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Perspective

The Value of Integrating the Nutritional Ecology into the Nutrition Care Continuum—A Conceptual and Systems Approach

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A B S T R A C T

The domestic and global diet, nutrition, and health context is becoming increasingly complex. Our ability to effectively address the daunting challenges presented by malnutrition in all its forms—both clinically and from a public health perspective—is constrained by a number of issues that coalesce around our understanding of nutrition and the what, why, and how of its assessment. This complexity is further enhanced when screening, assessment, diagnosis, and care are often performed in different settings (hospital compared with school compared with home), across populations, and with a limited care team (e.g. certain care teams may only have a nurse or dietitian within a school district). In this perspective, we make the case that our ability to improve the precision of assessment, diagnosis, and intervention demands a view of nutrition as a biological variable: a complex system resulting from the interactions between our internal (biology, health status, developmental stage, genetics, etc.) and external (social determinants of health, home, community, physical) environments, i.e. a nutritional ecology. We offer both *1*) a conceptual framework for more effectively integrating nutrition in medical assessment and etiology-based care; and *2*) suggest solutions to overcome some of the systematic challenges in the clinical care continuum. Leveraging the concept of nutrition as a biological variable that emphasizes the integration of both internal and external variables into an assessment within the Nutrition Care Process model allows for both the identification of the nutrition problem and also the root cause (etiology) of the problem. Suggestions are offered for how to integrate this approach from both a clinical and public health perspective.

Keywords: nutrition, malnutrition, dietetics, nutritional ecology, clinical care

Statements of significance

Stimulated by the White House Conference on Hunger, Nutrition, and Health in September 2022, and as evidenced by such efforts as the Nutrition for Precision Health, sponsored by the All of Us Research Program at the National Institutes of Health and the emerging importance of the Food Is Medicine movement, the role of nutrition in clinical care and public health has never been more pronounced. Our ability to actualize the goals of these various efforts is contingent on our core understanding of the what, why, and how of assessing nutritional status across the various settings providing care. This article provides a perspective on the core concepts and operating principles underpinning our efforts to determine what to do when someone enters the nutritional care system.

Introduction

Our ability to effectively address the daunting challenges presented by malnutrition in all its forms clinically and from a public health perspective is constrained by a number of issues that coalesce around our understanding of nutrition and the what, why, and how of its assessment. *The American Journal of Clinical Nutrition* recently began a series devoted to addressing challenges confronting the incorporation of nutrition into clinical assessment and care. The first article in the series was a compelling example of the complexity of not only interpreting a set of presenting symptoms but also the process of developing approaches to incorporate the biology of nutrition into the clinical care continuum—including context-specific assessments

Abbreviations: MNT, medical nutrition therapy; MUAC, mid upper arm circumference; NCP, Nutrition Care Process; RD, registered dietitian; RDN, registered dietitian nutritionist; SGA, subjective global assessment.

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to determine the presence of specific nutritional problems and evidence-based interventions [1]. This complexity is further enhanced when screening, assessment, diagnosis, and care are done in different settings (hospital compared with school compared with home), across populations, and with a limited care team.

In this perspective, we will both *1*) present a conceptual framework for more effectively integrating nutrition in medical assessment and etiology-based care; and *2*) suggest solutions to overcome some of the systematic challenges in that continuum.

Malnutrition: Definition Compared with Assessment

Although several definitions for malnutrition exist, there is no universal, gold standard for identifying when a person is malnourished. Malnutrition (see basic definition and relevant global status report: Box 1) has multiple causes but two of the primary etiologies are *1*) reduced or altered dietary intake associated with the food environment, food insecurity, and famine; and *2*) a lack of nutrients present at the level needed for metabolic processes, which can be caused by changes in the processes involved in nutrient digestion, absorption, metabolism, or utilization because of genetics, illness/inflammation, or xenobiotics (therapeutic/recreational drugs, toxins). Importantly, the confluence of either or both of these causes is particularly pernicious when present concomitantly with disease-related inflammation. An example of this would be when a person who is chronically food insecure suffers an acute infection such as pneumonia, HIV, malaria, or tuberculosis as is seen in many low-resource settings or in elderly individuals on a fixed income. The reciprocal nature of these relationships (i.e. malnutrition is both an input and an outcome of such conditions) makes them a challenge for assessment, diagnosis, and intervention (timing and type) [2–4].

