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Real-time dietary assessment using a validated IT-based approach within a Ghanaian setting

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Abstract

Meeting dietary needs represents a key element to guarantee food security. However, appropriate solutions for fast and precise assessments of dietary energy and nutrient intakes are still not available. This becomes particularly evident, if accurate pictures on individual level must be generated. Therefore, this study illustrates the Calculator for Inadequate Micronutrient Intake (CIMI) concept: a program assessing dietary intakes in real-time considering individual diets. Based on quantitative food consumption data, CIMI was adapted to a Ghanaian setting and validated by comparison with a reference method (NutriSurvey®). Results indicated a high comparability of the two dietary assessment methods and thus, the validity of CIMI. Dietary intakes of energy, macro- and micronutrients of men, women and children were calculated and compared to standardized nutrient recommendations. Dietary intakes of most micronutrients were largely met within the study regions, however, inadequate intakes in all subpopulations groups were determined for calcium, riboflavin and folic acid. Some regions additionally suffered from an insufficient intake of vitamin A. While women in reproductive age showed an inadequacy of dietary iron, vitamin D intakes of children were identified as insufficient. As a valid real-time dietary assessment tool, CIMI will assure fast and precise nutrient intake evaluation identifying dietary gaps. Within this context, datasets will serve as a profound basis to address and efficiently counteract dietary inadequacies.

Keywords: Food Security, Nutrition, Malnutrition, Hidden Hunger, Sub-Saharan Africa, CIMI

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Introduction

It is estimated that 815 million people worldwide are undernourished (FAO, 2017), while 2 billion are affected by chronic forms of micronutrient deficiencies, known as “hidden hunger” (Ritchie and Roser, 2018). Unlike undernourishment, health implications of micronutrient deficiencies are often overlooked, hence, clinical symptoms are largely missing and only recognizable in severe forms of malnutrition (e.g. night blindness, goiter, rickets etc.). However, the negative consequences of hidden hunger on the physical and mental development can be profound (Biesalski, 2013). To efficiently counteract malnutrition, affected regions, more specifically, subpopulation groups as well as the specific micronutrient deficiency must be identified and quantified. So far, several dietary scores (e.g. Household Dietary Diversity Score) are used as a first rough estimation for food security in large-scale surveys. Accurate and more detailed approaches to assess under- and malnourishment based on the actual individual food intake can be estimated by dietary assessments using Food Frequency Questionnaires (FFQs) and 24h-Recalls (24hRs). Meanwhile, these procedures are usually time-consuming and present difficulties for enumerators and respondents (Pisa et al., 2018). To provide an empirical evidence to address the existing gap for a standardized and valid tool to evaluate individual nutrient intakes within sub-Saharan settings, the aim of this study was to contribute to the Calculator for Inadequate Micronutrient Intake (CIMI) concept by developing a Ghana-specific configuration.

Methodology

<u>Construction and Validation</u>

Quantitative data on food consumption of adults in reproductive age and children under-five years of age were obtained by cross-sectional nutrition surveys (Demographics, FFQs, 24hRs etc.) conducted in the Ashanti, Brong Ahafo, Central and Eastern region of Ghana. Based on the FFQ findings, region-specific food groups and respective portion sizes were identified functioning as elemental calculation components of CIMI for the qualitative and quantitative assessment of dietary intakes. Nutrient profiles were accessed from food composition tables (FAO, 2012; Souci et al., 2016; USDA, 2018) and laboratory analysis (Wald et al., 2018). Subsequently, the program was validated by correlating and plotting results obtained through the analysis of 24hRs with CIMI and the reference nutrition software: NutriSurvey® (Fig. 1). Pearson correlations and Bland-Altman plots indicated the comparability of the two methods and thus, the validity of CIMI.

