

POCKET GUIDE TO

Micronutrient Management

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Academy of Nutrition and Dietetics Pocket Guide to Micronutrient Management

ISBN 978-0-88091-233-4 (print)
ISBN 978-0-88091-234-1 (eBook)
Catalog Number 233425 (print)
Catalog Number 233425e (eBook)

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10 9 8 7 6 5 4 3 2 1

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Library of Congress Cataloging-in-Publication Data

Names: Roberts, Kristen M., editor. | Estes-Doetsch, Holly, editor. | Nahikian-Nelms, Marcia, editor. | Academy of Nutrition and Dietetics, issuing body.

Title: Pocket guide to micronutrient management / [edited by] Kristen M. Roberts, Holly Estes-Doetsch, Marcia Nahikian-Nelms.

Description: Chicago, IL : Academy of Nutrition and Dietetics, [2024] | Includes bibliographical references and index.

Identifiers: LCCN 2024022368 (print) | LCCN 2024022369 (ebook) | ISBN 9780880912334 (spiral bound) | ISBN 9780880912341 (ebook)

Subjects: MESH: Micronutrients--deficiency | Deficiency Diseases--therapy | Dietary Supplements | Nutrition Therapy

Classification: LCC RM216 (print) | LCC RM216 (ebook) | NLM QU 145.5 | DDC 615.8/54--dc23/eng/20240703

LC record available at <https://lcn.loc.gov/2024022368>

LC ebook record available at <https://lcn.loc.gov/2024022369>

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Foreword

Micronutrient health is a fundamental component of medical and nutrition therapies but has suffered from a lack of published and usable guidelines for practitioners. With the *Academy of Nutrition and Dietetics Pocket Guide to Micronutrient Management*, the editors—Kristen M. Roberts, PhD, RDN, LD, CNSC, FASPEN, FAND; Holly Estes-Doetsch, MS, RDN, LD; and Marcia Nahikian-Nelms, PhD, RDN, FAND—have brought the top subject-matter experts together to provide an evidence-based review of micronutrient physiology, deficiencies, and treatment in a practical handbook. This pocket guide takes an interprofessional approach, which is critical in health care today. This text fills a void in the published guidance for the treatment of both hospitalized and outpatient populations.

I have been practicing internationally as a registered dietitian nutritionist for the past decade. In that time, I have seen firsthand the impact of micronutrient deficiencies on the health of individuals worldwide. From rampant iron deficiency in women and children, to neural tube defects related to folate deficiency during pregnancy, to vitamin C deficiency in patients with burns, to blindness caused by vitamin A deficiency in children—micronutrient deficiencies are more common than we think. Furthermore, they are not limited solely to developing countries, existing in developed countries as well. The registered dietitian nutritionist has the skill set to assess, identify, and treat micronutrient deficiencies through a combination of the nutrition focused physical exam, diet history, and biochemical data. This book brings together the relevant micronutrient information and enables clinicians to strengthen their deficiency-assessment skills, create treatment plans, and enhance their practices, resulting in positive impacts on patient outcomes.

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Acknowledgments

The editors give special thanks to the Academy of Nutrition and Dietetics, especially Stacey Zettle, MS, RDN, and Betsy Hornick, MS, RDN, for their ongoing support with planning, implementing, and editing this book. Thank you!

Thank you to my colleagues, specifically the nurse practitioners and gastroenterologists, for their support in making nutrition and micro-nutrient assessment a standard of care for all patients seen within the Division of Gastroenterology, Hepatology, and Nutrition at The Ohio State University. I also thank the students in the School of Health and Rehabilitation Sciences who continue to motivate me to be a better educator. Most importantly, I thank my family. Bryan, I could not be successful without your confidence in me and unconditional support for my career. Finally, to the “little people” in my life, Benjamin, Simon, and Anna—without you, this book would have been completed a year earlier.

Kristen M. Roberts, PhD, RDN, LD, CNSC, FASPEN, FAND

I extend a special thank-you to the students and faculty in the Master of Dietetics and Nutrition Program and the Division of Gastroenterology, Hepatology, and Nutrition at The Ohio State University for their support. I also wish to acknowledge the faculty in the Doctor of Clinical Nutrition program at Rutgers University for their mentorship and my family for their support.

