SYSTEMATIC REVIEW OF MICRONUTRIENT DEFICIENCY ONE YEAR OR MORE AFTER BARIATRIC SURGERY

by

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As members of the DNP Project Committee, we certify that we have read the DNP project prepared by *Ivy K. Radcliffe*, titled *Systematic Review of Micronutrient Deficiency One Year or More after Bariatric Surgery* and recommend that it be accepted as fulfilling the DNP project requirement for the Degree of Doctor of Nursing Practice.

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DEDICATION

The completion of this project is dedicated to my husband, who believes in my commitment to professional nursing and helping people with diabetes. He supported my conviction to continue my doctoral degree to completion, even though it took away time from our relationship. He stood by me during my struggles, reminding me to “take one step at a time.” He held our lives together. I am so grateful.

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ABSTRACT

Obesity is a global epidemic and a public health challenge. Currently more than one third of adults in the United States are obese (Center for Disease Control and Obesity, 2015). Although diet, lifestyle modification, and medications are minimally effective, bariatric surgery has demonstrated long-term weight loss and reduction of complications in obese populations.

Bariatric surgery has become the recommended treatment option for morbid obesity and obesity with comorbid disease (Buchwald et al., 2004). Studies on long-term follow up — beyond one-year post-surgery — demonstrate that bariatric surgery and extreme weight loss can cause co-morbid problems due to micronutrient deficiencies (Alvarez-Leite, 2004). Bariatric surgery and subsequent extreme weight loss can lead to malabsorption and serious complications from deficiencies in micronutrients — vitamins, minerals, and trace elements. The consequences of micronutrient deficiencies can be serious: disease, functional impairment, and decreased quality of life.

Advanced-practice nurses may not be familiar with bariatric surgeries or symptoms of micronutrient deficiency; however, they need to develop competency to provide evidence-based primary care to the rapid growing population of patients with a history of bariatric surgery. This practice inquiry conducts an evidence-based problem-solving approach using a systematic review to develop practice guidelines for advance practice nurses to assess and prevent complications in patient's one year or more after bariatric surgery. Results from this systematic review indicate that providers should consider screening for micronutrient deficiencies in pre- and post-operative bariatric surgery patients and that this population be routinely monitored for supplement adherence.

INTRODUCTION

Globally obesity rates are rising, causing increased strains on public health systems. In the United States (U.S.), more than one-third of adults are obese (Centers for Disease Control and Prevention [CDC], 2015) and the incidences of morbidly obese and super obese are increasing rapidly (Strum & Hattori, 2013). Research indicates that diet, lifestyle modification, and medications have been found to have minimal effect at decreasing weight (Patel, Mundi, Hurt, Wolfe, & Martindale, 2017). Therefore, bariatric surgery has become the recommended treatment choice for individuals who are morbidly obese or obese with comorbid diseases (Nguyen, Yu, Kim, Bodunova, & Phelan, 2015).

Bariatric surgery as a therapeutic option for weight loss, surgical management, and the reduction of comorbidities associated with obesity has been extensively researched (Sjostrom et al., 2004). Although most studies indicate a positive association between bariatric surgery and weight loss, studies on long-term follow up, beyond one year after surgery, are beginning to show that bariatric surgery and extreme weight loss can cause subsequent problems due to micronutrient deficiencies (Koch & Finelli, 2010). Malabsorption of vitamins and micronutrients from restrictive surgical procedures — coupled with extreme weight loss — can lead to serious complications, functional impairment, and decreased quality of life (Patel, Mundiq, Wolfe, & Martindale, 2017). Therefore, people who have bariatric surgery for weight loss need life-long follow-up to decrease complications and micronutrient deficiencies that can occur years after surgery (Obeid, Malick, Fielding, Kuran, & Ren-Fielding, 2016). Specifically, evidence-based guidelines need to be developed that promote clinical suspicion of micronutrient deficiencies in this population (Via & Mechanic, 2017) The purpose of this practice inquiry was to conduct a systematic review to develop evidence-based guidelines for advance practice registered nurses (APRN) to assess and prevent complications in patients one year or more after bariatric surgery.

Purpose and Aim of the DNP Project

The purpose of this DNP project is to conduct a systematic review and synthesis of the literature to develop EBP recommendations for advance practice nurses to assess and guide treatment of micronutrient deficiency in adults, one year or more after bariatric surgery. The specific aim of this project will be to perform a systematic review within the context of the Iowa Model to answer the clinical question: in adults, at one year after bariatric surgery, what micronutrient deficiencies are associated with currently performed procedures?

Objectives for this project will be:

1. Search and evaluate existing EBP guidelines for micronutrient deficiency at least one year after bariatric surgery.
2. Complete a systematic literature review of micronutrient deficiency at least one year after bariatric surgery.
3. Develop EBP guidelines for advance practice registered nurses to screen and diagnose micronutrient deficiency in bariatric surgery patients at least one year after surgery.

Background of the Problem

Obesity in the United States

The obesity epidemic in the United States is a significant and growing public health problem, leading to health care and social burdens. Currently more than one-third of adults in the United States, 97 million adults, are obese (CDC, 2015). With the number of people classified as severely obese increasing two to three times faster than other obesity categories (Strum & Hattori, 2013). Obesity leads to chronic health conditions including Type 2 diabetes, cardiovascular disease, and cancer (Sjostrom et al., 2004). In addition to risk of chronic diseases, obesity is also associated with an increased risk of death. Treating obesity and obesity-related conditions is an economic burden that costs billions of dollars a year. The report “F as in Fat,” commissioned by the Robert Wood Johnson Foundation predicted:

If obesity rates continue their current trajectory, it is estimated that rates for adults could reach or exceed 44% in every state and exceed 60% in 13 states. The number of new cases of type 2 diabetes, coronary heart disease and stroke, hypertension and arthritis related health care costs could increase by more than 10% in 43 states and by more than 20% in nine states (Robert Wood Johnson Foundation, 2012, p. 3).

The problem of obesity is a pressing health care issue that demands attention from medical professionals based on alarming trends and future predictions. In June 2013, the American Medical Association declared obesity a disease to begin recognition that 78 million American adults and 12 million children have a medical disease that needs treatment (American Medical Association, 2013). The official recognition of obesity as a disease acknowledges obesity is a chronic health condition with genetic and environmental pathology that requires evidence-based medical support by health care professionals.

Definition and Classification of Obesity

Obesity is the accumulation of abnormal or excess body fat. The CDC defines overweight and obesity as “labels for ranges of weight that are greater than what is generally considered healthy for a given height” (CDC, 2012, p. 1). These higher weight ranges are correlated with increased likelihood of diseases such as type 2 diabetes, high blood pressure or other systemic health problems. Obesity classifications use body mass index (BMI), weight in pounds multiplied by 703 divided by height in inches squared to decide categories. This measurement correlates with body fat, morbidity, and mortality to give a risk assessment of weight based on a ratio of body fat to height (National Institute of Health [NIH], 2000) (Table 1). The expert panel on the identification, evaluation, and treatment of overweight and obesity in adults uses three classes to categorize obesity (NIH, 2000).

TABLE 1. *Three classifications of obesity.*

Classification	**BMI (kg/m²)**
Class 1 Obesity	30—34.9
Class 2 Obesity	35—39.9
Class 3 Obesity (Extreme Obesity)	≥ 40

Prevalence of Obesity

The United States has two national sources for data on the prevalence of obesity. The Behavioral Risk Factor Surveillance System (BRFSS) is a United States health survey managed by the CDC (2013). In 2016, the estimated prevalence of obesity in the U.S. was 34.9 based on the BRFSS (CDC, 2016). All states reported more than 20% of adults with obesity and five states reported greater than 35% of adults with obesity" (Center for Disease Control and Prevention [CDC], 2016). The highest prevalence of obesity according to the BRFSS for 2016 is non-Hispanic blacks 38.3%, followed by Hispanics 28.1% (CDC, 2016). Obesity rates among middle age adults is 42.8% and older adults 60 and over 41%.

The second source of data for obesity is the National Health and Nutrition Examination Survey (NHANES). NHANES is a cross-sectional, nationally representative survey that aims to find the prevalence and risk factors of major diseases. The survey includes an interview and a physical examination conducted by the National Center for Health Statistics of the U.S. (NCHS) and the CDC (NCHS, 2017). Results from the survey indicate that in 2015-2016, obesity prevalence was 39.8% among U.S. adults (NCHS, 2017). Obesity rates were higher among middle age adults (42.8%) compared to adults aged 60 and over (41.0%) and adults aged 20–39 (35.7%) (NCHS, 2017).

From 1999 through 2016, a significant trend of increasing obesity in adults and youth occurred (Ogdon, 2017). “Women had a higher prevalence than men among non-Hispanic black, non-Hispanic Asian, and Hispanic adults” (Ogdon, 2017, p. 4). Obesity is highest in middle age adults, 42% (Ogdon, 2017). The NHANES shows significant increases for obesity in the non-Hispanic black and the Hispanic population. Forecasts using the NHANES data predict 50% of adults will be obese and 30% of children by the year 2030 (Wang, Beydoun, Caballero, & Kumanyika, 2008).

Between 2000 and 2010, the prevalence of a BMI over 40 (type III obesity) calculated from self-reported height and weight increased by 70%, the prevalence of BMI over 50 increased even faster (Strum & Hattori, 2013, p. 1). The National Institute of Diabetes and Digestive and Kidney Diseases estimates 1 in 13 adults have extreme obesity (National Institute of Diabetes and Digestive and Kidney Diseases [NIDDK], 2017). Due to higher rates of co-morbid conditions in the obese populations, it is expected that obese individuals will have higher rates of healthcare utilization leading to increased costs, and higher rates of mortality (Pi-Sunyer, 2009).

Cost of Obesity

As the prevalence of obesity increases, so do associated medical costs. In 2008, the Medical Expenditure Panel Surveys (MEPS) estimated the national cost stemming from obesity was $147 billion, or 9.1% of health care dollars (Finkelstein, Trogdon, Cohen, & Dietz, 2009). By 2016, the MEPS indicated that $209 billion, or 20.6% of U.S. national health expenditure was spent treating obesity (Cawley & Meyerhoefer, 2012). Obesity is not only costly for the nation, but also for the individual person. Healthcare costs associated with obese individuals were 42% higher than individuals with normal weight (Tsai, Williamson, & Glick, 2011). In 2014, being obese cost an individual an estimated $1,239 - $2,582 per year in healthcare associated fees (Kim & Basu, 2016). “Obesity significantly increases the likelihood of receiving treatment for many of the 10 costliest chronic diseases, such as diabetes, hypertension, and asthma and 60% of the increase in diabetes prevalence can be linked to weight gain” (Thorpe & Philyaw, 2012, p. 412). The excessive cost associated with obesity also stems from higher costs for comorbid conditions.

In addition to cost of diagnosis and treatment, obesity increases indirect costs for employers. Absenteeism, disability, and workers’ compensation cost employers in productivity and expenditures (Trogdon, Finkelstein, Hylands, Dellea, & Kamal-Bahl, 2008). In *A Heavy Burden: The Individual Costs of Being Overweight and Obese in The United States*, the individual and employer estimated annual costs of obesity were $8,365 for women and $6,518 for men (Dor, Ferguson, Langwith, & Tan, 2010). Furthermore, the cost of morbid obesity was 3.5 times greater than moderate obesity (Arterburn, Maciejewski, & Tsevat, 2005). The Affordable Health Care Act will also affect the costs of obesity by including provisions that cover and promote preventative care for obesity services (U.S. Centers for Medicare and

Medicaid Services [CMS], n.d.). Proposed services for obesity programs and counseling, medical supervision, prescription drugs, and bariatric surgery varies across states and plans.

Morbidity and Mortality of Obesity

A direct link has been established between rise in the prevalence of obesity and the rise of obesity related comorbidities (Flegal, Kit, Orpana, & Graubard, 2013). Obesity adversely affects health by causing many diseases ranging from metabolic and physiologic conditions — such as diabetes and cardiovascular disease — to psychological impairment and low quality of life. A meta-analysis by Guh et al. (2009) found 18 comorbidities that were significantly associated with obesity, including type 2 diabetes, multiple cancers, cardiovascular disease, asthma, osteoarthritis, and chronic back pain. Pathogenesis of medical conditions is due to two mechanisms: mass of fat and metabolic effects of fat cells (Bray, 2004).

Mass of fat contributes to sleep apnea, osteoarthritis, and physical disability. Metabolic effects from fat cause insulin resistance and metabolic syndrome that lead to diabetes and cardiovascular disease (Shamseddeen, Getty, Hamdallah, & Ali, 2011). Obese individuals are at increased risk of mortality from co-morbid disease. In the United States, 300,000 deaths per year are attributed to obesity (U.S. Department of Health and Human Services, 2013). Mortality risk increases for all classes of obesity and is significantly higher, 50% to 100%, for class 2 and 3 obesities (Flegal et al., 2013).

Causes of Obesity

Obesity is a multifactorial disease with genetic, environmental, and immune components. Obesity develops when there is an imbalance between energy intake and energy expenditure. Research on obesity and metabolic abnormalities has increased in the last 20 years and “There is growing recognition that environmental factors are likely to contribute to the obesity epidemic, both in the United States and worldwide" (Nguyen & El-Serag, 2009, p. 754). Although many environmental variables have been studied in relation to weight gain—increased television viewing, lack of community facilities to exercise, cost of healthy food, and social networks—decreased exercise and increased calorie intake are the two main environmental factors attributed to obesity in the United States over the last 40 years (NIH, n.d.). Specific genes also modify susceptibility to obesity from environmental factors. Family and twin studies suggest a strong inherited genetic component for metabolic rate, thermic response to food, and spontaneous activity that influence weight status (Bray, 2003). Although these factors play a role in weight gain, they do not explain the trend in the rapid increase in obesity. Genetic, medical, or psychiatric diseases contribute minimally to obesity (Bleich, Cutler, Murray, & Adams, 2008). Recently researchers trying to understand the role of adipose tissue in obesity are targeting hormonal gut-brain signaling to treat obesity. Proteins expressed from adipose tissue influence energy requirements, appetite, and satiety (Fonseca, 2006). Despite the growing literature on treating obesity, it is well document that obesity is a complex interaction of genetics, metabolism, environment, behavior, and culture (Waseem, Morgensen, & Lautz, 2007).

Treatment of Obesity

The health risks of obesity increase with weight gain. Diet therapy, exercise, and pharmaceutical agents to treat obesity have not been effective for long-term weight loss (Kang & Park, 2012). Pharmacologic therapies combined with dietary intervention produce limited weight loss results, around 5%, and are difficult to maintain without side effects from medication (Li, Maglione, Tu, Mojica, Arterburn, Shugarnan, & Suttort, 2005). Evidence shows that surgical intervention can produce short and long-term weight loss that brings remission of co-morbidities, and improves survival rates, quality of life, and social functioning (Diabetes Care, 2015). The most effective way for people with extreme obesity to lose substantial amounts of weight and improve their weight-related health conditions is through bariatric surgery.

Bariatric surgery studies have proven superior results when compared to intensive medical therapy. Results include greater weight loss, 27% compared to 5%, and reduction of metabolic disease, diabetes, and medication use (Schyer et al., 2012). Long-term prospective controlled trials of bariatric surgery intervention report weight loss of 20% and improved or resolved comorbidities, when compared to medical therapy over a 10-year follow up period (Sjostrom, 2013).

Bariatric Surgery

Bariatric surgery procedures date back to the 1950s, when weight loss was recognized as a favorable consequence of small bowel surgery. In 1991, the NIH Consensus Conference for Gastrointestinal Surgery for Severe Obesity concluded that bariatric procedures were effective treatment for weight loss in severe obesity (NIH, 1991). This report increased the development of bariatric surgical options with recommendations for choice of patients and further research. Incidence of weight loss procedures increased after 2001, as bariatric surgery gained acceptance and popularity with a growing obese population and poor results associated with non-surgical weight loss treatments (Livingston, 2010). Modification of surgical techniques to outpatient laparoscopic procedures have increased options and demand.

The American Society of Metabolic and Bariatric Surgery (ASMBS). estimated that 196,000 people in the United States had bariatric surgery in 2015 (American Society of

Metabolic and Bariatric Surgery, July 2016) Although the rate of bariatric procedures has plateaued in the United States, with increasing extreme obesity, improved laparoscopic techniques, and documented improvement in metabolic outcomes, bariatric surgery has gained acceptance and popularity.

Recommendations for Bariatric Surgery

The NIH recommends bariatric surgery for “clinically severe obesity (BMI ≥ 40) or a BMI ≥ 35 and serious comorbid conditions for medically significant sustained weight loss” (NIH, 2000, p. 4). In recent updated American College of Endocrine guidelines, the recommendations for bariatric surgery have been expanded to patients with diabetes or metabolic syndrome with a BMI of 30.0 to 34.9 kg/m^2 (Mechanic et al., 2013).

Outcomes for Bariatric Surgery

Long-term clinical data, including randomized controlled studies, are beginning to appear for bariatric outcome results more than one year after surgery. One meta-analysis results for surgical procedures in morbidly obese patients confirm significant weight loss of 20 kg to 30 kg one year after surgery with weight maintenance for 10 years after surgery (Haggard et al., 2005). A second meta-analysis assessed the impact of bariatric surgery on morbidly obese individuals and found that it eliminated or significantly relieved diabetes, hyperlipidemia, hypertension, and obstructive sleep apnea (Buchwald, Avidor, & Braunwald, 2004). Patients saw an average weight loss of 45 kg (99 lbs.), 75% of the patients had complete resolution of their diabetes, 70% improved hyperlipidemia, 62% improvement hypertension, and 85% resolved sleep apnea (Buchwald et al., 2004).

The Swedish Obese Subject (SOS) study is the first long-term, prospective, controlled trial to give outcome data for adults who underwent bariatric surgery (Sjostrom, 2013). The study started in 1987 has reported results at intervals from five to 20 years after surgery with multiple sub-study reports. The SOS study included 2010 obese subjects who had bariatric surgery matched with 2037 control subjects. "Changes in body weight after 2, 10, 15, and 20 years were -23%, -17%, -16%, and -18% in the surgery group and -0%, -1%, -1%, and -1% in the control group respectively" (Sjostrom, 2013, p. 219). The SOS study also showed that adults who underwent bariatric surgery experienced significant decreases in mortality, cardiac events, diabetes, and cancer when compared with non-surgery matches (Sjostrom, 2013). Decreases in comorbidities are comparable to the Buchwald et al. (2004) meta-analysis. Three randomized controlled trials (RCT) duplicated the improvement in diabetes, blood pressure, and lipids in adults who underwent bariatric surgery compared to control subjects with medical management interventions (Ikamuddin et al., 2013; Mingrone et al., 2012; Schauer et al., 2012). Recent data from RCT and observational studies are consistent in showing bariatric surgery is more effective than conventional medical therapy in reaching glycemic outcomes and preventing type 2 diabetes, while reducing diabetes comorbidities (Mingrone et al. 2012).