Whether in the context of clinical medicine or in the context of public health policy/programs, the core challenge of not only meeting nutritional needs of patients and populations, but critically developing consensus on both the criteria for the definition and assessment of malnutrition is paramount to inform equitable, context-specific, safe, and efficacious interventions [5].

We Live in a Digital Age but Consider Nutrition in an Analog Fashion

Historically our approaches to identifying nutritional problems have been relatively straightforward, i.e. comparing collected data on history (including qualitative dietary assessment), anthropometry, physical examination, and, on some occasions, measurements of relevant biomarkers of specific nutrients. These data were then compared with statistically validated standards of "adequacy" to determine nutritional status and the presence of a potential problem. We are now coming to appreciate that: *1*) the inputs for assessing nutritional status are more complex; *2*) the determination of the presence of a problem tells us little about its etiology; and *3*) our ability to use data to support the development of etiology-based interventions, standards of care, and policies demands a more comprehensive approach that is not only nutrition-sensitive but, critically, also nutrition-specific.

Furthermore, a candid discussion of the why's and how's of integrating nutrition into clinical care and public health programming needs to acknowledge that a tension exists between the desire/need to provide care and the time needed to develop a fundamental understanding of the role of the biology of nutrition to inform the generation of evidence-based standards of nutritional care. Are these differences reconcilable? Yes. In essence, this dichotomy reflects the spectrum of activity between translational science and implementation, which although often confused and conflated really represents essential components of a continuum of activities needed to create evidence-based programs, guidance, and standards of care.

As defined by the NIH's National Center for Advancing Translational Science (https://ncats.nih.gov), "the translational science spectrum represents each stage of research along the path from the biological basis of health and disease to interventions that improve the health of individuals and the public. The spectrum is not linear or unidirectional; each stage builds upon and informs the others" (Figure 1). In turn, implementation science is the scientific study of methods to promote the systematic uptake of research findings and other evidence-based practices into routine practice, and, hence, to improve the quality and effectiveness of health services and care. It takes the outputs of that translational activity and applies it to the provision of

BOX 1
WHO—Definition of Malnutrition.

Malnutrition refers to deficiencies, excesses, or imbalances in a person's intake of energy and/or nutrients. The term malnutrition covers two broad groups of conditions. One is "undernutrition"—which includes stunting (low height for age), wasting (low weight for height), underweight (low weight for age), and micronutrient deficiencies or insufficiencies (a lack of important vitamins and minerals). The other is overweight, obesity, and diet-related noncommunicable diseases (such as heart disease, stroke, diabetes, and cancer).

Malnutrition (who.int)

Global malnutrition (status update):

- In 2022, 738.9 million people faced hunger, 2.4 billion were moderately or severely food insecure, and >3.1 billion lacked access to healthy diets.
- The COVID-19 pandemic added 120 million to the chronically undernourished.
- By 2030, an estimated 590.3 million will suffer hunger.
- Progress toward global nutrition targets is not being universally met.

[From: Achieving SDG 2 without breaching the 1.5°C threshold: A global roadmap, Part 1 (fao.org)]

