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A systematic review and meta-analysis of the prevalence of childhood undernutrition in North Africa

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Abstract

Undernutrition (stunting, wasting and underweight) among children remains a public health concern in North Africa, especially following recent conflicts in the region. Therefore, this paper systematically reviews and meta-analyses the prevalence of undernutrition among children under five in North Africa to determine whether efforts to reduce undernutrition are on track to achieving the Sustainable Development Goals (SDGs) by 2030. Eligible studies published between 1st January 2006 and 10th April 2022 were searched for, using five electronic bibliographic databases (Ovid MEDLINE, Web of Science, Embase (Ovid), ProQuest and CINAHL). The JBI critical appraisal tool was used, and a meta-analysis was conducted using the 'metaprop' command in STATA, to estimate the prevalence of each undernutrition indicator in the seven North African countries (Egypt, Sudan, Libya, Algeria, Tunisia, Morocco, and Western Sahara). Due to the significant heterogeneity among studies (I^2 >50%), a random effect model and sensitivity analysis were conducted to examine the effect of outliers. Out of 1592 initially identified, 27 met the selection criteria. The prevalence of stunting, wasting and being underweight were 23.5%, 7.9% and 12.9%, respectively. Significant variations between the countries with the highest rates of stunting and wasting were reported in Sudan (36%, 14.1%), Egypt (23.7%, 7.5%), Libya (23.1%, 5.9%), and Morocco (19.9%, 5.1%). Sudan also had the highest prevalence of underweight (24.6%), followed by Egypt (7%), Morocco (6.1%), and Libya (4.3%) with more than one in ten children in Algeria and Tunisia having stunted growth. In conclusion, undernutrition is widespread in the North African region, particularly in Sudan, Egypt, Libya, and Morocco, making it challenging to meet the SDGs by 2030. Nutrition monitoring and evaluation in these countries is highly recommended.

Introduction

Malnutrition, whether under- or over-nutrition, affects hundreds of millions of children worldwide. Approximately, one hundred and forty nine (149.2) million, 45.4 million, 38.9 million and 12.6% of children under-five suffer from stunting, wasting, overweight and underweight, respectively [1]. Globally, undernutrition is responsible for approximately 45% of deaths among children under five [2]. To measure undernutrition, the three anthropometric indices, namely, stunting (low height-for-age), wasting (low weight-for-height), and underweight (low weight-for-age) are used. These three undernutrition indices also represent one of 100 indicators used to measure a community's progress toward achieving the 17 Sustainable Development Goals (SDGs) [3]. In this study, we focus on the three anthropometric indices of undernutrition (stunting, wasting, and underweight) in North African countries (Egypt, Sudan, Libya, Algeria, Tunisia, Morocco, and Western Sahara).

Nutrition during the first 2000 days (the first five years) of life is critical for the physical, cognitive, social, and emotional development of a child. Irreversible effects on a child's physical and mental health will occur if nutritional needs are not met during this period [2, 4, 5]. Yet, the burden of undernutrition remains high among children in North African countries. For instance, stunting affects more than 35% of under-five children in Libya and Sudan. At the same time, 22.3% of children suffer from stunting in Egypt, while 6.6% of children in the entire region suffer from wasting [1]. Undernutrition has profound direct and indirect effects on individuals and families due to a child's increased susceptibility to illnesses resulting in a heightened risk of morbidity and mortality [2]. Furthermore, undernutrition affects the economy and productivity of the entire community. Besides impairing physical growth, it also decreases academic performance, cognitive abilities, work efficiency, and earnings of individuals. Undernutrition may also result in increased costs of health care services, thereby causing the economy to grow slower, leading to less investment in human capital [6]. In Egypt and Sudan, the health costs of undernutrition among children amounts to approximately 1.10 billion Egyptian Pounds (EGP) and 11.66 billion Sudanese Pounds (SDG), respectively. In Egypt, 11% of child deaths are attributable to undernutrition and this is expected to increase by 32% by 2025, resulting in a cost of 26.8 billion EGP [7, 8].

To eliminate all forms of undernutrition, it is imperative to invest in interventions, monitor the progress of essential government initiatives and collect and analyse quality data [9]. In North African countries, there is a lack of current and specific information regarding undernutrition among children [10]. Previous studies on child undernutrition, carried out in various individual North African countries, namely Tunisia [11]; Egypt [12]; Sudan [13]; Algeria [14]; Morocco [15] and Western Sahara [16], highlighted the prevalence of undernutrition among children under five. Joulaei et al. [17]. conducted a review to examine the prevalence of stunting among children and adolescences aged 2–18 in 24 countries in the Middle Eastern and North African regions [17]. Apart from including a wide range of children ages with different growth requirements and health needs which affects the validity and generalizability of the results to all age groups, there was no information on Libya, Algeria, or Tunisia. A recent study in the Eastern Mediterranean region (including Afghanistan, Bahrain, Djibouti, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Pakistan, Oman, Palestine, Qatar, Saudi, Somalia, Sudan, Syrian, Tunisia, Emirates and Yemen) found a prevalence of malnutrition [18]. These findings did not specifically target North African countries as the results combined the area with other regions or countries; this may result in an over- or under-estimation of the problem due to a separation from local contexts. More concerningly, this may result in the misrepresentation of data used to inform local policies, strategies and decisions [19]. The limitations of the study included an over-reliance on grey literature, no peer-reviewed journal

articles, and the limited timeframe of the search (2019–2020). Two years is too short a period of time to gather and analyse trends in the wider literature, or to reach comprehensive representative results as nutrition guidelines are typically updated every 5 years [18, 20, 21]. Finally, Algeria was not included in the review which could affect the generalizability of the findings to all Eastern Mediterranean countries including North African countries.

As discussed above, childhood undernutrition plays an increasingly significant role in childhood morbidity and mortality. Despite this, there are currently no ongoing nutrition monitoring and evaluation programs in North Africa to target the reduction of childhood undernutrition. Investigating how the prevalence of stunting, wasting, and underweight varies across North African countries would offer insights into how well these countries are progressing towards SDGs 1, 2, and 3 by the year 2030.

This systematic review and meta-analysis study addresses this gap. It was conducted to determine the prevalence of undernutrition (stunting, wasting, and underweight) among children under five in the North African region. The findings of this systematic review aim to help strengthen existing child nutrition policies and practices and enable policymakers to determine whether countries in the North African region are on track to meet SDGs 1, 2, and 3 by 2030. Results of the study are specific to the region and may lead to more efficient and practical applications of detailed nutrition interventions aimed at improving child health and nutrition in North Africa.

Methods

Anthropometric indicators

The current systematic review utilised three anthropometric indicators for analysis:

1. *Stunting* (chronic malnutrition): an indicator of retardation of linear growth and cumulative growth deficits in children; height-for-age <-2 standard deviation (SD) of the World Health Organisation (WHO) child growth standards median.

2. *Wasting* (acute malnutrition): measuring of body mass concerning the height and describing the current nutritional status; weight-for-height <-2 SD of the WHO child growth standards median.

3. *Underweight*: is a composite index of height-for-age and weight-for-height. It takes into account both acute malnutrition (wasting) and chronic malnutrition (stunting), but it does not distinguish between the two; weight-for-age <-2 standard deviations (SD) of the WHO child growth standards median [22].

Search strategy

To review the existing literature, the study used the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) 2020 guidelines [23]. The PRISMA 2020 checklists for the manuscript and abstract are attached as additional S1 and S2 Tables. The protocol was submitted and registered with the Prospective Registry of Systematic Reviews (PROSPERO number CRD42022311922). Five databases were scanned for relevant peer-reviewed articles: Ovid MEDLINE, Web of Science, Embase (Ovid), ProQuest, and CINAHL. In addition, MeSH headings with related subheadings were combined with key terms for the included countries, region, and age-specific search terms were added to ensure all relevant studies were identified. In addition, the reference lists of retrieved articles and Google Scholar were screened for further relevant publications. Articles retrieved were imported from each database into an

EndNote library. The following combination of keywords was used in the search: (Child* or under-five* or paediatr* or infant* or bab*) AND (Malnutr* or malnourish* or undernourish* or undernutr* or stunt* or wast* or underweight*) AND (Egypt* or Sudan* or Libya* or Algeria* or Tunisia* or Morocco* or Western Sahara* or North Africa*) AND (prevalence* or rate*).

