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Maternal Anthropometry and Current Nutritional Interventions to Prevent Adverse Birth Outcomes in the Humanitarian Context: A Systematic Review

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An abstract of
a thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
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Abstract

Maternal Anthropometry and Current Nutritional Interventions to Prevent Adverse Birth Outcomes in the Humanitarian Context: A Systematic Review

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Background: Maternal undernutrition in the humanitarian setting is a prominent concern that leaves both mothers and newborns at-risk for adverse outcomes. These risks range from maternal mortality, low birth weight, intra-uterine growth restriction, pre-term birth, small-for-gestational-age, and stunting at birth. In 2013, Médecins Sans Frontiéres (MSF) Switzerland analyzed the relationship of maternal anthropometric indicators for acute malnutrition with adverse birth outcomes. Mid-upper-arm-circumference (MUAC) was established as the preferential indicator, with a proposed cut-off value of < 23 cm as the criteria for enrollment of pregnant women in nutritional programs.

Objectives: The primary goals of this systematic review were to provide an update to the MSF review by (1) determining if MUAC remains the preferential indicator to identify LBW and other potential risks in mothers and their children; (2) determining what specific anthropometric cut-offs have been used to identify adverse birth outcomes and enroll pregnant women in nutritional programs; (3) determining whether or not these nutritional programs, contingent upon enrollment based on anthropometry, are successful in preventing adverse birth or maternal outcomes.

Methods: Two literature reviews covering September 2012 to February 2021 were conducted on the topics of maternal anthropometry to identify adverse birth or maternal outcomes and maternal anthropometry and nutritional interventions. Adapted Quality Assessments for individual studies were completed.

Results: MUAC was demonstrated as a proxy for a BMI of < 18.5 kg/m^2 to detect undernutrition. A maternal MUAC threshold value of < 23 cm was found to be strongly predictive for identification of pregnant women as at-risk for adverse birth outcomes. Nutritional interventions with enrollment based on MUAC values defined as undernourished that demonstrated improvements in nutritional status were limited, but included ready-to-use-supplementary food and food-based balanced energy and protein supplementation.

Conclusion: The research analyzed in this systematic review supports maternal MUAC as an alternative and more feasible measurement to BMI for identifying pregnant women as undernourished and in need of nutritional intervention to prevent adverse birth outcomes in the humanitarian setting. The preferential MUAC indicator in this context is < 23 cm. Research on nutritional interventions with enrollment contingent upon anthropometry must be further studied.

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Acronyms

BEP	Balanced Energy and Protein
BMI	Body-Mass Index
CSB+	Corn-Soy Blend
ENN	Emergency Nutrition Network
IUGR	Intra-Uterine Growth Restriction
LBW	Low Birth Weight
IFA	Iron and Folic Acid
MMN	Multiple Micronutrient
MSF	Médecins Sans Frontiéres
MUAC	Mid-Upper-Arm Circumference
PTB	Pre-Term Birth
PW	Pregnant Women
RUSF	Ready-To-Use Supplementary Food
SFP	Supplementary Feeding Program
SGA	Small-For-Gestational-Age
SQ-LNS	Small-Quantity Lipid-Based Nutrient Supplementation
UNICEF	United Nations Children's Fund
UNIMMAP	United Nations International Multiple Micronutrient Antenatal Preparation
WHO	World Health Organization

INTRODUCTION

Background

Maternal undernutrition is a prominent global health concern leaving both mothers and newborns vulnerable to adverse health outcomes. Undernutrition is defined as the deficiency of essential nutrients and the inadequate intake of dietary energy[1]. Undernutrition can result in malnutrition, which is a condition that develops from the lack of sufficient vitamins, minerals, and specific nutrients required to maintain healthy tissue and organ function[2]. Malnutrition is the broad term for poor nutrition that can result from either undernutrition or overnutrition[3]. Acute malnutrition is the form of undernutrition that results from inadequate energy or protein intake from nutritional deficiency[4].

In 2013, Médecins Sans Frontiéres (MSF) Switzerland undertook a literature review of articles published between January 1995 and September 2012 covering anthropometric indicators that can identify pregnant women (PW) as acutely malnourished and at-risk for adverse birth outcomes. The focus was on the humanitarian setting, with an emphasis on the African and Asian contexts where many humanitarian emergencies occur[5]. Acute malnutrition in pregnant women in these settings of conflict or natural disaster is prevalent because of the lack of health care availability and food accessibility within their environments, often leading to health risks for both the mother and child[6]. These risks include maternal mortality, low birth weight (LBW), intra-uterine growth restriction (IUGR), pre-term birth (PTB), small-for-gestational-age (SGA) newborns, and stunting at birth.

After an extensive search, MSF concluded that maternal mid-upper-arm circumference (MUAC) can be used as a reliable indicator for risk of low birth weight. *Table 1* explains the differences between the various anthropometric measurements commonly used in reference to maternal health. Maternal MUAC is the preferential indicator, as opposed to body mass index (BMI), maternal weight for gestational age, maternal weight gain, or maternal stature because of the strong association it has with birth weight, the simplicity of the measurement in the humanitarian context, and its independence from gestational age. The proposed conservative cut-off value to enroll pregnant women in nutritional programs, such as supplementary feeding programs (SFP), is a MUAC of < 23 cm[5].

Table 1. Common Maternal Anthropometric Indicators

Measurement	**Description**
MUAC	Singular measurement of the circumference of PW's arm at the midpoint between the shoulder and elbow[7]
BMI	Calculation on the measure of body fat based on two measurements: height and weight[8]
Weight for gestational age	Single measurement of weight at specific time points during pregnancy; knowledge of gestational age necessary
Weight gain	Calculated difference in weight from two points during pregnancy; knowledge of gestational age not necessary
Stature	Single measurement of height; non-modifiable in adult PW[9]

Birth weight is a prominent barometer of fetal health, with LBW serving as an indication for risk of infant morbidity and mortality[10]. The prevention of poor birth outcomes, predominantly LBW, is being explored through nutritional programs with the inclusion of various types of nutrient supplementations. As recommended by the World Health Organization (WHO), the standard practice of care for maternal and fetus well-being to prevent LBW and PTB includes the use of daily iron-folic acid (IFA) supplementation[11]. Newly researched nutritional programs that address the issue of maternal undernutrition in efforts to improve maternal and birth outcomes include the utilization of fortified corn-soy blend (CSB+)[12], United Nations multiple micronutrient preparation (UNIMMAP)[13], lipid-based ready-to-use supplemental food (RUSF)[13], maternal balanced energy protein (BEP)[14] supplementation, antenatal multiple micronutrient (MMN)[15] supplementation, and preventative small-quantity lipid-based nutrient supplementation (SQ-LNS)[16]. *Table 2* describes each of these nutritional programs. Effective nutritional programs will compensate for potential macro- and micro-nutrient deficiencies and lead to a reduction in maternal and child undernutrition.

Table 2. Nutritional Programs to Address Maternal Malnutrition		
Nutritional Program	**Description**	**Contents**
Iron-folic acid (IFA) supplementation[17]	Recommended for all pregnant women, regardless of nutritional status (standard practice of care)	Elemental iron and folic acid
Fortified corn-soy blend (CSB+)[18]	Used as complementary food throughout the world by USAID implementing partners with an intended use of increasing nutrient values and caloric density	Cooked blend of milled, heat-treated corn with soybeans fortified with a vitamin and mineral premix
United Nations multiple micronutrient preparation (UNIMMAP)[19]	Formulated specifically for PW in emergency situations and research studies	Contains 15 vitamins and minerals at dosages that approximate the recommended dietary allowances (RDA) for pregnancy
Lipid-based ready-to-use supplemental food (RUSF)[20]	Medium-quantity lipid-based nutrient supplements with micronutrient-enriching paste designed to treat moderate acute malnutrition, providing 50-100% of energy needed	Heat treated seeds/pulses/cereals, sugar, milk powder, vegetable oils, vitamin, and minerals
Maternal balanced energy protein (BEP) supplementation[21, 22]	Proteins energy supplementation that provides less than 25% of the total energy content to fill nutrient gaps while not displacing food intake in PW	Lipid-based peanut paste and vanilla biscuit
Antenatal multiple micronutrient supplementation (MMN)[23]	Intended to fill nutritional gaps assumed to be common during pregnancy	~1 recommended dietary allowance (RDA) of vitamins and minerals
Preventative small-quantity lipid-based nutrient supplementation (SQ-LNS)[24]	Fortified lipid-based paste/spread providing less than 50% of energy needed	Heat treated peanut/pulses/cereals, milk powder, vegetable oils, sugar, maltodextrin, vitamins, and minerals (23 micronutrients)

Purpose Statement

A recommendation from the MSF review includes determining the extent to which enrollment in nutritional programs based on a maternal MUAC of < 23 cm averts the risk of LBW infants. An emphasis was also placed on evaluating if MUAC remains the favored anthropometric indicator or if the combined use of easily measurable anthropometric indicators is preferable for predicting the risk of adverse birth outcomes, specifically in the humanitarian context[5].

