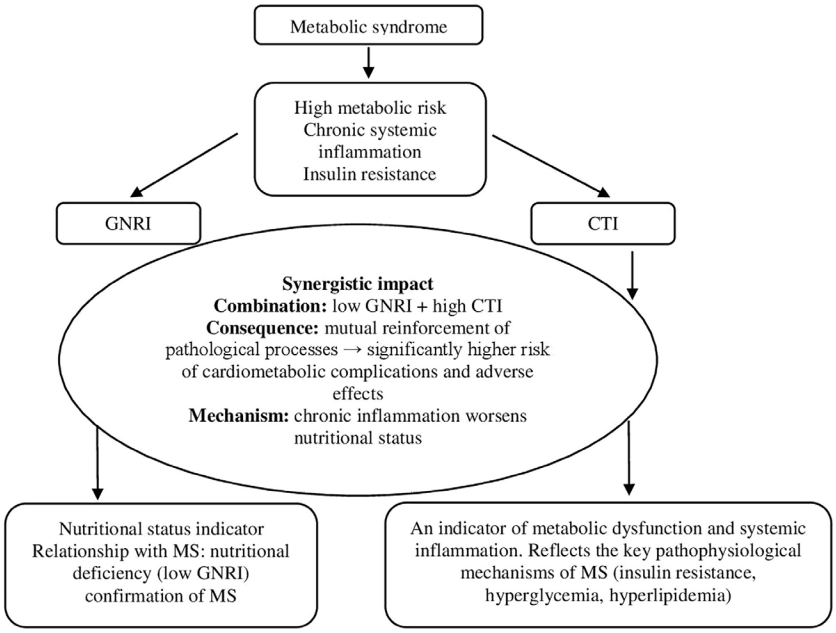

Fig 3 | Sequential mechanism of influence of GNRI and chronic inflammation/complex triglyceride–glucose index (CTI) on MS in elderly patients with MS

Table 3 | Global burden of MS (GBD data)

Indicator	Quantity	Source
DALYs due to hypertension (2021)	Elderly patients with hypertension	Kim et al.;[5] Zhou et al.[4]
DALYs due to type 2 diabetes (2021)	The total population of elderly patients in the United States with MS	Chen et al.;[24] Kim et al.[5]
The highest absolute burden	India, China, USA	Cui et al.;[30] Tang et al.[16]

Source: Created by the author based on Tang et al.;[16] Cui et al.;[30] Chen et al.;[24] Zhou et al.;[4] Kim et al.[5]

functional reserves, which increases the risk of complications and mortality.[2,13,28]

High-level CTI (a marker of metabolic inflammation) directly contributes to the development of atherogenesis and the progression of cardiovascular disease (e.g., stroke),[15,22,23] increased insulin resistance and diabetes development,[7,17] and progression of other components of MS (hypertension, dyslipidemia).[6,18] Inflammation impairs nutrient absorption and protein metabolism, and malnutrition weakens the body's ability to resist inflammation and repair damaged tissues, which in turn leads to a significant increase in the risk of cardiovascular complications.[14]

Thus, GNRI and CTI are not only independent prognostic markers but also indicators of interrelated pathophysiological processes. The mechanism of their joint effect is that chronic metabolic inflammation (CTI) worsens nutritional status (GNRI), and worsened nutritional status, in turn, increases inflammation and metabolic dysregulation. This synergistic interaction creates an increased risk of adverse clinical outcomes in elderly patients with MS. These results also confirm the need for a combined approach to risk assessment, including both nutritional (GNRI) and inflammatory-metabolic (CTI) parameters to optimize the management of patients with MS, especially in geriatric practice.