Eligibility criteria

To be included in the review studies needed to meet the following criteria: 1) participants aged between 0 and 59 months of age; 2) conducted in any or all of the North African countries (Egypt, Sudan, Libya, Algeria, Tunisia, Morocco and Western Sahara); (3) investigated one or more anthropometric indicators of undernutrition (stunting, wasting, and underweight); 4) observational studies only (no qualitative, intervention, review, or experimental studies were considered); (5) published in peer-reviewed journals (no abstracts, policy briefs, or conference proceedings were reviewed); (6) written only in English and (7) published between 1 January 2006 and 10 April 2022. The year 2006 was used as a baseline in this review to capture the period when WHO Child Growth Standards were introduced by the WHO.

Data extraction

All retrieved articles were imported from each database into EndNote X20 (Clarivate Analytics, USA) and sorted and ordering in a scientific and organised manner [24]. After removing duplicates, the first author, NFE, reviewed the study titles and screened all the publications. Following this initial screening, the second phase involved reading the abstracts and to identify the eligible studies. The third and final screening involved reading the full texts and ensuring each study met the eligibility criteria.

The identified studies are listed in Table 1, with the following information: The author, year of publication, geographic region, year of data collection, number of children and age, sample strategy, study design, population characteristics, and quality assessment score. In S4 Table, the included literature was classified according to the country of study and the prevalence of the three indices of undernutrition.

Reliability

A second reviewer (MVD) who was blinded to the primary reviewer (NFE), checked the article's relevance and the recorded details. In each stage, the articles' appropriateness was checked, with any differences of opinion discussed. A third reviewer (KEA) was available to clarify differences regarding the final publications for inclusion.

Quality assessment

The JBI critical appraisal tool was used to evaluate the degree of reliability, validity, and usefulness of the identified studies and to assess the quality of the reviewed studies. The tool is a set of 9 questions (a checklist) used to evaluate the external validity (bias in selection) and internal validity (information biases and bias of cofounders) [25]. The accuracy, suitability, and confidentiality of the JBI tool for critical appraisal of systematic reviews were confirmed [26]. For each reviewed study, a score ranging from zero to nine was allocated (zero if none of the criteria was met, and nine if all the criteria were met). This sum of points determined the overall quality of the study. Studies were rated as being high quality (7–9), medium (4–6) or poor quality (0–3), as shown in S3 Table.

Table 1. Characteristics of included publications in the literature.

Author; year	Geographical Region	Year of Data Collection	Children (No); Age	Sample Strategy	Study Design	Population Characteristics	Quality Assessment Score
Abdalla et al. 2009	El Fau (Rural area) in Sudan	2003	N = 150 6–60 months	Random sampling	Cross sectional study	Children under five in the three target villages	Medium
Abu-Manga et al. 2021	Sudan	2019	N = 145,002 0–5 years	Multi-stage stratified sampling design	Cross sectional study	Children under five from households in the Sudanese community	High
Aitsi-Selmi 2014	Egypt	1992–95	N = 9,201 0–5 years	Multi-stage stratified sampling design	Cross sectional study	Children under five in the community	High
		2005–8	N = 13,376 0–5 years				
Almasi et al. 2019	Egypt	2014	N = 14898.9 0–5 years	Multi-stage stratified sampling design	Cross sectional study	Children under five in the Eastern Mediterranean countries	Medium
	Libya	2007	N = 10723 0–5 years				
	Morocco	2011	N = 6872.6 0–5 years				
	Sudan	2014	N = 11712.3 0–5 years				
	Tunisia	2012	N = 2677.3 0–5 yrs.				
Barouaca 2012	Morocco	2004	N = 5311 0–5 yrs.	Multistage sampling surveys	Cross sectional study	Children under five in the community	Medium
		1997	N = 5240 0–5 years				
		1992	N = 4502 0–5 years				
Dahab et al 2020	Sudan	2014	N = 14,081 0–5 years	Stratified multistage cluster sampling design	Cross sectional study	Children under five from households in armed conflicts in Darfur in Eastern state, Blue Nile and South Kordofan	High
Elsary 2017	Egypt (Tamiya district in Fayoum)	2014	N = 400 0–5 years	Multi-stage stratified sampling design	Cross sectional study	Children under five who attend the health care facilities	High
El-Taguri et al. 2009	Libya	2003	N = 7232 0–5 years	Multistage sampling designs	Cross sectional study	Children under five in five Arab countries (Libya, Djibouti, Syria, Morocco and Yemen)	High
	Morocco	2003	N = 5380 0–5 years				
El Taguri et al. 2008	Libya	1995	N = 5348 0–5 years	Multi-stage stratified sampling design	Cross sectional study	Children under five from households across Libya	High
Fagbamigbe et al. 2020	Egypt	2014	N = 13,682 0–5 years	Multi-stage stratified sampling design	Cross sectional study	Children under five in the community	High
Figueroa and Kurdi 2019	Egypt	2014	N = 13601 6–59 months	Multi-stage stratified sampling design	Cross sectional study	Children under five in the community	Medium
		2008	N = 9103 6–59 months				
		2005	12131 6-59m				

(*Continued*)

Table 1. (Continued)

Author; year	Geographical Region	Year of Data Collection	Children (No); Age	Sample Strategy	Study Design	Population Characteristics	Quality Assessment Score
Ghattas et al. 2020	Egypt	2014	N = 13,857 6–59 months	Stratified cluster sampling	Cross sectional study	Children under five in Middle East and North African (MENA) region	High
	Algeria	2013	N = 13,077 6–59 months				
	Sudan	2014	N = 12,538 6–59 months				
	Morocco	2003	N = 5309 6–59 months				
	Tunisia	2012	N = 2593 6–59 months				
Kavle et al. 2015	(Egypt)	2008	N = 6091 6–59 months	Multi-stage stratified sampling design	Cross sectional study	Children under five from households across Egypt	High
		2005	N = 7794 6–59 months				
Kerac et al 2019	Egypt	2014	N = 1,210 0–6 months	Multi-stage stratified sampling design	Cross sectional study	Children less than six months of age in developing countries	High
Kiarie et al. 2021	Sudan Yambio country	2018	N = 630 6–59 months	Cluster multistage sampling method	Cross Sectional study	Children aged 6–59 months living in Yambio County, Sudan	High
Mberu et al. 2016	Egypt (Slum communities)	2003	N = 5761 0–5 years	Multi-stage stratified sampling design	Cross sectional study	Children under five in the community	Medium
Musa et al. 2014	Sudan (Khartoum State)	2014	N = 411 0–5 years	Simple random sampling	Cross sectional study	Children under five in Khartoum state, Sudan	Medium
Nikooyeh et al. 2022	Egypt	2020	N = 163 0–5 years	Online surveys	Cross sectional study	Children under five in Eastern Mediterranean countries	Medium
		2015	N = 258 0–5 years				
		2010	N = 409 0–5 years				
		2005	N = 713 0–5 years				
		2000	N = 1142 0–5 years				
	Sudan	2020	N = 29 0–5 years				
		2015	N = 99 0–5 years				
		2010	N = 266 0–5 years				
		2005	N = 80 0–5 years				
		2000	N = 28 0–5 years				

(Continued)

Table 1. (Continued)