Holly Estes-Doetsch, MS, RDN, LD

I gratefully acknowledge the ongoing support of the faculty, practitioners, and students in the School of Health and Rehabilitation Sciences in the College of Medicine at The Ohio State University.

Marcia Nahikian-Nelms, PhD, RDN, FAND

About the Editors

Kristen M. Roberts, PhD, RDN, LD, CNSC, FASPEN, FAND, has formal training as a clinical and translational scientist with a specialization designated from the Center for Clinical and Translational Science at The Ohio State University. She has been a practicing clinical registered dietitian nutritionist for nearly 20 years and has expert knowledge in the management of intestinal failure, enteral and parenteral nutrition, and gastrointestinal diseases. In addition, she has attended the National Institutes of Health training program on dietary supplements and runs an active laboratory focusing on the development of micronutrient treatment strategies through the use of physical and biochemical assessment. Roberts has authored several peer-reviewed publications and speaks nationally on micronutrient assessment, fluid and electrolyte status, and acid-base balance. Her joint appointment is in the Division of Gastroenterology, Hepatology, and Nutrition and the School of Health and Rehabilitation Sciences, both at The Ohio State University. In clinical practice, she manages a micronutrient assessment and treatment service. Roberts serves as a deputy editor for the journal *Nutrition in Clinical Practice* and is a fellow of the American Society for Parenteral and Enteral Nutrition (ASPEN) and the Academy of Nutrition and Dietetics. Most recently, she received the Distinguished Practice Award from the Dietitians in Nutrition Support dietetic practice group of the Academy of Nutrition and Dietetics, as well as the Distinguished Nutrition Support Dietitian, Advanced Clinical Practice Award from ASPEN.

Holly Estes-Doetsch, MS, RDN, LD, has been a registered dietitian nutritionist since 2006 and holds dual master of science degrees, one in nutrition and the other in exercise and sport science, from the University of Utah. She serves on the faculty of the School of Health and Rehabilitation Sciences at The Ohio State University, where she has taught medical nutrition therapy courses for graduate and undergraduate dietetics students since 2013. She has more than

10 years of clinical practice experience in acute care and outpatient settings and has worked with both pediatric and adult populations. Estes-Doetsch has presented on micronutrient management at the Academy of Nutrition and Dietetics Food & Nutrition Conference & Expo (FNCE) and manages a micronutrient assessment and treatment service in the Division of Gastroenterology, Hepatology, and Nutrition at The Ohio State University. She codeveloped a case-based student training experience on micronutrient management during the COVID-19 pandemic as an opportunity for students to acquire supervised practice hours. In 2018, she and her coauthors received the Innovations in Nutrition and Dietetics Practice and Education poster session award from the Academy of Nutrition and Dietetics Council on Future Practice for research highlighting the value of using patient simulation to teach assessment of malnutrition, as presented at FNCE. In 2022, she received the Outstanding Dietetics Educator award from the Ohio Academy of Nutrition and Dietetics.

Marcia Nahikian-Nelms, PhD, RDN, FAND, is a professor of clinical health and rehabilitation sciences, the Assistant Dean for Academic Affairs in the School of Health and Rehabilitation Sciences, and the Director of Teaching and Learning for Faculty Advancement, Mentoring, and Engagement in the College of Medicine at The Ohio State University. She has practiced as a registered dietitian nutritionist and public health nutritionist for more than 45 years. She is the lead author of several textbooks, including *Nutrition Therapy and Pathophysiology* (now in its fourth edition) and *Medical Nutrition Therapy: A Case Study Approach* (now in its seventh edition), and has authored peer-reviewed journal articles and chapters for other texts. Her clinical expertise focuses on the development and practice of evidence-based nutrition therapy for both pediatric and adult populations. Nahikian-Nelms serves as one of the leads for interprofessional education and has contributed to simulation development within the seven health science colleges at The Ohio State University. She has received the university's Alumni Award for Distinguished Teaching, the Governor's Award for Outstanding Teaching for the

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CHAPTER 1

Introduction and the Role of Interprofessional Care

Marcia Nahikian-Nelms, PhD, RDN, FAND

Introduction

Micronutrient deficiencies are often viewed as either a historical medical issue that has been resolved with improved food supplies, enrichment, and fortification or a problem of extreme malnutrition occurring primarily in countries experiencing issues with food supply. As nutrition research has evolved, we have expanded our understanding of the role of micronutrients in acute and chronic disease, the impact of disease and treatments on micronutrient status, and the potential role of micronutrients in enhancing recovery from disease through complementation, repletion, supplementation, or treatment.¹ To support patient health outcomes, micronutrients must be considered as part of the assessment and treatment plan of individual patients.

