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The Double Burden of Malnutrition among Women of Reproductive Age and Preschool Children in Low- and Middle-Income Countries: A Scoping Review and Thematic Analysis of Literature

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ABSTRACT

This review was conducted to map the literature on the double burden of malnutrition (DBM) among women of reproductive age (WRA) and preschool children in low- and middle-income countries (LMICs). The study aimed to provide an understanding of how DBM construct has been defined in the current literature, elucidate plausible mechanisms underlying DBM development and its common risk factor among the two sub-groups. We systematically searched for literature from the following databases: EMBASE, CINAHL, MEDLINE, LILACS, Scopus and ProQuest Dissertations & Thesis Global. We identified articles that specifically reported on the coexistence of undernutrition and overnutrition sequalae at the population, household, or individual levels among WRA and preschool children in LMICs. A thematic analysis using the Braun and Clarke approach was conducted on excerpts from the articles to reveal emerging themes underlying the occurrence of DBM from the included studies. Of the initial 15,112 articles found, 720 met the inclusion criteria. Anthropometric measures for overnutrition and undernutrition including body mass index for WRA and height-for-age, weight-for-age, and weight-for-height Z-Scores for preschool children were frequently used indicators for defining DBM across all levels of assessment. In fewer cases, DBM was defined by the pairing of cardiometabolic risk factors (e.g., hypertension) as measures for overnutrition and micronutrient deficiency (e.g., iron deficiency) as measures for undernutrition. The following themes emerged as plausible mechanisms for DBM development: nutrition transition, breastfeeding, diet behaviour, biological mechanism, and statistical artifact. Factors such as child age, child sex, maternal age, maternal education, maternal occupation, household food security, household wealth, urbanicity and economic development were commonly associated with most of the DBM phenotypes. Our review findings shows that the understanding of the DBM in current literature is very ambiguous. There is need for future research to better understand the DBM construct and its etiology.

INTRODUCTION

The double burden of malnutrition (DBM) is a term used to describe the coexistence of undernutrition and overnutrition [1]. The earliest characterization of the DBM construct was in 1992, at the international conference of nutrition [2] which then was meant to describe the simultaneous presence of overweight/obesity and undernutrition at the national level [2,3]. However, with the ongoing changes in diet behavior, physical activity levels, disease and life expectancy within communities [4–6], the DBM became increasingly common at micro levels of the society hence the construct expanded to capture the concurrence of overnutrition and undernutrition in households and among individuals-both at one time point or from a life-course perspective [3]. The evolution of this phenomena and the increasing burden of DBM over the world has led to its recent recognition by the World Health Organization (WHO), which instituted a framework termed the *double duty actions* [7]. This framework identifies potential interventions and policies that can be implemented to concurrently address multiple forms of malnutrition [7].

Different from undernutrition or overnutrition, the DBM presents a new nutrition reality that requires new ways of addressing the challenges it portends. From an individual's health standpoint, exposure to DBM is likely to increase the risk of diverse forms of illnesses and severe health outcomes. For instance, evidence suggests that DBM is strongly associated with high risk of non-communicable diseases through the elevation of inflammatory responses [8]. Similarly, higher risk of childbirth complications such as obstructed labour has also been associated with DBM due to the combined deleterious effect that maternal short stature and overweight/obesity have on cephalo-pelvic disproportion and maternal metabolism respectively [8,9]. Beyond the negative health outcomes, DBM also has major effects on educational outcomes such as reduced year of schooling and loss of labour productivity due to ill health or premature death [10]. Cumulatively these effects have economic consequences. For instance, the annual loss in Gross Domestic Product associated with the DBM has been estimated to be 2.3% in Ecuador and 4.3% in Mexico [11]. This showcases the importance of addressing the DBM problem since it does not only result in improvements of individual's health, but it may also accelerate economic growth.

Although everyone is susceptible, specific sub-groups are at high risk of encountering DBM. Elevated risk has been shown among people living in low- and middle- income countries (LMICs) [4,6]. This is a result of these countries experiencing a rapid growth in over-nutrition and, by extension, nutrition related non-communicable diseases (NCDs) coincident with the undernutrition burden persisting or reducing at a slower pace [4]. Within these countries, the risk levels are by no means similar across groups. Preschool children and women of reproductive age (WRA) have been shown to be high risk groups in LMICs [8]. Their vulnerability is, in part, informed by the nutrition demanding physiological stages that they

are in i.e., critical development stage for preschool children and reproductive stage for WRA [8]. Furthermore, literature suggests that the consequences of DBM are likely to be intergenerational, with malnutrition problems experienced in infantry likely to persist up to adulthood and further transferring to offspring born to malnourished mothers [12]. This signifies that these two sub-groups deserve special public health attention with regards to the emergence of the DBM.

Literature on DBM seems to be concentrated more at the population level, especially estimating the burden of DBM across different population sub-groups. Most of the studies have relied on national survey data to estimate the prevalence of various forms of DBM and examine the possible associations between DBM and various sociodemographic factors [8,13,14]. Anthropometric measurements have been frequently used in defining various DBM phenotypes across the three levels of assessment (i.e., population, household and individual levels) [8,15]. However, the usage of anthropometrics in conjunction with micronutrients and cardiometabolic indicators have emerged in recent literature to characterize DBM occurrences at the household and individual levels [16]. Additionally, a few studies have also made attempts to elucidate the plausible etiology of DBM, more so exploring the contributions of early-life nutrition environment in influencing the susceptibility to encountering DBM throughout the life course [8,17].

Despite the progress made in studying the DBM, the existing literature still lacks clarity that would facilitate advancements in research and policy geared towards reversing the effects of DBM. A great part of the problem is related to the broad definition of DBM that does not offer consistency in it's operational measurements. This has resulted in the emergence of numerous phenotypes describing the DBM phenomenon across all three levels of assessment. Scholars have argued that such broadness in the definitions presents a challenge in interpreting DBM data [16,18], which in turn makes it difficult to estimate the accurate prevalence of DBM, conduct surveillance and design effective intervention programs [16]. Furthermore, the mechanisms underlying the occurrence of DBM is poorly understood. Various hypotheses such as the diet transitions, physical inactivity, early life nutrition and epigenetics have been posited as plausible mechanisms underlying the DBM [6,8]. Conversely, some authors have questioned whether DBM is an independent biological phenomenon, with evidence from cross sectional studies suggesting that the clustering of under- and over-nutrition at the individual and household levels could occur purely by chance [19–21]. Therefore, given the diverse array of information available about DBM, this scoping review was set up to systematically map out literature concerning the DBM phenomenon in LMICs, with the aims of providing an understanding of how DBM has been defined in literature and plausible mechanisms underlying the occurrence of DBM. Specifically, this review intends to address the following research questions:

1. Which nutrition indicators have been used to operationally define the DBM at the individual, household, and population levels among WRA and preschool children?
2. What are the potential explanations for the occurrence of the identified DBM phenotypes at the individual, household, and population levels among WRA and preschool children?
3. What are the risk factors for the DBM at the individual, household, and population levels among WRA and preschool children?

METHODS

Search Strategy

We drafted a scoping review protocol in accordance with Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines [22]. After undergoing revisions with the research team, the protocol was published in the BMJ open journal on 26th November 2021 [23]. A comprehensive search strategy using the Population-Concept-Context framework [22] to guide criteria for study eligibility was developed in consultation with a librarian. In general, included studies were (1) focused on women aged 15 to 49 years and children aged 5 years and below; (2) highlighted or discussed the concept of the 'double burden of malnutrition' or its derivatives; (3) conducted or focused on populations domiciled in LMIC - as defined by the World Bank. No language restrictions were applied. Papers were excluded if they exclusively focused on men, school children between the ages of 6 and 14 years, adults aged 50 years and above and populations living in high-income countries.