Author; year	Geographical Region	Year of Data Collection	Children (No); Age	Sample Strategy	Study Design	Population Characteristics	Quality Assessment Score
	Libya	2020	N = 74 0–5 years				
		2015	N = 111 0–5 years				
		2010	N = 225 0–5 years				
		2005	N = 320 0–5 years				
		2000	N = 241 0–5 years				
	Morocco	2020	N = 286 0–5 years				
		2015	N = 347 0–5 years				
		2010	N = 640 0–5 years				
		2005	N = 652 0–5 years				
		2000	N = 679 0–5 years				
	Tunisia	2020	N = 507 0–5 years				
		2015	N = 960 0–5 years				
		2010	N = 1064 0–5 years				
		2005	N = 1212 0–5 years				
		2000	N = 985 0–5 years				
Özaltin et al. 2010	Egypt	2005–2008	N = 33440 0–59 months	Multi-stage stratified sampling design	Cross sectional study	Children under five in Egypt and Morocco	High
	Morocco	2003–04	N = 5544 0–59 months				
Rico et al. 2010	Egypt	2005	N = 3242 6–59 months	Multi-stage stratified sampling design	Cross sectional study	Children under five in the community	High
Seedhom et al. 2014	Egypt (El-Minia)	2014	N = 700 6–24 months	Non-random sampling	Cross sectional study	Children 6–24 months in Minia region, Egypt	Medium
Shaker-Berbari et al 2021	Egypt	2014	N = 5100 6–23 months	Multi-stage stratified sampling design	Cross sectional study	Children under five in the Middle East	High
	Sudan	2014	N = 4009 6–23 months				
Sharaf and Rashad 2016	Egypt	2014	N = 12,997 0–5 years	Multi-stage stratified sampling design	Cross sectional study	Children under five in the community	Medium
Sulaiman et al. 2018	North Sudan (Rural area)	2014	N = 1635 0–5 years	Cluster multistage sampling method	Cross Sectional study	Children under five who live in the Four Nile River rural area of Sudan	High

(*Continued*)

Table 1. (Continued)

Author; year	Geographical Region	Year of Data Collection	Children (No); Age	Sample Strategy	Study Design	Population Characteristics	Quality Assessment Score
Tzioumis et al. 2016	Egypt	2008	N = 9275 0–5 years	Multi-stage stratified sampling design	Cross sectional study	Children under five in the community	High
		2005	N = 12038 0–5 years				
		2003	N = 5911 0–5 years				
		2000	N = 10078 0–5 years				
		1995	N = 10165 0–5 years				
		1992	N = 7241 0–5 years				
Winskill et al. 2021	Egypt	2014	N = 11,706 0–5 years	Multi-stage stratified sampling design	Cross sectional study	Children under five in 39 low to middle-income countries	High
Zotarelli et al. 2007	Egypt	2000	N = 10194 0–5 years	Multi-stage stratified sampling design	Cross sectional study	Children under five in the community	High

High = 7–9; medium = 4–6, and poor = 0–3

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Statistical methods

The results were imported into STATA version 17 (Stata Corp LLC, Texas, USA) [27]. For each country, the prevalence of undernutrition indicators (stunting, wasting and underweight) was assessed through the forest plot. Each indicator was displayed in the forest plots with its corresponding weight, 95% confidence interval, and overall prevalence in the region.

A heterogeneity test of the different studies showed a high level of inconsistency ($I^2 > 50\%$), thereby indicating the use of a random effect model in all the meta-analyses conducted. Sensitivity analysis was also conducted by examining the effect of outliers. We employed a similar method to Patsopoulos et al. [28] which compared the pooled prevalence before and after eliminating one study at a time. The funnel plot was used to report potential bias and small/large study effects, and Begg's tests were used to assess asymmetry. Their respective funnel plots are shown as S1-S4 Figs.

Results

As displayed in Fig 1, a total of 1592 peer-reviewed articles were initially identified from the five databases. After removing 519 duplicates, 1073 articles remained. The screening of the titles in the first screening phase excluded 986 articles. Further screening of the remaining 87 abstracts excluded another 37 articles. In the final phase, the full texts of the remaining 50 articles were screened and a further 30 articles were excluded. During the screening processes seven more papers were identified from Google scholar and other papers [29, 30]. Accordingly, 27 peer-reviewed papers were eligible for critical appraisal.

Characteristics of included studies

As shown in Table 1, all 27 studies included in this review were cross-sectional surveys. Eighteen of these studies were investigated in Egypt [30–47], and 10 studies explored the problem in Sudan [32, 35, 38, 42, 48–53]. In addition, 6 studies assessed prevalence of undernutrition in Morocco [32, 35, 38, 39, 54, 55]; 4 studies assessed prevalence of undernutrition in Libya [32, 38, 55, 56], 3 studies demonstrated prevalence of undernutrition in Tunisia [32, 35, 38], and 1 study investigated in Algeria [35]. Six studies were conducted on children aged 6 to 60 months [30, 35, 40, 47, 48, 51], 2 studies investigated children aged 6–24 months [41, 42] and only 1 study investigated children from 0–6 months [36] and the remaining studies focused on children aged 0–60 months [31–34, 37–39, 43–47, 49, 50, 52–56]. Twenty two papers used secondary source data (nationally-representative data) [30–32, 34–40, 42–47, 49, 50, 53–56], and only 5 studies used a primary source data [33, 41, 48, 51, 52]. The prevalence of stunting was found in 22 studies [30–33, 35, 37–44, 46, 47, 49, 51–56], prevalence of wasting was found in 18 studies [32–34, 36–39, 41, 42, 45, 46, 48, 49, 51–53, 55, 56] and that of underweight in 12 studies [33, 37, 39, 41, 46, 49–54, 56].

Among the nine JBI criteria used to assess the quality of the studies, 18 (66.7%) articles scored seven points or higher [30, 31, 33–36, 39, 40, 42, 44–46, 49, 50, 51, 53, 55, 56], while 9 (33.3%) papers scored medium between 4 and 6 [32, 37, 38, 41, 43, 47, 48, 52, 54] as seen in S3 Table.

Meta-analysis of the prevalence of undernutrition

Stunting. A forest plot of the prevalence of stunting among children under five in study is shown in Fig 2. The overall random effect pooled prevalence of stunting was approximately one in five, 23.5% with high heterogeneity (I^2 = 99.7%). Funnel plots and the use of Begg's test for stunting in North Africa indicated homogeneity (S1 Fig), and meta-regression analysis of undernutrition by year of publication indicated that the year of publication increased as the proportion of undernutrition decreased as shown in S4 Fig. However, this relationship did not differ statistically (p = 0.0083). Countries with the highest significant prevalence of stunting in the North Africa region were Sudan 36% (95% CI: 33.8, 38.2; P < 0.001), Egypt 23.7% (95% CI: 22.1, 25.2; P < 0.001), Libya 23.1% (95% CI: 21.0, 25.3; P < 0.001) and Morocco 19.9% (95% CI: 17.8, 22.0; P < 0.001). However, the overall pooled prevalence of stunting was not significant in Algeria 10.7% (95% CI: 10.17, 11.2; P < 0.001) and Tunisia 10.2% (95% CI: 9.1, 11.3; P < 0.001).

Wasting. Fig 3 presents a forest plot of the prevalence of wasting among children under five in the North African region. The overall random effect pooled prevalence of wasting was 7.9% (95% CI: 6.5, 9.3); p <0.001), with high heterogeneity (I^2 = 99.5%). The Funnel plots and use of Begg's test for wasting shown in S2 Fig reported the absence of publication biases. The highest significant rate of wasting in the region was reported in Sudan 14.1% (95% CI: 11.4,16.7; P < 0.001); and medium rates were found in Egypt 7.5% (95% CI: 6.1, 8.8; P < 0.001), Libya 5.9% (95% CI: 4.5, 7.2; P < 0.001) and Morocco 5.1% (95% CI: 2.1, 8.2; P < 0.001). However, the weighted prevalence in Tunisia was minor at 2.9% (95% CI: 2.5, 3.3; P < 0.001).