The purpose of this systematic review is to incorporate these recommendations through an analysis of studies published post-September 2012 by (1) determining if MUAC remains the preferential indicator to identify LBW and other potential risks in mothers and their children; (2) determining what specific anthropometric cut-offs have been used to identify adverse birth outcomes and enroll pregnant women in nutritional programs; (3) determining whether or not these nutritional programs, contingent upon enrollment based on anthropometry, are successful in preventing adverse birth or maternal outcomes.

Significance Statement

This study addresses the vulnerability of pregnant women living in emergency settings in the African and Asian context. The prevention of poor birth outcomes is vital for the health of both the mother and newborn child. Identifying a practical anthropometric measurement and a cut-off point to identify pregnant women as undernourished in this particular setting can assist the implementation of necessary interventions to avoid unfavorable outcomes. Pregnant women in complex protracted crises often have an unknown exact gestational age, may not have access to healthcare facilities, and may maintain an inadequate nutritional status. Often, these pregnant women will not be seen again by a healthcare provider until birth, so a quick identification process to determine if they need immediate nutritional assistance will aid in the prevention of adverse effects.

A key gap in women's maternal nutrition is that there is no agreed upon standard set in the Sphere Handbook that defines acute malnutrition through an optimal, context-specific MUAC cut-off point[25]. The Emergency Nutrition Network's (ENN) 2022 Technical Briefing Paper on Women's Nutrition[26] recommends a clarification of the indicators of anthropometric status to be linked to nutritional program decision-making. This research is intended to assist necessary international guidance regarding maternal MUAC cut-off point guidelines and the formulation of nutritional programs based on these guidelines through the amalgamation of the presented current literature results.

METHODS

This study hypothesizes that in the humanitarian context, a MUAC of < 23 cm remains the preferential anthropometric indicator and cut-off point to identify adverse outcomes in mothers and newborns. Additionally, it is postulated that nutritional programs that incorporate this threshold as criteria for enrollment are effective at preventing LBW, IUGR, PTB, and SGA.

Search Strategy

This study is an analysis of data abstracted from two comprehensive literature searches conducted primarily in the PubMed and Embase electronic databases. Additional eligible studies were sought after reviewing the reference lists of identified articles. (1) The first literature search focused on anthropometry, with a priority on maternal MUAC, to identify risks of adverse birth outcomes. (2) The second literature search focused on using anthropometry to enroll pregnant women in nutritional interventions to prevent adverse birth or maternal outcomes.

Key terms:

(1) maternal anthropometry, pregnancy, mid-upper-arm-circumference, adverse birth outcomes, low birth weight, maternal outcomes

(2) maternal anthropometry, pregnancy, nutritional interventions, nutritional programs, adverse birth outcomes

Study Eligibility Criteria: *Inclusion Criteria*

The PRISMA guidelines were used to aid article and study selection. *Figure 1* displays search results from the (1) first literature search and *Figure 2* displays search results from the (2) second literature search. The dates covered for these searches in both databases were September

2012 through February 2021. The inclusion criteria to identify relevant studies include those available in full-text, peer-reviewed, available in English, and focused on adult maternal anthropometry; an exception was made regarding two studies relating BMI and MUAC, which involved non-pregnant adult women[39, 40]. This review was not specifically restricted to studies done in low- and middle-income countries or protracted humanitarian emergency settings. Publications with cross-sectional, retrospective cohort, prospective cohort, unmatched case-control, longitudinal, randomized control, evaluation, and any relevant systematic reviews or meta-analysis study designs were included.

Study Eligibility Criteria: *Exclusion Criteria*

For both literature searches, duplicate publications and studies analyzing the same study populations for similar outcomes were excluded. Additional exclusions from the literature review searches comprised of results involving or focusing on the following subjects: twins, triplets, adolescents, substance abuse, anemia, cigarette smoking, in-vitro fertilization, drugs and hormones, disease, and obesity. Further restrictions were placed on studies without full-text available and non-English and non-human studies.

Study Eligibility Criteria: *Outcome Measures*

The outcome measures for the studies from the first literature review focused on both maternal and newborn birth outcomes. These included LBW, IUGR, PTB, SGA, and stunted at birth. Definitions are presented in *Table 3*.

Table 3. Definitions of Outcome Measures	
Outcome	**Definition**
LBW	Newborn whose birth weight is < 2,500 g[27]
IUGR	Fetus whose estimated birth weight is below the 10th percentile for its gestational age, birth weight < 2,500 g for gestational age greater than 37 weeks, and abdominal circumference below the 2.5th percentile[28]
PTB	Newborn whose birth is before 37 weeks of gestation[29]
SGA	Newborn whose weight below the 10th percentile for its gestational age[30]
Stunted at Birth	Impaired linear birth; a newborn who falls below -2 standard deviations on the recommended length/height-for-age growth charts[31]

Data Synthesis

Since individual studies were not comparable, different approaches were taken for study analyses, and the data was limited, a meta-analysis was not conducted. Data was synthesized based on the results of each individual study, and quantitative results were extracted to be organized in thematic tables.

Quality Assessment

Studies that were determined to fit the indicated inclusion criteria were assessed by one reviewer on their strength, based on study type. According to individual study scores, each study can be categorized as good quality, fair quality, or poor quality. The Newcastle-Ottawa Quality Assessment Scale was adapted based on study type and used to assess and score the quality of selected, cross-sectional studies (*Appendix A)*, cohort studies (*Appendix B*), and case-control studies (*Appendix C)* based on three domains: Selection, Comparability, and Outcome/Exposure[32]. The Joanna Briggs Institute Critical Appraisal Checklist[33] was adapted and used to assess and score the quality of selected randomized controlled trial studies (*Appendix D)*. The AMSTAR Checklist[34] was adapted and used to assess and score the quality of select systematic reviews and meta-analyses (*Appendix E*).

RESULTS

Studies Identified

Figure 1 displays a flow diagram summarizing the systematic review process of literature selection for assessment for (1) Anthropometry to Identify Adverse Outcomes. A total of 5,099 articles were initially identified, with an additional 25 articles found through investigation of the reference lists of initially identified articles. These articles were sorted through and narrowed down to 39 relevant full-text articles. After complete screening and eligibility review, a total of 13 of articles were included in this systematic review. The Quality Assessments determined all included studies to be categorized as either good or fair quality. The studies included were conducted in the following countries: Bangladesh, Brazil, Cambodia, China, Ethiopia, India, Senegal, and South Africa (*Figure 3).*

Figure 2 displays a flow diagram summarizing the systematic review process of literature selection for assessment for (2) Anthropometry and Nutritional Interventions. A total of 109 articles were initially identified, with an additional 11 articles found through investigation of the reference lists of initially identified articles. These articles were sorted through and narrowed down to 11 relevant full-text articles. After complete screening and eligibility review, a total of 8 articles were included in this systematic review. The Quality Assessments determined all included studies to be categorized as either good or fair quality. The studies included were conducted in the following countries: Bangladesh, Burkina Faso, Ethiopia, Ghana, Indonesia, and Malawi (*Figure 4)*.