Article searches were conducted between 2nd April 2021 and February 24th, 2022 (re-run) in the following electronic databases: MEDLINE, CINAHL Scopus, EMBASE, LILACS and ProQuest Dissertations and Thesis Global (comprehensive information on search strings and article retrievals are documented on Appendix A in the supplementary document). Additionally, citation tracking of included articles after screening were done to obtain relevant records missed after database search. The bibliography obtained from the searches were imported into a citation management software (EndNote) for de-duplication [24]. All eligible articles, available online or in print by February 2022 were included in this review.

Screening

To minimize bias in selection of articles, all reviewers (J.M.W, I.S and J.C.V-G) conducted a pilot screening of 10 randomly selected articles. Findings from the pilot screening were discussed among the three reviewers with the aim of ensuring consistency in the application

of selection criteria. Afterwards the retrieved articles underwent two levels of screening: title and abstract screening, and full-text screening. At both levels, articles were sequentially screened by two independent reviewers and conflicts resolved through discussions with a third reviewer and/or the supervision team (S.S and M.K.C).

Data Extraction and Analysis

We developed our data charting form using Google forms to explicitly capture bibliographic information (author's name, study title and year of publication), study characteristics (objectives, study setting, population of interest, year of data collection, study design, sampling strategy, data sources, instrument of data collection, outcome, exposures and analytical strategy), DBM concepts of interests (operational definitions, level of DBM measurement, posited explanations for DBM mechanisms, and risk factors) and relevant miscellaneous findings [23]. We pilot tested and calibrated the form with the reviewer team by independently extracting information from 10% of the included articles chosen at random. In cases where articles were published in other languages, we sought translations to English by native speakers before data extraction was done.

Extracted excerpts from articles were analysed qualitatively using the Braun and Clarke's (2006) thematic analyses approach [23,25]. In brief, the analysis was conducted as follows: first, the reviewers re-read the excerpts and generated codes (shorthand descriptors) describing the content of the excerpts; second, all the codes (with accompanying excepts) were collated and construed to generate potential themes and sub-themes; third, the generated themes and sub-themes were actively reviewed and named by the research team to ensure they function accurately as meaningful interpretations of the extracted information; finally, a narrative synthesis with thematic maps/diagrams was produced that presents a cogent description of the themes in relation to the research questions.

RESULTS

Study Characteristics

The search yielded a total of 15,112 articles of which 720 met the inclusion criteria (Figure 1; Supplementary 1 Appendix A; Supplementary 2). While the oldest eligible article discussing DBM was published in 1992, the majority (95%) of the articles were published between 2007-2022 (Figure 2). Study designs were primarily cross-sectional studies using survey data and literature review articles (Table 1). Nearly three-quarters of the included articles (n=546) focused on populations from a single country with nearly half of these articles coming from Bangladesh (n=37), Brazil (n=28), China (n=26), India (n=95), Indonesia (n=23), Nigeria (n=22), and South Africa (n=38). The rest of the articles were either multi-country/multi-region studies or mechanistic/conceptual articles discussing the DBM phenomenon. Most articles

focused on DBM at the population level i.e., country level or specific targeted communities such as the urban slum populations whereas life course DBM was only captured in a paltry 26 articles (Supplementary Table B.1).

Nutrition indicators used to define DBM phenotypes

Figure 3 summarizes the indicators that have been regularly used to measure nutritional status. Overall, anthropometric measurements were the most common indicators used for estimating both under- and over-nutrition. In a small number of articles (n=32), various cardiometabolic risk markers related to frequent consumption of energy-dense foods and saturated fats (e.g., hypertension, diabetes, hyperglycaemia) were used as measures of overnutrition whereas a fifth of the articles (n=162) utilized several micronutrient deficiency biomarkers (e.g., anemia, iron deficiency, Vitamin A deficiency) as measures of undernutrition.

At the population level where DBM is characterised by a high burden of both undernutrition and overnutrition in at least one population group [15], the prevalence estimates of wasting (low weight-for-height), underweight (low weight-for-age), stunting (low height-for age) or a combination of the three in conjunction with the estimated prevalence of overweight (high weight-for-height) were frequently used phenotypes for the operational definition of DBM for preschool children [16,26,27]. Conversely, DBM for WRA subgroup was commonly defined by comparing the prevalence of underweight and overweight as measured by body mass index (BMI) thresholds [16,28]. However, only a few studies indicated specific criteria for determining DBM at the population level. For instance, some authors argued of an existence of DBM in the population if the ratio of underweight and overweight/obese people is close to one [13,29], whereas some articles employed prevalence thresholds for estimating DBM [28,30] e.g., when the concurrent prevalences of child stunting and female overweight were above 30% and 25%, respectively [31].

At the household level where DBM is defined by at least two household members experiencing contrasting forms of malnutrition [1], the most common phenotype defining DBM was the co-occurrence of an overweight/obese mother and a stunted child within the household [14]. In rare situations, the paring of a wasted/underweight or anemic child and an overweight/obese mother were also used as DBM phenotypes [32,33].

At the individual level (point in time), frequently used phenotypes for DBM were coexistence of stunting and overweight/obesity for preschool children [34,35], and the coexistence of anemia/iron deficiency and overweight/obesity for WRA [21,36]. In some limited cases, cardiometabolic risk measures and multiple micronutrient deficiency biomarkers were also incorporated in the DBM operational definitions. For example, one study defined DBM as coexistence of either hypertension, hyperglycaemia, insulin resistance, diagnosed diabetes or dyslipidemia along with iron depletion or vitamin A deficiency [37,38]. Individual-level depictions of DBM across the life course primarily centered around the growth trajectories of stunted children or low birth weight children and the potential of them being overweight/obese in adolescence or adulthood [39,40]. Some articles also highlighted the

coexistence of low birth weight and cardiovascular risk such as hypertension/diabetes mellitus across the life course [8].

Emerging themes explaining the occurrence of DBM

Of the 720 articles included, 219 articles mentioned or acknowledged the DBM concept without an ensuing underlying explanation/discussion of the DBM phenomenon. Below are the main themes that emerged from the remaining 501 articles that elaborated on the DBM concept.

Nutrition transition

Nutrition transition was by far the most dominant theme judged by its frequent appearance in a majority of the articles (n=390). This predominance may be due to the fact that this was the only theme that could explain the DBM phenomenon across all the levels of operationalization (Figure 4). Generally, this theme postulates that DBM is a result of the shifts in food culture across many LMICs from traditional starch and fibre-dense foods to calorie-dense foods, characterised by increased consumption of sugar, saturated fats and unrefined carbohydrates fondly known as 'western diet' [4,8,15]. Furthermore, this theme was associated with two sub-themes, 'diet' and 'pace' that offered succinct explanations for DBM across the three levels.

At the population level, many authors suggest that the rise in overnutrition has been brought about by the increase consumption of energy-dense diet [15,41]. These dietary changes are at first observed among the socio-economic elites since the early adoption of western diets is associated with affluence and high social standing in the society [42]. As countries continue to experience economic growth, overconsumption of energy-dense foods subsequently shifts to the economically disadvantaged communities as western dietary patterns becomes more affordable and by extension 'default choices' for the poor [15,42]. On the other hand, food insecurity is still persistent in many populations sub-groups due to poverty, famine, and high inequalities and thus undernutrition remains endemic within the same population [4,41]. Regarding the 'pace' sub-theme, evidence showed that growth in the prevalence of overnutrition among these populations have been more rapid in comparison to the eradication of undernutrition. For instance, between 1975 and 2016, the prevalence of overweight/obesity among adult women (18 years and over) in Sub-Saharan Africa increased from 14.5% to 38.4% whereas that of underweight reduced from 18.0% to 9.5% [43]. The high rate of increase in overnutrition has been linked to the rapid urban growth in LMICs that has been far much greater relative to what was experienced decades ago in western countries [4]. Furthermore, increased income, proliferation of modern mass media and globalization of food markets have also been highlighted as factors responsible for the rapid increase in overnutrition [4,15]. Conversely, the vicious cycle of poverty, diseases and climatic changes have

been attributed to the slower rate of undernutrition decline that does not match up to the increasing rate of overnutrition [44].