Underweight. The prevalence of underweight among children under five across the North African region, and in the individual countries under study is presented in Fig 4. Accordingly, the overall random effect pooled prevalence of underweight was 12.9% (95% CI:6.4, 19.5); p <0.001), with high heterogeneity (I^2 = 100.0%). The highest pooled prevalence of underweight was reported in Sudan 24. 6% (95% CI: 17.5, 31.6; P < 0.001) and the medium weighted rates of underweight were reported in Egypt 7% (95% CI: 5.1, 9.0; P < 0.001),
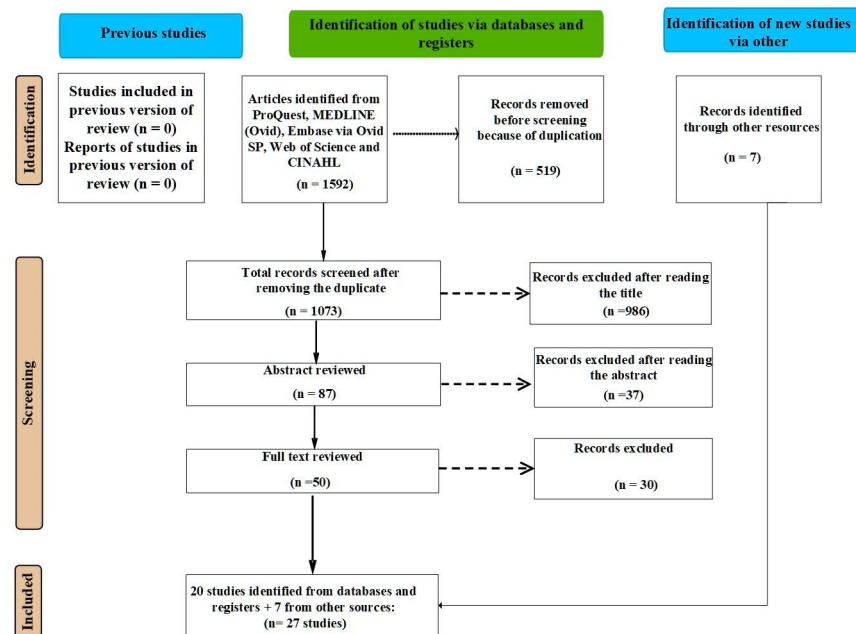
PRISMA 2020 Flow Diagram

Fig 1. Flow chart of the study selection process based on PRISMA 2020.

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Morocco 6.1% (95% CI: 3.4, 8.8: P < 0.001) and in Libya 4.3% (95% CI: 3.8, 4.9; P < 0.001). However, there was a little evidence of an effect on the prevalence, which implied homogeneity due to limited data. Funnel plots and the use of Begg's test for underweight, indicated an absence of publication biases, S3 Fig).

Discussion

In the current study, 27 studies within the last 15 years met the eligibility criteria to determine the prevalence of stunting, wasting and underweight in North African children under five years of age. The critical appraisal of the 27 studies ranged from medium (9) to high (18). No studies were appraised as low. The overall prevalence of stunting, wasting and underweight in the current study were 23.5%, 7.9% and 12.9%, respectively.

Accordingly, the overall pooled prevalence of stunting among children under five in North Africa was approximately one in four. This is higher than that the global average of one in five. It is however lower than that of West Africa one in three children have stunting [57]. The review also found that the overall pooled prevalence of wasting among children under five in North Africa was approximately 7.9% which is higher than the global average of 6.7% and higher than the West Africa value of 6.9% [57]. Furthermore, the overall pooled prevalence of underweight among the children under five in North Africa was approximately one in eight. This is higher than the 2020 global average of 12.6% [58], and lower than the WHO 2018 estimate for the Africa region of 17.1% [59].

As described above, the study revealed stunting (chronic undernutrition) and underweight rates in children under five in North African countries were higher than the global average, while wasting was moderate (acute undernutrition). The results are consistent with a study by by Akombi et al [60]. Our results are also consistent with the study of Joulaei et al. [17] that focused on children 2–18 years in Middle East and North African countries, and found high
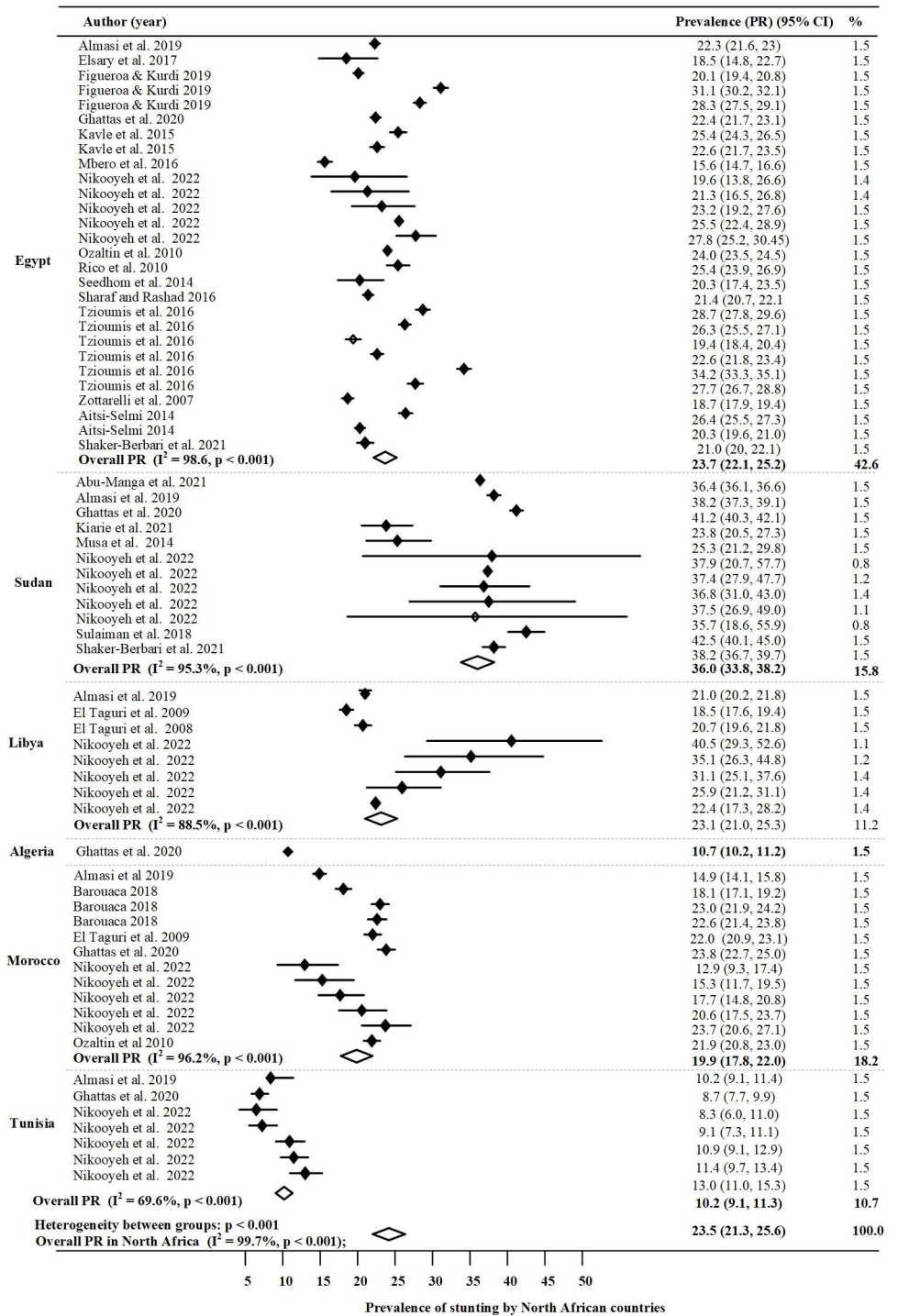
Fig 2. Prevalence of stunting in North Africa by country.

stunting rates among children [17]. Finally, our results agree with the 2021 WHO report which observed that stunting was prevalent and increasing in the North African region [1].