Micronutrients and Micronutrient Deficiency in Bariatric Surgery

Micronutrient is the collective term to describe essential vitamin, minerals, and trace elements that are needed by the body in small quantities (Lutz, Mazur, & Litch, 2015). A significant deficiency of an essential micronutrient can induce a clinical syndrome. Bariatric patients can have pre-existing nutritional deficiencies before and after bariatric surgery (Tucker, Szomstein, & Rosenthal, 2007). Malabsorptive and combination procedures are associated with higher risk when compared to restrictive procedures (Koch & Finelli, 2010). Deficiencies are due to inadequate intake of nutrients and altered digestive anatomy. All procedures decrease absorption of vitamins, minerals, and trace elements. Deficiencies vary with surgical technique, patient populations, supplementation protocols, and length and completion of patient follow up (Kushner, 2011). Mild to moderate deficiency can have health consequences. The presence of micronutrient deficiencies from surgery to one-year post procedure are thoroughly documented (Aasheim et al. 2009; Allis, Blankenship, Buffington, Furtado, & Parrot, 2008; Clements et al., 2006; Davies, Baxter, & Baxter, 2007). Deficiencies of iron, folate, B12, calcium, and fat-soluble vitamins are common after bariatric procedure (Rashti, Gupta, Shope, & Koch, 2015). Micronutrient deficiencies can cause secondary hypothyroidism, osteopenia, anemia, peripheral neuropathy, and changes in memory. Studies of long-term management of micronutrient deficiency one year or more after bariatric surgery describe serious sequelae. Bariatric patients are at risk for developing multiple water-soluble and fat-soluble vitamin and mineral deficiencies that can result in medical complications and other diseases (Sawaya, Friedenberg, & Friedenberg, 2012). Micronutrient deficiencies that are not diagnosed can result in severe and irreparable problems.

Because bariatric procedures restrict food intake and bypass sites of intestinal absorption, leading to malabsorption, patients require life-long monitoring, prophylactic supplementation, and treatment to prevent complications. Follow up from surgical physicians and programs vary in length and intensity. Patients often return to primary care centers and are in need of screening and treatment for the side effects associated with bariatric surgery.

Significance to Nursing Practice

Obesity is a disease that needs a range of interventions for prevention and management in the advance practice nursing community. At present, bariatric surgery is the only modality to offer significant long-term weight loss for obesity. The Centers for Medicare and Medicaid Services (2006) approved open and laparoscopic Roux-en-Y gastric bypass (LRenY), laparoscopic adjustable gastric banding (LAGB), and open and laparoscopic biliopancreatic diversion with duodenal switch (LBPD-DS) as reasonable and necessary medical treatment for those who have a BMI ≥ 35, have at least one co-morbidity related to obesity, and have been previously unsuccessful with medical treatment for obesity.

The American Diabetes Association recommends bariatric surgery as a treatment choice for type 2 diabetes with a BMI of 35 kg/m2 (Cefalu, 2016). Private insurance has followed these recommendations. Technical and safety improvements enhanced outcomes, and expanded insurance benefits may increase the volume of the procedures performed in obese patients.

Bariatric surgery is a safe and efficacious treatment for sustainable weight loss in obese patients. Over the last decade complications rates, readmissions from complications, and hospital days have declined, even though patients are older and have multiple comorbidities (Encinosa, Barnard, Du, & Steiner, 2009). The procedures produce significant weight loss, along with the reduction and resolution of associated comorbidities. However, micronutrient deficiency is common in obese patients before and after bariatric surgery. Bariatric surgery can cause or exacerbate micronutrient deficiencies that can result in life-long complications. There is emerging evidence of incidence and risks from micronutrient deficiency from bariatric surgery after one year. Despite a rapidly expanding body of data surrounding these procedures, limited evidence-based resources are available to guide long-term follow up care. Current guidelines only address post-operative monitoring and supplementation (Mechanick et al., 2013).

Identification of the Knowledge Gap

The trigger for researching micronutrient deficiency after bariatric surgery began with the author's clinical practice in endocrinology. The practice setting was a private endocrine practice with patients referred from primary providers or self-referred from Phoenix, Arizona to Flagstaff, Arizona. The role of the clinical nurse specialist was to provide diagnosis, treatment, and management to a population of patients 16 years of age or older with diagnoses of obesity, pre-diabetes, and diabetes. A trend emerged of post-bariatric surgery patients with a common presentation. Patients presented with similar reports of fatigue, weakness, muscle pain, and memory loss, which compromised quality of life and led to disability. Evaluation of these patients resulted in diagnosis of malabsorption and multiple micronutrient deficiencies. Patients received individualized medical nutrient supplementation over a period of weeks to years. Symptoms resolved, and patients returned to previous activity levels. The clinical nurse specialist and endocrinologist agreed that more information was needed to provide evidence-based care to this patient population.

In order to provide evidence-based care regarding the relationship between micronutrient deficiencies post bariatric surgery, a detailed literature review was undertaken to answer the question: *What micronutrient deficiencies are adult bariatric patients at risk for one or more years after surgery and what deficiencies are associated with each type of surgery?* An initial search for guidelines from specialized website resources demonstrated available publications. The first resource reviewed was UpToDate, a clinical decision support resource, used by point of care facilities for original and peer-reviewed text to answer clinical questions (UpToDate, 2014). The resource on the website documented vitamin and mineral supplementation from surgery up to one-year post-operative (Kushner & Cummings, 2013).

Information was limited on micronutrient deficiency after the one-year post-operative period. At the time of this inquiry, American Association of Clinical Endocrinologists (AACE) published guidelines for nutritional, metabolic, and nonsurgical support of bariatric patients (Mechanick et al., 2008). This guideline included evaluation and management of micronutrient deficiency from pre-operative to one-year post surgery. There was minimal discussion of micronutrient deficiency after the first year. Research over 10 years old used procedures discontinued in medical practice. Updated guidelines in 2013 included new evidence; however, high quality data on the effects of bariatric surgery on subsequent micronutrient deficiency were lacking and these guidelines made only general recommendations concerning nutrition and management (Mechanick et al., 2013). A search of the Cochrane Library found a review on the effects of bariatric surgery complications, weight loss, and improvement in co-morbidities (Colquit, Loveman, & Clegg, 2009), but did not answer the background question.

The providers in the practice determined micronutrient deficiency after bariatric surgery was a clinical issue of importance from the high volume of referrals, severity of the clinical presentation, and the dramatic response to treatment. This emerging health care problem from rising obesity rates and surgical intervention treatment revealed a gap of knowledge in the scientific field. Evidence-based clinical practice guidelines answering the question could provide new knowledge to advance practice nursing for assessment and treatment of post-procedure bariatric patients.

CONCEPTUAL FRAMEWORK

The conceptual framework was developed to provide structure for the key concepts and relationships in the background information to guide the systematic review. "A conceptual framework is made up of interrelated statements that attempt to describe, explain, and/or predict a phenomenon" (Melnyk & Fineout-Overholt, 2011, p. 410). The concepts are placed in a logical and sequential design to provide structure to interpret the study findings. The concepts in the conceptual framework are bariatric surgery, micronutrient deficiency, and follow up screening.

By restricting food intake and altering metabolic processes in the body, bariatric surgery has a greater success rate of achieving and sustaining significant weight loss than non-surgical medical interventions (Maciejewski, Arteburn, & Van Sciyoc, 2016). Furthermore, it significantly diminishes and can resolve obesity related co-morbidities. While bariatric surgery can achieve sustainable weight loss, it also causes functional alteration of the gastro-intestinal tract that can result in micronutrient deficiency (Valentino, Sriram, & Shankar, 2011). Post-surgical bariatric patients need to be medically screened and treated for long-term problems of micronutrient deficiency (Cefalu, 2016; Mechanick et al., 2013; Shankar, Boylan, & Sriram, 2010; Valentino et al., 2011). If left undiagnosed, irreparable complications can occur. Patients with bariatric surgery require medical follow-up focused on the type of bariatric surgery (Sawaya et al., 2012). Providers other than the original surgeon often provide long-term care. With increasing numbers of patients undergoing bariatric surgery, providers other than surgeons need to recognize micronutrient deficiency risks and treatment (Valentino et al., 2011). Figure 1 is a model of the conceptual framework by the author adapted from *Follow-up of nutritional and metabolic problems after bariatric surgery* (Fujioka, 2005).

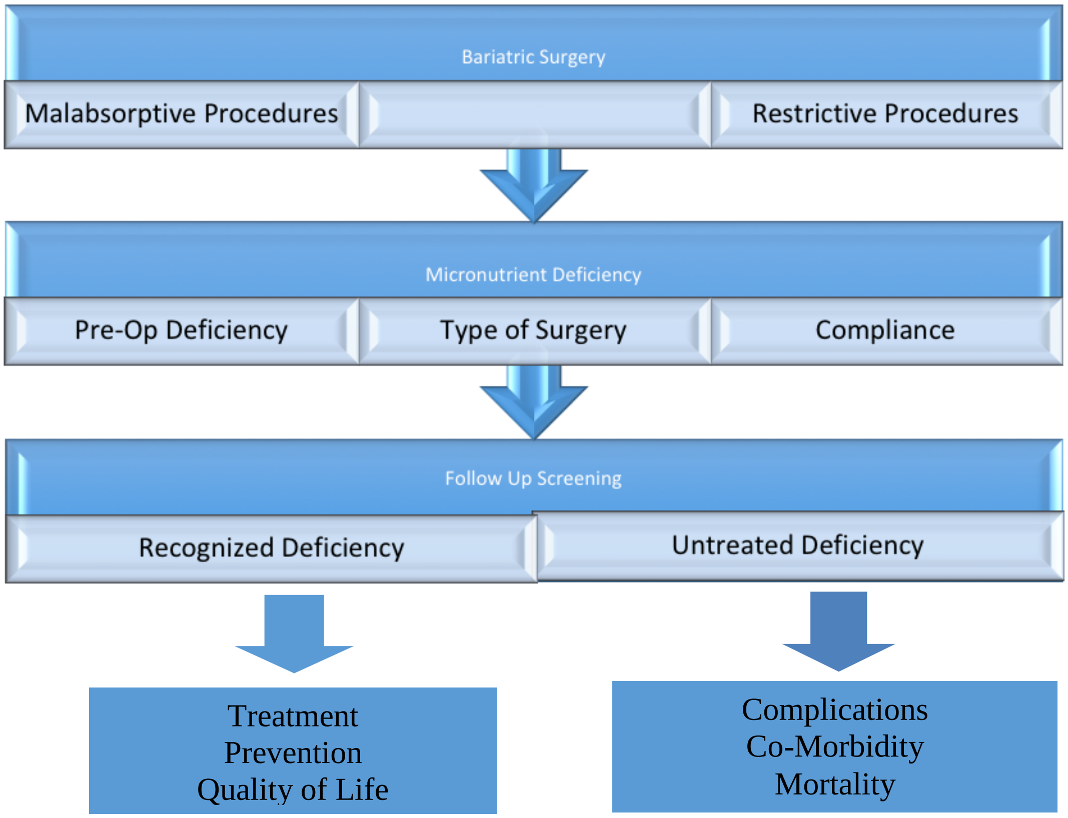

FIGURE 1. Conceptual framework: Micronutrient deficiency one or more years after bariatric surgery. (Adapted from "Follow-up of Nutritional and Metabolic Problems After Bariatric Surgery" by Fujioka, K. Diabetes Care, Volume 28/2, 2005, American Diabetes Association.)

Micronutrients

"Micronutrients are dietary components, often referred to as vitamins and minerals, which although only required by the body in small amounts, are vital to development, disease prevention, and wellbeing" (Lutz, Mazur, & Litch, 2015, p. 96). These nutrients are not produced in the body and must be derived from the diet (Lutz et al., 2015).

Micronutrients are essential to metabolism as co-factors and co-enzymes in metabolism and in modulating gene transcription and activation (Shenkin, 2006). They are also antioxidants that prevent free radicals, which have potential to cause disease (Shenkin, 2006). A clinical deficiency can result from inadequate intake or absorption, which results in metabolic changes that cause functional effects and disease (Alpers, 2012).

"Vitamins are organic substances needed by the body in small amounts for normal metabolism, growth, and maintenance" (Lutz, Mazur, & Litch, 2015, p. 97). Vitamins are ingested from food. There is some endogenous production, but this may not be enough for metabolic demands or may require the ingestion of a precursor (Shenkin, 2006). Vitamins are divided into water-soluble and fat-soluble groups (Lutz et al., 2015). In humans, there are 13 vitamins: four fat-soluble (A, D, E, & K) and nine water-soluble (eight B vitamins & vitamin C) (Lutz et al., 2015). Water-soluble vitamins are not readily stored, and a consistent intake is important (Shenkin, 2006). Fat-soluble vitamins are absorbed through the intestinal tract and require lipids to metabolize (Shenkin, 2006). They are more likely to accumulate in the body, which can lead to hypervitaminosis (Shenkin, 2006).

Minerals are essential dietary inorganic elements. Some of this group are not minerals and designated as trace elements. Minerals are abundant in human tissue and referred to as macro minerals. They are present in the body in amounts of 100 mg (Lutz et al., 2015). Macro minerals are calcium, phosphorus, magnesium, potassium, sodium, chloride, and sulfur (Lutz et al., 2015). Trace elements are present in milligram and microgram quantities. Trace elements include iron, copper, zinc, iodine, selenium, chromium, and iodine (Lutz et al., 2015). Trace elements are active in almost all enzymes as co-factors and co-enzymes for vitamins (Shenkin, 2006).

They are necessary for the maintenance of metabolism. Deficiency of trace elements may lead to a decrease in vitamin levels (Shenkin, 2006).

Absorption of Micronutrients in the Digestive Tract

The human digestive system is a series of organs that convert food into essential nutrients for absorption in the body and move unused waste material out of the body (Sanders & Scanlon, 2015). The primary function of the gastrointestinal tract is water, electrolyte, and nutrient transport (Pandol, Raybould, & Yeu, 2016). The esophagus guides food from the mouth down to the stomach where it is stored. The stomach is both a storage space, holding as much as a quart and a half of ingested food, and a secretory organ that produces the gastric acid necessary for digestion (Pandol et al., 2016). The stomach does not absorb food. The stomach uses peristalsis to empty food gradually into the duodenum, the first section of the small intestine (Barrett, 2014). The small intestine consists of three sections: the duodenum, the jejunum, and the ileum (Pandol et al., 2016). In these three organs, digestive secretions mix with food and the nutrients are absorbed into the blood stream (Pandol et al., 2016). Food, bile, enzymes, and liquids brought together in the duodenum pass into the jejunum (Valentino et al., 2011). The jejunum or second portion of the small intestine is approximately eight feet long (Sanders & Scanlon, 2015). It lies immediately behind the duodenum and continues the process of digestion, breaking down food into essential elements (Sanders & Scanlon, 2015). The ileum is the third portion of the small intestine and about 11 feet long. The ileum is the major part of the absorption of food products. Waste products from digestive process continue from the small intestine into the large intestine where they are stored or evacuated.

Micronutrients are absorbed in the small intestine (Tucker et al., 2007). Smaller sites of absorption are the stomach and large intestines (Barrett, 2014). The small intestine anatomy is designed for absorption. Membranes covered with epithelial cells have layers of microvilli for absorption (Lutz et al., 2015). The small intestines are highly vascularized to facilitate transport of nutrients from the epithelium to the blood (Lutz et al., 2015).

Water-soluble vitamins dissolve easily in water. Water- soluble vitamins include B1 (thiamine), B2 (riboflavin), B3 (niacin), biotin, pantothenic acid, B6, B12 (cobalamin), folate, and vitamin C (ascorbate). Most water-soluble vitamins are absorbed by simple diffusion if taken in sufficiently high doses except for vitamin B12 (Tucker et al., 2007). Absorption occurs in the duodenum and proximal small bowel of the jejunum (Sawaya et al., 2012). Vitamin B12 is bound to protein and food. The vitamin is cleaved from protein by the actions of gastric acid and pepsin in the stomach. It then binds to intrinsic factor before being absorbed in the terminal ileum (Barrette, 2014).

Fat-soluble vitamins, A, D, E, and K diffuse across the brush border plasma membrane of the intestinal epithelial cells (Barrette, 2014). They require lipid carriers, bile salts, and fat for absorption (Lutz et al., 2015). Most fat-soluble vitamin absorption occurs in the proximal two-thirds of the jejunum, although absorption can take place anywhere in the small intestine (Tucker et al., 2007).

Essential minerals and trace elements are absorbed in the small intestine (Sawaya et al., 2012). Mineral absorption is more complicated and involves multiple phases. Minerals require specific carriers for chemical reactions in the stomach and intestine. Absorption occurs across the intestinal cells of the mucosal membrane. They are stored or carried to intestinal cells into the blood stream. Calcium is absorbed primarily in the duodenum and proximal jejunum by an active saturation process mediated by vitamin D.

Micronutrient Deficiency in Bariatric Surgery

Preoperative Nutritional Status in Bariatric Patients

Obese individuals can have micronutrient deficiencies, even though obesity is a disease of macronutrient excess. Studies of extreme obesity in adults prior to bariatric surgery have identified pre-existing nutritional deficiencies. If not detected and treated, pre-existing deficiencies persist after surgery and are associated with higher post-operative complications (Valentino, Sriram, & Shankar, 2011). In morbidly obese candidates for bariatric surgery the highest prevalence of deficiencies is iron, ferritin, folic acid, and vitamin D (Schweiger, Weiss, Berry, & Keidar, 2010). Often, more deficiencies are observed as BMI increases (Schweiger et al., 2010).