<u>Features</u>

CIMI – once adapted to a specific setting – will calculate dietary energy, macro and micronutrient intake levels in real-time and directly compare them with standardized nutrient recommendations (WHO, 2004). Based on individual food consumption patterns, the bioavailability of iron and zinc is factored in the dietary intake calculation (Jati et al., 2014), providing more relevant results for both minerals. In addition, the real-time analysis without internet access allows a direct feedback to the respondents that might have an additional beneficial effect of motivating survey participants to trigger dietary changes, thus, increasing the compliance for interventions.

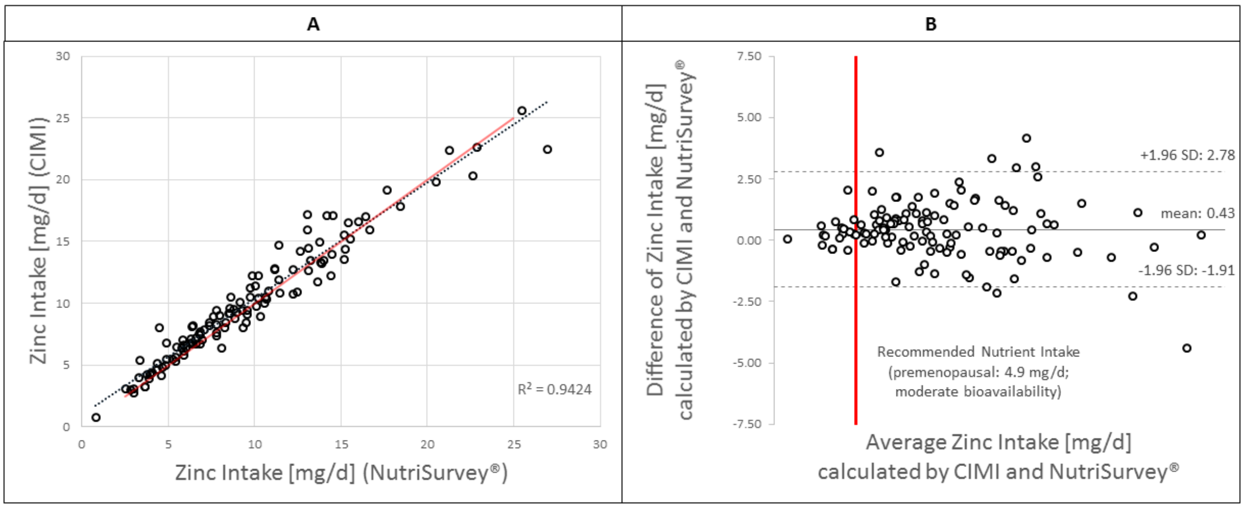

Fig. 1: Example for the correlation of CIMI with NutriSurvey®. Pearson correlation (A) and Bland-Altman-Plot (B) of dietary zinc intakes of women (15-50y) from Ashanti region (n=121). Results were calculated using an Excel-based pre-version of CIMI and NutriSurvey®.

Results and Discussion

Dietary Assessment of Micronutrient Intakes

The dietary patterns of the study regions were strongly characterized by the consumption of starchy staples (e.g. cassava, maize, rice etc.). In addition, fruits and vegetables were consumed in substantial amounts. Considerably fair amounts of meat, fish and eggs were consumed, however, the consumption of dairy products had to be considered as marginal. Recommended dietary intakes of most micronutrients were largely met within the investigated regions. While dietary intakes of calcium, riboflavin and folic acid, and in some regions, vitamin A were inadequate in all subpopulation groups. Women of reproductive age were suffering from inadequate dietary iron, whereas vitamin D intakes of children were below the recommended nutrient intake (RNI). The consequence of the negligible consumption of dairy products is a generally low calcium intake in all subgroups and study areas (Tab. 1). Nevertheless, the dietary (pro)vitamin A adequacy in Ashanti region was increased in comparison to the other study regions which was based on higher consumption of red palm oil (+58%), retinol-enriched vegetable oil (33%) and margarine (+707%). At this point, it is worth noting that the survey data indicated low individual consumption levels of all varieties of dark green leafy vegetables (<10g/day). Meanwhile, dark greens represent the third richest food group for riboflavin and folic acid within the respective setting. A portion of 100g leafy vegetables provides approximately one third of the recommended intake levels for both B-vitamins for women in reproductive age. Based on the defined portion sizes of CIMI, this is equivalent to three ladles of *kontomire* stew – a traditional meal made of cocoyam leaves.