Many patient populations under the care of specialized care teams are at risk for or present with micronutrient deficiencies. These include patients with renal disease, burns, wounds, and intestinal diseases, as well as those undergoing bariatric surgery or in critical care. A resource that captures this diversity of patients is needed to increase the identification and treatment of micronutrient concerns and subsequently improve patient outcomes. Published, disease-specific clinical guidelines for addressing micronutrient deficiencies when developing patient care plans are lacking, yet micronutrient deficiencies are present in a large percentage of inpatients and outpatients. This book is meant to serve as a reference for clinicians treating micronutrient deficiencies (not toxicities), and it approaches micronutrient management from an interprofessional perspective. Authors from various health disciplines have collaborated so that each chapter adequately reflects multidisciplinary perspectives of care. It was essential to have a *team* of health care professionals contribute to a publication of this importance, as micronutrient assessment and treatment are best achieved through an interprofessional approach.^{2,3}

This book generally does not cover micronutrient management in specialized nutrition support, as these guidelines have been published elsewhere.^{4,5} Conventional units are presented throughout this pocket guide to support the units most commonly seen by practicing clinicians. The international system of units (or SI units) can be accessed elsewhere.⁶ Within this book, cut-off levels may vary based on the references cited within the chapter and the indications for treatment. This book does not address pediatric nutrition (other than neonates). Lastly, due to the paucity of research on micronutrient repletion, the guidelines within this handbook are suggested based on current practice. More research is needed to formalize disease-specific guidelines.

Current Status of Micronutrient Management

The European Society for Clinical Nutrition and Metabolism (ESPEN) has clarified language for micronutrient management by defining the

terminology for micronutrient assessment, monitoring, and prescription. This language is adopted in this text, and Box 1.1 on page 4 outlines the definitions.¹ These new definitions may represent a shift from the way clinicians previously spoke about micronutrient management. For example, in the ESPEN terminology, giving a patient a dosage of a micronutrient to restore its level in the body to what is physiologically normal is called *repletion*, whereas previously it was referred to as *supplementation*. In the new terminology, *supplementation* refers to giving dosages higher than standard amounts (ie, greater than Dietary Reference Intakes or Recommended Dietary Allowances). Of note, Chapter 14 (Metabolic and Bariatric Surgery) does not employ the ESPEN terminology, as this area of nutrition therapy uses practice guidelines from the American Society for Metabolic and Bariatric Surgery, in which supplementation, assay cut-off levels, and repletion amounts are typically different from those for patients who have not had bariatric surgery.

Screening and assessment for micronutrient complementation, repletion, supplementation, or pharmacological dosing takes into consideration what we know from the field of population health, the requirements to support normal growth and development, the typical contributions from dietary patterns, and increased needs during disease states. The most common micronutrients at risk for deficiency in the United States include calcium, iron, magnesium, potassium, choline, folate, and vitamins A, C, D, and E. These potential deficiencies are highlighted in the *Dietary Guidelines for Americans, 2020–2025* and multiple studies assessing nutritional intake that stem from the National Health and Nutrition Examination Survey (NHANES) program.^{7–9} In addition, food-insecure households in the United States are at higher risk for inadequate dietary intakes of zinc and vitamins B6, B12, and K.⁷ An examination of NHANES data from 2001–2016 further identifies pediatric risk to include iron, calcium, B6, choline, and potassium.⁹ Another examination of NHANES dietary data, from 2005–2016, focused on specific nutrients known to support immune health. This analysis found that common inadequacies included zinc and vitamins A, C, D, and E.¹⁰ The translation of population-based assessment to individual risk does not necessarily mean that a physiologic deficiency exists based on laboratory and clinical indices, but it does provide a framework for the clinician to

BOX 1.1 European Society for Clinical Nutrition and Metabolism (ESPEN) Definitions of Micronutrient Prescriptions¹