North African countries, similar to other low- and middle-income countries, is experiencing increased malnutrition as a result of conflicts and civil wars, increased food insecurity,
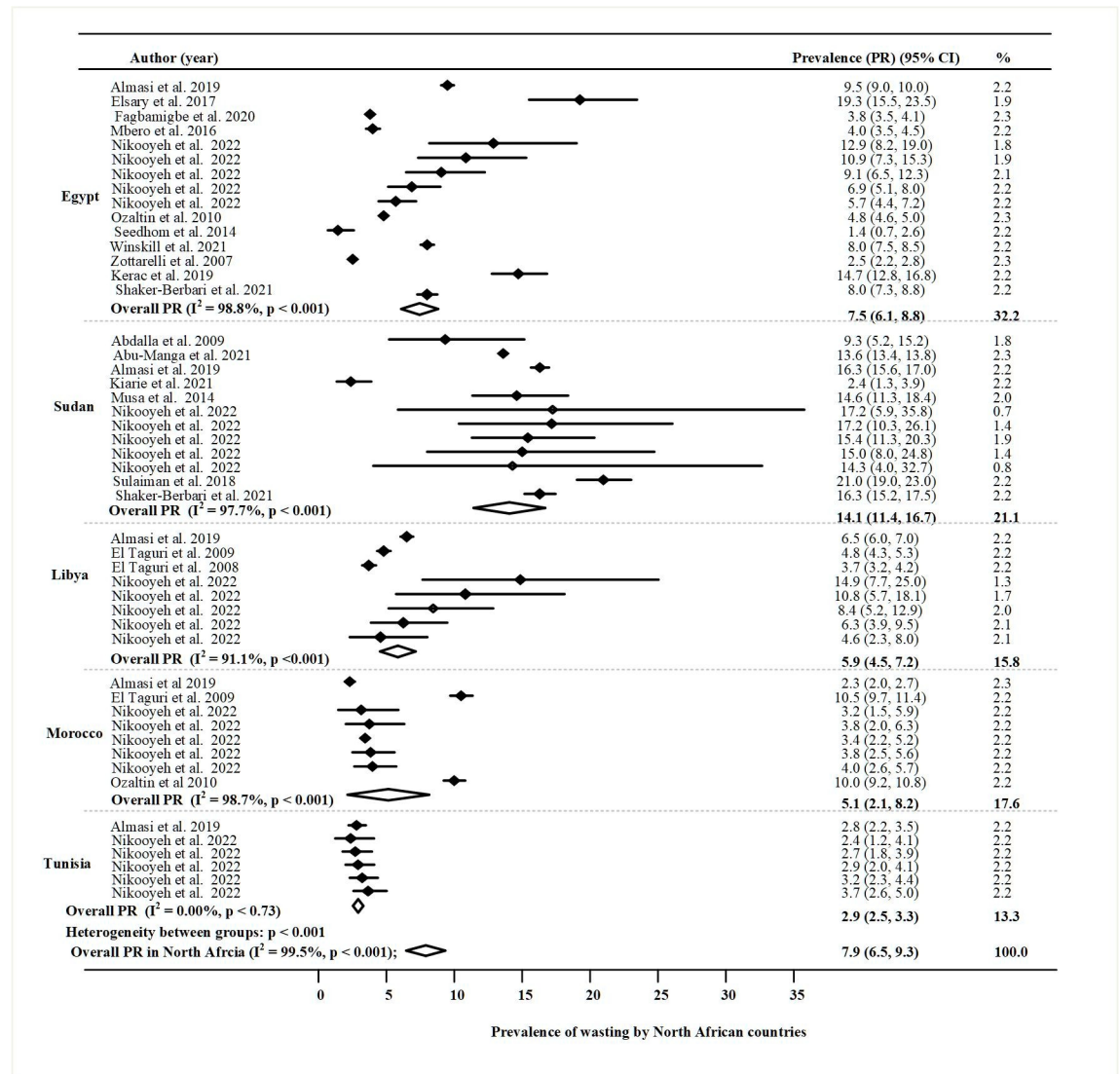
Fig 3. Prevalence of wasting in North Africa by country.

displacement, communicable diseases, and a changing climate [61–63]. For example, due to conflicts in Libya, children and families are experiencing inadequate dietary diversity and reduced access to food due to rapid declines in public services, particularly education and health services, as well as higher food and fuel prices, loss of shelter and livelihoods, loss of jobs and income [64]. Similarly, the ongoing crisis in Sudan has been exacerbated by a worsening economic situation, recurring violence throughout many states, a poor harvest, and global price shocks in grains and other food commodities. Children who live in conflict areas are often malnourished due to conflict displacement, infectious diseases, poverty, a decrease in food production, and a lack of essential resources such as food, water, and shelter. Most children aged 6 to 23 months did not consume the Minimum Acceptable Diet daily in Libya [64]. Additionally, families are unable to buy food at the market due to economic deterioration, political instability, and low salaries [65–68]. The effects of climate change are also possible contributors; Sudan and Libya, for example, are among the world's most water-scarce
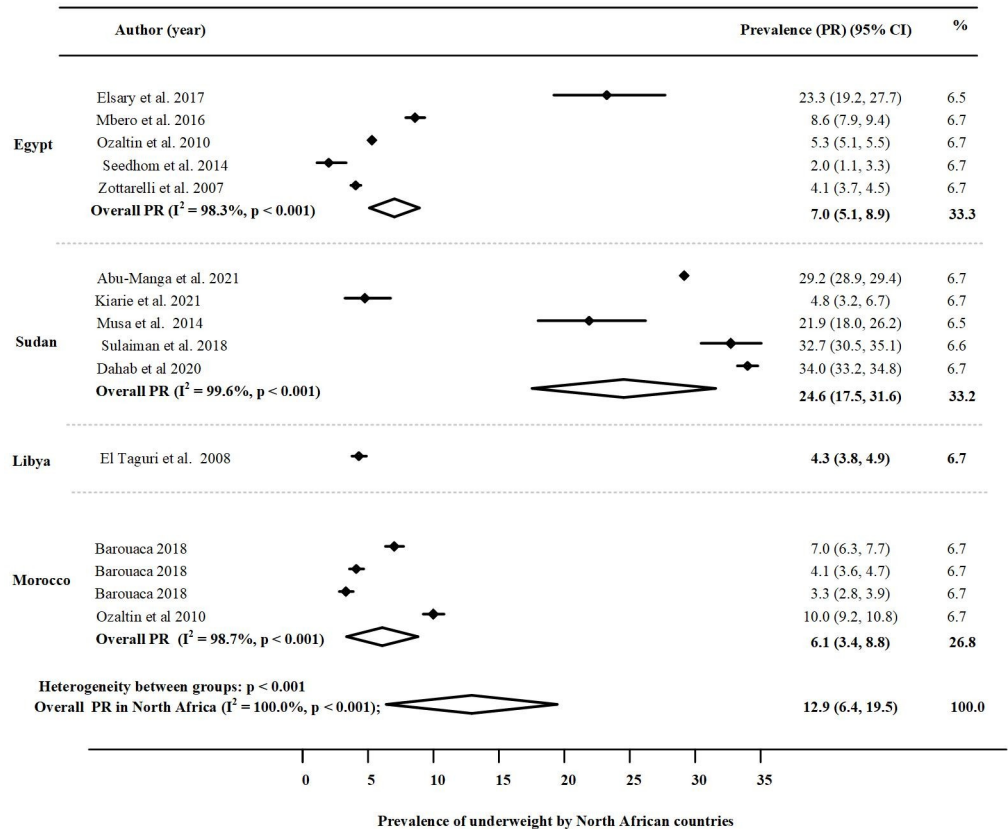
Fig 4. Prevalence of underweight in North Africa by country.

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countries. Water, sanitation, and hygiene (WASH) services and facilities have been severely impacted by conflict, non-renewable water supply, and climate change in these countries [69]. Poverty might also play a role; 29.7% of Egyptians live below the official poverty line in 2019, despite Egypt having the third highest GDP in Africa [70, 71].

In the current study, we also found a significant variation between the prevalence rates of stunting and wasting among the countries with the highest rates, Sudan, and the lowest, Morocco. Sudan had the highest prevalence of underweight, followed by Egypt, Morocco, and Libya. More than one in ten children under five in Algeria and Tunisia had stunted growth. These conclusions align with several other studies. For instance, a study by Akombi et al. [60] on Sub-Saharan African countries found a substantial prevalence of undernutrition in the region, higher within East and West African countries than in South or Central countries in the same region [60].

The previously mentioned observations could be attributed to the concluded variation in the region, which also shows the high prevalence of undernutrition in countries like Sudan and Libya. That are still experiencing violent conflicts or countries like Egypt and Morocco, where conflicts have recently ended, compared with countries that have never experienced conflict or war.