Figure 1. Flow Diagram Illustrating Article Review Process: Anthropometry to Identify Adverse Outcomes

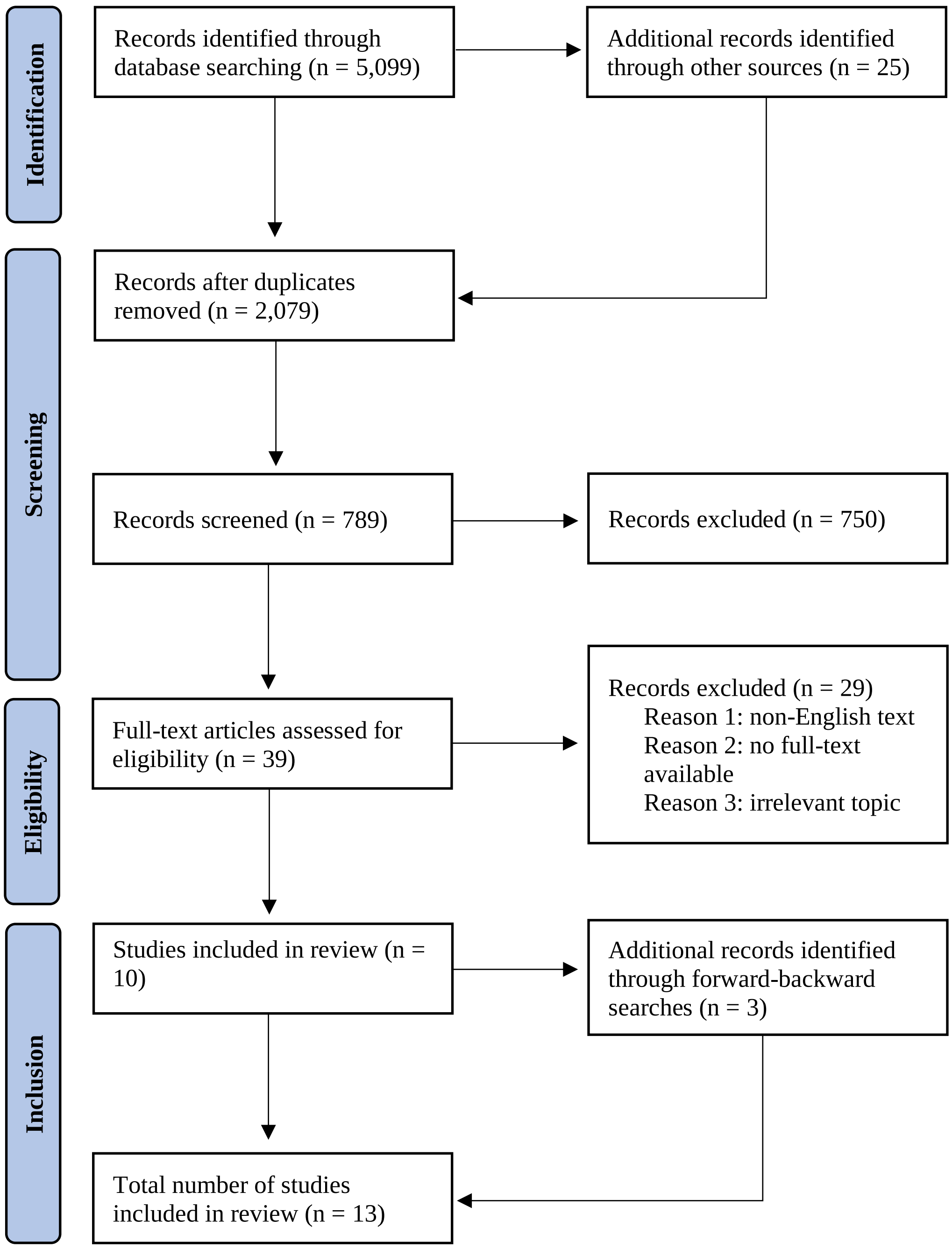


Figure 2. Flow Diagram Illustrating Article Review Process: Anthropometry and Nutritional Interventions

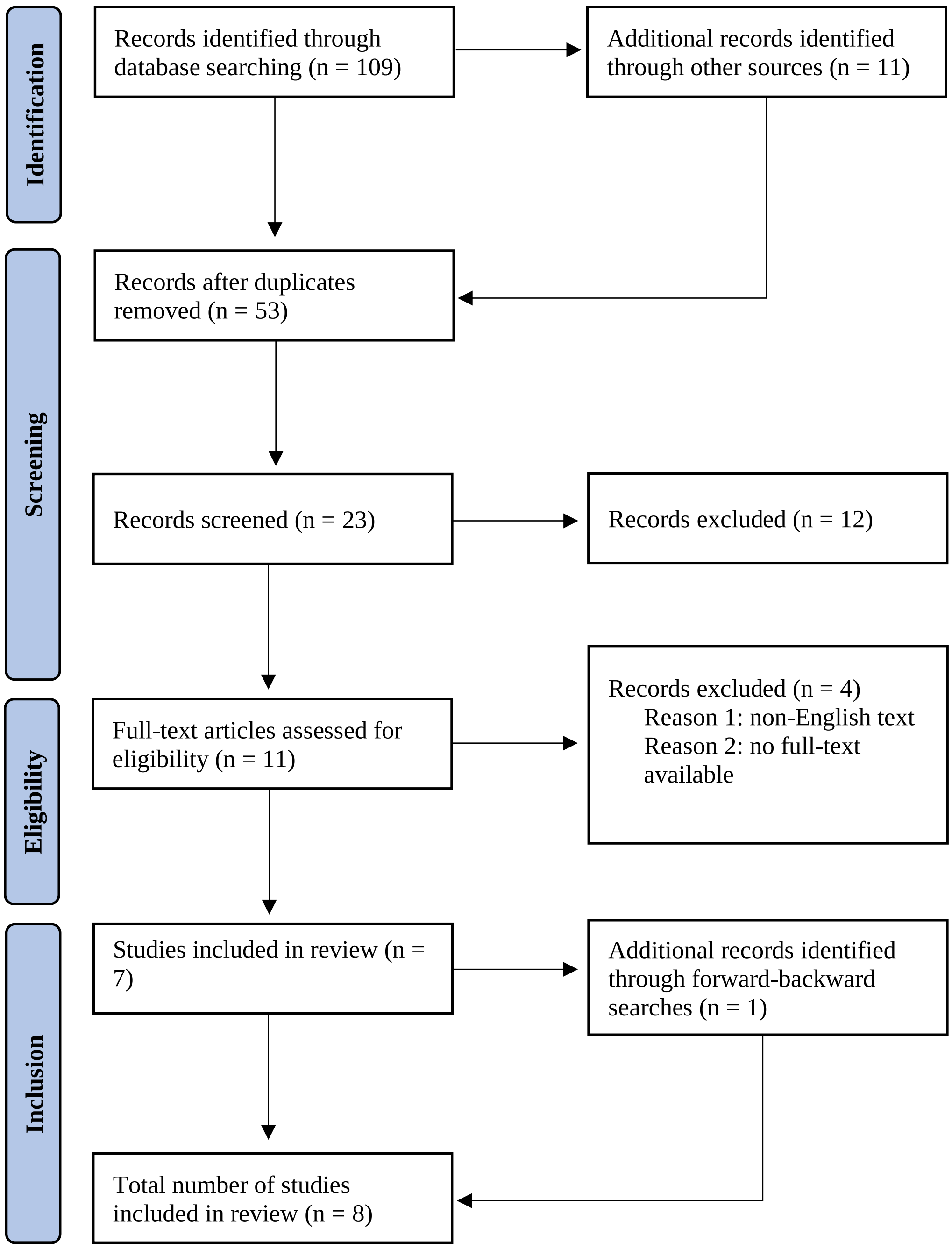


Figure 3. Countries of Studies Involving Anthropometry to Identify Adverse Outcomes