Low vitamin concentrations can be caused by dietary and lifestyle habits, abnormal body composition, systematic inflammation, and chronic disease (Aasheim et al., 2009). An increase in obesity has been observed in individuals with increased consumption of snacks, caloric drinks, and fast foods that are low nutrient, and calorie dense. Higher fat diets (>30% of total caloric intake) are associated with decreased intake of vitamins A and C and folate (Kaidar-Person, Person, Szonsteim, & Rosenthal, 2008). Patients eligible for bariatric surgery may not be outwardly symptomatic for micronutrient deficiencies. Therefore, a thorough preoperative nutritional assessment is indicated. Bariatric clinical practice guidelines from the AACE recommend a nutrient screening that includes iron, B12, folic acid, vitamin D, and a clinical nutrition evaluation (Mechanick et al., 2013).

Postoperative Nutritional Status of Bariatric Patients

Bariatric surgery accomplishes weight loss by altering the anatomy of the gastrointestinal tract. There are two mechanisms for alteration of the gastrointestinal tract: 1) the reduction of the capacity of the stomach; and/or, 2) bypassing regions of the small intestine to decrease energy absorption (Tucker et al., 2007). Procedures may use one or both approaches. The most commonly performed procedures in the United States, as identified by the ASMBS, are the laparoscopic adjustable gastric band (LAGB) and laparoscopic gastric sleeve (LGS), which are restrictive procedures, and Roux-en-Y gastric bypass (LRenY) which is a combination procedure (n.d.). A fourth procedure, biliopancreatic diversion with or without duodenal switch (LBPD-DS), is reserved for extremely obese patients (ASMBS, n.d.). Reported micronutrient deficiencies occurring in all procedures one year after bariatric surgery include iron deficiency, vitamin B12, folate, and vitamin D (Toh, Zarshenas, & Jorgensen, 2009).

Restrictive procedures. In LAGB, instead of cutting the stomach and/or intestine, a gastric band divides the stomach into a small upper pouch above the band and a larger pouch below the band (ASMBS, n.d.) (Figure 2). It is the simplest of the procedures and has a low perioperative risk (Diabetes Care, 2015). The band is adjustable for tightening or reversing. The LGS removes approximately 60% of the stomach, creating a tube or “sleeve” (ASMBS, n.d.) (Figure 3). This restricts the amount of food intake at one given time. This procedure reduces the size of the stomach by 85% and the secretion of ghrelin, a hormone associated with increased intake and stimulation of appetite (Diabetes Care, 2015). Both procedures are not associated with malabsorption because the stomach, duodenum, and small bowel are intact.

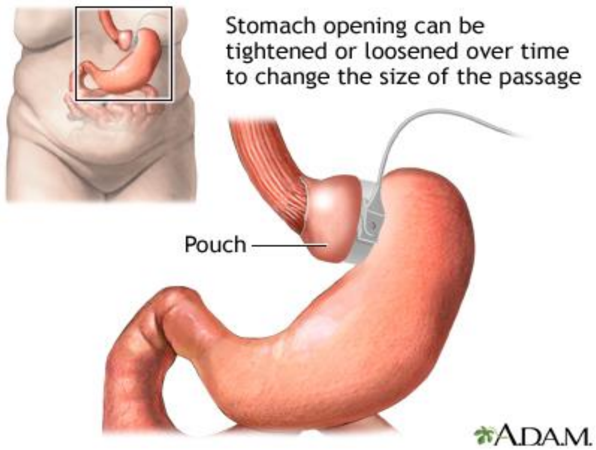

FIGURE 2. Laparoscopic adjustable gastric banding. (Source: Cleveland Clinic, 2016.) *"Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2014. All Rights Reserved."*

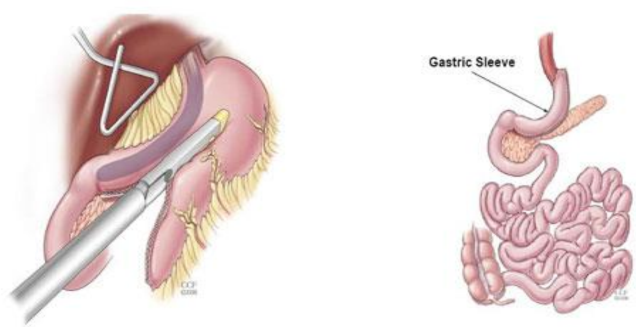

FIGURE 3. Gastric sleeve. (Source: Cleveland Clinic, 2016). *"Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2014. All Rights Reserved."*

Nutritional deficiencies are not common but may result from a decrease in caloric intake and food intolerance, such as meat and leafy green vegetables, leading to B12 and folate deficiency (Tucker, Szomstein, & Rosenthal, 2007). Vitamin D deficiency may occur with rapid weight loss (Koch & Finelli, 2010). The LGS has been associated with iron deficiency and secondary hyperthyroidism in the first post-operative year (Aarts, Jansen, & Berends, 2011).

Malabsorptive procedures. Malabsorptive and combination procedures are associated with a higher risk of nutritional disorders. Micronutrient deficiencies are most common in patients who undergo Roux-En-Y gastric bypass and biliopancreatic diversion with or without duodenal switch. Combined procedures with bypass limit the amount of food intake and alter the flow and absorption of micronutrients in the GI tract. “The nutrient deficiency is proportional to the length of the absorptive area and to the percentage of weight loss” (Alvarez-Leite, 2004, p. 569). The mixing of gastric acid, pancreatic enzymes, bile, and food in the optimal position for micronutrient absorption is essential (Valentino et al., 2011).

The standard RYGP procedure, involves connecting the jejunum to a small pouch, created at the proximal portion of the stomach, with a capacity of 15 mL to 30 mL (Baker, 2011) (Figure 4). “This causes cessation of nutrient exposure to the mucosa of the bypassed upper GI tract, resulting in rapid entry of nutrients into the jejunum and a distal shifting of the site of digestion and nutrient absorption” (Diabetes Care, 2015, p. 1574). The amount of small intestine bypassed in the standard procedure does not cause macronutrient malabsorption. However, the bypassed portion of the small intestine is where most iron and calcium absorption takes place, which can result in long-term complications such as anemia and osteoporosis.

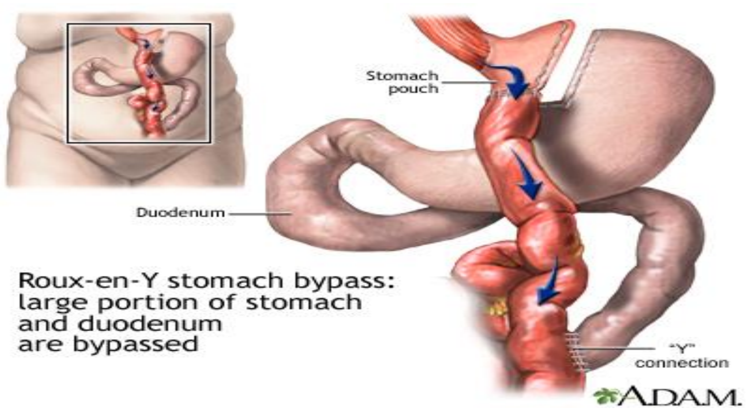

FIGURE 4. Roux-en-Y stomach bypass. (Source: Cleveland Clinic:2016). *“Reprinted with permission, Cleveland Clinic Center for Medical Art & Photography © 2014. All Rights Reserved."*

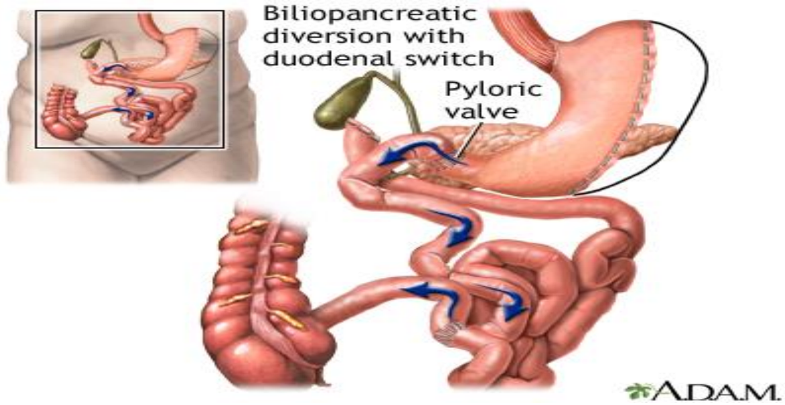

FIGURE 5. Biliopancreatic diversion with duodenal switch. (Source: Cleveland Clinic, 2016).

The biliopancreatic diversion (BPD) procedure results in weight loss through significant malabsorption of nutrients by removing 70% of the stomach and creating a much shorter anastomosis of the small intestine than the RYGB procedure (Baker, 2011) (Figure 5). The post-operation stomach produces significantly less gastric acid. The duodenal switch (DS) is a modification of BPD in which the stomach is fashioned into a small tube, preserving the pylorus (Baker, 2011). Then a lengthy portion of the duodenum is re-routed to create two separate pathways and one common channel. The digestive loop, the shorter of the two pathways, moves chime (partially digested food) from the stomach to the common channel. The longer biliopancreatic loop carries bile from the liver to the common channel. The common channel consists of 75 cm to 150 cm of the small intestine, in which the chime mixes with the bile before emptying into the colon. This reduces the amount of time the body needs to gain energy from the chime in the small intestine and limits fat absorption. Although it is superior for weight loss, the procedure is associated with short- and long-term complications (Pories, Mehaffey, & Staton, 2011).

Anemia can occur in the late post-operative period due to iron, folate, and vitamin B12 deficiencies. Vitamin B12 deficiency from malabsorptive procedures is due to bypass of the duodenum, decreased contact time with the terminal ileum, and intolerance of red meats after bariatric surgery (Mariella, 2008). Under normal conditions, vitamin B12 is released from animal protein sources by hydrochloric acid and pepsin in the stomach. After gastric bypass, the pouch does not produce sufficient hydrochloric acid and/or pepsin to cleave B12 from ingested protein. Decreased stomach acid and bypass of the duodenal and jejunum can also result in iron malabsorption (Koch & Finelli, 2010). Iron deficiency may also occur from intolerance and reduced intake of meat (Sawaya et al., 2012). Folate deficiency after malabsorptive procedures is due to lack of intake, B12 deficiency, and bypass of the intestinal absorption site (Shankar, Boylan, & Sriram, 2010). Folate is efficiently absorbed in the jejunum; however, if folate is not continuously supplemented, malabsorption and short bowel problems that result from gastric bypass can result in deficiency. Bile salt malabsorption causes steatorrhea that can result in deficiencies of fat-soluble vitamins (Koch & Finelli, 2010). Vitamin A and D deficiency and iron can occur from bile salt deficiency and with rapid weight loss (Koch & Finelli, 2010). "Multiple prospective case series after RYGB and BPD/DS estimate that over 50% of post-operative patients develop low levels of vitamin D and 25 - 50% develop hypocalcemia" (Sawaya et al., 2012, p 1349).

Compliance with Post-Surgical Recommendations

Weight loss is certain after bariatric surgery; however, patient compliance with post-surgical recommendations is necessary to optimize outcomes and prevent complications. After bariatric surgery, patients need to modify eating behavior. Procedures require reduced food volume consumed and a slow pace of eating with thorough chewing of food (Tucker et al., 2007). Failure to modify eating behavior can lead to obstruction, discomfort, and vomiting. Often red meat and poultry are not tolerated after restrictive procedures. The RYGB requires ground or pureed animal protein. Reduced protein intake can lead to micronutrient deficiencies of iron, folate, and calcium. Patients often return to previous unhealthy eating patterns of high-energy dense foods, binge eating, and decreased attentiveness that can lead to complications and micronutrient deficiency (Kushner, 2011). Snacking is the most common food non-compliance issue. In a retrospective study of behavioral compliance in bariatric surgery patients, 57% of patients were not following diet recommendations or taking prescribed supplements within two years after surgery (Toussi, Fujioka, & Coleman, 2009). In the same study, 72% of patients missed follow up physician appointments.

Summary

Surgical procedures for weight loss include the use of restriction of food intake by a limited small gastric pouch or reservoir, and the use of malabsorption for reducing the length of intestine available for nutrient absorption, or a combination of both techniques. Modification of the gastrointestinal tract affects absorption and may cause micronutrient deficiency. Micronutrients are essential nutrients that are required in very small quantities (milligrams or micrograms). They include vitamins, minerals, and trace elements. The severity of micronutrient deficits in bariatric surgery patients are dependent on multiple factors. This is illustrated in the conceptual framework. The primary variable is the type of surgery. Malabsorptive procedures are surgically complex and associated with long term complications. Both food intake and absorption are altered and reduced. Micronutrient deficiency risks can be increased by pre-operative deficiency and post-operative non-compliance. Life-long follow up screening and treatment care prevent complications from unrecognized micronutrient deficiencies and improve quality of life.

METHODS

The following sections provide a detailed outline of the steps completed while performing this systematic review. The steps to performing a systematic review are to: formulate a problem, establish inclusion criteria, develop and perform the search, select articles to be included, extract data, synthesize data, and establish recommendations for practice (Holly et al., 2012). The objectives of the systematic review were to: locate quality research articles on the relationship between micronutrient deficiencies and bariatric procedures; assess this relationship; compare the incidence of micronutrient deficiency across bariatric surgeries; and develop clinical guidelines for APRNs to screen bariatric patients and diagnose micronutrient deficiencies in patients.

Systematic review is a component of the evidence-based practice process. “A systematic review is a literature review that is designed to locate, appraise, and synthesize the best available evidence relating to a specific research question to provide informative and evidence-based answers” (Boland, Cherry, & Dickson, 2014, p. 3). Systematic reviews follow defined and transparent steps. The Cochrane Handbook identifies key characteristics: “a clearly stated set of objectives with pre-defined eligibility criteria for studies; an explicit, reproducible methodology; systematic search that attempts to identify all studies that would meet the eligibility criteria; an assessment of the validity of the findings of included studies, for example through the assessment of risk of bias; and a systematic presentation, and synthesis, of the characteristics and findings of the included studies" (Higgins & Green, 2009, p. 6).

Step 1. Problem Formulation

The PICOT question is a format for developing a research question that is answerable and focuses the process of finding and evaluating evidence (Moran, 2014). PICOT is an acronym for patient population (P), intervention or issue of importance (I), comparison intervention or issue of importance (C), outcomes (O), and time (T) (White & Dudley-Brown, 2012).

The PICOT question assists in the development of the "foreground question" (Melnyk & Fineout-Overholt, 2011). Formulating PICOT questions in a structured, specific way, assists the clinician in finding the right evidence to answer questions and to decrease uncertainty (Melnyk & Fineout-Overholt, 2011). The PICOT question format guides the search of evidence using the question components (White & Dudley-Brown, 2012). Components of the background question were used to organize the PICOT format (Table 2).

TABLE 2. *PICOT question components*.

Population	**Intervention**	**Comparison**	**Outcome**	**Time**
Adults >18 years of age	Bariatric Surgery	Surgical Procedures	Micronutrient Deficiency	1 year or more

The formulated PICOT question became: *Are adult patients greater than 18 years of age, who have different bariatric surgery procedures, at risk for micronutrient deficiency one year or more after surgery?*

Step 2. Establishing the Inclusion Criteria

In order to perform a systematic review, eligibility criteria should be established to identify relevant research (Meline, 2006). The inclusion and exclusion criteria determine boundaries for research articles selected for the review. Criteria address study type, population, disease or conditions of interest, setting, intervention, and outcomes (Holly, et al., 2012). Defining inclusion criteria before beginning the review makes a systematic review: systematic, transparent, and reduces the risk of bias (Bettany-Saltikov, 2012).

The *Cochrane Handbook for Systemic Review of Interventions* identifies that randomized trials should be used for systematic reviews of medical interventions (Higgins & Green, 2009). However, randomized controlled studies may not be available due to practical or ethical limitations. A pluralistic approach, described by the Joanna Briggs Institute (JBI), suggests inclusion of non-randomized studies with experimental design (Joanna Briggs Institute, 2014). Due to the nature of this systematic review, the JBI approach was adopted for this systematic review. All studies that met the following inclusion criteria were retained in this systematic review:

Inclusion: For this systematic review, the study's populations needed to include: males and non-pregnant female adults $\geq$ 18 years old who were $\geq$ 1 year post bariatric surgery. The types of bariatric surgery included: Laparoscopic adjustable gastric band (LAGB), laparoscopic gastric sleeve (LGS), Roux-en-Y gastric bypass (LRenY), and biliopancreatic diversion with duodenal switch (LBPD-DS). All studies also needed to contain one of the following outcomes associated with bariatric surgery: vitamin deficiencies (water or fat soluble), mineral deficiencies, or trace element deficiencies. Study designs for inclusion were: randomized controlled trials, non-randomized controlled trials, pre and post studies, interrupted-time series study, historically controlled, cohort, case-series, and case-control studies. All studies must have been written in English and published in peer-reviewed journals.

Exclusion: Studies that included pregnant woman, children and/or adolescents, only included patients with type 2 diabetes or whose outcomes were assessed under one year were excluded. Studies were also excluded if they were found in grey literature, conference proceedings, commentaries, review documents, were case studies, and/or qualitative studies.

Step 3. Developing and Performing the Search

The first step of performing the systematic review is to conduct a detailed literature search. The validity of the systematic review — and the resulting EBP guidelines — is dependent on performing a conscientious search and identifying all relevant studies (Bettany-Saltikov, 2010). This systematic review employed a three-step strategy to identify relevant studies (Holly et al., 2012). The first step involved a limited search of MEDLINE, followed by an analysis of the title and abstract for key words that were added to the list of search terms. Next, more databases were searched using all identified key words. Finally, the references of all articles were hand searched for additional studies not identified in the initial search. The IOM (2011) recommends that a librarian assist with the design of the search strategy to ensure appropriate translation across search concepts. Therefore, all searches were conducted by a research librarian. Detailed records of the search strategy were documented.

Databases Searched

Studies published between January 1, 2008 and May 16, 2017 were selected by searching MEDLINE, CINAHL, Cochrane Library, Web of Science, and Embase. A wide variety of databases were searched from different disciplines in order to obtain all relevant research. Because the search included multiple databases, duplicate articles were expected and were removed.

Search Terms

The search strategy used elements of the PICOT question to provide the basis for the search terms (Bettany-Saltikov, 2012). A broad range of synonymous keywords that focused on bariatric surgery and micronutrient deficiencies were used to search each database. Keywords were first established in PubMed and then formatted to individual databases in an attempt to find a range of articles from a variety of different fields. The initial search combined basic terms and synonyms linked with and or with or (Table 3 - initial search terms). Additional searches included the synonym terms and MeSH terms. Search terms linked to MeSH terminology were accessed to develop search strings (Table 4 - MeSH terms). The following MeSH terms were used: bariatric surgery (all fields), trace elements, micronutrients, micronutrient deficiency, mineral, mineral deficiency, vitamins, and vitamin deficiency. Filters used for all searches were human, English, greater than 18 years of age, and not pregnant.