The variation in undernutrition is likely due to high levels of disadvantage, inequality, and food insecurity in the North African region. This is exacerbated by conflict, displacement, and a changing climate. The United Nations Children's Fund (UNICEF) recently conducted a study of 11 countries in the Middle East and North Africa and found that poverty continues to

affect at least 29 million children, or one in four children in this region [72]. Poverty and unemployment rates, which are already high in Algeria, Tunisia, and Libya, are unevenly distributed across age, gender, and geography. Economic inequality is identified as a major obstacle to the global goal of ending global poverty by 2030 [73]. Africa represented the third unequal region after Latin America and Middle East [74]. The inequality may be attributed to economic, governmental, and social structures that limit the equal distribution of medical care, access to food, the impact on dietary intake, and other factors that affect child health directly or indirectly [75]. Poverty, food insecurity and inequality are the roots of undernutrition; these are exacerbated when regional conflicts and other environmental factors increase. For instance, studies from Bangladesh and South Asia found a strong direct, immediate association between higher income inequality and child health. The most vulnerable children suffer the most significant burden of stunting [76, 77]. Furthermore, in 2010, before recent conflicts begun, North African countries were already identified as food security-challenged countries, which faced challenges that prompted them to reconsider their approaches to development [78]. To achieve food security and development, it was suggested that these North African countries need to grow economically, increase employment, manage to sustain water resources, adapt to climate change in a timely manner [78].

Policy implications of the study

Findings from our study may inform governments, policymakers, public health researchers and other stakeholders to identify countries in North Africa whose children are most vulnerable to undernutrition. The current study also serves as a needs assessment indicator for specific countries that report a high prevalence of child undernutrition. Our findings suggest specific policies are needed to address undernutrition within each North African country as an important public health issue. The current review contributes to the evidence for aid organizations and programming to continue allocating resources within North African countries to address undernutrition. This study also provides the latest update on national and international levels of undernutrition which can help determine whether North African countries are making progress towards achieving SDG goals 1, 2 and 3 by 2030.

Strengths and limitations

The main strength of this review is its unique focus of undernutrition in the North African region, specifically in its seven countries of Egypt, Sudan, Libya, Algeria, Tunisia, Morocco, and Western Sahara. Other strengths include the use of uniform standards of measurement from the 2006 WHO standards for child health and the exclusion of studies in clinical settings (e.g., hospitalized children) thereby enhancing the generalizability of results to the general population. The study's eligibility criteria that evaluated the robustness of the study designs employed in each study was another strength. Nonetheless, this review has a certain number of limitations. Firstly, it was unable to investigate trends in the prevalence of undernutrition indices in the region due to inconsistent data collection and the limited number of studies from some included countries. Secondly, the selection of English-only studies likely biased the results towards studies in countries where the findings are reported in English. Nor did the current review examine the various factors that influence the epidemiology of undernutrition within this region.

Conclusions

Undernutrition is a concern for children under five years of age in North Africa. Considerable variations by country were determined in undernutrition for stunting, wasting and

underweight. The North Africa region is at risk of an escalating burden of child undernutrition (particularly in Sudan, Libya, Egypt, and Morocco) due to ongoing conflicts, increased disadvantages and impacts of a changing climate. Public health attention must be paid to this region due to the wide range of inequalities experienced by families and young children living there. This review indicates that ongoing nutrition monitoring and evaluation programs are needed in North African countries to determine and measure progress made by these countries in achieving Sustainable Development Goals (SDGs) 1, 2 and 3 by 2030.

Supporting information

S1 Fig. Funnel plots and 95% confidence intervals of stunting.
(TIF)

S2 Fig. Funnel plots and 95% confidence intervals of wasting.
(TIF)

S3 Fig. Funnel plots and 95% confidence intervals of underweight.
(TIF)

S4 Fig. A meta-regression analysis of undernutrition by year of publication. The vertical axis is the log proportion of undernutrition, and the horizontal axis represents the year of publication. Each dark dot represented one selected study, and the size of each dark dot corresponds to the weight assigned to each study. Given the slope of the regression line has descended slightly in this figure, this could be interpreted as the publication of year increased as the proportion of undernutrition decreased but this relationship differs statistically (p = 0.0083).
(TIF)

S1 Table. PRISMA 2020 checklist for the main.
(DOCX)

S2 Table. PRISMA 2020 checklist for the abstract.
(DOCX)

S3 Table. Quality assessment score.
(DOCX)

S4 Table. Prevalence of undernutrition among children under five in North Africa.
(DOCX)

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References

1. United Nations Children's Fund (UNICEF), World Health Organization, International Bank for Reconstruction and Development/The World Bank. Levels and trends in child malnutrition: key findings of the 2021 edition of the joint child malnutrition estimates. Geneva: World Health Organization; 2021.

2. WHO. Fact sheets: malnutrition. In fact sheets: malnutrition [Internet]. 2021 [cited 4 Jan 2023]. https://www.who.int/news-room/fact-sheets/detail/malnutrition.

3. WHO Nutrition Landscape Information System (NLiS). Stunting, wasting, overweight and underweight [Internet]. World Health Organization; [cited 4 Jan 2023]. Available from: https://apps.who.int/nutrition/landscape/help.aspx?menu=0&helpid=391&lang=.

4. Caulfield LE, de Onis M, Blössner M, Black RE. Undernutrition as an underlying cause of child deaths associated with diarrhea, pneumonia, malaria, and measles. The American journal of clinical nutrition. 2004; 80(1):193–8. https://doi.org/10.1093/ajcn/80.1.193 PMID: 15213048

5. NSW Ministry of Health. First 2000 days implementation strategy 2020–2025 [Internet]. NSW Goverment. 2021.

6. Akseer N, Tasic H, Onah MN, Wigle J, Rajakumar R, Sanchez-Hernandez D, et al. Economic costs of childhood stunting to the private sector in low-and middle-income countries. EClinicalMedicine. 2022; 45:101320. https://doi.org/10.1016/j.eclinm.2022.101320 PMID: 35308896

7. Abu-Fatima O, Abbas AA, Racalbuto V, Smith L, Pizzol D. Child undernutrition in Sudan: the social and economic impact and future perspectives. The American Journal of Tropical Medicine and Hygiene. 2021; 104(3):1149.

8. Union A. The cost of hunger in Africa: Social and economic impact of child undernutrition in Egypt, Ethiopia, Swaziland and Uganda background paper. Abuja, Nigeria. 2014 Mar.

9. United Nations. The Sustainable development goals report 2022. United Nations.

10. Kim W, Sandler T. Middle East and North Africa: terrorism and conflicts. Global Policy. 2020; 11 (4):424–38.

11. Rabeh RB, Missaoui N, Mazigh S, Atiattalah S, Yahyaoui S, Boukthir S. 268 Assessment of nutritional status in hospitalized children in Tunisian tertiary referral pediatric hospital. BMJ Publishing Group Ltd; 2021.

12. Abdelaziz SB, Youssef MRL, Sedrak AS, Labib JR. Nutritional status and dietary habits of school children in Beni-Suef Governorate, Egypt. Food and Nutrition Sciences. 2015; 6(01):54.

13. Kanan SO, Abd Elmoneim OE. Prevalence and causes of undernutrition among underfive Sudanese Cchildren: A mini-review. Journal of Advances in Medicine and Medical Research. 2020; 32(15):12–20.

14. Bouziane Nedjadi K, Hamous A, Hadjkadi A, Dida N, Benadouda S, Boureghda I, et al. Frequency of Malnutrition (Undernutrition, Overweight/Obesity) and Prevalence of Iron Deficiency in Western Algeria Infants. 2018.

15. Ahami A, Fadel H, Azzaoui F-Z. Anthropometric measurements of school children in North-Eastern Morocco. International Research Journal of Public and Environmental Health. 2020; 7(4):100–4.

16. Grijalva-Eternod CS, Wells JC, Cortina-Borja M, Salse-Ubach N, Tondeur MC, Dolan C, et al. The double burden of obesity and malnutrition in a protracted emergency setting: a cross-sectional study of Western Sahara refugees. PLoS Med. 2012; 9(10).