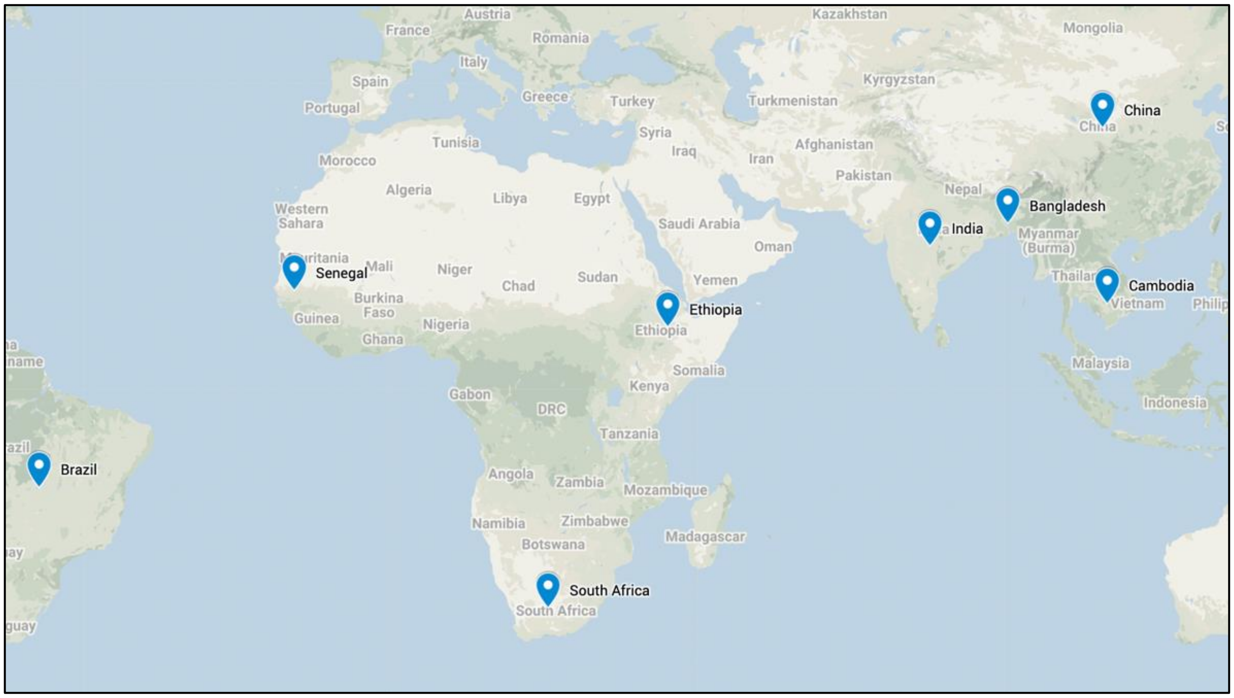
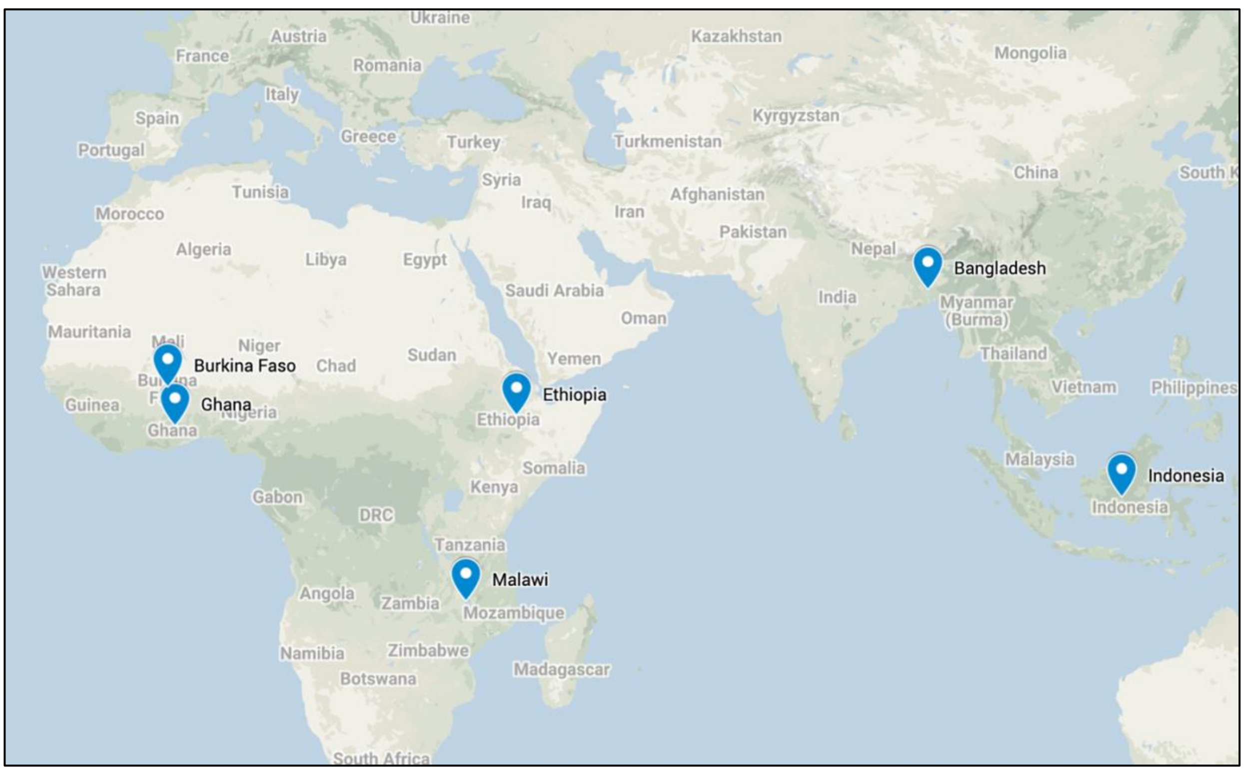


Figure 4. Countries of Studies Involving Anthropometry and Nutritional Interventions



Maternal BMI and Adverse Outcomes

The BMI cutoff point of < 18.5 kg/m^2 has been demonstrated to increase the risk of LBW, IUGR, and SGA, as shown in *Table 4*. The study looking at the relationship between maternal BMI and the outcome of LBW was a cross-sectional study conducted in urban and rural households in selected countries in Africa. It was not specified when in the pregnancy BMI measurements were taken and calculated. The association between maternal BMI and LBW was found to be statistically significant only for Senegal (OR = 1.961, 95% CI: 1.259, 3.055); however, in Burkina Faso, Malawi, and Uganda, underweight mothers – defined by a BMI of < 18.5 kg/m^2 – were also found to have a higher likelihood of LBW newborns[35]. In the South Gondar Zone of Ethiopia, a cross-sectional study was carried out in four hospitals where maternal BMI was measured at delivery for all pregnant women delivering in selected hospitals. Here a BMI of < 18.5 kg/m^2 was found to be a significant predictor of the outcome IUGR (aOR = 2.57, 95% CI: 1.72, 3.83)[36]. The study from Southwest China analyzed data from pregnant women enrolled in a randomized controlled trial also defined underweight BMI as < 18.5 kg/m^2. BMI was measured at the first visit during early pregnancy, which was defined as 11 to 14 weeks of gestation. Early pregnancy BMI classified as underweight was found to have a statistically significant association with increased risk for SGA newborns (Chinese BMI category: OR = 2.08, 95% CI: 1.17, 3.70; WHO Asian BMI category: OR = 2.04, 95% CI: 1.14, 3.66; WHO European BMI category: OR = 2.10, 95% CI: 1.18, 3.72). Early pregnancy BMI classified as underweight was not found to have a statistically significant association with increased risk for LBW newborns (Chinese BMI category: OR = 1.03, 95% CI: 0.20, 5.35; WHO Asian BMI category: OR = 1.11, 95% CI: 0.21, 5.81; WHO European BMI category: OR = 1.14, 95% CI: 0.22, 5.98)[37].