TABLE 3. *Initial search strategy.*

1.	Bariatric Surgery
2.	Weight loss surgery
3.	Obesity surgery
4.	Micronutrient Deficiency
5.	Micronutrient
6.	Calcium
7.	Vitamin
8.	Vitamin Deficiency
9.	Mineral
10.	Mineral Deficiency
11.	Vitamin D
12.	Calcium
13.	Iron
14.	B12
15.	Vitamin A
16.	Vitamin K
17.	Zinc
18.	Nutrient Absorption
19.	Gastric Band
20.	Adjustable Gastric Band
21.	Laparoscopic Adjustable Gastric Band

TABLE 3. – *Continued*

22.	Gastric Bypass
23.	Roux- En-Y Gastric Bypass
24.	Laparoscopic Gastric Bypass
25.	Gastric Sleeve
26.	Sleeve gastrectomy
27.	Laparoscopic gastric sleeve
28.	Duodenal Switch
29.	Sleeve Gastrectomy with duodenal switch
30.	Treatment of micronutrient deficiency
31.	Nutrient Supplementation
32.	Vitamin supplements
33.	Mineral supplements
34.	Diagnosis of micronutrient deficiency
35.	Diagnosis of vitamin deficiency
36.	Diagnosis of mineral deficiency
37.	Treatment of vitamin Deficiency
38.	Treatment of mineral deficiency

TABLE 4. *Database terminology and MeSH categories.*

Population	Intervention	Comparison	Outcome	Period
Adults > 18 year of age	Bariatric surgery	Surgical Procedures: Gastric Band Gastric Bypass Gastric Sleeve Duodenal Switch MeSH Terms: Gastric Bypass, Bariatric Surgery	Micronutrient Deficiency Vitamin Mineral MeSH Terms: Micronutrients/Deficiency Dietary Supplements	One year or more after surgery

Step 4. Selecting Articles to be Included in the Systematic Review

"The search process generates a bibliography of candidate studies that typically include titles and abstracts of potentially relevant studies" (Meline, 2006, p. 25). All articles identified using the predetermined search terms were extracted from the databases and the bibliographic software package EndNote (Version 8) computer software was used to remove duplicates and store search results. Titles and abstracts of identified studies were screened to assess their eligibility for inclusion in the review, using a predetermined extraction list (Table 5). Only studies with human subjects published in English that met the initial inclusion criteria were retained for further review. Finally, the potentially eligible articles were assessed for final inclusion. In the final stage of the selection process, articles that met all other inclusion criteria were screened for study quality.

TABLE 5**.** *Predetermined extraction list.*

Study Information
Study #
Year of Study
Age > 18
Language
Bariatric Procedure
Micronutrient
Period After Surgery
Study Design
Population
Inclusion, Exclusion, Undecided

Step 5. Data Extraction

Data extraction is the process of collecting information about the study characteristics and results. Relevant data are obtained from individual studies and stored on a single data extraction form (Boland et al., 2014), which was adapted to the research question. Data extraction forms standardize the process and improve the validity of results (Bettany-Saltikov, 2012). The extraction form needs to address bibliographic details of the study, purpose, study design, and the PICOT information.

For this systematic review, a data form was piloted to ensure relevant data were captured. The following data were extracted: study record number; year of publication; author; title; study funder; study design; sample characteristics; population characteristics; bariatric surgical procedure; time interval after surgery; micronutrient deficiency; study outcomes; recommendations; and limitations. Any discrepancies were resolved.

Step 6. Study Quality and Critical Appraisal

Critical appraisal of individual studies provides "confidence that both design and conduct are sufficiently robust for the results to be trustworthy and generalizable" (Boland et al., 2014, p. 64). Quality refers to the grading of individual studies for scientific process across all aspects of the study. It includes the methodological demonstration of internal and external validity (Bettany-Saltikov, 2012). "An expanded view holds that quality concerns the extent to which a study's design, conduct, and analysis have minimized biases in selecting subjects and measuring both outcomes and differences in the study groups" (Berkman et al., 2004, p. 12). Quality research provides the standard for validity and is the precursor of quality evidence. Critical appraisal tools are available and can provide a structured approach for assessing quality and relevance. Appraisal tools are available for specific types of research, rather than research questions (Gough et al., 2012).

The IOM (2011) identifies the following standards and elements for critical appraisal: "systematically assess the risk of bias, use predefined criteria, assess relevance to the study's populations, interventions, and outcome measures, and assess the fidelity of the implementation of interventions" (IOM, 2011, p. 277). Internal validity determines the quality of the study methodology and "the degree to which the trial design, conduct, analysis, and presentation have minimized or avoided bias" (Bettany-Saltikov, 2012, p. 91). Internal validity is the prerequisite for external validity. External validity refers to the application of the study results to a larger population (Bettany-Saltikov, 2012). The evaluation of external validity addresses relevance of research evidence for generalizability to practice, populations, and settings. External validity focuses on whether a relationship exists. External validity assesses the connection between the highly controlled experimental study environments and explores the data's relevance and adaptation to a practice environment.

Hierarchical rating systems are used to quantify study quality (Holly et al., 2012) and minimize the possibility of bias (National Health and Medical Research Council [NHMRC], 2009). The NHMRC in Australia identified meta-analyses of random control trials and randomized controlled studies as the top levels for determination of strength of evidence. The NHMRC Evidence Hierarchy was used for this review (Appendix A). Additionally, all studies retained in this systematic review were assessed for study quality using the following critical appraisal tool.

Critical Appraisal Tool

The critical appraisal standardizes the review of individual studies "to minimize bias and base conclusions on the highest quality of evidence" (Glasziou et al., 2001, p. 27). "The most important components of the critical appraisal are an evaluation of the appropriateness of the study design for the research question and a careful assessment of the key methodological features of this design" (Young & Solomon, 2009, p. 1). The Critical Appraisal Skills Programme (CASP) tools address methodological quality of studies for validity and generalizability. The tools provide checklists for a structured approach to screen the studies (CASP, 2013). The CASP is a training organization who provides resources, learning modules, and tools for guided critical appraisal. The tools, available on the website, address the internal validity, results, application of results, and external validity of research (CASP, 2013). They are free to download and use.

CASP tools are formatted into checklists for the following study designs: randomized controlled trials, systematic reviews, and cohort and case control studies. Each tool has questions assessing three steps for study evaluation: validity and bias; results; and how the results apply to the research question. The CASP tool questions are ordered numerically and answered by yes/no/do not know. In this systematic review, studies that were included in the final review were appraised using an adaptation of individual CASP appraisal tools per study design.

The CASP checklists used in this review were: systematic reviews, randomized controlled trials, cohort studies, and case control studies. The tools consist of 10 to 12 questions, within three sections, to direct evaluation of internal validity, results, and the clinical importance of results. The first two questions of the CASP tool address the validity of trial. If the answers to both questions were 'yes,' the study was included for full review. The last question in the tool decides if the results are valid — that is, if the evidence supports the review question. If the last question was 'yes,' the study was included in the final review. Study appraisals were documented.

Some studies were excluded based on the critical appraisal. For example, if the study sample was small (less than 10), if the study sample size cannot be determined, or if there were high rates of attrition in long term follow up studies.

Step 7. Data Synthesis

All information extracted from relevant articles must be synthesized in order to provide a complete picture of the relevant research information. For the purpose of this systematic review, data were synthesized in two ways: quantitatively and narratively.

Quantitative Synthesis

Quantitative synthesis refers to collating, combining, and summarizing the systematic review data (IOM, 2011). Quantitative synthesis categorizes individual studies into similar groups to interpret the findings in relation to the review question. The results from the critical appraisal of individual research studies were analyzed, merged, and summarized in an organized and meaningful format. The synthesis organized groups and findings into tables and charts for easy comparison. Studies were synthesized based on the following elements:

1. Developing an initial description of the results of the included studies by: extracting descriptions, highlighting key features of each article, comparing key features of each article, and grouping patterns of related outcomes via thematic analysis to identify ranges of factors across the included articles;
2. Identifying whether a relationship was found between type of bariatric surgery and micronutrient deficiencies;
3. Assessing the relationships of the data; and
4. Assessing the robustness of the synthesis by creating conclusions about the synthesis results and generalizability (Popay, Britton, Rodgers, & Roen, 2006).

Narrative Synthesis

Narrative synthesis describes the results of the review using words to summarize and explain findings of the synthesis (Bettany-Saltikov, 2012). In this systematic review, information provided in the included articles were combined to provide a descriptive summary of the characteristics, of major findings, and results of the included articles. Qualitative data are presented in a narrative form that include study characteristics, risk of bias within studies, and results from individual studies (Moher et al., 2009). Summaries are related back to the research questions. All key findings of the quantitative synthesis are presented as a narrative synthesis in the results chapter.

Guidelines

The outcome of this systematic review was to develop evidence-based guidelines to assess micronutrient deficiency associated with individual bariatric procedures in a primary care setting. “Credible guidelines provide linkages to the scientific evidence” (Holly et al., 2012, p. 272). Guidelines support implementation of evidence into practice and assist practitioner’s decisions for appropriate health care (Holly et al., 2012). “When rigorously developed, they have the power to translate the complexity of scientific research findings into recommendations for clinical practice, and potentially enhance healthcare quality and outcomes” (Graham, Mancher, Wolman, Greenfield, & Steinberg, 2011, p. 1). Evidence-based guidelines are not algorithmic and do not replace clinical skill or critical thinking (Holly et al., 2012). Guidelines allow for flexibility in patient-care decisions (Dunphy et al., 2007). The guidelines from this systematic review were intended to provide general direction for decision-making.

Summary

This methodology chapter described the steps undertaken while conducting a systematic review of micronutrient deficiency ≥ 1 year post-op bariatric surgery to support EBP for clinical practice guidelines. In order to increase transparency and replicability of the systematic review, the methods were laid out in a detailed fashion. This should allow for future researchers to replicate the methodology as more research is conducted. This chapter also provides the framework for the results and discussion.

RESULTS

This section will discuss the results of the systematic review. This systematic review aimed to answer the question: *Are adult patients greater than 18 years of age, who have different bariatric surgery procedures, at risk for micronutrient deficiency one year or more after surgery?*

Literature Search

The number of articles comparing the MeSH category bariatric surgery (unrefined) and bariatric surgery combined with filters and combination MeSH terms for micronutrient deficiency (refined) were quantified (Figure 6). The unrefined search resulted in 25,963 articles indexed under the MeSH term bariatric surgery. The refined search using the search criteria outlined in the methods yielded 4,165 articles of which 1,056 were unique, non-duplicated studies. Only the refined search results were assessed for study inclusion.

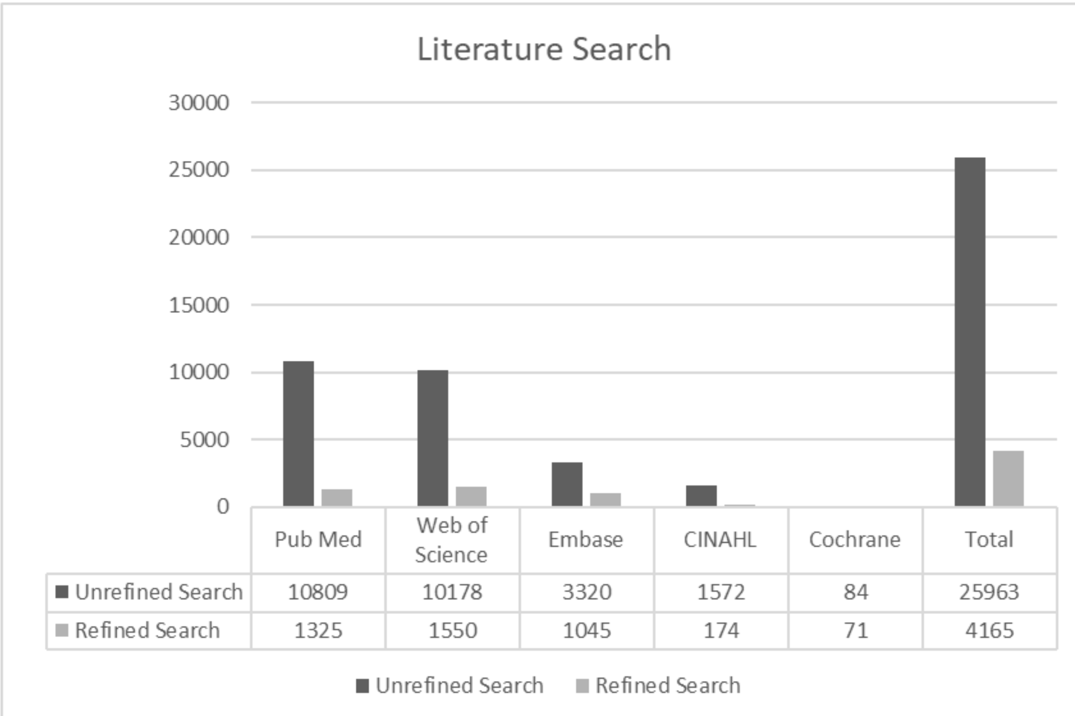

FIGURE 6. Summary of studies by database, reported by search type.

Based on titles and abstracts, 911 studies were excluded. Reason for exclusion included: results presented in the study were < one year after bariatric surgery (n=597); study outcomes were not related to micronutrient deficiency (n=362); the study included patients <18 years of age (n=72) or included women who were pregnant (n=29); the studies were published outside of the dates set in the inclusion parameters (n=14); or the paper was not published in English (n=3) Duplicate studies with multiple publications were also removed (Figure 7).

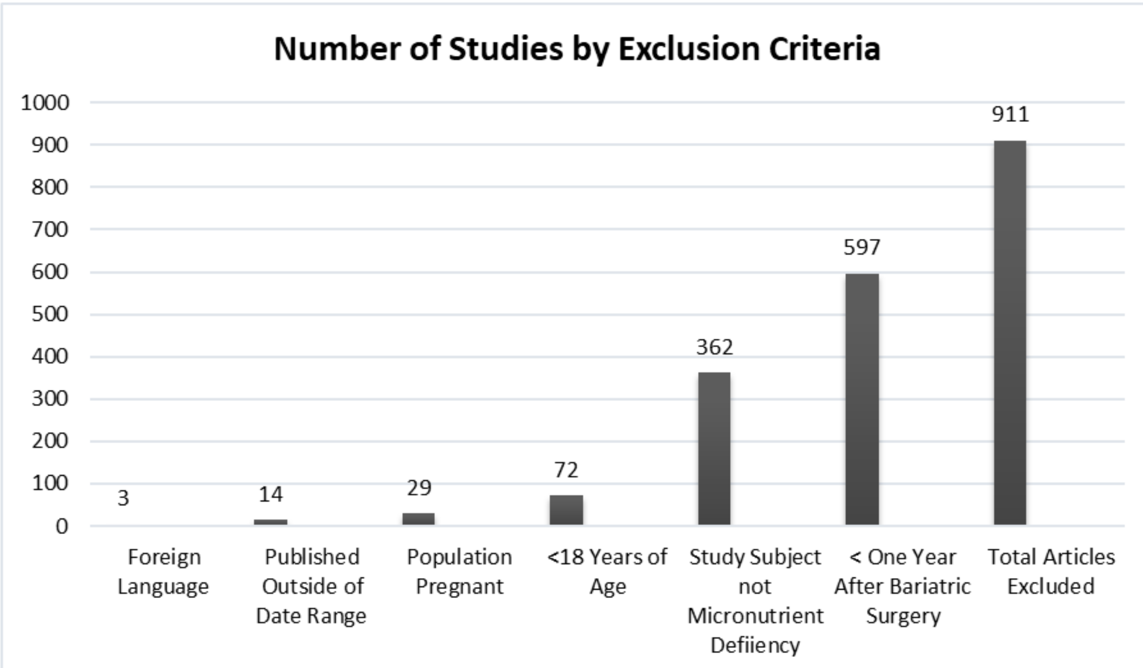

*FIGURE 7. S*ummary of studies by exclusion criteria. (Results from first step literature review.)

In total, 145 full text articles were screened for study inclusion, of which, 89 were excluded based on the exclusion criteria. The reasons for exclusion of the articles were: the study design was a case study (n=10), commentary (n=5), or review (n=9); the outcomes were less than 12 months from time of surgery or the time period was not defined (n=5); study outcomes did not include micronutrients (n=8); or the procedure was not laparoscopic, or the procedure limited to type 2 diabetes patients (n=52) (Table 6). There were 56 articles that were retained for critical appraisal.

TABLE 6. *Exclusion summary for second step literature review.*

Criteria for Exclusion	**Number of Articles**
Case Studies	10
Commentaries	5
Reviews	9
Less than 12 months from time of surgery or period not defined	5
Article not on micronutrients	8
Other: Procedure not laparoscopic, micronutrients not focus of article, procedure limited to type 2 diabetes patients	52
Total	89

Critical Appraisal Review

All 56 articles that met inclusion criteria were retained for critical appraisal review. The critical appraisal standardized the review of individual studies "to minimize bias and base conclusions on the highest quality of evidence" (Glasziou et al., 2001, p. 27). In total 24 articles were excluded based on the critical appraisal using the CASP tools. Table 7 provides a summary of reasons for exclusion of studies after critical appraisal. Most studies were excluded because they focused on topics other than micronutrient deficiency (n=6). Studies were excluded because they did not meet the screening questions for the review focus: the study population was solely individuals with type 2 diabetes (n=1); and the procedure was outside of the inclusion criteria (n=1). Studies that did not demonstrate statistical analysis to control factors such as dose of supplements or the presence of micronutrient deficiency before the surgical procedure were excluded (n=8). Other reasons for exclusion included: selection and attrition bias, small study sample size, less than 10 (n=4); large sample attrition (n=1), Three studies were excluded due to unclear results of patients <1 year post-op were not separated from results ≥1 year post-operative (n=1); results between identified cohorts could not be separated from each other (n=1); incomplete results. Citations for articles excluded during critical review are documented in Appendix C.