Complementation

Oxford definition	The act of adding to something in a way that improves it or makes it more attractive, complete
ESPEN definition	The delivery of micronutrients to cover basal needs (eg, to complete enteral feeds or parenteral nutrition [PN])
Comment	This action is typically needed to cover basal needs in case of progressive or insufficient enteral nutrition (EN).
Example	Provision of a multivitamin for a patient receiving EN (ie, a clinically stable patient with low body weight) when the prescribed EN volume meets energy and protein requirements but does not meet micronutrient requirements

Repletion

Oxford definition	The act of making something full again by replacing what has been used
ESPEN definition	The delivery of micronutrients with the aim of restoring a normal status when the deficit is known; sometimes called supplementation, but this should be avoided
Comment	Repletion is employed when deficiencies or losses are identified or presumed; it aims to restore a normal status.
Example	Provision of additional copper to a patient receiving long-term jejunal feeding who is identified as copper deficient, with the intent of reversing symptoms and restoring serum levels

Supplementation

Oxford definition	The act of adding something to something else to improve or complete it
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BOX 1.1 European Society for Clinical Nutrition and Metabolism (ESPEN) Definitions of Micronutrient Prescriptions¹ (cont.)

ESPEN definition	The delivery of higher than standard doses (ie, superior to Dietary Reference Intake or PN recommendation); does not include pharmaconutrition but designates doses higher than basal requirements delivered in an attempt to correct depletion or deficiency
Comment	This term is applied without differentiation of amount whenever a micronutrient is prescribed.
Example	Addition of vitamin D and calcium for an individual at risk for osteoporosis

Pharmacologic dosing

Oxford definition	Relating to the scientific study of drugs and their use in medicine
ESPEN definition	The delivery of a specific micronutrient to improve host defenses or any other biologic end point associated with good clinical evolution and to improve the outcome of patients who are critically ill
Comment	Generally, only one micronutrient is prescribed. The administration route is not determined. This is not a nutritional effect but rather a pharmacologic action.
Example	Therapeutic use of a high intravenous dose of vitamin C and thiamin in the intensive care unit as an adjunctive treatment for sepsis

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realize the potential risk. During times of increased growth and need, such as infancy, adolescence, pregnancy, or lactation, micronutrient needs are higher. These additional requirements are accounted for in any screening or assessment and are reflected in the standard guidelines, Recommended Dietary Allowances, and nutrition support guidelines.^{1,11}

Micronutrient deficiencies are logically associated with decreased dietary intake and with inferior-quality dietary intake. However, the recognition of malnutrition in the United States and in other countries has risen in importance. Patients who are hospitalized or of advanced age, those with chronic disease, and those who are experiencing acute inflammatory conditions are at substantial risk for malnutrition and micronutrient concerns.¹²⁻¹⁵ The role of micronutrients in public health is also of the highest priority when creating evidence-based care guidelines as a component of disease prevention and treatment.¹⁶⁻¹⁸

Throughout this text, our clinicians draw from the literature to provide expert guidance for addressing micronutrient requirements influenced by acute disease and their subsequent treatments. Chapter 2 reviews regulatory standards for micronutrient formulations and discusses bioavailability, labeling, and third-party verification of content. Chapter 3 focuses on differences in product formulations and routes of micronutrient delivery, the awareness of which will aid clinical decision-making. Chapter 4 provides an overview of the impact of inflammation on micronutrient status and management, and Chapter 13 addresses the impact of critical illness on micronutrient status and the potential role of micronutrients in the treatment of critical illness. In acute-care crises, such as sepsis or traumatic brain injury, micronutrients are essential to support the metabolic pathways induced during inflammatory responses. Without replenishing stores or meeting increased requirements, health outcomes may be negatively affected. For example, during the COVID-19 pandemic, both vitamin C and D deficiencies were reported in patients hospitalized with the disease.¹⁹ Chapters 5 through 8 outline the specifics of fat-soluble, water-soluble, iron, and trace mineral deficiencies. The remaining chapters review micronutrient deficiencies and treatment as related to various populations, including patients with gastrointestinal disease, renal disease, bariatric surgery, wounds, burns, and neonatal patients.