Table 4. Studies Post-September 2012 Looking at Maternal BMI and Adverse Outcomes										
Study	**Country**	**Study Population**	**Sample Size (n)**	**Study type**	**Time of Measurement**	**Cut-off Value**	**Statistical Test**	**LBW**	**IUGR**	**SGA**
He et al. 2018[35]	Senegal	PW of urban and rural households	1665 women	Cross-sectional	Not specified	< 18.5 kg/m^2	OR (95% CI)	**1.961 (1.259, 3.055)**		
Tesfa et al. 2020[36]	Ethiopia	PW delivering in a hospital	803 women	Cross-sectional	Delivery	< 18.5 kg/m^2	OR (95% CI)		**2.57 (1.72, 3.83)**	
Chen et al. 2021[37]	China	PW attending antenatal services	1273 women	Randomized controlled trial	Early pregnancy (11-14 weeks of gestation)	< 18.5 kg/m^2	OR (95% CI)	* Chinese BMI category: 1.03 (0.20, 5.35,); ** WHO Asian BMI category: 1.11 (0.21, 5.81); *** WHO European BMI category: 1.14 (0.22, 5.98)		* Chinese BMI category: **2.08 (1.17, 3.70)**; ** WHO Asian BMI category: **2.04 (1.14, 3.66)**; *** WHO European BMI category: **2.10 (1.18, 3.72)**

* Chinese BMI category: underweight: < 18.5 kg/m2, normal weight: 18.5–23.9 kg/m2, overweight: 24.0–27.9 kg/m2 and obese: > 28.0 kg/m2

** WHO Asian BMI category: underweight: < 18.5 kg/m2, normal weight: 18.5–22.9 kg/m2, overweight: 23.0–24.9 kg/m2 and obese: > 25.0 kg/m2

*** WHO European BMI category: underweight: < 18.5 kg/m2, normal weight: 18.5–24.9 kg/m2, overweight: 25–29.9 kg/m2 and obese: > 30 kg/m2

Statistically significant values are in bold

Relationship Between MUAC and BMI

Five studies post-September 2012 were identified demonstrating MUAC as a functional surrogate for BMI. *Table 5* demonstrates the relationship between BMI and MUAC measurements. All studies here utilize a BMI measurement of < 18.5 kg/m^2, which has been established by the WHO as indicating an adult within the underweight range and an adult pregnant woman as at-risk for adverse birth outcomes[38]. Two of these studies had a study population consisting of non-pregnant adult women, but were included because of the relevance of evaluating the relationship between BMI and MUAC. From these individual cross-sectional studies conducted in Bangladesh and India, MUAC measurements of < 23.9 cm (rounded to < 24 cm)[39] and < 23.2 cm[40], respectively, were found to be correlated to a BMI of < 18.5 kg/m^2.

From the three studies specifically looking at populations consisting of pregnant women, three different MUAC values were all found to have a relationship with being underweight, as indicated with a BMI of < 18.5 kg/m^2. In the cross-sectional study from South Africa, a MUAC of < 22.8 cm (rounded to < 23 cm) was found to correlate strongly ($r = 0.92$, $p < 0.0001$) with BMI in pregnant women up to 30 weeks' gestation[41]. In another cross-sectional study from India, it was found that a MUAC of < 23.5 cm is significantly associated with BMI of < 18.5 kg/m^2 (aOR = 7.91, 95% CI: 4.27, 14.65) during the first trimester of pregnancy[42]. In the retrospective cohort study from Brazil, a MUAC of < 25.75 cm was correlated with a BMI of < 18.5 kg/m^2 ($r = 0.872$, $p < 0.0001$) during weeks 19 to 21 of pregnancy[43].

Table 5. Studies Post-September 2012 Looking at the Relationship Between MUAC and BMI								
Study	**Country**	**Study Population**	**Sample Size (n)**	**Study Type**	**Time of Measurement**	**BMI Measurement**	**MUAC Measurement**	**Statistical test Results**
Sultana et al. 2015[39]	Bangladesh	Non-pregnant adult women	650 women	Cross-sectional	N/A	< 18.5 kg/m^2	< 23.9cm (rounded to < 24 cm)	Sensitivity of 92.6% and Specificity of 76.64%; Pearson Correlation, r = 0.828 (p < 0.001)
Fakier et al. 2017[41]	South Africa	PW attending maternity services	164 women	Cross-sectional	< 30 weeks of gestation	< 18.5 kg/m^2	< 22.8 cm (rounded to < 23 cm)	Correlation, r = 0.92 (p < 0.0001)
Kumar et al. 2019[40]	India	Non-pregnant adult women	1716 women	Cross-sectional	N/A	< 18.5 kg/m^2	< 23.2 cm	Correlation, r = 0.860 (95% CI: (0.831, 0.883); p < 0.001)
Mishra et al. 2020[42]	India	PW attending maternity services	440 women	Cross-sectional	1st trimester	< 18.5 kg/m^2	< 23.5 cm	aOR = 7.91 (4.27–14.65); Correlation, r = 0.57 (p < 0.001)
Miele et al. 2021[43]	Brazil	PW attending prenatal care services	1165 women	Retrospective cohort	Three set points: 19-21 weeks, 27-29 weeks, 37-39 weeks	< 18.5 kg/m^2	< 25.75 cm (19-21 weeks)	Correlation, r = 0.872 (p < 0.0001)

MUAC Cut-off Threshold

The five studies in *Table 6* demonstrate the specific maternal MUAC cut-off threshold values and the corresponding birth outcomes of LBW, IUGR, SGA, and stunted at birth. Three of these studies indicated a MUAC of < 23 cm as strongly predictive for identifying pregnant women as at-risk for at least one of these adverse outcomes, while one study used a MUAC cut-off value of ≤ 23 cm and another study used < 22 cm. None of these cut-off values were found to be linked to gestational age.

Three studies looked at the adverse birth outcome of LBW; two studies in Ethiopia and one study in India. The first study from Ethiopia was a cross-sectional facility based study aiming to identify factors associated with LBW. This study found that a MUAC < 23 cm measured at delivery was significantly associated with LBW (aOR = 3.4, 95% CI: 1.38, 8.60)[44]. The second study from Ethiopia was an unmatched case-control study that found that a MUAC < 22 cm measured at delivery was significantly associated with LBW (aOR = 2.89, 95% CI: 1.58, 5.29)[45]. From the prospective cohort study in India, a MUAC of ≤ 23 cm measured during the first and second trimester was found to be associated with LBW (OR = 1.083, 95% CI: 0.46, 2.58), though despite this particular association with LBW, this result was not statistically significant at the 0.05 significance level[46].

Another cross-sectional study in Ethiopia looked at the adverse birth outcome of IUGR. Here, a MUAC < 23 cm measured at delivery was found to be significantly associated with IUGR (aOR = 2.10, 95% CI: 1.39, 3.01)[47]. The prospective cohort study in India looked at the adverse birth outcome of SGA. Here, a MUAC of ≤ 23 cm measured during the first and second trimester was found to be associated with SGA (OR = 0.90, 95% CI: 0.42, 1.93), though this result was not statistically significant at the 0.05 significance level[46]. A longitudinal study done in Cambodia looked at the adverse birth outcome of being stunted at birth. Here, a MUAC of < 23 cm measured during the third trimester was found to be associated with being stunted at birth (aOR = 1.621, 95% CI: 0.998, 2.636), although this result was borderline significant with a p-value of 0.051[48].

Table 6. Studies Post-September 2012 Using Maternal MUAC to Identify Adverse Birth Outcomes

Study	Country	Study Population	Sample Size (n)	Study type	Time of MUAC Measurement	MUAC Cut-off Value	Statistical Test	LBW	IUGR	SGA	Stunted at Birth
Adane, Dachew 2018[44]	Ethiopia	PW delivering in a hospital	662 women	Cross-sectional	Delivery	< 23 cm	OR (95% CI)	**3.4 (1.38, 8.60)**			
Vasundhara et al. 2019[46]	India	PW attending antenatal services	928 women	Prospective cohort	1st and 2nd trimester	≤ 23cm	OR (95% CI)	1.083 (0.46, 2.58)		0.90 (0.42, 1.93)	
Siyoum, Melese 2019[45]	Ethiopia	PW delivering in a hospital	330 women	Unmatched case-control	Delivery	< 22 cm	OR (95% CI)	**2.89 (1.58, 5.29)**			
Kpewou et al. 2020[48]	Cambodia	PW attending antenatal services	779 women	Longitudinal	3rd trimester	< 23cm	OR (95% CI)				1.621 (0.998, 2.636)
Tesfa et al. 2020[47]	Ethiopia	PW delivering in a hospital	803 women	Cross-sectional	Delivery	< 23 cm	OR (95% CI)		**2.10 (1.39, 3.01)**		

Statistically significant values are in bold

Applying Nutritional Interventions Based on Anthropometry

Table 7 demonstrates four studies looking at the application of different nutritional interventions on the basis of anthropometry. In Malawi, a single-blind randomized controlled clinical trial was conducted in pregnant women in their second or third trimester. Moderate malnutrition was defined at enrollment with a MUAC between ≥ 20.6 cm and ≤ 23.0 cm. Pregnant women who fit this categorization received one of three dietary treatment regimens: RUSF, CSB+ with UNIMMAP, or CSB+ with IFA (standard of care). The incidence of LBW infants for the RUSF intervention group was 18%, for the CSB+ with UNIMMAP intervention group was 24% and for the CSB+ with IFA standard of care group was 17% ($p = 0.02$)[49].