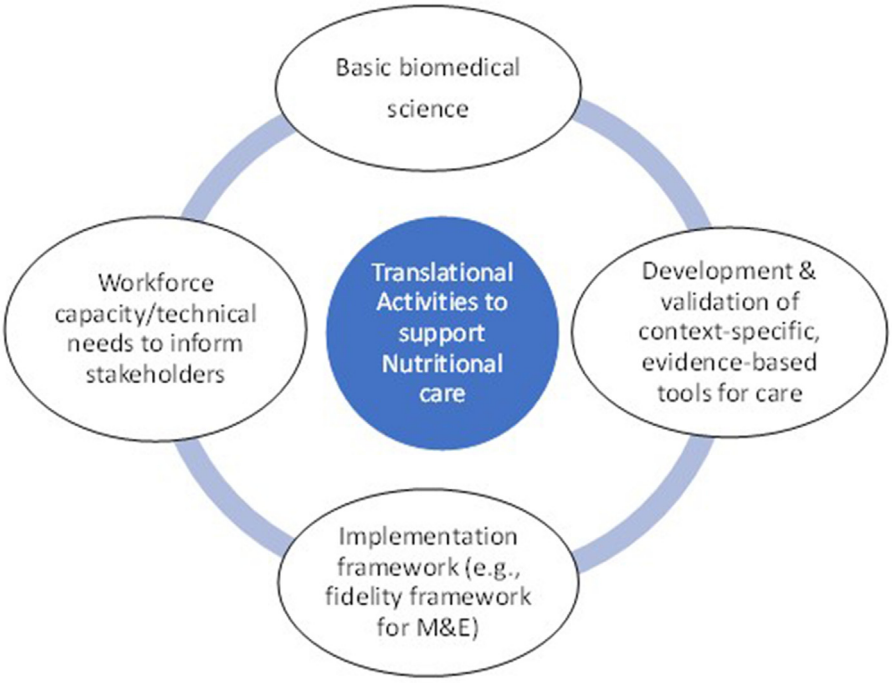

FIGURE 1. Representation of the translational science continuum.

context-specific and equitable programs, policies, and standards of care. The critical element of this continuum is that from basic science to implementation, each stage informs and is informed by the others via the provision of continuous feedback.

For the clinician, the priority is a common vernacular, nosology, and methodology that can be applied to the classification and assessment required to determine what to do for an individual patient based on that assessment. The questions with specific regard to nutrition are: *1*) what constitutes malnutrition?; *2*) what evidence is needed to inform that decision?; and *3*) how best to convert and implement that evidence to support safe and efficacious standards of care? Although there are validated single assessments used to classify malnutrition [e.g. mid upper arm circumference (MUAC)], and validated composite malnutrition diagnostic tools used clinically [e.g. subjective global assessment (SGA)], the challenge is that these indicators—although validated and perhaps nutrition-sensitive—may not be nutrition-specific nor reflect the complexity of the role of nutrition in health [6–8]. Additionally, even although the composite malnutrition diagnostic tools are better at capturing etiology and complexity than single indicators such as BMI or MUAC, for the most part they have not been studied for detection of problem resolution over time.

Herein we make the case that our ability to improve precision of assessment, diagnosis, and intervention demands a view of nutrition as a biological variable: a complex system resulting from the interactions between our internal (biology, health status, developmental stage, genetics, etc.) and external (social determinants of health, home, community, physical) environments, i.e. a nutritional ecology [9,10].

The Target

To inform guidance in the nutritional care continuum, there are four core questions (see below) that need to be addressed, all stemming from our need to know the role of nutrition in health promotion, disease prevention, and treatment. And, in the context of providing clinical care, an additional question is determining whether malnutrition is the primary cause of an illness or secondary to a presenting condition. So here is the challenge that needs to be addressed: is the person sick because they are malnourished or are they malnourished because they are sick? Fundamentally, we need to understand the etiology of an individual's malnutrition so an effective treatment plan can be implemented.

The first step in assessing the nutritional status of an individual is to have fundamental knowledge about past and current dietary intake, clinical status and metabolic needs, and the environmental factors impacting intake and metabolism. More specifically, we list below several challenges and scientific opportunities we need to address:

- Where do normal nutrient requirements end and specific health/physiological condition-related metabolic processes and needs begin?
- What is the role of diet/nutrition in conditions that require special consideration above and beyond the provision of a balanced diet that contains all essential nutrients required for growth, development, and health?
- What is the role of factors within an individual's internal (health, genetics, developmental stage, etc.) and external (home, school, community, food system, physical) environments that contribute to these differences?
- What are the best types and amounts of evidence to support the establishment of standards of care and the development of nutrition-specific or nutrition-sensitive programs to address the role of nutrition in health promotion and disease prevention from either a clinical or public health perspective?

These questions are answerable by the translational science continuum described above and codified via such efforts as the

development of Dietary Reference Intakes (Dietary Reference Intakes | https://odphp.health.gov). The application and implementation of this knowledge represents the aspiration of the nutritional care continuum and needs to account for the technical capacity of the target user group, e.g. clinical and community care providers across a range of settings. These users need to be informed by codified standards of care such as the disease and population specific guidelines developed by professional organizations (e.g. the American Academy of Pediatrics, the Academy of Nutrition and Dietetics' Evidence Analysis Center, the National Kidney Foundation's Kidney Disease Quality Outcome Initiative, the American Society of Parenteral and Enteral Nutrition, and the American Heart Association). However, beyond guideline development, the nutrition community and professional organizations need to engage in implementation studies to determine whether the guidelines are in fact implementable and improve health outcomes [11]. For guidelines targeting the general public, evaluation of public health programs and policies informed by such efforts as the Dietary Guidelines for Americans (Home | https://www.dietaryguidelines.gov/) should occur systematically over time.