'Diet' as a sub-theme at the household level suggests that DBM, commonly assessed by the overweight mother–stunted child phenotype, arises from frequent consumption of the same meal (mostly western diets) by all household members despite the differences in nutritional requirements between family members [33,45]. The majority of these diets are known to be calorie-rich but nutrient-poor, hence their regular consumption within the households results in the simultaneous elevated risk of the mother being overweight and the child being undernourished due to deficiencies of important micronutrient to support growth in this critical window of development [8,45]. Additionally, some studies provided evidence showcasing that a child's undernourished status could rapidly change within short time intervals, whereas the overweight/obese status of their mothers tend to persist for a long time. For example, studies conducted in South Africa [46] and Indonesia [47] found that household level DBM could be a transitionary status, with most households previously categorised as DBM switching to overweight/obese households after the children grew from their undernourished status. Therefore, this supports the argument that the 'pace' of the transition could also be an important explanator of the occurrence of DBM at the household level.

At the individual level at a single point in time, many authors argued that diet culture involving regular consumption calorie-dense but nutrient poor foods would be a potential way through which DBM would occur for both women (i.e., overweight/obese-micronutrient deficient phenotype) and preschool children (i.e., overweight/obese-stunting/micronutrient deficient phenotype) [8,20,21,48]. Furthermore, studies supported the notion that overnutrition status at the individual level is rapidly developing and tends to be persistent for a long time compared to the exclusion of underweight status [49], therefore lending credence to the argument that the 'pace' of the nutrition transition contributes to explaining DBM phenomenon at the individual level.

Transitions in 'diet' was also found as an important sub-theme in explaining DBM across the life course. Many authors argued that the majority of residents from low-resourced settings were likely to be born malnourished or to experience undernourishment during their infant years [50,51]. Authors suggest that high energy feeding of preschoolers recovering from undernutrition results to accelerated catch-up growth that is characterized by disproportionately higher replenishment of body fat [12,51]. This is likely to exceed their metabolic capacity and as a consequence they become overweight/obese [12]. With regards to the 'pace' sub-theme, studies suggests that the shift from undernutrition to overnutrition is happening in quick succession with previously undernourished preschoolers becoming overweight in a matter of weeks/months [52,53].

Alternative Themes

Besides nutrition transitions, our thematic analysis further revealed other themes explaining DBM (Figure 5). These themes were named as follows: breastfeeding, diet behavior, biological mechanisms, and statistical artifact. Of note, there were no additional themes explaining DBM at the population level besides the nutrition transition theme.

Breastfeeding

Twenty-six articles highlighted breastfeeding as a potential explanation of DBM. This theme was broadly associated with DBM at the household level. It referred to how the exclusivity and the length breastfeeding was useful in concurrently reducing the risk of mothers being overweight/obese and preschool children being stunted. Studies found exclusive breastfeeding for at least six months and breastfeeding for a longer period (up to two years or more) offered protection against child stunting by providing essential nutrients to support optimal growth and strengthening the immune system which guards against infections [54–56] . Many authors also argued that the high energy cost of lactation could facilitate post partum weight loss hence mothers who infrequently breastfeed have higher chances of being overweight/obese [54]. Recent estimates suggests that 37% of infants below the age of six months are exclusively breastfeed in LMIC [57], a proportion way below the 90% benchmark set by the WHO [58]. Such low rates may imply that the aforementioned nutrition benefits of breastfeeding are missed by both the mother and the child resulting in the possibility of occurrence of DBM within the household.

The other dimension of this theme relates to complementary feeding. Arguments were made that early introduction of complementary feeding (below six months), was linked to reduced production of breast milk and subsequent cessation of breastfeeding thus increasing the risk of infections due to infants compromised immunity [59,60]. Additionally, authors argued that infants from LMICs are likely to be undernourished due to suboptimum complementary feeding with foods lacking essential growth-promoting micronutrients [61,62]. On the other hand, arguments also ensued that complementary feeding with energy dense foods increases the propensity of children being overweight/obese [59,62]. Therefore, complementary feeding practices witnessed in LMICs creates a possibility of preschool children being either under- or over-nourished thus increased the probability of observing DBM at the household level.

Diet behavior

In twenty-seven articles included in this review, authors attributed household DBM to intra-household diet behaviour. A common dimension of this theme related to intra-household food distribution. Most arguments emerging from literature supported the notion of the

existence of unequal food distribution among household members with women and children often being disadvantaged. Biases in food allocation within households are guided by complex social norms based on gender, age groups and cultural perceptions on wealth and beauty [63,64]. For instance, evidence has shown that mothers consume more macronutrients compared to their preschool children [65]. Furthermore, preschool boys have been shown to receive more macronutrients relative to girls, a finding that has been linked to preferential treatment of boys in some communities [65]. Another dimension of this theme relates to eating behaviours of mothers in periods of food adversities. Some authors argued that mothers may sacrifice their own nutritional intake to cushion their children and other family members [66]. This encompasses skipping nutritious meals and substituting that with calorie dense diets, and/or cyclical eating that encompasses fasting/starvation during food insecure seasons and overeating during periods of plenty [66].

Biological mechanisms

Of the 720 included articles, 180 articles highlighted the potential biological mechanisms underlying the existence of DBM. This theme emerged prominently in explaining DBM at the individual level, both at a single point in time and across life-course. The predominant mechanism that emerged from the literature with regards to overweight/obesity and micronutrient (mainly iron) deficiency DBM (at a single timepoint) was chronic low-grade inflammation (n=42). It is well established that among obese individuals, there is an upregulation and persistence of inflammatory response which seems to be responsible for some of the obesity related illness [63]. An offshoot of this inflammation is the increased production of hepcidin hormone, the main regulator of iron homeostasis [67,68]. Evidence suggests that hepcidin is responsible in impairing duodenal iron absorption and/or promote iron sequestration in iron stores [69]. This implies that even if there is sufficiency in dietary iron of overweight/obese individuals, they could still suffer from deficiencies due to this low-grade inflammation. Additionally, a few articles also indicated that micronutrient deficiency among overweight/obese people could be because of increased requirements due to higher blood volume and basal losses that accompanies higher body weight [70,71].

The other dimension of this theme centers around the *thrifty phenotype hypothesis*, highlighted as the main mechanism explaining life course DBM (n=131). Many authors argued that the majority of residents from low-resourced settings were likely to be born malnourished or experienced undernourishment during their infant years [50,51]. Given the food insecure environments during their critical stages of growth (the first 1000 days of life), their bodies underwent physiological and metabolic modifications aimed at conserving energy (e.g., impaired fat oxidation and lowering of the resting energy expenditure). These epigenetic survival adaptations, that are likely to be irreversible, were meant to insulate the individual from the deleterious effects of the anticipated food scarce environment [50].

However, changes in diet habits have caused the energy-saving adaptation to be counter-productive, hence these populations have experienced rapid catch-up growths and higher risk of being overweight/obese [51].