In Bangladesh, a village-matched evaluation study was conducted in pregnant women in their first or early second trimester. Undernourishment was defined at enrollment as having a MUAC ≤ 22.1 cm. Pregnant women who were identified as undernourished using this definition were either enrolled in the intervention group, which received food-based BEP supplements, or the control group, which did not receive the food-based BEP supplements. The intervention reduced the risk of LBW by 88.58% (RRR = 0.8858)[50].

For an unmatched case-control study conducted in the Sidama Zone of Ethiopia, cases considered were LBW newborns and controls were healthy newborns (≥ 2500 g). The likelihood of MUAC < 23 cm at delivery was 4.27 times higher among mothers of the cases than the controls, as compared to having a MUAC ≥ 23 cm at delivery (aOR = 4.27, 95% CI: 2.24, 8.12). The odds of taking not IFA during pregnancy was 3.92 times higher in mothers of the cases compared to the controls (aOR = 3.92, 95% CI: 1.80, 8.50)[51]. Here, not receiving IFA supplementation and maternal malnutrition indicated by MUAC < 23 cm were found to be independent determinants of birth weight among newborns.

In Indonesia, an evaluation study defined malnourishment as having a MUAC < 23.5 cm, where MUAC was measured at two points in the pregnancy, but the timing of measurements was not specified. Malnourished pregnant women received a complementary feeding program in the form of a supplementary feeding biscuit containing 260 kcal of energy, 13 g of fat, and 8 g of protein, and healthy pregnant women did not receive any intervention. Regardless of biscuit dose, the supplementary feeding biscuit did not have an effect on pregnancy outcomes in malnourished pregnant women, including MUAC, gestational weight, and birth weight[52].

Table 7. Studies Post-September 2012 Looking at the Application of Nutritional Interventions Based on Maternal Anthropometry

Study	Country	Study Population	Sample Size (n)	Study Type	Time of Measurement	Anthropometric value for enrollment	Intervention	Outcomes
Callaghan-Gillespie et al. 2017[49]	Malawi	PW attending antenatal clinics	1828 women	Single-blind randomized controlled clinical trial	Enrollment in 2nd and 3rd trimester; measurements taken every 2 weeks after enrollment	Moderate malnutrition defined as MUAC ≥ 20.6 cm and ≤ 23.0 cm	RUSF; CSB+ with UNIMMAP; or CSB+ with IFA (standard of care)	Incidence of LBW infants: RUSF = 18%; CSB+ with UNIMMAP = 24%; CSB+ with IFA = 17% ($p = 0.02$)
Stevens et al. 2018[50]	Bangladesh	Undernourished PW	87 women	Village-matched evaluation[a]	Enrollment in 1st and early 2nd trimester	Undernourished defined as MUAC ≤ 22.1 cm	Food-based balanced protein energy supplementation	Intervention reduced risk of LBW by 88.58% (RRR[b] = 0.8858); NNT[c] = 6.32
Bekela et al. 2020[51]	Ethiopia	PW delivering in selected public hospitals	354 women	Unmatched case-control	Delivery	N/A	IFA supplementation	Not taking IFA supplementation in pregnancy in cases vs. controls: OR = 3.92 (95% CI = 1.80-8.50). MUAC < 23 cm in cases vs. controls: 4.27 (2.24, 8.12) ($p = 0.001$)
Henrick et al. 2020[52]	Indonesia	PW enrolled in complementary feeding program	211 women	Evaluation study	Not specified; measurements taken 2 times in pregnancy (specific timing unclear)	Malnourished defined as MUAC < 23.5 cm	Supplementary feeding biscuit	No effect of the supplementary biscuit on MUAC or gestational weight among malnourished pregnant women

[a] the village-matched evaluation used principles of a cluster randomized controlled trial

[b]RRR = Relative Risk Reduction

[c]NNT = Number Needed to Treat

Additional Potential Nutritional Interventions

Additional potential interventions to address maternal undernourishment include the use of MMNs and SQ-LNS, as shown in *Table 8*. These studies do not use anthropometry as a basis of enrollment, but serve as a demonstration of potential prospective effective interventions to address maternal malnutrition. A randomized controlled study from Malawi had three intervention groups: IFA, MMN, or SQ-LNS. Here, SQ-LNS did not demonstrate improvements in child weight, MUAC, or stunting, when compared to IFA or MMN[53]. A similar randomized controlled study from Ghana also had the same three intervention groups: IFA, MMN, or SQ-LNS. Here, the SQ-LNS group had a lower prevalence (57.4%) of inadequate GWG than the MMN group (67.2%)[54]. No differences in maternal mortality were found between any of the groups.

A systematic review examined four studies from Bangladesh (LNS compared to IFA), Burkina Faso (LNS compared to MMN), Ghana (LNS compared to both IFA and MMN), and Malawi (LNS compared to both IFA and MMN). Here, LNS had a slight positive effect on birth weight, SGA, and newborn stunting, but no difference in maternal mortality or GWG, when compared to IFA. LNS and MMN did not have a significant difference in maternal and birth outcomes. LNS compared to both IFA and MMN did not have a significant different in maternal and birth outcomes[55].

A systematic review and meta-analysis evaluating different supplementation interventions on maternal, birth, child health, and developmental outcomes found that MMN compared to IFA improved LBW, SGA, and PTB. LNS compared to MMN slightly reduced the risk of SGA, but had no effect on LBW or PTB.

Table 8. Studies Post-September 2012 Looking at the Additional Potential Nutritional Interventions

Study	Country	Study Population	Sample Size (n)	Study Type	Intervention	Outcomes
Ashorn et al. 2015[53]	Malawi	PW attending antenatal clinics	869 women	Randomized controlled trial	IFA, MMN, or SQ-LNS (enrollment at ≤ 20 weeks of gestation)	No effect with SQ-LNS on improving child growth (mean child weight, MUAC, head circumference, prevalence of stunting, and mean length) compared to IFA or MMN
Adu-Afarwuah et al. 2017[54]	Ghana	PW attending antenatal clinics (at ≤ 20 weeks of gestation)	1320 women	Randomized controlled trial	IFA, MMN, or SQ-LNS (enrollment at ≤ 20 weeks of gestation)	SQ-LNS group (57.4% prevalence) had lower prevalence of inadequate GWG than the MMN group (67.2% prevalence) ($p = 0.03$)
Das et al. 2018[55]	Bangladesh, Burkina Faso, Ghana, and Malawi	PW from a total of 4 studies	8018 women, collectively	Systematic review	(1) LNS compared to IFA; (2) LNS compared to MMN; (3) (4) LNS compared to both IFA and MMN (enrollment timing varies)	LNS vs. IFA: no maternal outcome differences; LNS had slightly higher mean birth weight, length and reduction in SGA and stunting; no difference in PTB, stillbirth, or neonatal mortality LNS vs. MMN: no maternal outcome differences; no difference in LBW, mean birth weight, length, SGA, PTB, or neonatal mortality
Oh et al. 2020[56]	N/A	PW from a total of 72 studies	451,723 women, collectively	Systematic review and meta-analysis	IFA compared to folic acid; MMN compared to IFA; LNS compared to MMN (enrollment timing varies from < 13 to < 37 weeks of gestation)	MMN vs. IFA: MMN improved LBW, PTB, SGA LNS vs. MMN: LNS slightly reduced risk of SGA, no effect on LBW or PTB

DISCUSSION

In this systematic review, an exploration of recently published literature was conducted concerning anthropometric indicators that can identify pregnant women as undernourished and at-risk for adverse birth outcomes, as well as nutritional programs and their effectiveness. The purpose was to serve as a follow-up of the research updates presented in the 2013 MSF Switzerland[5] review by focusing on MUAC as a satisfactory substitute for BMI to identify risks such as LBW, IUGR, PTB, and SGA; establishing the specific anthropometric context-specific cut-off points to identify adverse outcomes and enroll pregnant women in nutritional programs; and analyzing if the nutritional programs are successful in achieving the desired outcome of reducing adverse birth and/or maternal outcomes. All included studies were deemed good or fair quality, with none being categorized as poor quality, according to the adapted Quality Assessments based on specific study type, thus further supporting the recommendations extrapolated from this systematic review.