Fundamentally, at the individual level, we need sensitive and specific measures to improve the precision of assessment of nutritional status to define malnutrition. Functionally, nutritional status has been defined as "the operational measure of the adequacy of the diet to support health and is achieved by a series of genetic, behavioral, physiological, and metabolic processes involved in acquiring and utilizing dietary substances/nutrients required to support growth, repair, and maintenance of the body as a whole or in any of its parts" [12]. Conceivably, from both a clinical and public health perspective, nutritional assessment should be viewed as involving more than just one nutrient; rather, it should be viewed as the result of myriad interactions of multiple nutrients within biological systems of interest [9]. The culmination of the assessment findings is then used to determine whether the individual's nutritional status reflects a nutrition-related diagnosis, i.e. some form of malnutrition. Some key considerations regarding the value of nutritional status are highlighted in Box 2.

As noted, the sensitivity and specificity of the measures used are critical elements of the assessment process. For example, serum albumin has been historically used as a biomarker of nutritional status. Serum albumin has a 3-wk half-life, and in a nutrient-deficient state such as starvation the serum albumin will decrease only slightly as the body compensates to maintain visceral protein status. However, if an individual enters a state of catabolism because of trauma, infection, or burns, the serum albumin concentration decreases rapidly, even when their nutritional status may be preserved. Thus, although it may be nutritionally sensitive, serum albumin concentrations lack the specificity to be a reliable single biomarker of nutritional status in the absence of other supporting evidence. Clearly, the nuances of interpreting nutrition-related biomarkers in a context-specific manner assumes greater importance for individuals with conditions that can potentially compromise nutrition-sensitive systems, e.g. those with compromised immune systems or disease-related inflammation and the concomitant acute phase response [13–17].

Importantly, although a critical contributor to our understanding of the role of nutrition in health and disease, knowing an individual's nutrient status in isolation reveals little about function, effect, or etiology. Similarly, reliance on a syndromic approach to individuals focused on treating observable symptoms (e.g. poor growth/aberrations in anthropometry, pallor, lethargy, etc.) lack the specificity needed for a precise diagnosis and etiology-informed nutritional care. Alternatively, a comprehensive/ecological assessment can result in an accurate nutrition diagnosis and an evidence-informed intervention that not only considers the diagnosis, but also targets its etiology, and is more likely to result in improved health outcomes. Future studies will be needed to test and confirm this hypothesis.

Ultimately, the challenge facing nutrition care providers is determining the nature and level of information needed to define malnutrition in a given setting. Figure 2 is a conceptual representation of the nutritional ecology that might be integrated into the nutritional care continuum.

BOX 2
Key features to consider regarding nutritional status.

- Nutritional status as a biological variable reflects an appreciation of its intimate and inextricable role in all biological systems.
- The nature of these relationships in most systems is reciprocal (i.e. nutrition affects and is affected by the function of the particular system).
- Nutritional status is both an input and an outcome of health and disease.

Measures and Expectations

Historically, our tools for nutritional assessment have been limited to the following four categories:

- Exposure: what has been consumed, including bioavailability.
- Status: where an individual/population stands relative to accepted cut-offs (e.g. adequate, marginal, deficient); often based on some measure of biochemical levels of nutrient(s) of concern. (Anthropometric measures can also be used to assess status.)
- Function: reflecting the role of a nutrient within a relevant biological system such as the enzyme stimulation assays used to assess vitamins B1 (thiamine), B2 (riboflavin), and B6 (pyridoxine) [18].
- Effect: impact of a given status or intervention on relevant functional outcome(s) such as handgrip strength, other physical, cognitive, or behavioral outcomes, or immune function.