Statistical artifact

The notion of statistical artifact was reported in 29 articles included in this review. This theme captures arguments suggesting that DBM at the household and individual levels may not necessarily be a distinct condition informed by non-random clustering of discordant malnutrition forms, but it is rather a statistical artifact that may occur purely by chance [20,21,72]. Proponents of this argument supported their claims by conducting further analysis on DBM data. For example, with the assumption that overnutrition and undernutrition are independent conditions, some studies used tests of independence to ascertain whether the observed prevalences were different from the expected. The majority of the studies found minimal evidence in support of clustering beyond chance bolstering the argument that DBM may not be a distinct entity within households [19,47] and among individuals at a single point in time [21,48].

Risk Factors for DBM

Table 2 highlights the variables that were regularly examined with regards to their association with the DBM (n=434). In the majority of the studies, there was recognition that these factors operate in a multilevel manner (e.g., individual, household, and community/population) inline with how the society is structured, even though this acknowledgement was not necessarily reflected in most of the analytical procedures. Furthermore, most of these factors were similar across the three levels of DBM analysis as highlighted in the subsequent sections.

Population Level Risk Factors

Urbanicity was frequently examined with the majority of the studies that found urban living to be associated with DBM at the household and individual levels [73,74]. A plausible explanation for these findings relates to the fact that urban populations tend to experience faster dietary changes since supermarkets and fast food restaurants first emerge in urban spaces [14]. Since such retail supply chains are the main sources of food in major cities and towns, urban dwellers are likely to become regular consumers of nutrient poor foods [73,74]. Regions experiencing poor or medium economic growth were also found to be associated with DBM [29,75,76]. This could reflect disinvestments in infrastructure with such regions experiencing deteriorated living environment as characterised by overcrowding and limited access to social and healthcare services, which elevates the risk of infections and other conditions [29,77]. Besides being at high risk of infections that may lead to undernutrition, this population sub-

group is also likely to compromise on their diet quality by consuming affordable energy-dense foods [77].

Some studies observed a positive association between income inequality and DBM mostly at the population levels [28,75]. A single study [75] attributed this association to an indication of mal-distribution of food and other resources which leads to the privileged groups having plenty to consume while the underprivileged face food insecurities. Few studies examined the impact of ecological zones and found marginal association between ecological factors such as deforestation and DBM [73,78]. This association was linked to DBM based on the impact that climatic conditions such as rainfall patterns and increases in temperature may have on agriculture production and food security thus subsequently affecting diets [78]. To a lesser extent, some articles also discussed the unintended influence of government nutrition policy/programs on DBM. Some authors expressed caution against food subsidy programs as their use, with the intention of reducing undernutrition could inadvertently be promoting overnutrition and/or micronutrient deficiencies. For example, the Egyptian government established a food program that provides subsidies for four high-energy staples i.e., *baladi* bread, sugar, wheat flour and cooking oil for which their affordability and wide consumption has been associated the increased risk of DBM among women of reproductive age [79]. Cash-transfer programs provided to poor families have also been associated with higher risk of overnutrition [80,81]. Authors have suggested that increasing disposable income to poor families may affect dietary quality since the cash is used to purchase more calorie-dense foods [80].

Household Level Risk Factors

Salient among many studies was the examination of the relationship between household wealth and DBM. In a majority of the studies, DBM was found to be associated with individuals from wealthy households [55], whereas in some studies DBM occurred among individuals from the poor or middle wealth quintiles [33,82]. Some authors attributed these mixed findings to the interaction between urban residence and wealth [83,84] whereas others noted that the level of a country's economic development mediates this relationship since overnutrition seems to transition from the wealthy to the poor as countries develop economically [5,15]. Households experiencing food insecurity as well as low food diversity were more likely to experience DBM [85–87]. The link to DBM in these scenarios was explained by inadequate food consumption both in quantity and quality [86,87]. Dietary diversity, especially among preschool children was shown to be important in protection against DBM as growth promoting bioavailable nutrients were mostly noted to be found from animal source foods [85].

Other common factors examined included household sanitation, which was deemed to influence infections and disease spread within the household hence influencing individual nutrition status [88,89]. Large family sizes were also found to be associated with DBM as this creates a challenge in equitable food and resource distribution within the family [88,90]. Male-headed households were also associated with household DBM [46,47,91]. This association could be explained by the fact that in many male-headed households, women have lower bargaining power and play a minor role in the household decision-making process with regards to household purchases, diet and allocation of resources [91]. In corroboration of this hypothesis, some studies did find that female-headed households had lower odds of being DBM [46,91], suggesting that women play a critical role in shaping the nutritional outcomes among household members.

Individual Level Risk Factors

In general, common individual risk factors for DBM could be grouped into biological, socio-cultural, socio-economic, and behavioral.

With regards to biology, increased maternal age, maternal short stature, young maternal age at first birth, hormonal contraceptive use, no breastfeeding/shorter breastfeeding duration, parity (multiple pregnancies), shorter birth intervals, low-birth weight, increased child age, female child and diseases (e.g., HIV/AIDS) were all physiologically associated with an increased risk of DBM [28,92–94].

Socio-cultural factors commonly found to associate with DBM were religion, marital status, and ethnicity [28,95,96]. In general, the mechanism underlying their influence on nutrition status was linked to the role these factors play in guiding individual's diet patterns, physical activity lifestyle and food choices. For instance, some authors argued that ethnicity influences women perceptions on body weight (e.g., preference of 'plump' body as a sign of beauty) and childcare practices (e.g., early introduction of complementary feeding to boys) which results in the occurrence of DBM [59,97,98].

Maternal education and occupation were noticeable socio-economic factors of interest across all the levels of assessment. Findings with regards to education levels were mixed with studies that mostly focused on population level DBM finding a positive association between high levels of education and overnutrition [23,99], whereas some household and individual level DBM studies finding a negative association between education and DBM [100–102]. For studies that provided insights into the mechanisms, authors linked higher education levels to higher income and white-collar occupations that were associated with an increased consumption of energy-dense processed foods [28,99]. On the contrary, the negative associations were attributed to mother's lack of nutrition knowledge and/or instability in income due to such women having less opportunities to engage in modern labour markets

hence they are likely to inculcate affordable energy-dense foods in their family routine meals [102].

Behavioral patterns such as physical activity patterns and smoking were also examined in studies focusing on DBM at the population level with sedentary lifestyle commonly associated with overweight/obesity [77,103], while smoking being marginally associated weight undernutrition [104,105]. Few studies also found the effect of these behavioral factors on DBM at the individual level [106,107]. Evidence from literature suggests that smoking could increase the risk of cardiometabolic conditions by provoking inflammatory reactions through the release of oxidants [108], while conversely it could also elevate the risk of micronutrient deficiency due to its impact on nutrients malabsorption and low dietary intake of essential micronutrients among smokers [109]. Similarly, sedentariness has been associated with overweight/obesity by slowing glucose homeostasis and also independently associated with iron deficiency through low-grade inflammatory response that impairs iron absorption [107].

DISCUSSION

This scoping review examined the existing literature on the DBM phenomenon in LMICs with a specific focus on WRA and preschool children. Our findings showed that the term double burden is loosely defined with many operational definitions in extant literature. Across all levels of operationalization, anthropometric measurements were commonly used to characterise DBM phenotypes. Drawing from the Braun and Clarke thematic analysis approach [25], multiple themes and sub-themes including nutrition transition, breastfeeding, diet behavior, biological mechanism, and statistical artifact emerged from the literature to as postulated mechanisms underlying the existence of DBM across the individual, household and population levels. Our findings also revealed multiple socio-demographic risk factors of DBM, with the majority of the included studies examining the impact of these factors at the individual levels of measurement.