TABLE 7. *Reasons for exclusion after critical appraisal by research design.*

Type of Study	**Reason for Exclusion**	**Number of Studies (N=24)**
Systematic Review	Did not separate results for greater than 12 months	1
Randomized Control Trial	Study data related to micronutrients incomplete	1
	Focus of study not micronutrients	1
Comparative	Subjects with type 2 diabetes, limited application	1
	Small sample	2
	Focus of study not micronutrients	3
	Results between cohorts could not be separated	1
	Large sample attrition	1

TABLE 7. – *Continued*

Type of Study	Reason for Exclusion	Number of Studies (N=24)
Comparative (Cont.)	Incomplete methodology to address confounding variables	7
	Procedure outside of inclusion criteria	1
Case Series	Focus of study not micronutrients	2
	Incomplete methodology to address confounding variables	1
	Small samples	2

Note: Reasons for exclusion after critical appraisal by type of research design according to NHMRC Evidence Hierarchy (NHMRC, 2009). Studies excluded for insufficient methodology to address confounding variables and primary focus of study not micronutrients were the most common exclusions.

After critical appraisal, 32 articles met the full inclusion criteria and were retained for this systematic review.

The Prisma Flow Diagram is a graphical representation of the search of information, diagraming the numbers of articles identified, included and excluded, and the reasons for exclusions (Moher et al., 2009). After critical appraisal, 32 articles remained for final inclusion. Figure 8 is the completed Prisma Flow Diagram for the systematic review

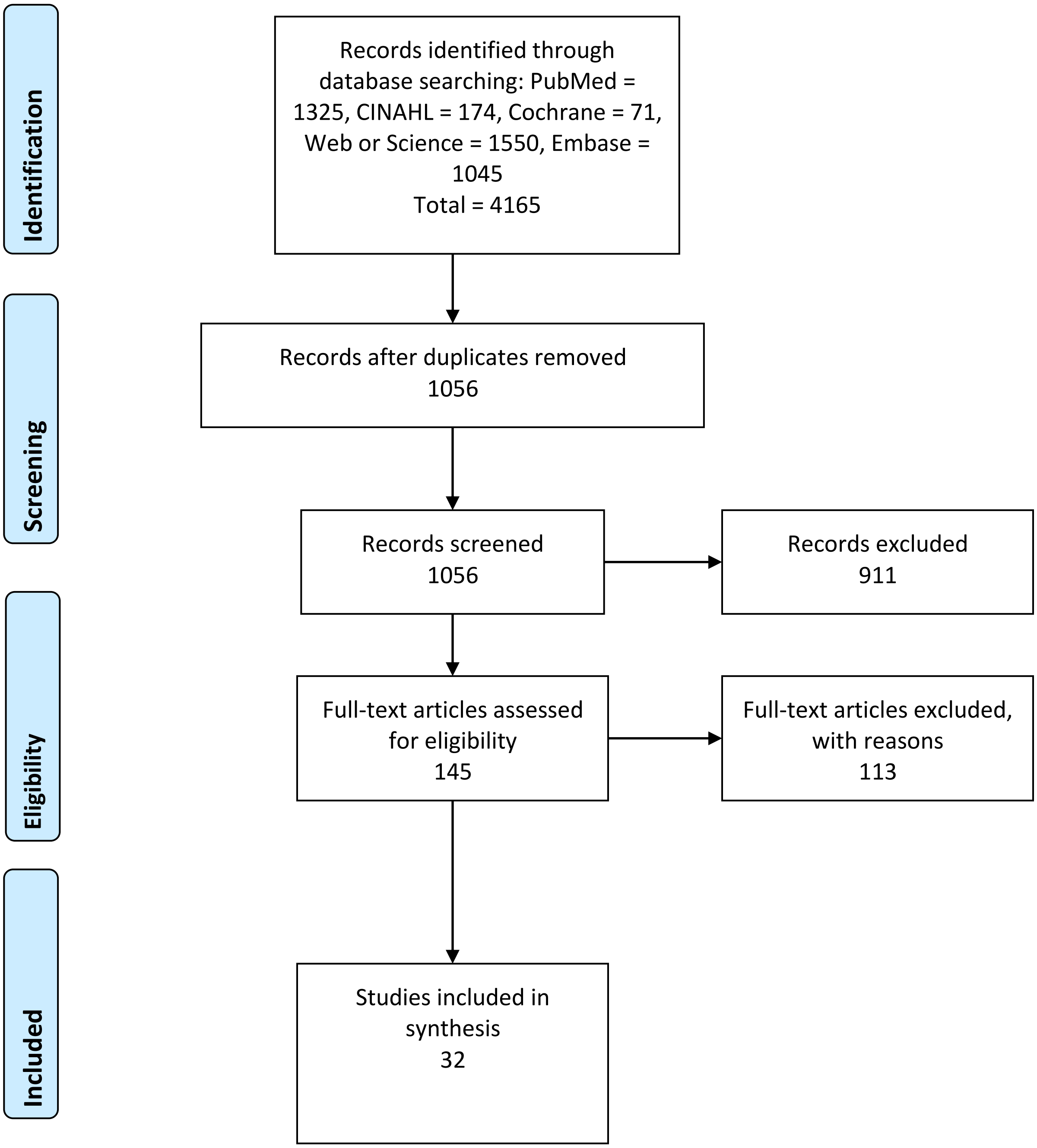

FIGURE 8. Prisma flow diagram. (Number of studies identified, excluded, and remaining from literature search and critical appraisal displayed in the Prisma Flow Diagram.)

Study Characteristics

In total, 32 articles were included in the final review. The number of studies that met this strict inclusion criterion ranged from one to seven from 2008 to 2016 (Table 8).

TABLE 8. *Number of studies by year.*

Year Published	Number of Studies (N=32)
2008	1
2009	1
2010	3
2011	4
2012	5
2013	1
2014	3
2015	7
2016	7

Of the 32 articles included, 16 unique countries were represented**.** Six articles were from the United States (USA), five from Spain, four from the United Kingdom (UK), three from Brazil, two from Denmark and France, and one from the following countries: Australia, Belgium, Denmark, Greece, Korea, Netherlands, Norway, Saudi Arabia, Sweden, and Switzerland (Table 9).

TABLE 9. *Number of studies by country.*

Country of Origin	Number of Studies (N=32)
Australia	1
Belgium	1
Brazil	3
Chile	2
Denmark	1
France	2
Greece	1
Korea	1
Netherlands	1
Norway	1
Saudi Arabia	1
Spain	5
Sweden	1
Switzerland	1
UK	4
USA	6

Most research took place at university medical centers (n=23) or private settings (n=7). Two research study sites were unknown (Table 10). Within each setting, procedures, pre-operative and post-operative care were consistent with standard of care for bariatric surgery.

TABLE 10. *Setting characteristics.*

Setting	Number of Studies (N=32)
Unknown	2
Private Hospital	7
University Medical Center	23
Total	32

Note: Not applicable are systematic reviews.

Classifying Included Study Design Based on NHMRC Evidence Hierarchy

Study designs included in this systematic review were classified by the NHMRC Evidence Hierarchy as follows: Level I: Systematic Review (n=3); Level II: Randomized Controlled Trial (n=2); Level III-1: Pseudo-Randomized Controlled Design (n=1); Level III-2: Comparative Study with Concurrent Controls (n=2); Level III-3: Comparative Study without Concurrent Controls (n=22); and Level IV: Case-Series with pre-test or post-test outcomes (n=2) (Table 11).

TABLE 11. *Number of studies by NHMRC evidence hierarchy.*

NHMRC Evidence Hierarchy	Number of Studies (N=32)
I: Systematic Review	3
II: Randomized Controlled Trial	2
III-1: Pseudo-Randomized Controlled Design	1
III-2: Comparative Study with Concurrent Controls	2
III-3: Comparative Study without Concurrent Controls	22
IV: Case-Series with pre-test or post-test outcomes	2

Bariatric Surgery Types

Studies included all bariatric procedures from the inclusion criteria. Laparoscopic Roux-en-Y and LGS were the most studied procedures (n=19 & n=12, respectively), followed by

LBPD-DS (n=8) and LAGB (n=1) (Table 12). Numerous articles had data pertaining to more than one procedure; therefore, the number of articles exceeds the number of articles included in this systematic review.

TABLE 12. *Number of times bariatric procedures studied.*

Bariatric Procedures	Number of Studies*
Laparoscopic Biliary Pancreatic Diversion with Duodenal Switch (LBPD-DS)	8
Laparoscopic Adjustable Gastric Band (LAGB)	1
Laparoscopic Gastric Sleeve (LGS)	12
Laparoscopic Roux-en-Y (LRenY)	19

**Note. The number of articles discussing each procedure will not equal the number of articles included in this systematic review.*

Summary of Included Studies

From the 1,056 articles, 146 studies were on micronutrient deficiency in adults one year after surgery. This is a small percent (4.3%), demonstrating a continued lack of evidence on this topic. Studies originated from 16 countries. The United States produced the most articles. Many of the samples were from academic hospitals and universities that support databases on bariatric surgical outcomes. Patients in the studies represented men and women. Numbers of women participants were greater than men. Studies had large numbers of subjects obtained from ongoing data bases. Patients in long-term studies dropped out due to distance of research institution or loss to follow-up.

Synthesis

Data synthesis is the combination of included studies to summarize the current evidence for the best solution to answer the PICO question. Study variables were grouped together based on similarity, to identify themes, and interpret the outcomes (Holly et al., 2012). Because this systematic review aims to address the question: *Are adult patients greater than 18 years of age,* *who have different bariatric surgery procedures, at risk for micronutrient deficiency one year or more after surgery?* Results are first grouped by pre-operative micronutrient deficiencies that may have confounded the results. Bariatric surgery type and the associated micronutrient deficiencies were discussed next, followed by studies that assessed the compliance with taking nutrient supplements.

Pre-Operative Deficiency

"Pre-operative deficiencies are prone to postoperative deficiency" (Homan et al., 2015, p. 1631). Inclusion studies reported a high prevalence of micronutrient deficiencies prior to surgery. Reported deficiencies were vitamin D, B12, folate, zinc, and iron. Baseline levels of vitamin D were reported at 14% - 22% (Saif et al., 2012; Vix et al., 2013; Zarshenas, Nacher, Loi, & Jorgensen, 2016). Casagrande et al. (2012) also reported a preoperative level of vitamin D deficiency, 9 - 18%, that may be responsible for calcium malabsorption and increased bone resorption. Donadelli et al. (2012) reported multiple deficiencies, vitamin A, vitamin B12, folic acid, and vitamin C, at baseline. Zinc levels were reported to be under the limit of lower levels (De Luis et al., 2011; Salle et al., 2010). Less than 10% of patients reported taking vitamin D, before surgery and less than 5% of individual supplements (Gillon, Jeanes, Anderson, & Vage, 2016). Micronutrient deficiency before surgery predicts micronutrient deficiency after surgery (Roust & DiBaise, 2017)

Micronutrient Deficiency by Bariatric Procedure

The conceptual framework proposed individual bariatric procedures would vary for deficiency at different periods of time after surgery. The most frequent micronutrient studied was vitamin D, followed by B12, iron, and folate. Articles included in this review had follow-up length of times that ranged from 12 months to 10 years; most studied followed micronutrient deficiency up to 24 months post-op. Malabsorptive procedures, laparoscopic Roux-en-Y or laparoscopic biliary pancreatic diversion with duodenal switch were followed for the longest time frames. Table 13 is a summary of the micronutrient synthesis.

TABLE 13. *Micronutrient deficiency one or more years after bariatric surgery.*

Bariatric Procedure	Micronutrient	Time Post-Surgery	Deficiency Status	Deficiency Results in Percentage Range	First Author, Year
Laparoscopic Adjustable Gastric Band	*Copper, Zinc, Selenium*	18 - 36	Stable	Rare	Papamargaritis, 2015
Laparoscopic Gastric Sleeve	*Vitamin A*	12 - 60	Stable		Saif, 2012
	Vitamin B1	36 - 48	Deficiency	14.3 – 30.8	Saif, 2012
	Vitamin B6	12 - 48	Deficiency	8.3 – 16.7	Moize, 2013
	Vitamin B12	12	Variable	Stable, if supplement - 26.2	Donadelli, 2012; Gillon, 2016; Hakeam, 2009; Kwon, 2014; Moize, 2013; Saif, 2012, Kwon, 2014
		24 - 36	Deficiency	0 - 18	Donadelli, 2012; Gehrer, 2010; Gillon, 2016; Moize, 2013, Saif, 2012
		48	Deficiency increased in menstruating women	5 - 5.8	Alexandrou, 2014; Moize, 2013;
		60	Stable	0 - 10	Moize, 2013; Saif, 2012
	Calcium	12-36	Stable		Gehrer, 2010
	Copper	12-36	Stable	Rare	Papamargaritis, 2014
	Vitamin D	12	Deficiency	23- 48	Moize, 2013; Saif, 2012; Vix, 2014
		24	Deficiency	8.2-51.5	Gehrer, 2010
		36	Deficiency	20 - 55.6	Saif, 2012; Zarshenas, 2016
		48	Deficiency	43.3 - 50.7	Alexandrou, 2014; Moize, 2013
		60	Deficiency	6,7 – 42.1	Gillon, 2016, Moize, 2013, Saif, 2012
	Folate	12	Deficiency	7.3	Hakeam, 2009; Saif, 2012
		24	Deficiency	2	Gehrer, 2010
		48	Deficiency		Alexandrou, 2014
		60	Variable	0 - 10.6	Gillon, 2016

TABLE 13. – *Continued*

Bariatric Procedure	Micronutrient	Time Post-Surgery	Deficiency Status	Deficiency Results in Percentage Range	First Author, Year
Laparoscopic Gastric Sleeve *(Cont.)*	*Iron*	12	Variable increase in menstruating women	3 – 10.3	Hakeam, 2009; Kwon, 2014; Moize, 2013; Ruz, 2012; Saif, 2012
	Selenium	12-36	Stable	Rare	Papamargaritis, 2015
	Zinc	12 24	Deficiency	10.7 – 18.4	Gehrer, 2010; Saif, 2012
		36	Stable	10.8	Saif, 2012
		48 - 60	Deficiency	12.8 - 21.5	Saif, 2012
Laparoscopic Roux-en-Y	*Vitamin A*	12-36	Variable	4.9 -27.6	Donadelli, 2012; Gong, 2008; James, 2016
		60	Stable		Aaseth, 2015
	Vitamin B6	12 60	Variable	2.8 – 8.3	Aaseth, 2015
	Vitamin B12	12	Variable	0 -7	del Villar Madrigal, 2015; Donadelli, 2012; James, 2016; Moize, 2013, Kwon, 2014
		18 - 36	Variable decreased with injectable B12	3.7 – 19.5	Gong, 2008; James, 2016; Moize, 2013; Weng, 2015; Worm, 2015
		48	Variable	5.8 – 10	Alexandrou, 2014; Moize, 2013
		60	Deficiency	Rare – 5	Aaseth, 2015; Moize, 2013; Weng, 2015
		120	Stable	2%	Karefylakis, 2015
	Vitamin C	12	Deficient	21.7	Donadelli, 2012
	Calcium	60	Stable	Rare	Aaseth, 2015
	Copper	18 - 36	Variable	0 -22.5	Baha, 2010; Gletsu-Miller, 2012; Kumar, Papamargaritis, 2015
	Vitamin D	12	Deficiency	15 - 35	Casagrande, 2012; Vix, 2014
		18-36	Variable	1.6 - 357	Gong, 2008; James, 2016; Worm, 2015
		48-60	Deficiency	39.6	Aaseth, 2015; Alexandrou, 2014; Worm, 2015
	Folic Acid	12	Deficiency	3.4	Donadelli, 2012
		24	Stable		Worm, 2015
		48	Deficiency	18.4	Alexandrou, 2014
		60	Stable		Aaseth, 2015
		120	Deficiency	12	Karefylakis, 2015

TABLE 13. – *Continued*

Bariatric Procedure	Micronutrient	Time Post-Surgery	Deficiency Status	Deficiency Results in Percentage Range	First Author, Year
Laparoscopic Roux-en-Y *(Cont.)*	*Iron*	12 - 120	Deficiency increase in menstruating women	11.2 - 20	Alexandrou, 2014; del Villar Madrigal, 2015; Karefylakis, 2015; Kwon, 2014; Leiro, 2014; Ruz, 2012
	Selenium	18 - 36	Deficiency	12-14%	Papamargaritis, 2015
	Zinc	18	Deficiency	14	Papamargaritis, 2015
		24	Stable		Gong, 2008
			Deficient	15 - 21	Balsa, 2011
Laparoscopic Biliary Pancreatic Diversion with Duodenal Switch					
	Vitamin A	90 120	Deficiency	51 – 72.3	Bolckmans, 2016; Khandalavala, 2010
	Vitamin B6	42	Deficiency	50	Homan, 2015
	Vitamin B12	120	Stable		Ballesteros-Pomar, 2016
	Vitamin C	12-	Deficiency	29.3	Donadelli, 2012; Vix, 2014
	Copper	12 - 90	Deficiency	76.9 - 90	Bolckmans, 2016; de Luis, 2011; Salle, 2010
	Vitamin D	24	Deficiency	72.3	Khandalavala, 2010
		90	Deficiency	60 – 72.3	Khandalavala, 2010
		120	Deficiency	45 - 61	Ballesteros-Pomar, 2016; Bolckmans, 2016,
	Vitamin E	120	Deficiency	45	Ballesteros-Pomar, 2016
		12 - 90	Deficiency	10	Bolckmans, 2016
	Iron	12-120	Deficiency	32	Bolckmans, 2016
	Vitamin K	12-90	Deficiency	60	Bolckmans, 2016
		120	Deficiency	40	Ballesteros-Pomar, 2016
	Zinc	12 – 60	Deficiency	45 - 91	Balsa, 2011; de Luis, 2011
		120	Deficiency	40 - 68	Ballesteros-Pomar, 2016; Bolckmans, 2016

Laparoscopic gastric band (LGB). One study examined the relationship between laparoscopic adjustable gastric band (LAGB) and and the trace elements copper, selenium, and zinc (n=437 at baseline (Papamargaritis, Aasheim, Sampson, & LeRoux, 2015). This study was a Level III retrospective review with patients from the United Kingdom. Patients were followed for over 36 months. The results indicated that with multi-vitamin supplements, trace elements were stable > 36 months' post-operative.