Importantly, the reliance on one of these categories to the exclusion of others presents an incomplete picture of an individual's condition. For example, reliance on intake data to the exclusion of biochemistry reveals nothing about how/whether the individual is actually able to utilize the nutrients consumed. Similarly, reliance on only biochemistry prevents a determination of whether the aberrant status observed is the result of a dietary intake problem (i.e. too much or too little or too much of

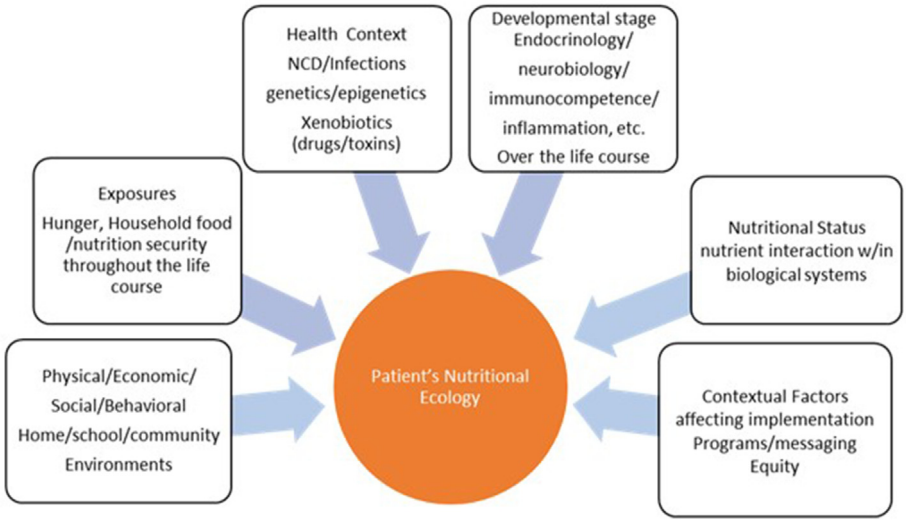

FIGURE 2. Contributors to a patient's nutritional ecology. The figure includes many—but not all—of the contributors to a patient's nutritional ecology.

poor-quality diet), or some other issues affecting the achievement of an adequate status (e.g. physiology, health, genetics, xenobiotics, etc.). Although there are physical status indicators of malnutrition based on anthropometrics, there are currently no biomarkers for malnutrition beyond micronutrients because of the limitations discussed above with acute phase proteins such as albumin. With regard to assessment of impact, the measures used must reflect a sufficient level of both sensitivity and specificity—allowing clinicians to make a reliable and valid connection between diet, nutrition, and the outcome of interest.

Figure 3 includes three primary categories of measurement commonly used to address impact and their relative value. Again, the interdependency of these measures influences our ability to be precise on both the identification of a problem and its etiology. The use of well-established reliable biomarkers of nutrient status by itself reveals little about either function or etiology; similarly, a bioindicator reflecting the function of a given biological system (e.g. hemoglobin, or other phenotypic observations in the absence of dietary intake, health history, and biomarkers of specific nutrients) reveals little about the role of nutrition in that system or the individual's presenting problem. With regard to public health nutrition, the value of public health indicators, such as stunting, disability adjusted life years, years lost to disability, etc., provides evidence of perturbations with the larger systems but provides little details with regard to specific etiologies.

More recently, we have seen the development of composite diagnostic tools such as the SGA, the Mini Nutrition Assessment, the Academy of Nutrition and Dietetics-American Society of Enteral and Parenteral Nutrition Indicators for Malnutrition, and STRONGKids (pediatrics) [19–21]. Although each of these tools rely on a composite of nutrition sensitive but not necessarily specific indicators, the integrative approach being used by these tools and the newly developed Global Leadership In Malnutrition tool—all of which utilize a combination of indicators reflecting both phenotypic change and potential etiology—is an important step toward the development of a practical and applicable method to define malnutrition in clinical settings [22,23].