Role of the Interprofessional Team

This text seeks to approach micronutrient management through an interprofessional lens. The physician (medical doctor or doctor of osteopathic medicine), registered dietitian nutritionist (RDN), registered nurse or nurse practitioner, and pharmacist (doctor of pharmacy or registered pharmacist) all bring unique knowledge, skills, and training to patient care, as described in Box 1.2.²⁰⁻²³

The RDN has extensive knowledge of each of the micronutrients and its role in normal physiology and disease pathophysiology. RDNs are trained to assess dietary adequacy and perform biochemical and physical

BOX 1.2 American Society for Parenteral and Enteral Nutrition (ASPEN) Standards of Professional Performance²⁰⁻²³

Physician	The nutrition-support physician should know the patient's macronutrient, micronutrient, electrolyte, and fluid requirements, summarize and document these requirements in the medical record, and communicate them to the patient's primary health care team. ²³
Pharmacist	In collaboration with other health care professionals, the nutrition-support pharmacist should participate in the routine assessment of the patient's energy, protein, vitamin, mineral, fluid, and electrolyte requirements according to the patient's age, disease states, clinical conditions, and pharmacotherapy. ²¹
Registered dietitian nutritionist (RDN)	The RDN should evaluate nutrition screening results, conduct a nutrition assessment using a nutrition focused physical exam, confer with interprofessional team members, determine a plan of care, and provide ongoing monitoring and adjustments to the plan of care. ²⁰
Registered nurse or nurse practitioner	The nursing professional should analyze data to determine the patient's nutritional status, as well as the energy, nutrient, and fluid requirements of the patient relevant to the impact of the clinical situation on nutrient requirements. ²²

assessments using a nutrition focused physical exam to help determine micronutrient status. The 2017 Academy of Nutrition and Dietetics scope of practice for RDNs states that they may also “initiate, implement, and adjust protocol- or physician-order-driven nutrition-related medication orders and pharmacotherapy plans in accordance with established policy or protocols consistent with organizational policy and procedure.”²⁴ The standards of professional performance for RDNs in nutrition support state that the individual scope of practice depends on the level of education and training (competent, proficient, and expert) and the competence level translates to the ability to make the appropriate decisions for assessment and treatment.²⁰ Federal regulations allow for RDNs to write orders without having to be appointed to the medical staff.²⁵

The pharmacist is uniquely trained to determine the route and the type of formulation for micronutrients. The standards of practice for the nutrition-support pharmacist state that “in collaboration with other healthcare professionals, the [nutrition support professional] shall participate in the routine assessment of the patient’s energy, protein, vitamin, mineral, fluid, and electrolyte requirements.”²¹ The registered nurse or nurse practitioner brings additional skills of physical assessment and clinical interviewing to the team, collaborates with other health care providers to assess nutritional requirements, and assists with the management of nutrition support devices, such as feeding tubes or vascular access devices.²² The physician ultimately provides the medical governance over the patient’s plan of care, informs other team members of the broader medical plan, and places the micronutrient treatment within that context.²³ Communication among these professionals promotes a complete plan for assessment, treatment, and monitoring.

Accreditation and licensing standards for all professions emphasize interprofessional collaboration. For example, pharmacy standards of practice require that pharmacists collaborate with other health care providers to ensure care coordination that will lead to positive patient outcomes.²⁶ The Accreditation Council for Graduate Medical Education expects medical residents to work within interprofessional teams to ensure patient safety and optimal patient outcomes.²⁷ Nursing practice standards also require collaboration with interprofessional teams to ensure positive outcomes.²⁸ Similarly, the standards of practice for RDNs

encompass competencies of collaboration and team-based decision-making, not only in training but also in entry-level practice.²⁹ In 2021, the National Collaborative for Improving the Clinical Learning Environment published the first guidelines to create educational and treatment pathways for interprofessional learning.³⁰ Micronutrient management is an excellent model for bridging the classroom and clinical environments and, thereby, for demonstrating interprofessional practice and competence while ultimately improving patient outcomes.

Micronutrient management is uniquely suited to interprofessional collaboration. Evidence-based guidelines for many of the recommendations needed in complex management are lacking, and thus extensive critical thinking and clinical decision-making are required, necessitating a team-based approach. The *Pocket Guide to Micronutrient Management* models this collaborative clinical decision-making within each chapter as it guides the clinician through the existing literature and its application for care as it relates to each micronutrient and patient population. As each patient is unique, clinicians are encouraged to combine this information with their own clinical judgment for the best patient outcomes.

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