Anthropometric Indicators

BMI has remained the gold standard for measuring the amount of body fat; however, the question remains whether or not it is the most feasible anthropometric method to determine nutritional status in pregnant women who are living in humanitarian and low-resource settings[41]. The BMI cutoff point of < 18.5 kg/m^2 has been demonstrated to be a sufficient predictor of adverse outcomes, such as LBW[35], IUGR[36], and SGA[37]. Studies have found that pre-pregnancy weight and pre-pregnancy BMI may serve as good indicators of risk for adverse birth outcomes[56]; however, these studies were not included in this review because pre-pregnancy measurements are often unknown or not verifiable, rendering pre-pregnancy weight and pre-pregnancy BMI to have no significant practical value in this context.

Based on the current findings, maternal MUAC appears to remain the most reliable and practical anthropometric indicator to detect undernutrition, which increases the risk of adverse birth outcomes and the need for nutritional interventions, serving as a proxy for maternal BMI. The two studies that were included that involved non-pregnant adult women for the sake of demonstrating the association between MUAC and BMI[39, 40] should be considered with care, since maternal body composition changes during pregnancy[57]. While all studies used the BMI cutoff point of < 18.5 kg/m^2 as the definition of underweight, the MUAC values from studies specifically looking at pregnant women that were associated with underweight BMI ranged between < 22.8 cm to < 25.75 cm.

Since MUAC is established as the preferential indicator over BMI, the next research question focuses on specific MUAC cut-off point(s) to identify pregnant women at-risk for adverse outcomes. All studies in *Table 6* determined maternal MUAC cut-off values to be independent of gestational age, which is particularly important for this context since gestational age is often unknown for pregnant women in humanitarian emergencies. A majority of these studies utilized a MUAC threshold of < 23 cm to identify pregnant women at-risk for the following birth outcomes: LBW[44, 45, 46], IUGR[47], SGA[46], and stunted at birth[48]. This confirms the use of MUAC as the context specific preferential indicator over BMI.

The study from India that used a maternal MUAC cut-off value of ≤ 23 cm did not demonstrate any significant associations with LBW or SGA. Here, the usage of the less than or equal to symbol (≤) is unclear since it leaves the specific threshold open for interpretation[46]. Since measurements were not completed in millimeters, but rather in centimeters, it is unclear whether values between 23.1 cm to 23.9 cm are included in this threshold criteria. Additionally, this study states that a MUAC of < 24 cm had poor specificity, but higher sensitivity, so it is recommended that a MUAC of ≤ 23 cm be used. Although this study was established as good quality, it should be considered in perspective of other studies that determined a MUAC of < 23 cm as the potential indicator of birth risks.

Nutritional Programs

RUSF was found as a better intervention to address maternal weight gain and prevention of LBW infants, compared to CSB+ with UNIMMAP[49]. BEP could potentially serve as an alternative to RUSF to treat acute malnutrition, with an additional benefit being its sustainability and cost-effectiveness[50].

Timing of enrollment in nutritional program based on anthropometry is essential. The primary goal is to accurately detect undernutrition in pregnant women as early as possible in pregnancy to implement a nutritional intervention that improves nutritional status and reducing the risk of adverse birth and maternal outcomes. If length of enrollment in the specific nutritional program is not long enough, such as beginning in the third trimester, there is the possibility that any changes in birth or maternal outcomes are not associated or unrelated to the nutritional program itself, but rather attributed to an external factor.

The 2021 Lancet Series on Maternal and Child Undernutrition Progress[58] reiterated the importance of the effectiveness of antenatal MMNs, along with preventative SQ-LNSs as an emerging intervention that has shown positive effects on childhood growth and low- and middle-income countries. While studies MMN and SQ-LNS supplementations were not using MUAC or any particular anthropometry as enrollment criteria for undernutrition, they may serve as the starting point for future studies. In the systematic review and meta-analysis presented, MMN did demonstrate improvement in LBW, PTB, and SGA compared to IFA alone[56].

Limitations

Limitations of the current literature include the lack of research on the outcome of maternal mortality and the limited research on nutritional interventions with enrollment based on anthropometry. Additionally, the context of these studies was not necessarily in humanitarian emergencies or conflict settings, though the results can be applied to this context. In some studies, a less than or equal to sign was indicated, which lacks clarity for exact cut-off thresholds.

Limitations of this particular systematic review are that there was only one Quality Assessment reviewer, which has the potential of introducing bias. Ideally, having at least two independent reviewers would limit this bias and ensure all relevant studies are included in the review. Additionally, the studies are not all comparable since they varied in sample size, methodology, and context. The studies included were limited to availability in English only, which could have filtered out valuable results. Since grey literature is not peer-reviewed, it was not included, which also could have contained noteworthy data.

Recommendations

Future recommendations would be to enroll pregnant women in nutritional interventions based on the well-supported MUAC < 23 cm in efforts to reduce the risk of adverse outcomes. Additionally, these studies primarily focus solely on adverse birth outcomes rather than maternal outcomes. Maternal anthropometry and maternal mortality should be further researched.

CONCLUSION

The current research supports using maternal MUAC as an alternative anthropometric measurement to BMI for identifying pregnant women as acutely malnourished and in need of nutritional intervention to prevent adverse birth outcomes. This is particularly noteworthy in resource-limited settings, such as protracted humanitarian settings or emergencies. An advantage of measuring MUAC is that it requires minimal training and is reliable in identifying nutritional status. Initially, there has been no universal absolute cut-off value identified; however, this review supports the specific cut-off threshold for maternal MUAC in this context as < 23 cm. According to current findings, enrollment in nutritional programs such as RUSF and food-based BEP supplements based on a MUAC value defined as undernourished may address the issue of LBW and other adverse outcomes. In addition to standard of care IFA supplementation, preventative SQ-LNS may serve as a promising intervention to prevent maternal and newborn undernutrition, but more research must be conducted before recommending SQ-LNS as an effective intervention to prevent adverse birth and maternal outcomes.