Despite seeking clarity, this review did not find a clear consensus in which studies operationally defined the DBM concept. This lack of consensus was also supported by previous reviews [14,16]. This review also corroborated the loose usage of the term double burden of malnutrition and its derivatives as a 'buzz word' without a rationale in support of the construct. Some articles also argued the existence of a 'triple burden of malnutrition', thus advancing the complexity experienced in this area [56,110,111]. Without a proper structure in defining the DBM concept, we foresee challenges in conducting and interpreting research. This will in turn lead to difficulties in designing suitable interventions as well as a dearth of concrete evidence to inform public health policies. Davis et al, [16] proposed a framework to guide DBM operational definitions based on specific objectives that scholars are interested in. For instance, when the aim of the study is to test potential interventions, cardiometabolic

risk factors such as hypertension in conjunction with micronutrients indicators may be more impactful as opposed to BMI which is used in prevalence studies [16]. In line with Davis et al.'s proposition, we suggest that scholars and public health practitioners should be more explicit with their choices of DBM definitions and indicators and provide a rationale for the decisions they make. In addition, we suggest that researchers should be driven by a conceptual framework embedded in theory, that not only characterizes DBM based on levels of assessments and the target population but also illustrates shared drivers for the identified DBM phenotypes. Additionally, nutritional problems vary between countries and therefore we opine that DBM operational definitions also ought to consider country specific needs to ease decision making with regards to priority areas and recourse allocation.

Importantly, the current study observed that there were multiple mechanisms postulated to explain the occurrence of DBM. Although these themes were discussed separately, it is important to note that they do not act independently. There are substantial interactions, and overlaps, that requires further explorations [8]. Furthermore, with the ongoing nutrition transition experiencing a wide degree of heterogeneity in terms of space and time [112], the identified themes are likely to have different influences in different countries/communities even among similar population subgroups [6,28]. For example, the 'biology mechanism' theme may be more pronounced among the South Asian populations as compared to other LMICs populations with evidence showcasing a higher risk of cardiometabolic diseases at lower levels of weight change [31,113].

Overall, it appeared that the 'nutrition transition' theme dominated the literature as the main proposed mechanism of DBM. Furthermore, the available arguments from the literature facilitated the decomposition of this to two sub-themes in which both were sufficient explanations of DBM across each level of operationalization. The proponents of nutrition transition theory (i.e., Popkin [4,15] and colleagues [5]) have shown that the gradient of transition in LMICs differs greatly from the patterns observed in developed countries. Developing countries have experienced a more rapid transition that created the double burden scenario because overnutrition has increased rapidly whereas majority of the population are yet to recover from undernutrition. This has been driven by processes such as industrialization, high-income growth, urbanisation, changes in food systems, and increase in life expectancy [6,15,28]. For example, most LMICs are demonstrated to be experiencing an accelerated annual urban growth of approximately 2-5% [114]. Such rapid growth has been shown to attract investments in food markets, advancements in technology, aggressive marketing, and efficiency in processing and distribution infrastructure [15,114]. With these processes established to have major influences on dietary shifts and lifestyle patterns across all populations, it is not surprising that the 'nutrition transition' theme emerged as an important mechanism in explaining DBM across all the levels of analysis.

Of note to our findings was the emergence of a theme suggesting that the assertion of DBM, at the household and individual levels could be a statistical artifact. This theme calls into question the current understanding of the etiology of DBM i.e., a reflection of biological and social processes that lead changes in nutrition status. Proponents of this theme suggest that interventions targeting specific malnutrition forms could be adequate since the appearance of DBM could be by chance [21,48]. In our view, we think that lack of statistical significance does not necessarily infer that DBM is not a clinical entity or should not be viewed as such. Our caution is grounded on the fact that there is a dearth of longitudinal and mechanistic studies exploring the DBM phenomenon and hence it could be premature to nullify its existence.

This review further highlighted the complexity of factors that are associated with the DBM among the target populations. Several studies acknowledged the interlinkages between biological and contextual factors across different levels of the society [115–117]. However, few studies integrated this assertion in their analytical designs. In general, it appeared that most individual level variables had similar influences on DBM despite the variations in geographical context and analytical methods. For example, increasing maternal and child age, higher parity and being in a marital union were both associated with a higher risk of DBM across the board [93,94,118]. However, socio-economic factors such as urbanicity, household wealth, and maternal education showed contrasting effects in different studies [14]. Authors argued that the influence of such factors was highly dependent on the stage of nutrition transition that the population displayed, with high socio-economic status being a risk factor in low-income societies experiencing the emergence of nutrition related NCDs whereas the same being a protective effect in developed societies experience behavioral change [15,73,119].

Having comprehensively mapped DBM literature focusing on preschool children and WRA, we identified some key areas for future focus. First, it is evident that there is an overreliance of anthropometric measurements in defining DBM phenotypes despite the known limitations of such measures. Furthermore, the frequent usage of imprecise anthropometric measures may indirectly imply biases in current literature, and more so studies exploring nutrition-specific interventions since indicators such as BMI may not solely represent a specific nutritional problem[16]. Secondly, this review also revealed a lack of clear structure in defining DBM especially at population levels. In our judgement, we think that such confusion has resulted in the use of the term 'double burden of malnutrition' as a buzz word in a lot of studies that have examined multiple discordant malnutrition forms without explicitly providing a rationale underlying the concept. Third, there is an important gap in mechanistic knowledge that precisely documents physiological, genetic, and epigenetic mechanisms of the DBM. In part, this gap stems from the dearth of studies exploring DBM across the life course. Posited explanations from current DBM studies were either speculative or made based on evidence from secondary data, mostly obtained from cross sectional surveys.

Additionally, imprecision in measuring salient DBM drivers such as dietary patterns and physical activity lifestyle could also have contributed to this problem [14]. Finally, there is a need for researchers to the explore interrelationships between different predictors of DBM since literature suggests of an existence of multiple pathways.

Findings from this review should be interpreted in light of the following limitations. Even though we implemented a rigorous search strategy to identify all eligible articles, it is possible that we may have missed relevant literature due to the broad definitions of the DBM concept. Furthermore, full text articles of some abstracts were unavailable/irretrievable at the time of completion of this study. Given the large number of articles included in this review, we are confident that our findings are likely to remain unchanged despite the possible exclusion of some articles. Furthermore, the potential exclusion bias was limited by conducting citation tracking of included articles and re-rerunning database search prior to the study completion. Study screening and thematic analysis processes involved subjective judgement which could have resulted in some biases in our findings. However, we limited this bias by performing duplicate screening and biweekly meetings to address any disagreements. In cases where the review team could not achieve consensus, we involved our supervision team in finding the resolution. Finally, this review comprehensively included all literature that discussed the DBM phenomenon. Some studies and gray literature may have been of low quality, potentially introducing bias into our findings. Despite these limitations, we believe that our review is contributing substantial knowledge in advancing the current DBM discourse.

CONCLUSION

In summary, there is wide recognition that the DBM represents a new nutrition reality in the majority of the LMICs. However, the understanding of the DBM phenomenon is still contentious due to inconsistent operational definitions used and lack of clarity with regards to mechanisms underlying the DBM. In this review, we observed that anthropometric measurements are frequently used to characterize DBM phenotypes across the three levels of its operationalization. Additionally, we also identified five themes (nutrition transition, breastfeeding, diet behaviour, biological mechanism, and statistical artifact) that could potentially provide plausible explanations for the underlying etiology of DBM. Our study further revealed different socio-demographic risk factors operating at various levels of society. Emerging themes and common risk factors may provide target areas for public health interventions. However, heterogeneity in operational definitions, divergent findings in mechanisms underlying the DBM and overreliance on evidence from cross sectional studies suggests that high quality longitudinal and mechanistic studies are needed to succinctly understand the DBM phenomenon.