17. Joulaei H, Keshani P, Ashourpour M, Bemani P, Amiri S, Rahimi J, et al. The prevalence of stunting among children and adolescents living in the Middle East and North Africa region (MENA): A systematic review and meta-analysis. Journal of global health. 2021; 11. https://doi.org/10.7189/jogh.11.04070 PMID: 35003712

18. Al-Shameri EA, Al-Shahethi AH, Wafa SW. Nutritional status and its determinants in the Eastern Mediterranean region. A review. Saudi Med J. 2022; 43(4):423–7. https://doi.org/10.15537/smj.2022.43.4.20210676 PMID: 35414622

19. Scott N, Delport D, Hainsworth S, Pearson R, Morgan C, Huang S, et al. Ending malnutrition in all its forms requires scaling up proven nutrition interventions and much more: a 129-country analysis. BMC medicine. 2020; 18(1):1–9.

20. Fanzo J. Food policies' roles on nutrition goals and outcomes: connecting of food and public health systems. In international food law and policy; Springer: Berlin/Heidelberg, Germany, 2016; pp. 213–251.

21. World Health Organization. Developing nutrition guidelines [Internet]. World Health Organization; [cited 4 Jan 2023]. Available from: https://www.who.int/activities/developing-nutrition-guidelines.

22. De Onis M. WHO child growth standards: length/height-for-age, weight-for-age, weight-for-length, weight-for-height and body mass index-for-age: WHO; 2006.

23. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. Updating guidance for reporting systematic reviews: development of the PRISMA 2020 statement. Journal of clinical epidemiology. 2021; 134:103–12. https://doi.org/10.1016/j.jclinepi.2021.02.003 PMID: 33577987

24. EndNote. The best reference management tool [Internet]. EndNote. 2022 [cited4 Jan 2023]. Available from: https://endnote.com/

25. Munn Z, Moola S, Lisy K, Riitano D, Tufanaru C. Methodological guidance for systematic reviews of observational epidemiological studies reporting prevalence and cumulative incidence data. International journal of evidence-based healthcare. 2015; 13(3):147–53. https://doi.org/10.1097/XEB.0000000000000054 PMID: 26317388

26. Munn Z, Barker TH, Moola S, Tufanaru C, Stern C, McArthur A, et al. Methodological quality of case series studies: an introduction to the JBI critical appraisal tool. JBI evidence synthesis. 2020; 18 (10):2127–33. https://doi.org/10.11124/JBISRIR-D-19-00099 PMID: 33038125

27. StataCorp. Stata statistical software: Release 17. College Station. TX: StataCorp LLC. 2021.

28. Patsopoulos NA, Evangelou E, Ioannidis JP. Sensitivity of between-study heterogeneity in meta-analysis: proposed metrics and empirical evaluation. International journal of epidemiology. 2008; 37 (5):1148–57. https://doi.org/10.1093/ije/dyn065 PMID: 18424475

29. De Onis M, Blössner M, Borghi E. Prevalence and trends of stunting among pre-school children, 1990–2020. Public health nutrition. 2012; 15:142–8. https://doi.org/10.1017/S1368980011001315 PMID: 21752311

30. Kavle JA, El-Zanaty F, Landry M, Galloway R. The rise in stunting in relation to avian influenza and food consumption patterns in Lower Egypt in comparison to Upper Egypt: results from 2005 and 2008 Demographic and Health Surveys. BMC public health. 2015; 15(1):1–18. https://doi.org/10.1186/s12889-015-1627-3 PMID: 25884171

31. Aitsi-Selmi A. Households with a Stunted Child and Obese Mother: Trends and Child Feeding Practices in a Middle-Income Country, 1992–2008. Matern Child Health. 2014; 19:1284–91.

32. Almasi A, Saeidi S, Zanganeh A, Ziapour A, Choobtashan M, Saeidi F, et al. Investigation of some factors affecting stunting and wasting among the under-five children in eastern Mediterranean region. International Journal of Pediatrics. 2019; 7(7):9759–72.

33. Elsary AY, Abd El-moktader AM, Alkassem Elgameel W, Mohammed S, Masoud M, Abd El-Haleem NG. Nutritional survey among under five children at Tamyia district in Fayoum, Egypt. International Journal of Community Medicine and Public Health. 2017; 4(6):1813.

34. Fagbamigbe AF, Kandala N-B, Uthman OA. Correction: Mind the gap: What explains the poor-non-poor inequalities in severe wasting among under-five children in low-and middle-income countries? Compositional and structural characteristics. Plos one. 2021; 16(6):e0253831. https://doi.org/10.1371/journal.pone.0253831 PMID: 34161382

35. Ghattas H, Acharya Y, Jamaluddine Z, Assi M, El Asmar K, Jones AD. Child-level double burden of malnutrition in the MENA and LAC regions: Prevalence and social determinants. Maternal & child nutrition. 2020; 16(2):e12923. https://doi.org/10.1111/mcn.12923 PMID: 31828957

36. Kerac M, Frison S, Connell N, Page B, McGrath M. Informing the management of acute malnutrition in infants aged under 6 months (MAMI): risk factor analysis using nationally-representative demographic & health survey secondary data. PeerJ. 2019; 6:e5848.

37. Mberu BU, Haregu TN, Kyobutungi C, Ezeh AC. Health and health-related indicators in slum, rural, and urban communities: a comparative analysis. Global health action. 2016; 9(1):33163. https://doi.org/10.3402/gha.v9.33163 PMID: 27924741

38. Nikooyeh B, Ghodsi D, Amini M, Rasekhi H, Rabiei S, Doustmohammadian A, et al. The Analysis of Trends of Preschool Child Stunting, Wasting and Overweight in the Eastern Mediterranean Region: Still More Effort Needed to Reach Global Targets 2025. Journal of Tropical Pediatrics. 2022; 68(3): fmac028. https://doi.org/10.1093/tropej/fmac028 PMID: 35393613

39. Özaltin E, Hill K, Subramanian S. Association of maternal stature with offspring mortality, underweight, and stunting in low-to middle-income countries. Jama. 2010; 303(15):1507–16. https://doi.org/10.1001/jama.2010.450 PMID: 20407060

40. Rico E, Fenn B, Abramsky T, Watts C. Associations between maternal experiences of intimate partner violence and child nutrition and mortality: findings from Demographic and Health Surveys in Egypt, Honduras, Kenya, Malawi and Rwanda. Journal of epidemiology & community health. 2011; 65(4):360–7. https://doi.org/10.1136/jech.2008.081810 PMID: 20841374

41. Seedhom AE, Mohamed ES, Mahfouz EM. Determinants of stunting among preschool children, Minia, Egypt. International Public Health Forum [Internet]. 2014; 1(2):[6–9 pp.].

42. Shaker-Berbari L, Qahoush Tyler V, Akik C, Jamaluddine Z, Ghattas H. Predictors of complementary feeding practices among children aged 6–23 months in five countries in the Middle East and North Africa region. Maternal & child nutrition. 2021; 17(4):e13223.

43. Sharaf MF, Rashad AS. Regional inequalities in child malnutrition in Egypt, Jordan, and Yemen: a Blinder-Oaxaca decomposition analysis. Health economics review. 2016; 6(1):1–11.

44. Tzioumis E, Kay MC, Bentley ME, Adair LS. Prevalence and trends in the childhood dual burden of malnutrition in low-and middle-income countries, 1990–2012. Public health nutrition. 2016; 19(8):1375–88. https://doi.org/10.1017/S1368980016000276 PMID: 26905921

45. Winskill P, Hogan AB, Thwing J, Mwandigha L, Walker PG, Lambert B. Health inequities and clustering of fever, acute respiratory infection, diarrhoea and wasting in children under five in low-and middle-income countries: a Demographic and Health Surveys analysis. BMC medicine. 2021; 19(1):1–11.