APPENDICES

Appendix A. Adapted Newcastle Ottawa Quality Assessment Scale: Cross-Sectional Studies

Selection (maximum 3 points)

1) Representative: 1 point was given if the sample was truly representative of the target population (underweight or undernourished PW)
2) Sample Size: 1 point was given if sample size was justified and satisfactory
3) Non-Respondents/Non-Included Subjects: 1 point was given if comparability between respondents and non-respondents characteristics is established and the response rate is satisfactory

Comparability (maximum 2 points)

1) Comparability of Subjects: 1 point was given if subjects in different outcome groups are comparable
2) Confounding Factors: 1 point was given if study was adjusted for confounding factors

Outcome (maximum 3 points)

1) Assessment of Outcome: up to 2 points given if the assessment of the outcome is satisfactory and well-explained
2) Statistical Test: 1 point was given if the statistical test used to analyze the data was clearly described and appropriate, and the measure of association was presented, including confidence intervals and the probability level (p-value)

Total Points:
7, 8: good quality
5, 6: fair quality
4 points or less: low quality

Appendix A. Adapted Newcastle Ottawa Quality Assessment Scale: Cross-Sectional Studies							
Study	**Tesfa et al. 2020**	**He et al. 2018**	**Sultana et al. 2015**	**Fakier et al. 2017**	**Kumar et al. 2019**	**Mishra et al. 2020**	**Adane, Dachew 2018**
Selection (maximum 3 points)							
Representative	1	1	0	1	0	1	1
Sample Size	1	1	1	0	1	1	1
Non-Respondents/Non-Included Subjects	1	1	0	1	1	1	1
Comparability (maximum 2 points)							
Comparability of Subjects	1	1	1	1	1	1	1
Confounding Factors	1	1	0	0	0	1	1
Outcome (maximum 3 points)							
Assessment of Outcome	1	1	2	2	1	1	1
Statistical Test	1	1	1	1	1	1	1
Total Points (maximum 8 points)	**7**	**7**	**5**	**6**	**5**	**7**	**7**

Appendix B. Adapted Newcastle Ottawa Quality Assessment Scale: Cohort Studies

Selection (maximum 4 points)

1) Representative: 1 point was given if the sample was truly representative of the exposed cohort (underweight or undernourished PW)
2) Selection of Non-Exposed Cohort: 1 point was given if the non-exposed cohort was drawn from the same community as the exposed cohort
3) Ascertainment of Exposure: 1 point was given ascertainment of exposure was from secure record, structured interview, or healthcare provider
4) Outcome of Interest at Start of Study: 1 point was given if demonstration that outcome of interest was not present at start of study

Comparability (maximum 2 points)

1) Adjusted for Risk Factors: 1 point was given if study was adjusted for most important/relevant risk factors
2) Adjusted for Additional Confounders: 1 point was given if study was adjusted for confounding factors

Outcome (maximum 3 points)

1) Assessment of Outcome: 1 point was given if the assessment of the outcome is satisfactory
2) Follow-up Time: 1 point was given if follow-up was long enough for outcomes to occur
3) Adequacy of Follow-Up Cohorts: 1 point was given if complete follow-up for all subjects was accounted for or subjects loss to follow-up was low

Total Points:
8, 9: good quality
6, 7: fair quality
5 points or less: poor quality

Appendix B. Adapted Newcastle Ottawa Quality Assessment Scale: Cohort Studies		
Study	**Miele et al. 2021**	**Vasundhara et al. 2019**
Selection (maximum 4 points)		
Representative	1	1
Selection of Non-exposed Cohort	1	1
Ascertainment of Exposure	1	1
Outcome of Interest at Start of Study	0	1
Comparability (maximum 2 points)		
Adjusted for Risk Factors	1	1
Adjusted for Additional Confounders	0	0
Outcome (maximum 3 points)		
Assessment of Outcome	1	1
Follow-Up Time	1	1
Adequacy of Follow-Up Cohorts	1	1
Total Points (maximum 9 points)	**7**	**8**

Appendix C. Adapted Newcastle Ottawa Quality Assessment Scale: Case-Control Studies

Selection (maximum 4 points)

1) Representative: 1 point was given if the sample was truly representative of the target population (underweight or undernourished PW)
2) Case Definition: 1 point was given if the case definition was adequate with independent validation
3) Selection of Controls: 1 point was given if selection of controls was from the same source population as cases
4) Definition of Controls: 1 point was given if definition of controls was adequate

Comparability (maximum 2 points)

1) Adjusted for Risk Factors: 1 point was given if study was adjusted for most important/relevant risk factors
2) Adjusted for Additional Confounders: 1 point was given if study was adjusted for confounding factors

Exposure (maximum 3 points)

1) Ascertainment of Exposure: 1 point was given if the ascertainment of exposure was from secure record, structured interview, or healthcare provider
2) Method of Ascertainment: 1 point was given if method of ascertainment of exposure was the same for cases and controls
3) Non-Response Rate: 1 point was given if non-response rate was explained and similar for both groups

Total Points:
8, 9: good quality
6, 7: fair quality
5 points or less: poor quality

Appendix C. Adapted Newcastle Ottawa Quality Assessment Scale: Case-Control Studies		
Study	**Siyoum, Melese 2019**	**Bekela at al. 2020**
Selection (maximum 4 points)		
Representative	1	1
Case Definition	1	1
Selection of Controls	1	1
Definition of Controls	1	1
Comparability (maximum 2 points)		
Adjusted for Risk Factors	1	1
Adjusted for Additional Confounders	0	0
Exposure (maximum 3 points)		
Ascertainment of Exposure	1	1
Method of Ascertainment	1	1
Non-response Rate	1	1
Total Points (maximum 9 points)	**8**	**8**

Appendix D. Adapted Joanna Briggs Institute Critical Appraisal Checklist: Randomized Controlled Trials

1. Randomization: Was true randomization used for assignment of participants to treatment groups?
2. Allocation: Was allocation to groups concealed?
3. Treatment Groups at Baseline: Were treatment groups similar at the baseline?
4. Identical Treatment: Were treatment groups treated identically other than the intervention of interest?
5. Follow-Up: Was follow-up complete, and if not, were differences between groups in terms of follow-up adequately described and analyzed?
6. Intention-to-Treat Analysis: Were participants analyzed in the groups to which they were randomized?
7. Identical Outcome Measurements: Were outcomes measured in the same way for treatment groups?
8. Outcome Measurement Reliability: Were outcomes measured in a reliable way?
9. Statistical Analysis: Was appropriate statistical analysis used?
10. Trial Design: Was the trial design appropriate for the topic, and any deviations from the standard RCT design accounted for in the conduct and analysis?

1 point given to each question above answered with “yes”, 0 points given to each question above answered with “no” or non-applicable

Total Points:
9, 10: good quality
7, 8: fair quality
6 points or less: poor quality

Appendix D. Adapted Joanna Briggs Institute Critical Appraisal Checklist: Randomized Controlled Trials					
Study	**Chen et al. 2021**	**Callaghan-Gillespie et al. 2017**	**Stevens et al. 2018**	**Ashorn et al. 2015**	**Adu-Afarwuah et al. 2017**
1. Randomization	1	1	1	1	1
2. Allocation	0	0	1	1	1
3. Treatment Groups at Baseline	0	1	1	1	1
4. Identical Treatment	1	1	1	0	1
5. Follow-up	1	1	1	1	1
6. Intention-to-Treat Analysis	1	1	1	1	1
7. Identical Outcome Measurements	1	1	1	1	1
8. Outcome Measurement Reliability	1	1	1	1	1
9. Statistical Analysis	1	1	1	1	1
10. Trial Design	0	1	1	1	1
Total Points (maximum 10 points)	**7**	**9**	**10**	**9**	**10**

Appendix E. Adapted AMSTAR Checklist: Systematic Reviews and Meta-Analyses

1. ‘a priori’: Was an ‘a priori’ design provided?
2. Duplicates: Was there duplicate study selection and data extraction?
3. Literature Search: Was a comprehensive literature search preformed?
4. Status of Publication: Was the status of publication (i.e. grey literature) used as an inclusion criteria?
5. List of Studies: Was a list of studies (included and excluded) provided?
6. Characteristics: Were the characteristics of the included studies included?
7. Scientific Quality: Was the scientific quality of the included studies assessed, documented, and used appropriately in formulating conclusions??
8. Methods: Were the methods used to combine the findings of studies appropriate?
9. Bias: Was the likelihood of publication bias assessed?
10. Conflict of Interest: Was the conflict of interest included?

1 point given to each question above answered with “yes”, 0 points given to each question above answered with “no” or non-applicable

Total Points:
9, 10: good quality
7, 8: fair quality
6 points or less: poor quality

Appendix E. Adapted AMSTAR Checklist: Systematic Reviews and Meta-Analyses		
Study	**Das et al. 2018**	**Oh et al. 2020**
1. 'a priori'	1	1
2. Duplicates	1	1
3. Literature Search	1	1
4. Status of Publication	1	1
5. List of Studies	1	1
6. Characteristics	1	1
7. Scientific Quality	1	1
8. Methods	1	1
9. Bias	1	1
10. Conflict of Interest	1	1
Total Points (maximum 10 points)	**10**	**10**

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