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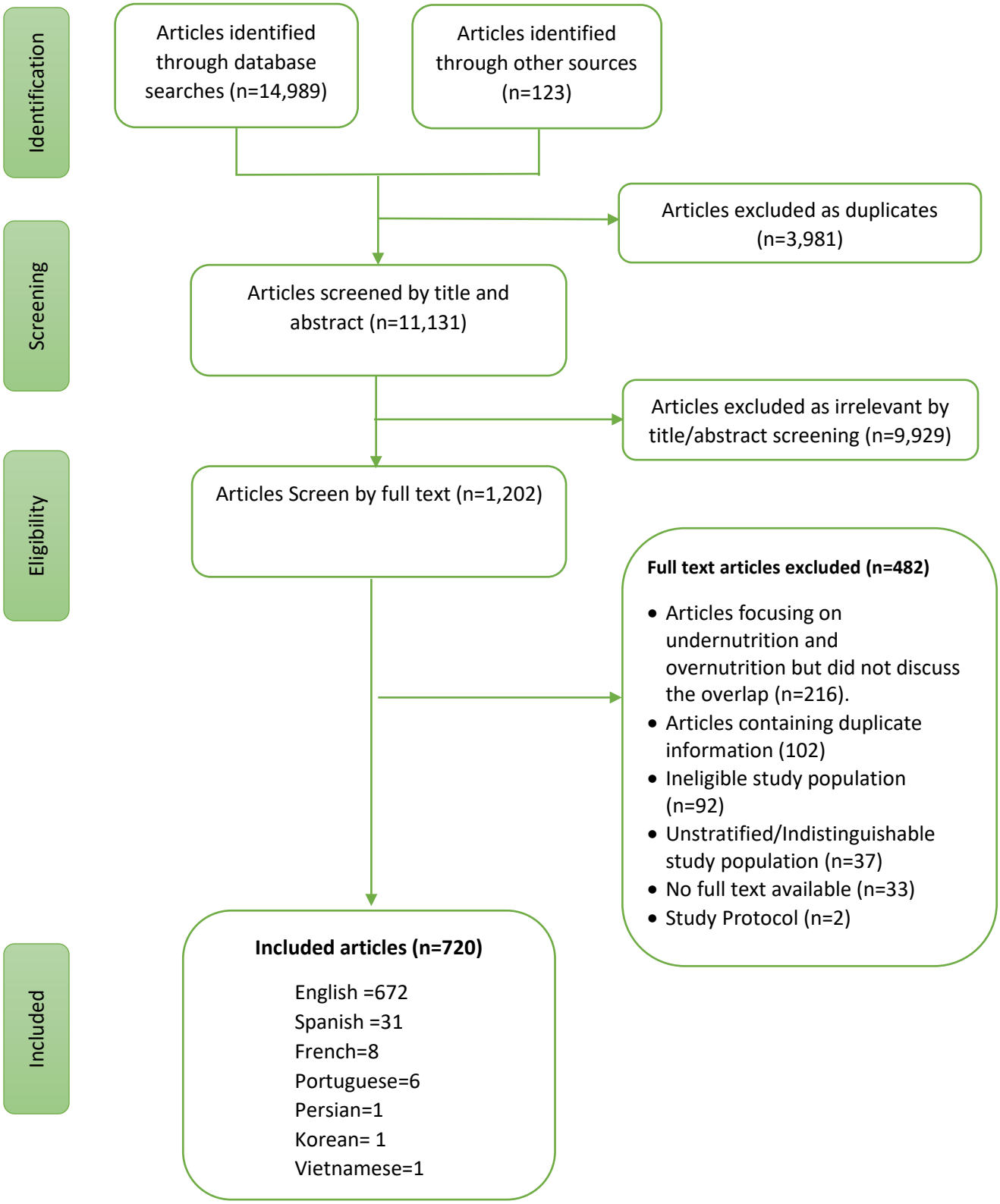

Figure 1: Scoping Review Flow Diagram

Table 1: Characteristics of Included Articles

Characteristics	Frequency (n=720)	Percentage (100%)
Publication Decade		
1992-2002	7	1.0
2003-2012	136	18.9
2013-2022 (Through February 24th)	577	80.2
Article type		
Peer Reviewed Journal Article	640	88.9
Thesis	34	4.8
Reports	20	2.8
Book Chapters	10	1.4
Others	18	2.5
Study Setting		
Multicountry/Regional	106	14.8
National Studies	264	36.7
Sub-National/Community-Based	299	41.6
Nonspecified	51	7.1
Study Design		
Cross-sectional	540	75.0
Reviews (Literature + reports)	141	19.6
Cohort/Longitudinal	27	3.8
Ecological studies	8	1.2
Experimental studies	4	0.6
Sampling Strategy		
Probability sampling	494	68.7
Non-Probability sampling	47	6.6
None (Not Applicable)	179	24.9
Data Sources		
Primary	216	30.0
Secondary	474	65.9
Not Applicable	30	4.2
Nutrition Status Measurements Used		
Anthropometry only	548	76.2
Anthropometry and Biochemicals Measures	169	23.5
Not specified	3	0.5
Level of DBM Discussed		
Population	350	48.7
Individual	146	20.3
Household	113	15.7
Population and Household	17	2.4
Population and Individual	21	3.0
Household and Individual	38	5.3
Population, Household and Individual	35	4.9