Laparoscopic gastric sleeve (LGS). Laparoscopic gastric sleeve was discussed in 13 articles (Alexandrou et al., 2014; Donadelli et al., 2010; Geher et al., 2010; Gillon et al., 2014; Hakeam et al., 2009; Kwon et al., 2014; Moize et al., 2012; Papamargaritis et al., 2014; Ruz et al., 2012; Salle et al., 2016; Saif et al., 2012; Vix et al., 2014; Zarshenas et al., 2016). In total, 11 micronutrient deficiencies were discussed in the 13 articles. The following micronutrients were discussed: vitamin A - 1 (Saif et al., 2012), vitamin B1- 1 (Saif et al., 2012), vitamin B6 - 6 (Moize et al., 2013), vitamin B12 - 8 (Alexandrou et al., 2015; Donadelli et al., 2012; Geher et al., 2010; Gillon et al., 2017; Hakeam et al., 2009; Kwon et al., 2014; Moize et al., 2013; Saif et al., 2012), calcium -1 (Geher et al., 2010), copper - 1 (Papamargaritis et al., 2014), vitamin D - 6 (Alexandrou et al., 2015; Geher et al., 2010; Gillon et al., 2017; Moize et al., 2013; Saif et al., 2012; Zarshenas et al.,2016), folate -5 (Alexandrou et al., 2015; Geher et al., 2010; Gillon et al., 2017; Hakeam et al., 2014; Saif et al., 2012), iron -5 , (Hakeam et al., 2009; Kwon et al., 2014; Moize et al., 2013; Ruz et al., 2012; Saif et al., 2012), selenium - 1 (Papamargaritis et al., 2014), and zinc - 3 (Geher et al., 2010; Saif et al., 2012; Salle, et al., 2010). Follow-up time intervals varied from: >12 months (Donadelli et al., 2012; Geher et al., 2010; Gillon et al., 2017; Hakeam et al., 2009; Kwon et al., 2014; Moize et al., 2013; Papamargaritis et al., 2014; Ruz et al., 2012;

Saif et al., 2012; Salle, et al., 2010), to 60 months post-op (Gillon et al., 2017; Moize et al., 2013; Saif et al., 2012). Eight studies were Level III (Alexandrou et al., 2015; Gillon et al., 2017; Hakeam et al., 2009; Moize et al., 2013; Ruz et al., 2012; Saif et al., 2012; Salle et al., 2010; Zarshenas et al., 2016). One Level I (Kwon et al., 2014), one Level II (Papamargaritis et al., 2014) and, one Level IV (Alexandrou et al., 2015). Geographical location varied according to each article with patients from each of the following countries: Australia (Zarshenas et al., 2016); Brazil (Donadelli et al., 2012); United Kingdom - 2 (Gillon et al., 2017; Papamargaritis et al., 2014); Saudi Arabia (Hakeam et al., 2009); Spain (Moize et al., 2013); Chile (Ruz et al., 2012); USA (Saif et al., 2012); France - 2 (Salle et al., 2010; Vix et al., 2014); Switzerland (Geher et al., 2010), and, Greece (Alexandrou et al., 2015). The dose of supplements taken post-operatively varied between studies. The most common micronutrient deficiencies in *laparoscopic adjustable gastric ban*d were vitamin B12, vitamin D, folic acid, iron, and zinc. Each micronutrient is described in detail below.

Vitamin B12. The relationship between LGS and vitamin B12 deficiency was assessed in representing populations from seven counties: Brazil (Donadelli et al., 2012); United Kingdom (Gillon et al., 2017), Saudi Arabia (Hakeam et al., 2009); Spain (Moize et al., 2013); USA (Saif et al., 2012); Switzerland (Geher et al., 2010), and Greece (Alexandrou et al., 2015). Reports varied by length of time after surgery, patient’s sex assigned, and use of supplements. Sample size ranged from 50 (Donadelli et al., 2012) to 355 (Moize et al., 2013).

Eight studies found a relationship between LGS and vitamin B12 deficiency post-op (Alexandrou et al., 2015; Donadelli et al., 2012; Geher et al., 2010; Gillon et al., 2017; Hakeam et al., 2009; Kwon et al., 2014; Moize et al., 2013), one reported no deficiency (Saif et al., 2012).

The quality of the study types and the length of follow-up varied between studies. Four Level III studies were 12 months' post-surgery (Donadelli et al., 2012; Gillon et al., 2016; Hakeam et al., 2009; Moize et al., 2013), and demonstrated varying degrees of vitamin B12 deficiencies among patients taking vitamin and mineral supplements. Vitamin B12 deficiencies in these studies ranged from 7 - 26% (Donadelli et al., 2012; Hakeam et al., 2009), respectively. Deficiency continued in 5 - 18% of patients 24 months' post-surgery (Donadelli et al., 2012; Geher et al., 2010; Gillon et al., 2017; Moize et al., 2013). At 36 to 60 months, B12 deficiency decreased to 0 - 5% (Alexandrou et al., 2014; Moize et al., 2013; Saif et al., 2012). A systematic review of vitamin deficiencies post-op demonstrated less B12 deficiency was observed in patients when vitamin B12 supplements were used after surgery (Kwon et al., 2014). Vitamin B12 deficiency was attributed to decreased dietary intake of meat, as well as, type, dose, and compliance with supplementation (Gillon et al., 2016; Kwon et al., 2014). Continuation of supplements and addressing deficiency lowered occurrence (Gillon et al., 2016).

Vitamin D is the one of the most prevalent deficiencies after gastric sleeve. The relationship between LGS and vitamin D deficiency was assessed in six studies (Alexandrou et al., 2014; Geher et al., 2010; Moize et al., 2013; Saif et al., 2012, Vix et al., 2013; Zarshenas et al., 2016) and representing populations from six different countries: Australia (Zarshenas et al., 2016); Greece (Alexandrou et al., 2014); Switzerland (Geher et al., 2010; Spain (Moize et al., 2013); USA (Saif et al., 2012); France (Vix et al., 2013). Sample size ranged from 82 (Saif et al., 2012) to 355 participants (Moize et al., 2013).

Study type varied as following: one study was one Level II (Vix et al., 2013), four studies were Level III (Geher et al.; 2010; Moize et al., 2013; Saif et al., 2012; Zarshenas et al., 2016), and one was Level IV (Alexandrou et al., 2014). Studies examined vitamin D deficiency from 12 – 60 months (Alexandrou et al., 2014; Donadelli et al., 2012; Gehrer et al., 2010; Gillon et al., 2016; Moize et al., 2013; Saif et al., 2012; Vix et al., 2014; Zarshenas et al., 2016). At 12 months, vitamin D deficiency ranged from 23% (Saif et al., 2012) to 48% at 12 months (Vix et al., 2014) and increased (in all time interval) to 60 months, 42% (Saif et al., 2012; Alexandrou et al., 2014). Supplement doses varied between studies; however, vitamin D deficiency was present with supplementation.

Folate. Folate deficiency was reported in five studies (Alexandrou et al., 2015; Geher et al., 2010; Gillon et al., 2017; Hakeam et al., 2014; Saif et al., 2012). Study designs are four Level III (Geher et al., 2010; Gillon et al., 2017; Hakeam et al., 2014; Saif et al., 2012) and one Level IV (Alexandrou et al., 2015). Sample size ranged from 67 (Hakeam et al., 2014) to 336 (Gillon et al., 2017). Rates varied at post surgery intervals: 12 months - 7% (Hakeam et al., 2014; Saif et al., 2012); 24 months - 2% (Geher et al., 2010); and at 60 months - 0 to 10% (Gillon et al., 2016). Folate stabilized at 60 months, with supplements (Gillon et al., 2016; Saif et al., 2012). Even though the small intestine is not involved in the surgery, studies concluded that LGS is associated with a risk of folate deficiency (Gehrer et al., 2010; Van Rutte, Aarts, Smulders, & Nienbuijs, 2014).

Iron. Five studies cited iron deficiency over 12 to 36 months after surgery (Hakeam et al., 2014; Kwon et al., 2014; Moize et al., 2013; Ruz et al., 2012; Saif et al., 2012). Sample size ranged from 43 (Ruz et al., 2012) to 335 (Moize et al., 2013). Study designs included one Level 1 (Kwon et al., 2014) and four Level III (Hakeam et al., 2014; Moize et al., 2013; Ruz et al., 2012; Saif et al., 2012). A meta-analysis by Kwon et al. (2014), analyzed studies with iron deficiency, anemia, and B12 to compare risk of LGS to LRenY (Kwon et al., 2014). According to the study, LGS was superior to preventing anemia and B12 deficiency when supplements were taken regularly (Kwon et al., 2014). Two studies reported stability of iron in LGS, from 12 to 36 months based on adherence to supplements (Hakeam et al., 2009; Saif et al., 2012).

Calcium. Calcium was normal, over 12 to 36 months, in a level III study (Gehrer et al., 2010).

Trace elements. Copper and selenium deficiency were rare in a Level III study from 12 to 36 months, with vitamin and mineral supplementation (Papamargaritis et al., 2015). Zinc deficiency was reported in three Level III studies, between 12 and 60 months (Gehrer et al., 2010; Saif et al., 2012; Salle et al., 2010). Results were variable at 12 months from rare (Gehrer et al., 2010) to 18.8 (Salle et al., 2010). In a small sample (14) zinc deficiency decreased with supplements at 36 months and increased at 60 months (Saif et al., 2012).

Summary of LGS deficiencies. Fewer and less severe deficiencies are associated with LGS (Gehrer et al., 2010). B12 deficiency is less in LGS, but more significant in menstruating women (Alexandrou et al., 2015; Kwon et al., 2014). Iron, B12, and folic acid deficiency can lead to anemia (Kwon et al., 2014). Deficiencies revert to baseline values as time from surgery increases, however, baseline measurements are not always done prior to surgery (Saif et al., 2012). Vitamin D can affect bone mineral density and increase parathyroid hormone (Ruiz-Tovar et al., 2013). Mineral supplements decrease deficiency of copper, selenium, and zinc levels (Papamargaritis et al., 2015). Iron is one of the most scrutinized deficiencies in gastric sleeve for its relationship to anemia as a complication and to justify a surgical alternative to LRenY (Aarts et al., 2012). Evidence demonstrates that LGS is associated with micronutrient deficiency.

Laparoscopic Roux-en-Y (LRenY). Laparoscopic Roux-en-Y was studied in 22 articles, from 12 to 120 months, 10 years (Aaseth et al., 2015; Alexandrou et al., 2014; Balsa et al., 2011; Casagrande et al., 2012; del Villar Madrigal et al.,2015; Donadelli et al., 2012; Geher et al., 2009; Gletsu-Miller et al., 2012; Gong et al., 2016; James et al., 2016; Karefylakis et al., 2015; Kumar et al., 2016; Kwon et al., 2014; Leiro et al., 2014; Moize et al., 2013; Papamargaritis et al., 2014; Ruz et al., 2012; Ruz et al., 2011; Salle et al., 2010; von Drygalski et al., 2015; Weng et al., 2017; Worm et al., 2015; Vix et al., 2016). Eleven micronutrients were represented: vitamin A - 4 (Aeseth et al., 2015. Donadelli et al., 2012; Gong et al., 2008; James et al., 2016), B6 - 1 (Aeseth et al., 2015), vitamin B12 - 11 (Aeseth et al., 2015, Alexandrou et al., 2017; del Villar Madrigal et al., 2014; Donadelli et al., 2012; James et al., 2016; Karyeflykis et al., 2015; Kwon et al., 2014; Moize et al., 2013; Salle et al., 202010; Weng et al., 2013; Worm et al., 2015), vitamin C - 1 (Donadelli et al., 2012), copper – 5 (Gletsu-Miller et al., 2012; Kumar et al., 2016; Papamargaritis et al., 2015), vitamin D – 7 (Aeseth et al., 2015, Alexandrou et al., 2017; Casagrande et al., 2012; Gong et al., 2008; James et al., 2016; Vix et al., 2013; Worm et al., 2015), folic acid – 5 (Aeseth et al., 2015, Alexandrou et al., 2017; Donadelli et al., 2012; Karyeflykis et al., 2015; Worm et al., 2015), iron - 6, (Alexandrou et al., 2017; del Villar Madrigal et al., 2014; Karyeflykis et al., 2015; Kwon et al., 2014; Leiro et al., 2014; Ruz et al., 2012), selenium - 1 (Papamargaritis et al., 2015), and zinc - 2 (Balsa et al., 2010; Papamargaritis et al., 2015). Study designs included: Level 1- 3 (Kwon et al., 2014; Kumar et al., 2016, Weng et al., 2015); Level III - 19 (Aeseth et al., 2015, Alexandrou et al., 2017; Baha et al., 2010; Casagrande et al., 2012; del Villar Madrigal et al., 2014; Gletsu-Miller et al., 2012; Geher et al., 2009; Gong et al., 2008; James et al., 2016; Karyeflykis et al., 2015; Leiro et al., 2014; Moize et al., 2013, Papamargaritis et al., 2015; Salle et al., 2012; Ruz et al., 2012; Ruz et al., 2011; Vix et al., 2013; von Drygalski et al., 2011; Worm et al., 2015) and, Level IV - 1 (Donadelli et al., 2012). Sample size ranged from 22 (Casagrande et al., 2012) to 1125 (von Drygalski et al., 2011. Populations represented: Australia - 1 (Kumar et al. 2016); Brazil - 3 (Casagrande et al., 2012; Donadelli et al., 2012; Leiro et al., 2014), Chile - 2 (Ruz et al., 2012; Ruz et al., 2011), Denmark - 1 (Worm et al., 2015), France - 2 (Sall, et al., 2012; Vix et al., 2013), Greece - 1 (Alexandrou et al., 2017), Korea - 1 (Kwon et al., 2014), Norway - 1 (Aeseth et al., 2015), Spain - 3(Baha et al., 2010; del Villar Madrigal et al., 2014; Moize et al., 2013), Sweden - 1 (Karyeflykis et al., 2015), Switzerland -1 (Geher et al., 2009), United Kingdom - 1 (Papamargaritis et al., 2015), and USA - 4 (Gletsu-Miller et al., 2012; Gong et al., 2008; James et al., 2016; von Drygalski et al., 2011). Results varied between studies. Deficiencies are similar to the gastric sleeve, although more lasting after the procedure (Alexandrou et al., 2017; Kwon et al., 2014; Moize et al., 2013; Ruz et al., 2012; Ruz et al., 2011). The micronutrients studied the most are B12, iron, folate, and vitamin D. These micronutrients are related to anemia, B12 and folate, and secondary hyperparathyroidism, and vitamin D.

Vitamin B12. Vitamin B12 is regularly studied in LRenY due to removal of a large part of the stomach and risk of anemia. Eleven articles studied B12 deficiency (Aeseth et al., 2015; Alexandrou et al., 2017; del Villar Madrigal et al., 2014; Donadelli et al., 2012; James et al., 2016; Karyeflykis et al., 2015; Kwon et al., 2014; Moize et al., 2013; Salle et al., 2010; Weng et al., 2013; Worm et al., 2015). Study designs included Level 1 - 2 (Kwon et al., 2014; Weng et al., 2013), Level 3 - 7 (Aeseth et al., 2015; del Villar Madrigal et al., 2014; James et al., 2016; Karyeflykis et al., 2015; Moize et al., 2013; Salle et al., 2010; Worm et al., 2015), and Level IV -

2 (Alexandrou et al., 2017; Donadelli et al., 2012). Variable results were reported for B12 deficiency, 12 to 48 months after surgery (Aaseth et al., 2015; Alexandrou et al., 2014; del Villar Madrigal et al., 2015; Donadelli et al., 2012; 2010; James et al., 2016; Karefylakis et al., 2015; Kwon et al., 2014; Moize et al., 2013; Weng et al.; Worm et al., 2015). Five studies at 12 months reported a low range, 0-7% (del Villar Madrigal et al., 2015; Donadelli et al., 2012; James et al., 2016; Kwon et al., 2014; Moize et al., 2013). Deficiency was reported rare at 12 months (del Villar Madrigal et al., 2015), 60 months (Alexandrou et al., 2014), and 10 years (Karefylakis et al., 2015). Kwon's meta-analysis emphasized "studies that provided prophylactic iron and vitamin B12 supplementation did not show a significant odds ratio in anemia or vitamin B12 deficiency risk (Kwon et al., 2014, p. 591). Weng et al.'s, (2015), meta-analysis reported B12 deficiency at 24 and 36 months, between 5.4 and 7.2%. The highest levels were at 36 months, men - 19.5 and women - 14.5 (Worm et al., 2015). Stable levels of B12 are credited to continued and adequate supplementation, including intra-muscular injections (Aaseth et al., 2015; Gong, Gagner, Pomp, Almahmeed, & Bardaro, 2008; Worm et al., 2015). A higher percentage of B12 deficiency is found in LRenY than gastric sleeve (Alexandrou et al., 2014; Gehrer et al., 2010; Kwon et al., 2014). "Differences in the definition of deficiency, patient populations, surgical techniques, supplement protocols and length and follow up of post-operative programs" contribute to anemia (Kwon et al., 2014, p. 589).

Folate. Five studies reported stable folate values if supplements were prescribed and taken consistently (Aaseth et al., 2015; Alexandrou et al., 2014; Donadelli et al., 2012; Karefylakis et al., 2015; Worm et al., 2015). There were Level 3 studies - 3 (Aaseth et al., 2015; Karefylakis et al., 2015; Worm et al., 2015) and Level IV - 2 (Alexandrou et al., 2014; Donadelli et al., 2012). Studies occurred after 2012, when the concern of anemia was recognized. Elevated deficiency was at 48 months - 18.4% (Alexandrou et al., 2014) and at 10 years - 12% (Karefylakis et al., 2015). Folate deficiency is higher in LRenY than LGS (Gehrer et al., 2010; Kwon et al., 2014). Deficiency at 48 to 120 months was linked to non-adherence to supplements (Aaseth et al., 2015; Alexandrou et al., 2014).

Iron. Iron deficiency is also related to anemia. Deficiency factors included malabsorption, low intake of red meat, menstruating women, and abnormal bleeding. Iron deficiency included six studies (Alexandrou et al., 2014; del Villar Madrigal et al., 2015; Karefylakis et al., 2015; Kwon et al., 2014; Leiro & Melendez-Araujo, 2014; Ruz et al., 2012). Time period ranged from 12 months to 10 years. Study designs included: Level 1 - 1 (Kwon et al., 2014), Level III - 4 (del Villar Madrigal et al., 2015; Karefylakis et al., 2015; Leiro & Melendez-Araujo, 2014; Ruz et al., 2012), and Level 4 - 1 (Alexandrou et al., 2014). Iron deficiency varied from 11% (del Villar Madrigal et al., 2015) to 20% (Alexandrou et al., 2014; Karefylakis et al., 2015), from 12 to 120 months (Alexandrou et al., 2014; del Villar Madrigal et al., 2015; Karefylakis et al., 2015; Kwon et al., 2014; Leiro & Melendez-Araujo, 2014; Ruz et al., 2012). Iron deficiency continued to 10 years, 20% (Karefylakis et al., 2015). Iron deficiency is a concern in menstruating woman and increased iron supplementation is recommended (Alexandrou et al., 2014; Ruz et al., 2012; von Drygalski et al., 2011).