46. Zottarelli LK, Sunil TS, Rajaram S. Influence of parental and socioeconomic factors on stunting in children under 5 years in Egypt. Eastern Mediterranean Health Journal. 2007; 13(6):1330–42. https://doi.org/10.26719/2007.13.6.1330 PMID: 18341183

47. Figueroa JL, Kurdi S. Ex post adjustment for measurement error in stunting calculations: an illustration from Egypt. Public health nutrition. 2020; 23(5):776–81. https://doi.org/10.1017/S1368980019003100 PMID: 31760968

48. Abdalla MA, Sulieman SA, El Tinay AH, Khattab AGH. Socio-economic aspects influencing food consumption patterns among children under age of five in rural area of Sudan. Pakistan Journal of Nutrition. 2009; 8(5):653–9.

49. Abu-Manga M, Al-Jawaldeh A, Qureshi AB, Ali AME, Pizzol D, Dureab F. Nutrition assessment of under-five children in sudan: Tracking the achievement of the global nutrition targets. Children. 2021; 8 (5):363. https://doi.org/10.3390/children8050363 PMID: 34062925

50. Dahab R, Bécares L, Brown M. Armed conflict as a determinant of children malnourishment: a cross-sectional study in The Sudan. BMC public health. 2020; 20(1):1–10.

51. Kiarie J, Karanja S, Busiri J, Mukami D, Kiilu C. The prevalence and associated factors of undernutrition among under-five children in South Sudan using the standardized monitoring and assessment of relief and transitions (SMART) methodology. BMC NUTRITION. 2021; 7(1). https://doi.org/10.1186/s40795-021-00425-3 PMID: 34044874

52. Musa TH, Musa HH, Ali EA, Musa NE. Prevalence of malnutrition among children under five years old in Khartoum State, Sudan. Polish Annals of Medicine. 2014; 21(1):1–7.

53. Sulaiman AA, Bushara SO, Elmadhoun WM, Noor SK, Abdelkarim M, Aldeen IN, et al. Prevalence and determinants of undernutrition among children under 5-year-old in rural areas: A cross-sectional survey in North Sudan. Journal of family medicine and primary care. 2018; 7(1):104–10. https://doi.org/10.4103/jfmpc.jfmpc_73_17 PMID: 29915742

54. Barouaca H. Situation of malnutrition in Morocco: Results after 40 years of struggle. Nutr Clin Diet Hosp. 2012; 32:76–81.

55. El Taguri A, Besmar F, Abdel Monem A, Betilmal I, Ricour C, Rolland Cachera M. Stunting is a major risk factor for overweight: results from national surveys in 5 Arab countries. Eastern Mediterranean Health Journal. 2009; 15(3):549–62. PMID: 19731771

56. El Taguri A, Rolland-Cachera MF, Mahmud SM, Elmrzougi N, Abdel Monem A, Betilmal I, et al. Nutritional Status Of Under-Five Children In Libya; A National Population-Based Survey. LIBYAN JOURNAL OF MEDICINE. 2008; 3(1):13–9. https://doi.org/10.4176/071006 PMID: 21499476

57. Global Nutrition Report. Country Nutrition Profiles. West Africa. The burden of malnutrition at a glance. [Available from: https://globalnutritionreport.org/resources/nutrition-profiles/africa/western-africa/.

58. The World Bank. Prevalence of underweight, weight for age (% of children under 5) [Available from: https://data.worldbank.org/indicator/SH.STA.MALN.ZS.

59. Development Education.ie. Factsheet: Child under-nutrition in Africa [Available from: https://developmenteducation.ie/feature/factsheet-child-under-nutrition-in-africa/.

60. Akombi BJ, Agho KE, Merom D, Renzaho AM, Hall JJ. Child malnutrition in sub-Saharan Africa: A meta-analysis of demographic and health surveys (2006–2016). PloS one. 2017; 12(5):e0177338. https://doi.org/10.1371/journal.pone.0177338 PMID: 28494007

61. Malley R. 10 conflicts to watch in 2021 [Internet]. International Crisis Group. 2022 [cited 4 Jan 2023]. Available from: https://www.crisisgroup.org/global/10-conflicts-watch-2021

62. Cho R, How climate change impacts the economy [Internet]. State of the Planet. 2019 [cited 4 Jan 2023]. Available from: https://news.climate.columbia.edu/2019/06/20/climate-change-economy-impacts/

63. UNICEF for every child. Childhood diseases [Internet]. UNICEF. 2022 [cited 4 Jan 2023]. Available from: https://www.unicef.org/health/childhood-diseases

64. Where we work: Libya [Internet]. World Food Programme: Saving lives changing lives. 2022 [cited 4 Jan 2023]. Available from: https://docs.wfp.org/api/documents/wfp-0000114546/download/

65. Fore H. Libya: Tens of thousands of children at risk amidst violence and chaos of unrelenting conflict [Internet]. UNICEF for every child. 2020 Jan [cited 1 Dec 2022]. Available from: https://www.unicef.org/press-releases/libya-tens-thousands-children-risk-amidst-violence-and-chaos-unrelenting-conflict.

66. Amusan L. Libya's Implosion and its Impacts on Children. Journal of international Women's studies. 2013; 14(5):66–79.

67. O'hare BA, Southall DP. First do no harm: the impact of recent armed conflict on maternal and child health in Sub-Saharan Africa. Journal of the Royal Society of Medicine. 2007; 100(12):564–70. https://doi.org/10.1177/0141076807100012015 PMID: 18065709

68. Dureab F, Al-Falahi E, Ismail O, Al-Marhali L, Al Jawaldeh A, Nuri NN, et al. An overview on acute malnutrition and food insecurity among children during the conflict in Yemen. Children. 2019; 6(6):77. https://doi.org/10.3390/children6060077 PMID: 31195654

69. UNICEF. Water, sanitation and hygiene (WASH) [Internet]. UNICEF. 2023 [cited 4 Jan 2023]. Available from: https://www.unicef.org/wash

70. Kamer L. Africa: GDP by country 2021 [Internet]. Statista. 2022 [cited 4 Jan 2023]. Available from: https://www.statista.com/statistics/1120999/gdp-of-african-countries-by-country/

71. Genoni ME. Poverty & Equity Brief Arab Republic of Egypt Middle East & North Africa. 2022.

72. UNICEF for every child. At least one in four children live in poverty in the Middle East and North Africa [Internet]. UNICEF for every child; 2017 May [cited 1 Jan 2022]. Available from: https://www.unicef.org/press-releases/least-one-four-children-live-poverty-middle-east-and-north-africa#:~:text=Press%20release.

73. World Bank Group. Poverty has fallen in the Maghreb, but inequality persists [Internet]. World Bank. World Bank Group; 2016 [cited 4 Jan 2023]. Available from: https://www.worldbank.org/en/news/feature/2016/10/17/poverty-has-fallen-in-the-maghreb-but-inequality-persists

74. WID World. Global inequality data 2020 update. World inequality database [Internet]. WID. 2020 [cited 4 Jan 2023]. Available from: https://wid.world/news-article/2020-regional-updates/#:~:text=The%20World%20Inequality%20Lab%20releases,over%20time%2C%20countries%20and%20regions.

75. Perez-Escamilla R, Bermudez O, Buccini GS, Kumanyika S, Lutter CK, Monsivais P, et al. Nutrition disparities and the global burden of malnutrition. Bmj. 2018; 361. https://doi.org/10.1136/bmj.k2252 PMID: 29899012

76. Krishna A, Mejía-Guevara I, McGovern M, Aguayo VM, Subramanian S. Trends in inequalities in child stunting in South Asia. Maternal & child nutrition. 2018; 14:e12517. https://doi.org/10.1111/mcn.12517 PMID: 29048726

19 / 20

77. Hong R, Banta JE, Betancourt JA. Relationship between household wealth inequality and chronic childhood under-nutrition in Bangladesh. International journal for equity in health. 2006; 5(1):1–10. https://doi.org/10.1186/1475-9276-5-15 PMID: 17147798

78. Breisinger C, Van Rheenen T, Ringler C, Pratt AN, Minot N, Aragon C, et al. Food security and economic development in the Middle East and North Africa. Current State and Future Perspective IFPRI Discussion Paper. 2010; 985.