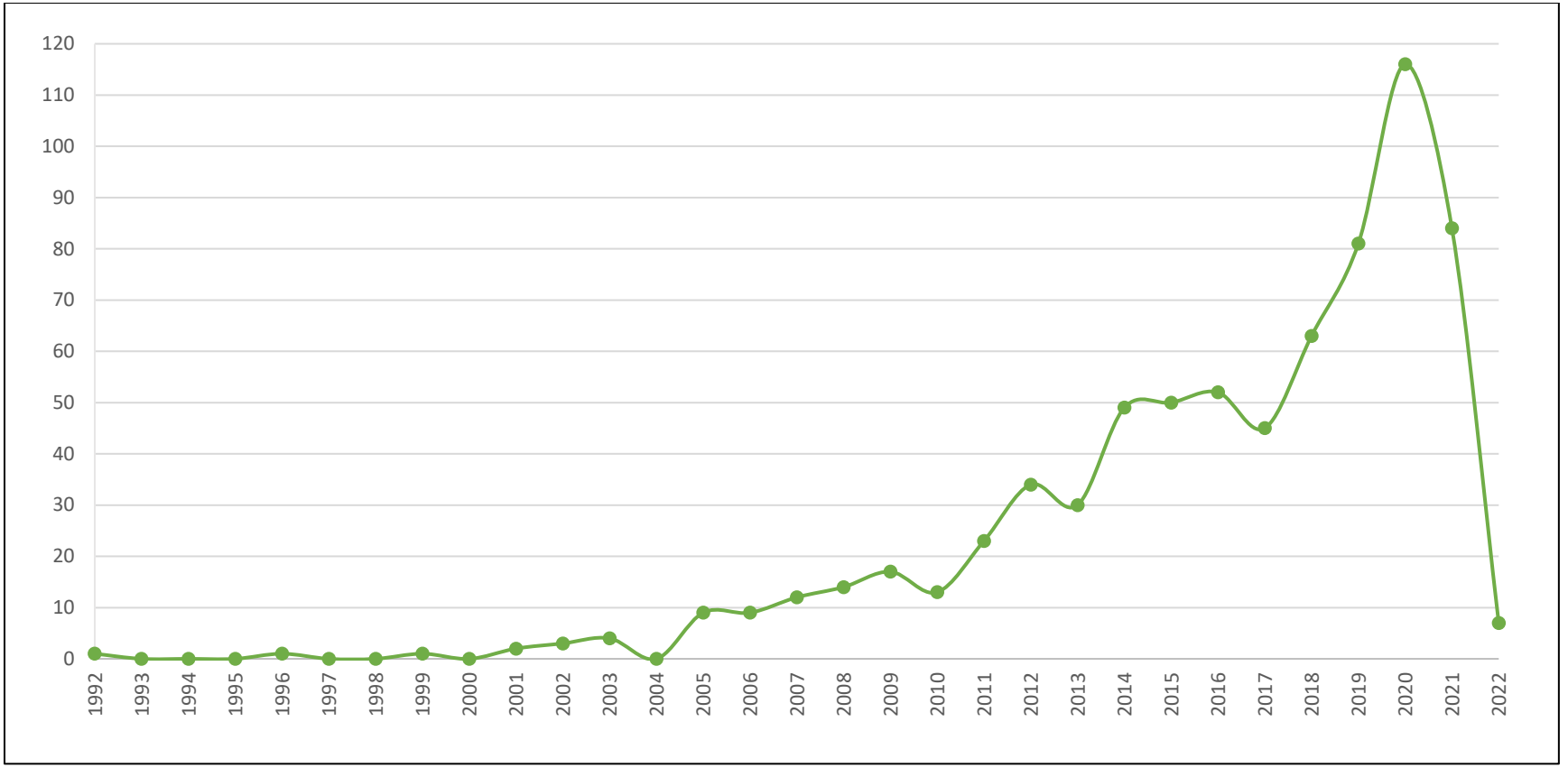

Figure 2: Time-trend of DBM Articles included in this Scoping Review (n=720)

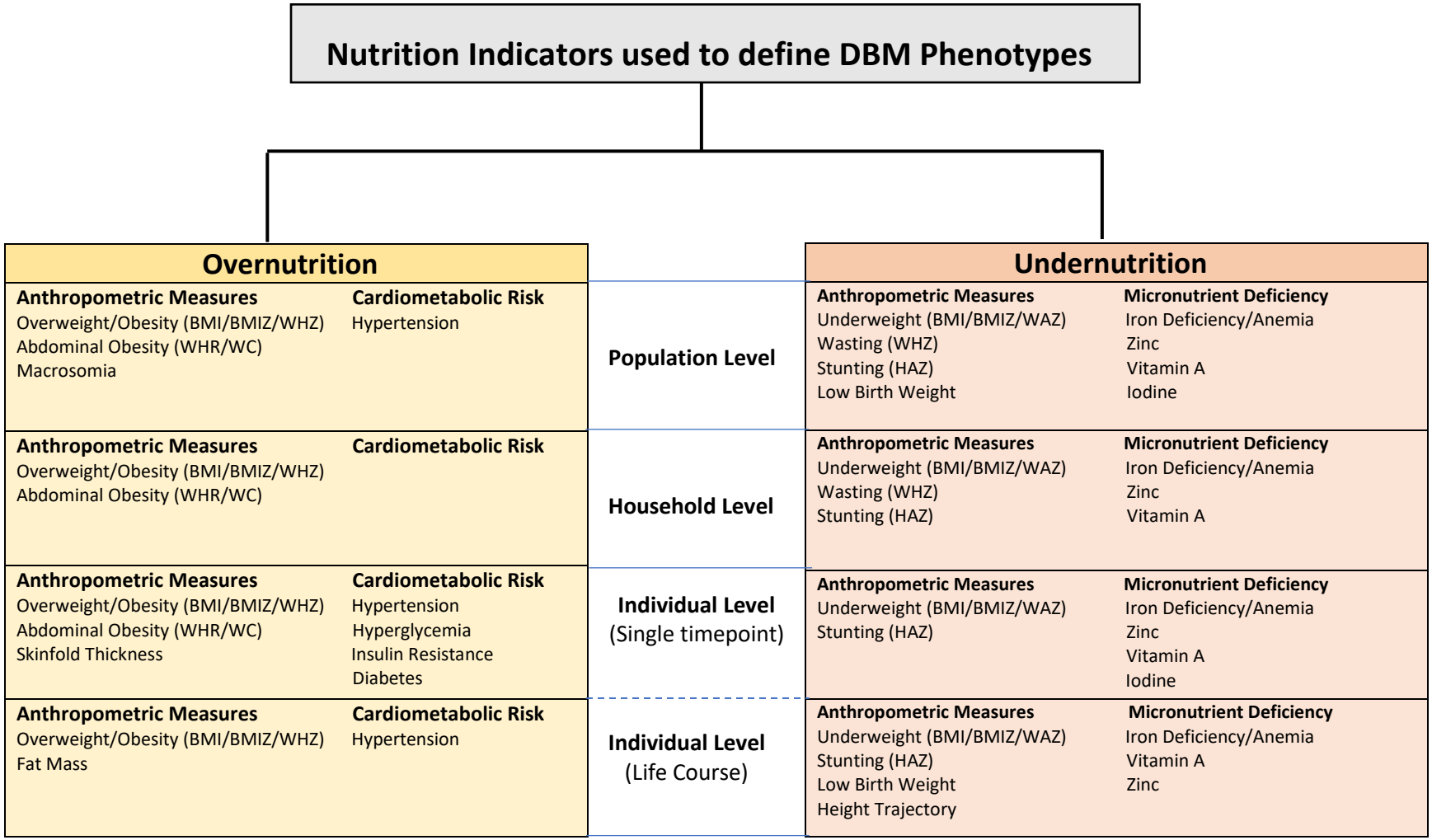

Figure 3: Nutritional Indicators Frequently used to Characterize DBM phenotypes**.** BMI, Body Mass Index; BMIZ, Body Mass Index Z score; WHZ, Weight-for-Length/Height Z score; WHR, Waist-to-Hip Ratio; WC, Waist Circumference; WAZ, Weight-for-Age Z score; HAZ, Height-for-Age Z score.