According to the results shown in Table 3, the total burden of DALYs due to hypertension in 2021 was more than 226 million life years, while for type 2 diabetes mellitus, it was about 75 million DALYs.[29]

The highest absolute burden of metabolic disorders and their consequences, according to the GBD, is observed in countries with large populations and high rates of urbanization, such as India, China, and the United States.[6,7,18] This is due to the combination of high calorie intake, decreased physical activity, and an aging population, which is especially relevant in the context of geriatric medicine. It should also be emphasized that global trends indicate a steady increase in metabolic load, especially among people over 60 years of age.[14,17]

Thus, the GBD data reinforce the empirical results of the NHANES studies on GNRI and CTI and form a global basis for the informed implementation of integrated approaches to metabolic risk assessment, in particular in older patients. It is at the intersection of clinical (local) and global (population) data that effective healthcare strategies and individualized patient management plans can be developed.

The immune system dysfunction caused by malnutrition supports the inflammation that results from poor nutritional status (low-level GNRI), leading to a weakened immune system. Inflammation, in turn, can further impair the absorption and utilization of nutrients, creating a vicious cycle. Chronic inflammation, exacerbated by malnutrition, directly contributes to the development of insulin resistance, dyslipidemia, and endothelial dysfunction, which are central to MS. Inflammation can interfere with insulin signaling pathways and contribute to adipose tissue dysfunction. Malnutrition and inflammation together contribute to organ dysfunction, which can further impair metabolic regulation (e.g., liver, pancreas, adipose tissue) and increase the risk of MS components.

Analysis of the data presented in Table 4 confirms the high predictive value of the GNRI and CTI indices for overall mortality among elderly individuals with metabolic risk.

All included cohort studies show a statistically significant increase in the risk of fatal outcomes in patients with low GNRI or high CTI values. In particular, GNRI < 92–98 is associated with a 56–141% increase in the risk of overall or cardiovascular mortality, depending on the population and comorbidities, indicating its sensitivity to different clinical contexts (diabetes, fractures, hospitalization). The combined use of GNRI and CTI is a promising tool for early risk stratification and the development of individualized preventive and therapeutic strategies in geriatric patients.

It has been proven that nutrient deficiencies weaken the body's defenses, exacerbate inflammatory processes and increase the risk of metabolic disorders, which is reflected in CTI. Cohort studies are needed to determine the exact synergy between GNRI and CTI.

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Table 4 | HR for GNRI and CTI for All-cause mortality in cohort studies

Authors (Year)	Study Population	n (Sample Size)	Index	Categories/Limits	HR (95% CI)	*p*-value	Additional Information
Zhao et al. (2024)[2]	Geriatric patients (NHANES)	4,598	GNRI	Lowest vs. highest tertile	1.98 (1.33–2.94)	<0.001	All-cause and CVD mortality
Kim et al. (2023)[5]	Patients with type 2 diabetes mellitus	2,152	GNRI	<98 vs. ≥98	1.56 (1.18–2.05)	<0.01	Renal progression & mortality
Zhou et al. (2024)[4]	Patients with hip fractures	1,040	GNRI	<92 vs. ≥92	1.74 (1.22–2.49)	0.003	Adjusted for comorbidities
Chen et al. (2024)[1]	Geriatric patients	620	GNRI	<92 vs. ≥92	2.41 (1.63–3.56)	<0.001	Postoperative delirium risk
Shan et al. (2025)[17]	Geriatric patients (NHANES)	6,112	CTI	Q4 vs. Q1	2.14 (1.76–2.55)	<0.001	New-onset diabetes risk
Tang et al. (2024)[16]	Patients with hypertension (NHANES)	2,489	CTI	High vs. Low	1.68 (1.47–1.92)	<0.001	Stroke risk prediction
Qu et al. (2024)[23]	People with impaired glucose metabolism (CHARLS)	890	CTI	Q4 vs. Q1	1.96 (1.32–2.91)	0.001	Stroke incidence
Guo et al. (2023)[18]	People with MS	1,404	CTI	>8.5 vs. ≤8.5	1.81 (1.25–2.62)	0.002	MetS incidence in elderly

Synergy arises from a vicious cycle in which nutritional status impairment according to GNRI directly impairs the body's anti-inflammatory and metabolic regulatory capabilities. This leads to an intensified inflammatory response, which then further worsens nutritional and metabolic status, accelerating the progression of MS. This suggests that interventions targeting both nutritional status and inflammation simultaneously will be more effective than treating them separately.