Vitamin D. Vitamin D deficiency is related to secondary hyperthyroidism, bone metabolism, and calcium. Seven studies researched vitamin D deficiency (Aeseth et al., 2015, Alexandrou et al., 2017; Casagrande et al., 2012; Gong et al., 2008; James et al., 2016; Vix et al., 2013; Worm et al., 2015). Study designs included: Level II - 1 (Vix et al., 2014), Level III -5

(Aeseth et al., 2015; Casagrande et al., 2012; Gong et al., 2008; James et al., 2016; Worm et al., 2015), and Level IV - 1 (Alexandrou et al., 2017). At 12 months, vitamin D deficiency was significant, ranging from 15%, (Casagrande et al., 2012) to 35%, (Vix et al., 2014). Variable results are reported at 18 to 36 months, stable (Gong et al., 2008; Worm et al., 2015) and 16%, (James et al., 2016). Deficiency was significant between 48 and 60 months, 40% (Aaseth et al., 2015; Alexandrou et al., 2014; Worm et al., 2015). Studies reporting Vitamin D deficiency are recent and revolve around the concern of elevated parathyroid hormone and risk of fracture (Alexandrou et al., 2014; Casagrande et al., 2012). Gong et al. (2008) is the oldest study and the only one stating Vitamin D stability (Gong et al., 2008). In comparison studies between LGS and LRenY, vitamin D hypovitaminosis was increased in gastric sleeve (Alexandrou et al., 2014; Moize et al., 2013; Vix et al., 2014).

Vitamin A. Vitamin A is a fat-soluble vitamin that must be ingested. Three studies reported vitamin A deficiency (Donadelli et al., 2012; Gong, et al., 2008). Study designs included: Level 3 - 2 (Gong et al, 2008; James et al., 2016), and Level IV - 1 (Donadelli et al., 2012). Deficiency was present at 12 and 48 months (Donadelli et al., 2012; Gong et al., 2008; James et al., 2016). Prevalence was 27.6% at 12 months (Donadelli et al., 2012) and stabilized at 24 months, 5% (Gong et al., 2008; James et al., 2016). Vitamin A stabilized from 18 to 60 months with supplements (Aaseth et al., 2015; James et al., 2016).

Trace mineral. Trace mineral deficiency is reported in gastric bypass. Copper deficiency varied between 18 and 36 months from rare (Gletsu-Miller et al., 2012; Papamargaritis et al., 2015) to significant 22% (Balsa et al., 2011). Selenium was stable at 24 to 36 months, with supplements, but below normal levels (Papamargaritis et al., 2015). Zinc levels were studied at three periods, each with one article: at 18 months - 14% (Papamargaritis et al., 2015), stable at 24 months (Gong et al., 2008) and elevated at 48 to 60 months - 15 to 21% (Balsa et al., 2011).

Other micronutrients. Vitamin B6 deficiency was low, 2 to 8% between 12 and 60 months, in one, Level I study (Aaseth et al., 2015). Vitamin C was found to be significantly deficient at 12 months, 21%, with routine supplements, in one Level IV study (Donadelli et al., 2012). Calcium deficiency in women, 12 months after surgery was attributed to decreased intake of dairy, due to gastric intolerance (Leiro & Melendez-Araujo, 2014). Stable calcium levels were attributed to monitoring and supplementation (Gehrer et al., 2010).

Summary of micronutrient deficiency in LR-en-Y. LRenY is both a restrictive and malabsorptive procedure. Surgical alteration of the stomach and the small intestine decreases absorption of nutrients and increases risk of micronutrient deficiency. Deficiencies of B12, folate, and vitamin D were the most studied micronutrients. Anemia with LRenY is attributed to deceased levels of iron, folate, and vitamin B12 (del Villar Madrigal et al., 2015; Karefylakis et al., 2015; Weng et al., 2015). These deficiencies are also higher in menstruating females (Ruz et al., 2012). Long term studies demonstrate deficiency in LRenY can be reduced with compliance taking supplementation (Aaseth et al., 2015). Studies recommended pre-surgical evaluation for micronutrient evaluation, consensus on the type and number of supplements, and long-term follow-up (Aaseth et al., 2015; Casagrande et al., 2012; Donadelli et al., 2012; Gletsu-Miller et al., 2012; Karefylakis et al., 2015).

Laparoscopic biliopancreatic diversion with duodenal switch (LBPD-DS). Eight authors studied laparoscopic biliopancreatic diversion with duodenal switch (Bolckmans & Himpens, 2016; Ballesteros-Pomar, et al., 2016; de Luis et al., 2011, Donadelli et al., 2012;

Homan et al., 2015; Khandalavala, 2010). Study designs included: Level III - 7 (Ballesteros-Pomar et al., 2016; Bolckmans & Himpens, 2016; de Luis et al., 2011; Donadelli et al., 2012; Homan et al., 2015: Khandalavala et al., 2010; Salle et al., 2010) and Level IV - 1 (Donadelli et al., 2012). Sample size ranged from 29 (Ballesteros-Pomar, 2016) to 219 (Khandalavala, 2010). Time periods studied were from 12 months to 10 years. Micronutrients in patients having LBPD-DS were measured at single or multiple points after bariatric surgery. Ten micronutrients were studied: vitamin A - 2 (Bolckmans, & Himpens, 2016; Khandalavala, et al., 2010), vitamin B6 - 1 (Homan et al., 2015), vitamin B12 - 1 (Ballesteros-Pomar et al., 2016); copper - 2 (de Luis et al., 2011; Salle et al., 2010), vitamin D - 3 (Ballesteros-Pomar et al., 2016; Bolckmans & Himpens, 2016; Khandalavala et al., 2010); vitamin E - 2 (Ballesteros-Pomar et al., 2016; Bolckmans & Himpens, 2016), iron - 1 (Bolckmans & Himpens, 2016), vitamin K - 2 (Ballesteros-Pomar et al., 2016; Bolckmans & Himpens, 2016), and zinc - 2 (de Luis et al., 2011; Salle et al., 2010). Vitamin D was studied the most in three studies. Other micronutrients were represented by one to two studies

Fat soluble vitamins. Fat soluble vitamins are a concern with LBPD-DS due to impaired fat digestion and food absorption limitations. Three studies evaluated vitamin D (Ballesteros-Pomar et al., 2016; Bolckmans & Himpens, 2016; Khandalavala et al., 2010). All studies were Level III. At 24 to 90 months, the range of deficiency was reported from 60% to 72% (Khandalavala et al., 2010). At 10 years' deficiency continued to be high, 45%-61% (Ballesteros-Pomar et al., 2016; Bolckmans & Himpens, 2016; Magee et al., 2011). Long term studies of Vitamin A deficiency, from 90 to 120 months, were significant, 51% to 72%

(Bolckmans & Himpens, 2016; Khandalavala et al., 2010). Vitamin E deficiency was present in 45% of patient at 10 years (Ballesteros-Pomar et al., 2016).

Trace elements. Zinc and copper were associated with LBPD-DS with supplementation. Zinc results were consistently deficient from 12 months to five years - 20% to 86% (de Luis et al., 2011; Salle et al., 2010). The authors concluded that the standard preparations in multivitamin and mineral supplements were too low. Two studies reported consistent copper deficiency, between 12 and 60 months, in the range 30% to 50%, with increases over time (de Luis et al., 2011; Salle et al., 2010).

Other micronutrients. Iron deficiency was reported at 32.3% at 10 years (Bolckmans & Himpens, 2016). Additional deficiencies reported in single studies were: B6 - 50% (Homan et al., 2015), vitamin B12 - stable (Ballesteros-Pomar et al., 2016; Homan et al., 2015), and iron - 32% (Bolckmans & Himpens, 2016).

Summary of laparoscopic biliopancreatic diversion with duodenal switch. LBD-DS is the bariatric procedure associated with the greatest risk of post-operative malnutrition and metabolic complications. The procedure is both restrictive, removal of 70% of the stomach and malabsorptive, removal of most of the duodenum. Deficiency for fat soluble vitamins and trace elements is consistent. LBPD-DS patients experience deficiencies over 10 years (93%), while taking supplements (Bolckmans & Himpens, 2016). Authors agreed a rigorous multivitamin supplementation regimen is needed, due to the high frequency of deficiencies that increase over time from surgery (Homan et al., 2015). Micronutrient supplementation is recognized postoperatively and throughout life (Khandalavala et al., 2010).

CLINICAL GUIDELINES

The aim of the systematic review was to develop a practice guideline for advance practice nurses to understand the risk of micronutrient deficiency in adult patients, one year or more after bariatric surgery. The guidelines differentiate micronutrient deficiency based on the bariatric procedure. This systematic review results were developed into a guideline based on format and criteria of the 2013 (Revised) *Criteria for Inclusion of Clinical Practice Guidelines in NGC* (Agency for Healthcare Research and Quality [AHRQ], 2018). "AHRQ's National Guideline Clearinghouse is a public resource for evidence-based clinical practice guidelines" (AHRQ, 2018). These guidelines are not thought to be all-inclusive as the author acknowledges that a more thorough systematic review, with multiple specialists as reviewers, would need to be performed. For proposed guidelines, see Table 14.

TABLE 14. *Proposed guidelines for detecting micronutrient deficiencies in patients one or more years after bariatric surgery.*

Guidelines: Micronutrient Deficiency of Patients One or More Years After Bariatric Surgery	
Age of the Target Population	Adults, over the age of 18
Sex of the Target Population	Male and female.
Disease/ Conditions	Obesity surgery, bariatric surgery, weight loss surgery, gastric banding, gastric bypass (ICD 10 code Z98.84). Intestinal bypass and anastomosis (ICD 10 code Z98.0). Nutritional deficiency (ICD 10 code E63.1). Vitamin deficiency (E56.9) Mineral deficiency (ICD 10 codeE83).
Clinical Specialty	Endocrinology, Family Practice, Gastroenterology, Hematology, Internal Medicine, Nursing, Nutrition, Preventive Medicine, Plastic Surgery, Surgery
Other Disease Conditions	Encounter for screening for nutritional disorder Z13,21 Copper deficiency E61.0 Iron Deficiency E61.1 Magnesium deficiency E61.3 Deficiency of multiple nutrient elements E61.7 Deficiency of other specified nutrient E61.8 Deficiency of nutrient element, unspecified E61.9 Vitamin D deficiency E55.9

TABLE 14. – *Continued*

Guidelines: Micronutrient Deficiency of Patients One or More Years After Bariatric Surgery	
Other Disease Conditions (continued)	B12 deficiency E53.8 Deficiency of other specified B group vitamins E53.8 Vitamin A deficiency E50 Thiamine deficiency E51 Dietary calcium deficiency E58 Deficiency of vitamin E E56.04 Abnormal level of blood mineral R79.0
Care Need	Living with Illness, Staying Healthy
Domain	Patient
Intended Users	Advance practice registered nurses, Dieticians, Health Care Providers, Physicians
Guideline Category	Prevention, screening
Guideline Objectives	Recognition of micronutrient deficiencies associated with bariatric surgery procedures for optimal management.
Target Population	Males and females, 18 years or older, one or more years after bariatric surgery. Women who are not pregnant.
Methods of Guideline Development	Systematic review by subjective review. Search of electronic databases. Review of 32 source documents. Rating scheme for the strength of evidence: NHMRC Evidence Hierarchy. CASP Critical Appraisal Tools. Evidence synthesis.
Major Recommendations	1. Assess and treat micronutrient deficiencies prior to surgery. 2. Annual and on-going follow-up for micronutrient deficiencies one year or more after bariatric surgery. 3. Assessment of: • pre-surgery micronutrient deficiency and use of supplements, • type and date of bariatric surgery, • assessment, compliance with supplements, • dietary intake, food intolerance • signs and symptoms that may indicate micronutrient deficiency 4. Common micronutrient deficiencies to evaluate: • Fat soluble vitamins – vitamin D • Water soluble vitamins – vitamin B12, folate • Trace Minerals - Zinc • Anemia increased in menstruating, B12, folate, iron • For those patients who present with anemia, B12, folate, and iron levels should also be assessed.
Clinical Algorithm	Table 12. *Micronutrient Deficiency One or More Years After Bariatric Surgery*
Potential Benefits	Screening micronutrient deficiency one year or more after bariatric surgery leads to prevention of complication, co-morbidities, and mortality, and increases quality of life.

TABLE 14. – *Continued*

Guidelines: Micronutrient Deficiency of Patients One or More Years After Bariatric Surgery	
References Supporting Recommendations	Aaseth, E., Fagerland, M. W., Aas, A., Hewitt, S., Risstad, H., Kristinsson, J., ... & Assheim, E. T. (2015). Vitamin concentrations 5 years after gastric bypass. *European Journal of Clinical Nutrition*, *69*, 1249-1255. https://doi.org/10.1038/ejcn.2015.82 Alexandrou, A., Armeni, E., Kouskouni, E., Tsoka, E., Diamantis, T., & Lambrinoudaki, I. (2014). Cross-sectional long-term micronutrient deficiencies after sleeve gastrectomy versus Roux-en-Y gastric bypass: A pilot study. *Surgery for Obesity and Related Diseases*, *10*, 262-268. Ballesteros-Pomar, M. D., De Francisco, T. G., Urioste-Fondo, A., Gonzales-Herraez, L., Calleja-Fernandez, A., Vidal-Casariego, A., ... Cano-Rodriguez, I. (2016). Biliopancreatic diversion for severe obesity: Long-term effectiveness and nutritional complications. *Obesity Surgery*, *26*, 38-44. https://doi.org/10.1007/s11695-015-1719-2 Balsa, J. A., Botella-Carretero, J. I., Arrieta, R. P., Santiuste, C., Zammarin, I., & Vazquez, C. (2011). Copper and zinc serum levels after derivative bariatric surgery: Difference between Roux-en-Y bypass and biliopancreatic diversion. *Obesity Surgery, 21*, 744-750. https://doi.org/10.1007/s11695-011-0389-y Bolckmans, R., & Himpens, J. (2016, December). Long-term (>10 yrs) outcome of the laparoscopic biliopancreatic diversion with duodenal switch. *Annals of Surgery*, *264*(6), 1029-1037. Casagrande, D. S., Repetto, G., Mottin, C. C., Shah, J., Pietrobon, R., Worni, M., ... Schaan, B. D. (2012). *Obesity Surgery*, *22*, 1287-1292. https://doi.org/10.1007/s11695-012-0687-z de Luis, D. A., Pacheco, D., Izaola, O., Terroba, M. C., Cuellar, L., & Martin, T. (2011). Zinc and copper serum levels of morbidly obese patients before and after biliopancreatic diversion: 4 years of follow-up. *Journal of Gastrointestinal Surgery*, *15*(12), 2178-2181. del Villar Madrigal, E., Neme-Yunes, Y., Clavellina-Gaytan, D., Sanchez, H. A., Mosti, M., & Herrera, M. F. (2015). Anemia after Roux-en-Y gastric bypass: how feasible to eliminate the risk by proper supplementation? *Obesity Surgery*, *25*(1), 80-84. Donadelli, S. P., Junqueira-Franco, M. V., Donadelli, C. A., Salgado, W., Ceneviva, R., Marchini, J. S., ... Nonino, C. B. (2012). Daily vitamin supplementation and hypovitaminosis after obesity surgery. *Nutrition*, *28*, 391-396. https://doi.org/10.1016/j.nut.2011.07.012 Gehrer, S., Kern, B., Peters, T., Christoffel-Courtin, C., & Peterli, R. (2010). Fewer nutrient deficiencies after laparoscopic sleeve gastrectomy than after laparoscopic Roux-en-Y gastric bypass: A prospective study. *Obesity Surgery*, *20*, 447-453. Gillon, S., Jeanes, Y. M., Anderson, J. R., & Vage, V. (2016). Micronutrient status in morbidly obese patients prior to laparoscopic sleeve gastrectomy and micronutrient changes 5 years post-surgery. *Obesity Surgery*, *27*, 606-612. https://doi.org/10.1007/s11695-016-2313-y

TABLE 14. – *Continued*

Guidelines: Micronutrient Deficiency of Patients One or More Years After Bariatric Surgery	
References Supporting Recommendations (Cont.) ***References Supporting Recommendations (Cont.)***	Gletsu-Miller, N., Broderius, M., Frediani, J. K., Zhao, V. M., Griffith, D. P., Davis, S. S., ... Ziegler, T. R. (2012). Incidence and prevalence of copper deficiency following Roux-en-Y gastric bypass surgery. *International Journal of Obesity, 36,* 328-335. https://doi.org/10.1038/ijo.2011.159 Gong, K., Gagner, M., Pomp, A., Almahmeed, T., & Bardaro, S. J. (2008). Micronutrient deficiencies after laparoscopic bypass: Recommendations. *Obesity Surgery, 18,* 1062-1066. https://doi.org/10.1007/s11695-008-9577-9 Hakeam, H. A., O'Regan, P. J., Salem, A. M., Bamehriz, F. Y., & Eldali, A. M. (2009). Impact of laparoscopic sleeve gastrectomy on iron indices: 1 year follow up. *Obesity Surgery, 19,* 1491-1496. Homan, J., Betzel, B., Aarts, E. O., Dogan, K., Van Laarhoven, K. J., Janssen, I. M., ... Berends, F. J. (2015). Vitamin and mineral deficiencies after biliopancreatic diversion and biliopancreatic diversion with duodenal switch-the rule rather than the exception. *Obesity Surgery, 25,* 1626-1632. https://doi.org/10.1007/s11695-015-1570-5 James, H., Lorentz, P., & Collazo-Clavell, M. L. (2016). Patient-reported adherence to empiric vitamin/mineral supplementation and related nutrient deficiencies after Roux-en-Y gastric bypass. *Obesity Surgery, 26,* 2661-2666. https://doi.org/10.1007/s11695-016-2155-7 Karefylakis, C., Naslund, I., Edholm, D., Sundbom, M., Karlsson, F. A., & Rask, E. (2015). Prevalence of anemia and related deficiencies 10 years after gastric bypass: A retrospective study. *Obesity Surgery*, 25, (6), 1019-1023. https://doi.org/10:1007/s11695-014-1500-y Khandalavala, B. N., Hibma, P. P., & Fang, X. (2010). Prevalence and persistence of vitamin D deficiency in biliopancreatic diversion patient: A retrospective study. *Obesity Surgery, 20,* 881-884. https://doi.org/10:1007/s11695-010-0185-0 Kumar, P., Hamza, N., Madhock, B., DeAlwis, N., Sharma, M., Miras, A. D., ... Mahawar, K. K. (2016). Copper deficiency after gastric bypass for morbid obesity: A systematic review. *Obesity Surgery, 26,* 1335-1342. https://doi.org/10.1007/s11695-016-2162-8 Kwon, Y., Kim, H. J., Menzo, E. L., Park, S., Szomstein, S., & Rosenthal, R. J. (2014). Anemia, iron and vitamin B12 deficiencies after sleeve gastrectomy compared to Roux-en-Y gastric bypass: A meta-analysis. *Surgery for Obesity and Related Diseases, 10,* 589-599. Leiro, L. S., & Melendez-Araujo, M. S. (2014). Diet micronutrient adequacy of women after 1 year of gastric bypass [Supplemental material]. Arquivos Brasileiros de Cirurgia Digestiva: ABCD, 27(1), 21-25. Moize, V., Andreu, A., Flores, L., Torres, F., Ibarzabal, A., Delgado, S., ... Vidal, J. (2013). Long-term dietary intake and nutritional deficiencies following sleeve gastrectomy or Roux-en-Y gastric bypass in a Mediterranean population. Academy of Nutrition and Dietetics, 113(3), 400-410.