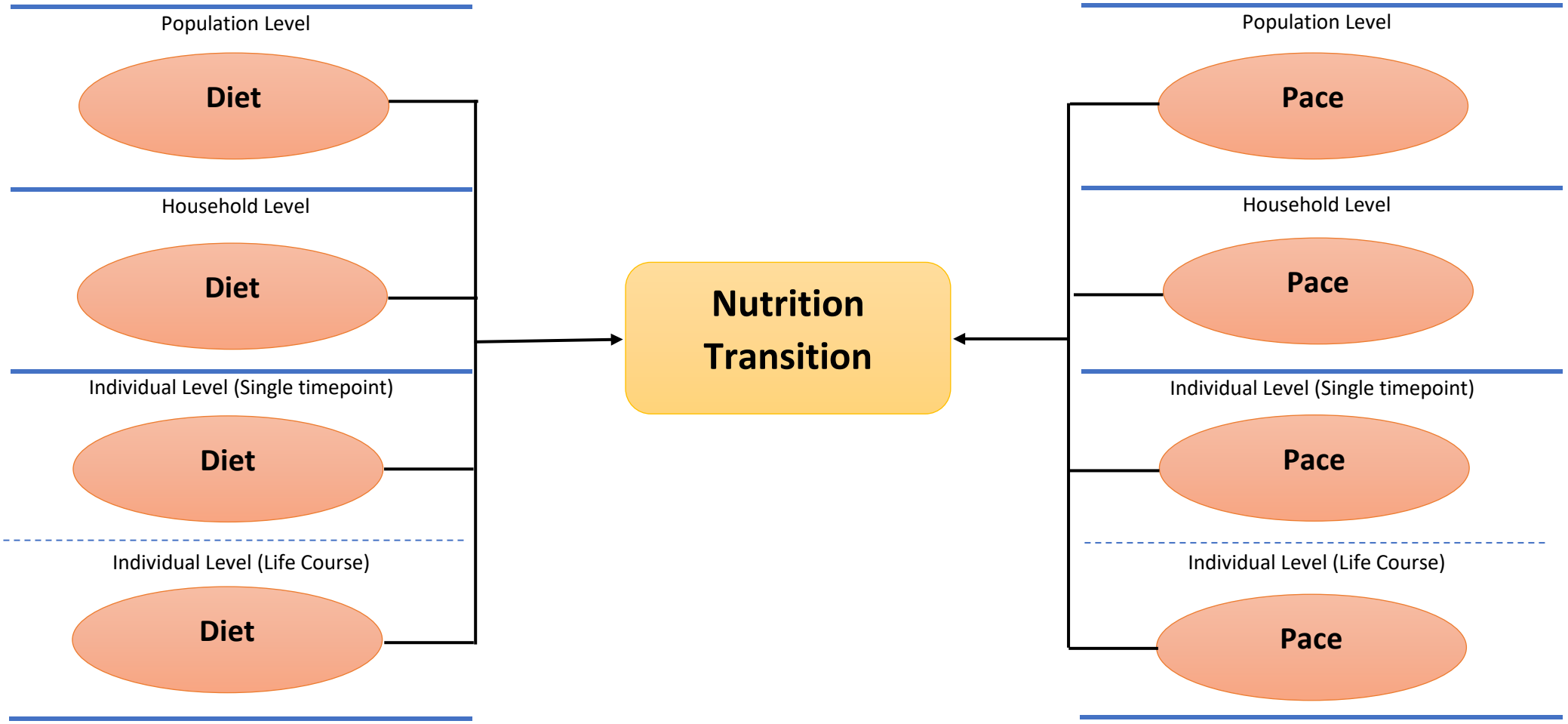

Figure 4: Thematic map demonstrating the level in which the two sub-themes of 'nutrition transition' theme provide explanations for the mechanism underlying the DBM phenomenon

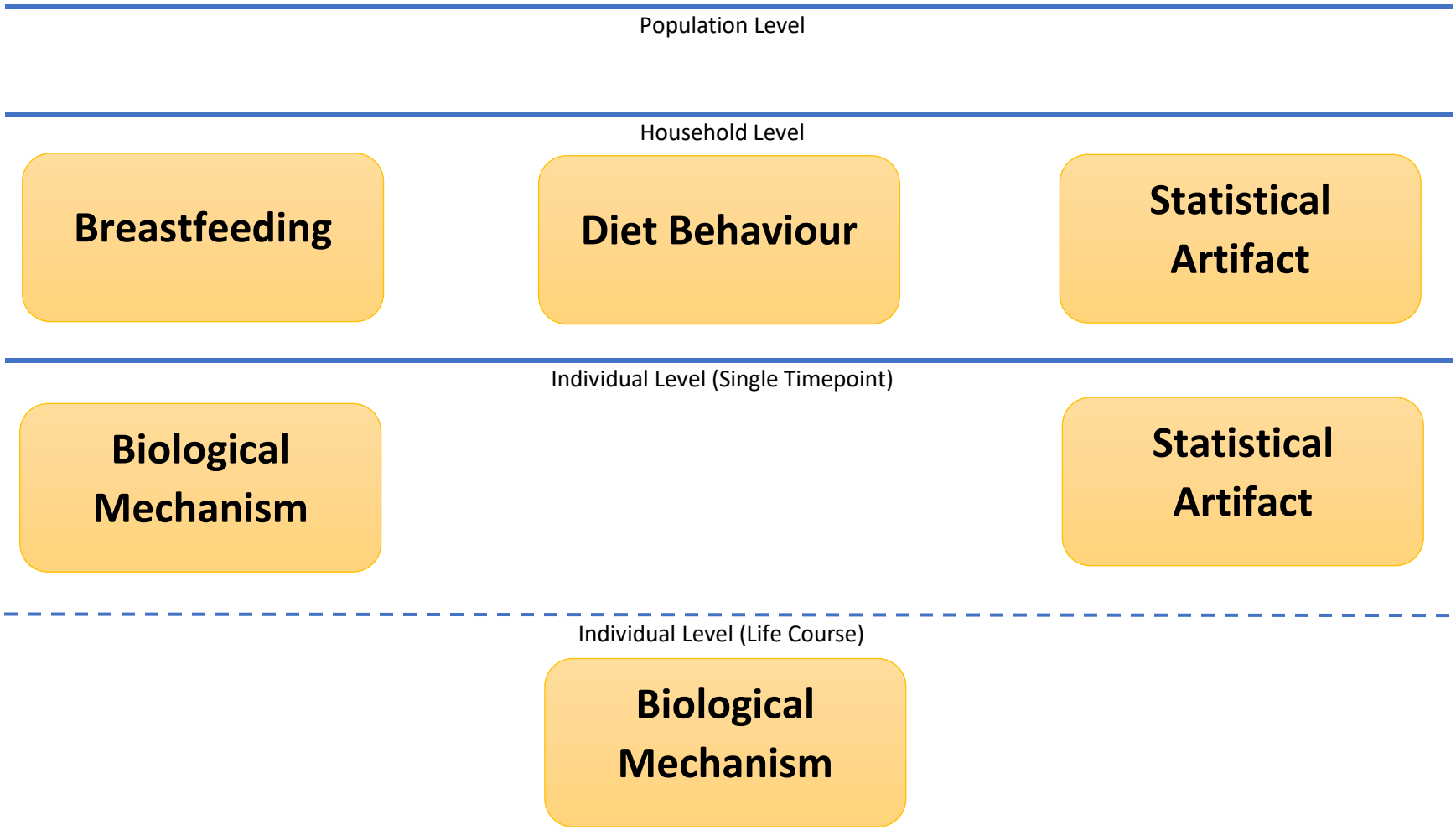

Figure 5: Thematic map demonstrating levels in which the alternate themes to nutrition transition theme offer explanations to the underlying DBM mechanism.

Table 2: Multilevel factors associated with the Double Burden of Malnutrition

		Level of Double Burden Malnutrition Analysis		
		Population (Community)	**Household**	**Individual (Life course)**
Level of Variable Measurement	**Population (Community)**	Urbanicity Population density Government policy Rural-Urban migration Economic development Ecological zone (Region) Socio-economic inequality	Urbanicity Population density Economic development Ecological zone (Region) Socio-economic inequality	Urbanicity Government policy Ecological zone (Region) Economic development
	Household	Wealth Sanitation Family size Food security Dietary diversity Access to media Paternal education Gender of household head Number of under five children Study period	Wealth Sanitation Diet quality Antenatal visits Housing quality Dietary diversity Women autonomy Gender of household head Number of under five children Family size Food security Study period	Wealth Sanitation Family size Diet quality Food insecurity Housing quality Gender of household head
	Individual	Smoking Child age Child sex Birth order Maternal age Marital status Disease/illness Physical activity Contraceptive use Maternal ethnicity Maternal education Breastfeeding status Maternal occupation Parity Religion Ethnicity	Child age Child sex Birth order Birth spacing Maternal age Disease/illness Physical activity Age at first birth Birth weight Maternal stature Caesarean delivery Maternal education Breastfeeding status Parity Religion Ethnicity	Smoking Ethnicity Child age Child sex Gravidity Birth weight Maternal age Marital status Disease/illness Physical activity Maternal stature Maternal education Breastfeeding status Parity Religion