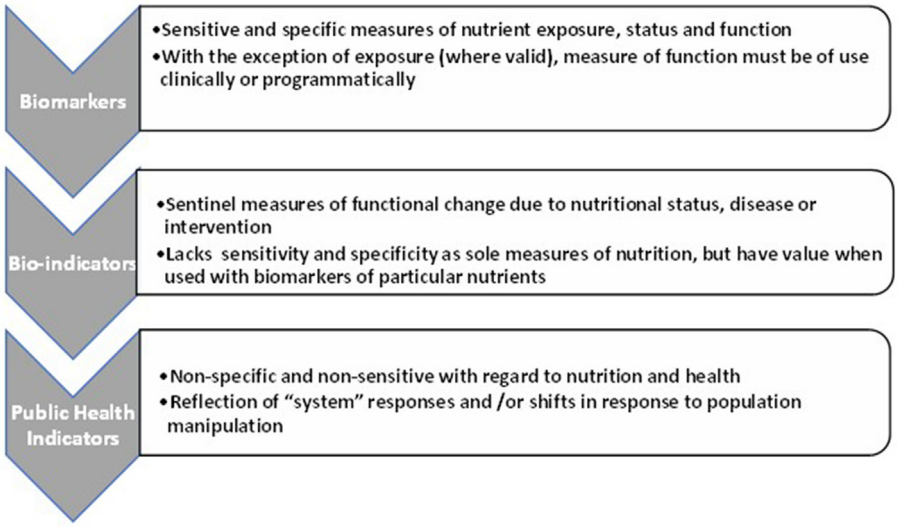

FIGURE 3. Primary categories of measurement commonly used to address impact.

Issues to address to move the field forward include, but are not limited to:

- Determining if the presenting clinical situation is primarily because of poor nutrition or if the poor nutritional status is secondary to the presenting condition (i.e. is an individual malnourished because they are sick or are they sick because they are malnourished?).
- Assessing if the algorithm has sufficient precision to be able to develop etiological personalized nutrition care irrespective of setting.
- Understanding if the algorithm is realistically implementable from both a resource and training perspective.
- Determining if the approach reflects the temporal relationships and breadth of the individual's relevant ecology.
- Evaluating whether the tools detect change over time and resolution.

Our Options

For quality of care and optimization of health outcomes, a consistent diagnosis and treatment of malnutrition—regardless of setting or population—is needed. However, because there is not currently a commonly used biomarker or indicator that can detect, for example, protein-calorie deficient malnutrition, particularly in the presence of catabolism, the nutrition community must rely on other methods for detection. This inherently provides a challenge because there are multiple tools that have not been used consistently. The community setting has also not widely adopted these tools but instead continues to use single anthropometric or micronutrient assessments (i.e. specific nutrient biomarkers). Thus, the exact prevalence of mild, moderate, and severe malnutrition involving protein-calorie and/or micronutrient(s) remains unknown.

This problem is not unique to malnutrition. For example, there are many diagnostic tools that just indicate whether something is present or not (e.g. glomerular filtrate rate indicates the degree of kidney disease but does not tell the clinician what has caused the disease). The clinician uses the tool to verify disease status but still needs to understand the complexity of the condition and the underlying etiology. Malnutrition is similar [22]. Clinicians need to have a consistent, valid way to determine if malnutrition is present, but they still need to do a comprehensive assessment to understand its context and etiology so an appropriate intervention can be implemented. Examples of challenging questions to answer include: *1*) is a patient losing weight because they are not eating, because they are food insecure, and/or because of loss of appetite consequent to a disease or its treatment; and *2*) is a patient anemic because they are iron deficient and/or because they are in a chronic inflammatory state because of an infectious or other disease [24]? These scenarios all point to the importance of understanding context to inform etiologically based diagnosis and treatment.

It Is Time to Embrace the Complexity—and It Is Worth It!

Although diagnosing malnutrition is complex, it is doable and when done correctly has the potential to greatly improve health outcomes. In a new meta-analysis by Moloney and Jarrett [25], medical nutrition therapy (MNT)—a nutrition-based treatment plan typically developed by a registered dietitian (RD)/registered dietitian nutritionist (RDN) to help manage or treat various health conditions—was found to slightly reduce mortality and significantly reduce length of stay in adult hospitalized patients with malnutrition. Unfortunately, similar evidence in community-dwelling adults is inconsistent because of the lack of studies examining health outcomes in patients with malnutrition outside the hospital setting [26], poor study design, or lack of essential contextual information to allow for more definitive conclusions. There are also studies demonstrating the impact of oral nutrition supplements on nutrition status in both adult and pediatric patients diagnosed with malnutrition and multiple studies that demonstrate a persistent inconsistency in the impact of micronutrient supplementation across a range of public health challenges [27–32].