TABLE 14. – *Continued*

Guidelines: Micronutrient Deficiency of Patients One or More Years After Bariatric Surgery	
References Supporting Recommendations (Cont.)	Papamargaritis, D., Aasheim, E. T., Sampson, B., & LeRoux, C. W. (2015). Copper, selenium, and zinc levels after bariatric surgery in patients recommended to take multivitamin-mineral supplementation. *Journal of Trace Elements in Medicine and Biology, 31*, 167-172. Ruz, M., Carrasco, F., Rojas, P., Codoceo, J., Inostroza, J., Basfi-fer, K., ... Csendes, A. (2012). Heme- and nonheme-iron absorption and iron status 12 months after sleeve gastrectomy and Roux-en-Y bypass in morbidly obese women. *American Journal of Clinical Nutrition, 96,* 810-7. Ruz, M., Carrasco, F., Rojas, P., Codoceo, J., Inostroza, J., Basfi-fer, K., ... & Sian, L. (2011). Zinc absorption and zinc status are reduced after Roux-en-Y gastric bypass: A randomized study using 2 supplements. *The American Journal of Clinical Nutrition, 94*(4), 1004-1011. Saif, S., Strain, G. W., Dakin, G., Gagnet, M., Costa, R., & Pomp, A. (2012). Evaluation of nutrient status after laparoscopic sleeve gastrectomy 1, 3, and 5 years after surgery. *Surgery for Obesity and Related Diseases, 8,* 542-547. Salle, A., Demarsy, D., Porter, A. L., Toppart, P., Guilloteau, G., Becouarn, G., ... Romer, V. (2010). Zinc deficiency: A frequent and underestimated complication after bariatric surgery. *Obesity Surgery, 20,* 1660-1670. https://doi.org/10.1007/s11695-010-0237-5 Vix, M., Liu, K., Diana, M., D'Urso, A., Mutter, D., & Marcescaux, J. (2014). Impact of Roux-en-Y gastric bypass versus sleeve gastrectomy on vitamin D metabolism: Short term results from a prospective randomized clinical trial. *Surgical Endoscopy, 28,* 821-826. von Drygalski, A., Andris, D. A., Nuttleman, P. R., Jackson, S., Klein, J., & Wallace, J. R. (2011). Anemia after bariatric surgery cannot be explained by iron deficiency alone: Results of large cohort study. *Surgery for Obesity and Related Diseases, 7,* 151-156. https://doi.org/10.1016/j.soard.2010.04.008 Weng, T., Chang, C., Dong, Y., Change, Y., & Chuang, L. (2015). Anaemia and related nutrient deficiencies after Roux-en-Y gastric bypass surgery: A systematic review and meta-analysis. *British Medical Journal, 5: e00694*. https://doi.org/10.1136/bmjopen-2014-006964 Worm, D., Madsbad, S., Kristiansen, V. B., Naver, L., & Hansen, D. L. (2015). Changes in hematology and calcium metabolism after gastric bypass surgery: A 2-year follow-up study. *Obesity Surgery, 25,* 1647-1652. https://doi.org/10.1007/s11695-014-1568-4 Zarshenas, N., Nacher, M., Loi, K. W., & Jorgensen, J. O. (2016). Investigating nutritional deficiencies in a group of patients 3 years post laparoscopic sleeve gastrectomy. *Obesity Surgery, 26,* 2936-2943. https://doi.org/10.1007/s11695-016-2211-3

DISCUSSION

Bariatric surgery has become the recommended treatment option for morbid obesity and obesity with comorbid disease (Noria & Grantcharov, 2013). Although bariatric surgery is effective for weight loss, results from this systematic review indicated that micronutrient deficiency can occur 1 to 10 years after surgery. Some 93% of post-operative patients were diagnosed with a deficiency and require supplementation of vitamins and minerals (Homan et al., 2015). Studies on long-term follow up, beyond one year after surgery, are beginning to emerge and demonstrate that bariatric surgery and extreme weight loss can cause co-morbid disease due to micronutrient deficiencies (Aasheim et al., 2009). “Micronutrient deficiency is an important complication of bariatric surgery, with 50% of cases of vitamin deficiency being observed at the end of the first postoperative year, possibly arising from the substantial decrease of food intake, from food intolerance, and from dysabsorption” (Donadelli et al., 2012, p. 392; Leiro & Melendez-Araujo, 2014). Deficiencies still occur with micronutrient supplementation, as recommended amounts do not always meet the needs of patients (Donadelli et al., 2012; Shankar et al., 2010). Because deficiency may be present without symptoms (Gletsu-Miller et al., 2012) life-long follow-up is necessary to monitor the effect of the deficiency and to verify that supplements are maintaining adequate levels in the blood (Salle et al., 2010). Without proper care, the consequences of micronutrient deficiencies can be serious, cause further disease, functional impairment, and decreased quality of life.

Results from this systematic review indicate that the severity and type of micronutrient deficiency varied by bariatric surgery and time after surgery. The most prevalent micronutrient deficiencies were: B12 - 19 (Aeseth et al., 2015, Alexandrou et al., 2017; Alexandrou et al., 2015, Ballesteros-Pomar et al., 2016; del Villar Madrigal et al., 2014; Donadelli et al., 2012; Geher et al., 2010; Gillon et al., 2017; Hakeam et al., 2009; James et al., 2016; Karyeflykis et al., 2015; Kwon et al., 2014; Moize et al., 2013; Saif et al., 2012; Salle et al., 2010; Weng et al., 2013; Worm et al., 2015), vitamin D - 13 (Aeseth et al., 2015; Alexandrou et al., 2015; Ballesteros-Pomar et al., 2016; Casagrande et al., 2012; Geher et al., 2010; Gillon et al., 2017; Gong et al., 2008; James et al., 2016; Moize et al., 2013; Saif et al., 2012; Vix et al., 2013; Worm et al., 2015; Zarshenas et al.,2016), iron - 12 (Alexandrou et al., 2017; Bolckmans & Himpens, 2016; del Villar Madrigal et al., 2014; Hakeam et al., 2009; Karyeflykis et al., 2015; Kwon et al., 2014; Leiro et al., 2014; Moize et al., 2013; Ruz et al., 2012; Saif et al., 2012), folate - 8 (Aeseth et al., 2015; Alexandrou et al., 2015; Donadelli et al., 2012; Geher et al., 2010; Gillon et al., 2017; Hakeam et al., 2014; Karyeflykis et al., 2015; Saif et al., 2012; Worm et al., 2015), zinc - 7 (Balsa, et al., 2010; de Luis et al., 2011; Geher et al., 2010, Papamargaritis et al., 2015; Saif et al., 2012; Salle et al., 2010). "Data continue to suggest that the prevalence of micronutrient deficiencies [after bariatric surgery] is increasing, while the monitoring of patient follow-up is decreasing" (Parrott et al., 2017, p. 1). Mid and long-term deficiencies increased risk of anemia, bone mineral density impairment, neuropathy, and cognitive impairment (Patel et al., 2017). Current guidelines for long-term post-operative follow-up for micronutrient deficiency lack agreement on screening, deficiencies associated with individual surgeries, and adequate supplementation (Bazuin et al., 2017). "Furthermore, the guidelines sometimes disagree with respect of cutoff levels to detect deficiencies and generally do not specify the corresponding biochemical assays" (Bazuin et al., 2017, p. 198). This leads to further confusion among practitioners and decreases in the quality of care for patients undergoing bariatric surgery.

Bariatric procedures are increasing, and they require life-long follow-up to decrease complications that can occur years after surgery (Ziegler, Sirveaux, Brunaud, & Quilliot, 2009). APRNs need to become familiar with bariatric surgeries and their associated micronutrient deficiencies. Developing clinical competency is necessary to provide effective primary care to the rapidly growing number of patients with a history of bariatric surgery. This practice inquiry provides an evidence-based problem-solving approach to increasing advance practitioner's knowledge of the association of bariatric surgery and micronutrient deficiencies by using a systematic literature search to develop practice guidelines. The guideline *Micronutrient Deficiency of Patients One or More Years After Bariatric Surgery* details an approach for an assessment of patients with a history of bariatric surgery. The guidelines provide advance practice registered nurses with different assessments and processes to evaluate micronutrient deficiency. Along with the proposed guidelines (see Clinical Guidelines), health care practitioners can also consult the ASMBS guidelines for laboratory screening, reference values for results, and indications for supplementation.

The results of this systematic review indicated a gap in the literature assessing the long-term consequence of bariatric surgery on micronutrient deficiency. With recent estimates, indicating 200,000 bariatric surgeries performed a year in the U.S., with trends increasing annually (ASMBS, 2018); there is an urgent need for additional research. Current research does not take into consideration variables that may confound the relationship between bariatric surgery and micronutrient deficiencies such as: existing deficiency, adherence to supplements, sex of the patient, geographical location, or sociocultural factors that may influence adherence.

Studies that use a standardized protocol and combined institutional data could improve the reliability of the data.

This systematic review also established the need for the creation of more rigorous clinical practice guidelines for detecting micronutrient deficiencies in patients one or more years after bariatric surgery. Increasing advance practice nurses' ability to recognize the risk of micronutrient deficiency after bariatric surgery could improve patient outcomes and decrease harmful complications. However, it is important to note that this systematic review is not without its limitations.

Compliance

Micronutrient supplementation is a requirement for bariatric surgery due to the changes in gastrointestinal anatomy and physiology along with decreased dietary intake and rapid weight loss (Leiro & Melendez-Araujo, 2014). Aaseth et al. (2015), reported < 9% of patients take multivitamins, calcium, and vitamin D supplement before LRenY surgery. Adherence to post-operative vitamin routines is essential to maintain healthy levels in the body. Results from this systematic review indicate that patients reported high adherence, up to 98%, to supplements even up to three years following LRenY surgery (James et al., 2016). By five years, 52 - 82% reported taking supplements (Aeseth et al., 2015). "Vitamin concentrations were significantly higher in patients who reported taking supplements" (Aaseth et al., 2015, p. 1250). At 10 years, Bolckmans and Himpens (2016) described 77% of patients with LBPD-DS were taking calcium, vitamin D, zinc, and iron on a regular basis. "Despite the use of supplementation, at least one nutritional deficiency was found in 91% of LBPD-DS patients" (Homan et al., 2015, p. 1629).

Vitamin D deficiency was also reported despite supplement use (James et al., 2016; Khandalavala et al., 2010; Moize et al., 2013).

Limitations

There are several limitations for this review. The selection of articles was based on publications that met eligibility requirements, were written in English, and available through The University of Arizona, Medical Library Services. Although the library has access to ample databases and journals, the author may not have had access to all the available research. Therefore, selection bias may have occurred in the literature search and study selection stage. At the time of the review, there were also limited critical appraisal tools available for a single nurse reviewer. The CASP tools use the judgement of the reviewer to reach their own conclusions (2013). Although the author had clinical expertise, doctoral level knowledge of research, and attempted to stay neutral in the review process, some bias may have been introduced in the critical appraisal stage

The studies included in this review were heterogeneous. Participants were from 16 different countries and data were collected over eight years. All studies had various methodologies, came with their own unique biases, and reported results in slightly different manners. If more studies are conducted on micronutrient deficiencies in patients $\geq$1 year post-bariatric surgery, concrete definitions of micronutrient deficiencies need to be established so results can be pooled, and a meta-analysis can be performed.

In addition, many studies in this review had missing data, high rates of loss to follow up, and small samples. Many of the studies also failed to monitor supplement use or adherence. More prospective or retrospective cohort studies, with adequate sample sizes, need to be conducted to assess the long-term consequences of the distinct types of bariatric surgeries. Due to the considerable number of individuals in the United States who receive bariatric surgery every year, this should become a public health priority.

Conclusions

Although more research needs to be conducted to establish conclusive clinical guidelines on the care for bariatric surgery patients, the author of this study was able to draw some conclusions based on the available research. The following themes were observed while performing this systematic review. Currently no uniform accepted guidelines for postoperative supplementation include current research. Micronutrient deficiencies may have existed pre-operatively and can continue to become post-operative medical problems. Micronutrient deficiencies vary by bariatric procedure and length of time post procedure. The most common deficiencies included fat soluble vitamin, D, the water-soluble vitamin B12, folate, and trace mineral, zinc. For those patients who present with anemia, B12, folate, and iron levels should also be assessed. Adherence to supplements decreased the risk and incidence of post-operative micronutrient deficiency in post-operative bariatric surgery patients. Therefore, it is this author's recommendation that providers consider screening for micronutrient deficiencies in pre- and post-operative bariatric surgery patients and that this population be routinely monitored for supplement adherence.

APPENDIX A:

NHMRC EVIDENCE HIERARCHY

NHMRC Evidence Hierarchy: designations of 'levels of evidence' according to type of research question

Level	Intervention [1]	Diagnostic accuracy [2]	Prognosis	Aetiology [3]	Screening Intervention
I [4]	A systematic review of level II studies	A systematic review of level II studies	A systematic review of level II studies	A systematic review of level II studies	A systematic review of level II studies
II	A randomised controlled trial	A study of test accuracy with: an independent, blinded comparison with a valid reference standard,[5] among consecutive persons with a defined clinical presentation[6]	A prospective cohort study[7]	A prospective cohort study	A randomised controlled trial
III-1	A pseudorandomised controlled trial (i.e. alternate allocation or some other method)	A study of test accuracy with: an independent, blinded comparison with a valid reference standard,[5] among non-consecutive persons with a defined clinical presentation[6]	All or none[8]	All or none[8]	A pseudorandomised controlled trial (i.e. alternate allocation or some other method)
III-2	A comparative study with concurrent controls: ▪ Non-randomised, experimental trial[9] ▪ Cohort study ▪ Case-control study ▪ Interrupted time series with a control group	A comparison with reference standard that does not meet the criteria required for Level II and III-1 evidence	Analysis of prognostic factors amongst persons in a single arm of a randomised controlled trial	A retrospective cohort study	A comparative study with concurrent controls: ▪ Non-randomised, experimental trial ▪ Cohort study ▪ Case-control study
III-3	A comparative study without concurrent controls: ▪ Historical control study ▪ Two or more single arm study[10] ▪ Interrupted time series without a parallel control group	Diagnostic case-control study[6]	A retrospective cohort study	A case-control study	A comparative study without concurrent controls: ▪ Historical control study ▪ Two or more single arm study
IV	Case series with either post-test or pre-test/post-test outcomes	Study of diagnostic yield (no reference standard)[11]	Case series, or cohort study of persons at different stages of disease	A cross-sectional study or case series	Case series

APPENDIX B:

EXCLUDED STUDIES AFTER CRITICAL APPRAISAL

Billeter, A. T., Probst, P., Fischer, L., Senft, J., Kenngott, H. G., Schulte, T., . . . Muller-Stich, B. P. (2015). Risk of Malnutrition, Trace Metal, and Vitamin Deficiency Post Roux-en-Y Gastric Bypass-a Prospective Study of 20 Patients with BMI < 35 kg/m(2). *Obes Surg, 25*(11), 2125-2134. doi:10.1007/s11695-015-1676-9

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Kehagias, I., Karamanakos, S. N., Argentou, M., & Kalfarentzos, F. (2011). Randomized Clinical Trial of Laparoscopic Roux-en-Y Gastric Bypass Versus Laparoscopic Sleeve Gastrectomy for the Management of Patients with BMI < 50 kg/m(2). *Obes Surg, 21*(11), 1650-1656. doi:10.1007/s11695-011-0479-x

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Risstad, H., Sovik, T. T., Engstrom, M., Aasheim, E. T., Fagerland, M. W., Olsen, M. F., . . . Olbers, T. (2015). Five-Year Outcomes After Laparoscopic Gastric Bypass and Laparoscopic Duodenal Switch in Patients With Body Mass Index of 50 to 60 A Randomized Clinical Trial. *JAMA Surg, 150*(4), 352-361. doi:10.1001/jamasurg.2014.3579

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APPENDIX C:

PERMISSION TO USE BARIATRIC SURGERY IMAGES

Loerch, Jeff <LOERCHJ@ccf.org> Mon, Nov 30, 2015 at 10:14 AM
To: Ivy Radcliffe <ivyrad@gmail.com>

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From: Ivy Radcliffe [mailto:ivyrad@gmail.com]
Sent: Friday, November 27, 2015 1:38 PM
To: Loerch, Jeff
Subject: Permission to Use Images of Bariatric Surgery

I would like to request permission to use the surgical images for bariatric surgery on the AMBS website. I am writing a nursing doctoral dissertation titled Systematic Review of Micronutrient Deficiency One Year After Bariatric Surgery. Your approval and assistance is appreciated.
Ivy Radcliffe, MN, APRN, BC-ADM

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