Discussion

This article outlines the mechanisms by which malnutrition can trigger and exacerbate systemic inflammation, creating a detrimental feedback loop that profoundly affects metabolic health. While the individual links between nutritional status, inflammation, and components of MS (e.g., diabetes, cardiovascular disease) are well documented in current work, this analysis examines the current lack of direct, large-scale population-based empirical data (NHANES and GBD) that clearly quantify their synergistic effects on MS as a cumulative outcome.[31,32]

The study by Kong et al.[8] highlights the link between sarcopenic obesity and systemic inflammation, emphasizing that these conditions form a vicious circle in MS. This suggests that malnutrition, as reflected in the GNRI, may be both a cause and a consequence of metabolic disorders and inflammation, which reinforce each other.

As shown by a prospective cohort study by Ruan et al.[12] based on CHARLS, elevated CTI was significantly associated with an increased risk of stroke in individuals with high metabolic risk. These data reinforce the understanding of CTI not only as a laboratory test but also as a comprehensive indicator of cardiometabolic risk.[33,34]

The most important aspect of the study is the investigation of the synergistic effect of GNRI and CTI. This conclusion is based on the understanding that chronic systemic inflammation and insulin resistance, reflected in high-level CTI, can worsen nutritional status through catabolic processes and malnutrition (low-level GNRI), which exacerbates systemic inflammation.

There are virtually no studies that determine the synergistic effect of CTI and GNRI, but the concept of the relationship between MS, inflammation, and nutritional status is widely discussed.[10]

The study by Min et al.[14] highlights the prognostic effect of parameters associated with the TyG index on overall and cardiovascular mortality in adults with metabolically associated steatohepatitis, which further indirectly confirms the importance of metabolic parameters that can affect nutritional status and GNRI. The mechanisms of this synergy suggest that poor nutritional status impairs immune function and metabolic regulation, contributing to increased inflammation. Therefore, a comprehensive assessment of nutritional status and inflammation is necessary in geriatric clinical practice to improve metabolic disorders.

The results emphasize the need for active implementation of GNRI and CTI in routine clinical practice for a comprehensive risk assessment in elderly patients with MS. Early detection of deteriorating nutritional status and increased metabolic inflammation will allow timely implementation of targeted therapeutic interventions aimed at dietary correction, optimization of nutritional support, control of inflammation, and metabolic parameters.

Conclusion

The study provides an in-depth understanding of the systemic interaction and clinical significance of GNRI and CTI in the context of MS in the geriatric population. The results confirm that GNRI and CTI are not only independent prognostic markers, but also markers of interrelated pathophysiological processes that form a synergistic effect and significantly worsen the clinical course and prognosis in elderly patients.

GNRI is a reliable indicator of nutritional status and a powerful predictor of a wide range of adverse outcomes in elderly patients with MS.

Elevated CTI values are a reliable predictor of the development and progression of MS, as well as an

independent and powerful predictor of adverse cardiovascular events, including stroke, which is critically important for the geriatric cohort, where the risk of cerebrovascular complications increases exponentially.

Confirmation of the prognostic value of GNRI and CTI, as well as their synergistic interaction, is of significant clinical importance. Integrating these two indicators into the routine assessment of elderly patients with MS will allow for more accurate risk stratification. This paves the way for the development and implementation of targeted interventions that simultaneously aim to correct nutritional status and reduce metabolic disorders. Further prospective studies with large cohorts and randomized controlled trials are needed to confirm the effectiveness of such integrated approaches.

The results obtained indicate the feasibility of including GNRI-based nutritional risk assessment in algorithms for early detection and dynamic monitoring of patients with MS in the geriatric population. They also lay the groundwork for the hypothesis of a potential synergistic effect of GNRI and indicators of inflammation and insulin resistance (in particular, CTI) on clinical prognosis, which will be discussed in the following sections.

Further research should focus on the development and validation of combined integrative risk scales that include these indicators for more accurate prediction and stratification of elderly patients with MS. It is promising to study the effectiveness of treatment strategies developed and applied using GNRI and CTI to improve long-term clinical outcomes in elderly patients.

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