Importantly, there are several points to consider as the nutrition research community prepares to address malnutrition assessment, diagnosis, and intervention efficacy:

- The more homogenous the health outcomes being measured, and the more homogeneous the criteria used to determine malnutrition, the stronger the body of evidence will be. The data from these studies can then be used in robust systematic reviews and shape standards of care in the form of clinical practice guidelines.
- Currently, a paucity of data exists that demonstrates the validated tools we currently use detect the resolution of malnutrition. Thus, more studies are needed that track patients over time and across settings to understand the nature and capacity of these tools.
- Studies that are designed to address malnutrition need to be explicit in how the diagnosis of malnutrition was determined in terms of who did the determination, what tool was used, and how the researchers or clinicians who used the tool were trained. Similarly, if it is an interventional study, the intervention needs to describe in detail the baseline nutritional context (i.e. why was a nutritional intervention needed?), what was delivered, and by whom. We need to understand the nature of the condition and the dose and duration of the intervention to determine what is effective in improving outcomes and what is not.
- The methods developed need to be implementable in the setting they are intended for. Thus, incorporating implementation science into the full spectrum of research around malnutrition will be essential to ensure adoption.

Putting it into Practice—The Nutrition Care Process

How can we raise awareness of the need to incorporate an ecological approach into practice and to support nutritional care across the multiple entry points for care? It is a tremendous need, and fortunately a working model for this is already in use.

RDs/RDNs—instrumental members of the healthcare team—in many countries globally are trained to use the Nutrition Care Process (NCP) as the foundation of their practice regardless of setting [33,34]. The NCP was first sited as an important model

in 2003 by Lacey and Pritchett [35]; it is a systematic method with four steps including assessment, diagnosis, intervention, and monitoring and evaluation. At the core of the process is the nutrition diagnosis or the problem, etiology, and signs and symptoms statement that describes the nutrition diagnosis, the probable cause of the problem, and the signs that were used to determine the diagnosis. The clinician then uses the determined etiology to develop an individualized intervention that may include coordination of care, delivery of nutrients through meals, parenteral or enteral nutrition or micronutrient supplementation, nutrition counseling, and/or nutrition education. In the United States, knowledge of the NCP and its use is a component of the registration examination for dietitians and is used specifically when caring for individuals with specific medical conditions as a part of MNT. Additionally in the latest International NCP Implementation Survey, conducted in 2024, >20 countries participated and indicated implementation of the NCP to some degree within clinical and public health practice (data analysis in process). Lewis et al. [36] examined retrospective data from the Veterans Health Administration medical records and found that the odds of improving the nutrition diagnosis were 51.4 times higher when the etiology-intervention link was present and for every added nutrition visit by an RDN, the odds of improving the nutrition diagnosis increased by 32.5%. Figure 4 represents the adaptation of the ecological approach as part of the NCP.

Conclusions

The world is increasingly complex and the factors influencing human health reflect that complexity. We have attempted here to reinforce the notion that assessment of human health and nutrition must not only allow us to identify when a problem exists but why. The historical medical approaches to nutritional assessment will not suffice to get us the answers we

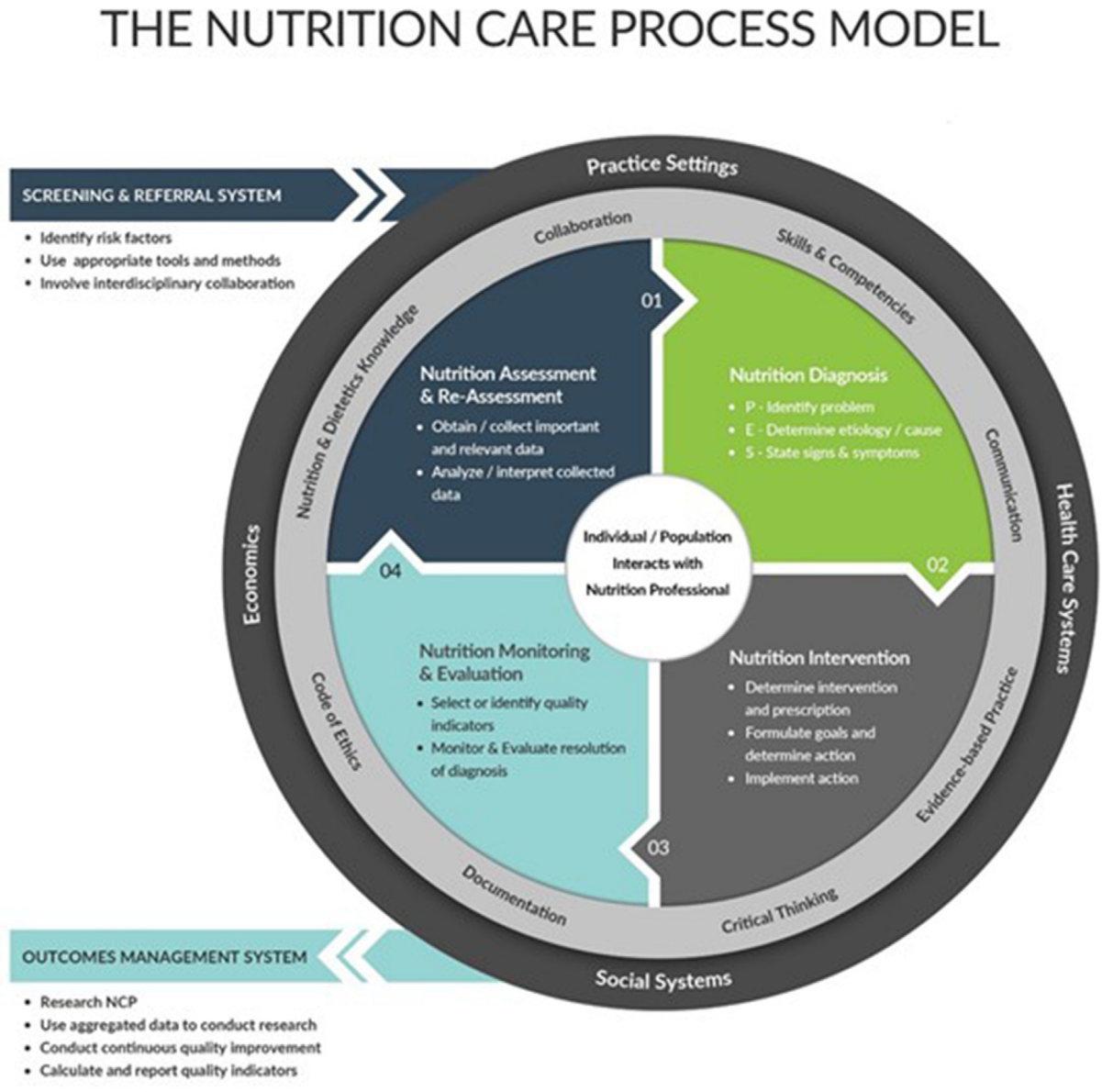

FIGURE 4. An adaptation of the ecological approach as part of the Nutrition Care Process.

need to provide care either clinically or in a public health setting. But fortunately advancements have been made, allowing us to now generate complex composites of data that can be compiled, managed, and analyzed using approaches such as computational systems biology, artificial intelligence/machine learning, and a range of –omic approaches to support a more comprehensive assessment of the nutritional ecology. The need to advance this agenda, both in terms of research and public health programs, is exemplified by such initiatives as "Nutrition for Precision Health" (Nutrition for Precision Health, powered by the All of Us Research Program | https://commonfund.nih.gov/nutritionforprecisionhealth) and "Food Is Medicine" (Food is Medicine: A Project to Unify and Advance Collective Action | https://odphp.health.gov).

To support the actualization of this new contemporary framework for nutritional assessment, diagnosis, and care, we suggest three critical elements: *1*) prioritize nutrition in medical education [37] to ensure appropriate and timely referrals across the healthcare team; *2*) use of the NCP that implicitly includes etiology as part of problem identification and nutrition intervention; and *3*) implementation of a team approach to care and management—including medical doctors working in consort with trained RD/RDNs (and international equivalents) and informed physician assistants and nurses where available across the range of entry points of care. Such an approach would reflect not only the realities of the world in which patients live but the spectrum of expertise needed to address that complexity and meet the needs of those for whom we provide care.

Author contributions

The authors' responsibilities were as follows – DJR: had the original idea for the perspective and wrote the initial manuscript draft; ALS, AAB: provided intellectual input and contributed to the writing of subsequent manuscript drafts; and all authors: read and approved the final manuscript.

Conflict of interest

AAB is an Editor for Advances in Nutrition and played no role in the Journal's evaluation of the manuscript. All other authors report no conflicts of interest.

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