Food Security Indicators

Diversified or "balanced" diets are generally considered as healthier and associated with nutrient adequacy (Ruel, 2002). To evaluate the diversification of diets, Dietary Diversity Scores (DDS) are often used as a proxy indicator, considering the number of different food groups or single food items being consumed over a given reference period (usually 24h) within, e.g., the household (HDDS; Swindale and Bilinsky, 2006). By correlating dietary mineral and vitamin intakes with the HDDS, the linkage between dietary diversity and micronutrient adequacy is illustrated reaching

Tab. 1: Percentage fulfillment of WHO RNIs through dietary intakes of men, women and children in different regions of Ghana. "Adequate" intakes were defined to be achieved, if the median was equivalent to ≥100% RNI, whereas "moderate risk", "risk" and "high risk" intake levels corresponded to >75-100% RNI, >50-75% RNI and ≤50% RNI, respectively.

ASHANTI	Men (19-65y; n=89)	Women (15-50y; n=121)	Children (<5y; n=83)
	% RNI Median (IQR)	% RNI Median (IQR)	% RNI Median (IQR)
Minerals			
Calcium [mg/d]	35.1 (23.3; 42.8)†††	29.9 (21.9; 39.8)†††	22.5 (15.3; 27.9)†††
Iron [mg/d]	164 (96.4; 248)	60.1 (38.4; 89.4)††	131 (69.0; 200)
Magnesium [mg/d]	171 (120; 270)	192 (139; 267)	293 (185; 418)
Zinc [mg/d]	160 (101; 228)	183 (125; 261)	89.6 (55.4; 138)†
Fat-soluble Vitamins			
Vitamin A [µg/d]	97.8 (48.7; 281)†	105 (57.9; 354)	62.4 (35.6; 162)††
Vitamin D [µg/d]	197 (48.0; 303)	152 (22.7; 303)	48.0 (5.67; 98.1)†††
Vitamin E [mg/d]	125 (78.7; 193)	177 (111; 251)	155 (107; 220)
Water-soluble Vitamins			
Thiamin [mg/d]	119 (75.3; 183)	116 (79.1; 175)	104 (71.4; 153)
Riboflavin [mg/d]	69.2 (43.6; 90.7)††	62.8 (45.3; 94.0)††	59.7 (34.6; 85.1)††
Niacin [mg/d]	110 (68.5; 144)	90.6 (67.3; 128)†	76.6 (49.6; 111)†
Pyridoxine [mg/d]	196 (132; 305)	158 (114; 257)	158 (98.1; 206)
Folate [µg/d]	74.9 (52.7; 139)††	69.5 (51.4; 115)††	72.4 (51.2; 112)††
Cobalamin [µg/d]	237 (73.2; 313)	145 (45.2; 290)	145 (45.0; 218)
Ascorbic Acid [mg/d]	281 (164; 421)	309 (164; 425)	151 (88.3; 228)

Brong Ahafo Central Eastern	Men (19-65y; n=166)	Women (15-50y; n=231)	Children (<5y; n=108)
	% RNI Median (IQR)	% RNI Median (IQR)	% RNI Median (IQR)
Minerals			
Calcium [mg/d]	29.4 (22.3; 38.6) †††	25.8 (18.4; 37.2) †††	19.9 (10.1; 29.6) †††
Iron [mg/d]	148 (102; 202)	59.3 (39.3; 85.6) ††	125 (55.2; 210)
Magnesium [mg/d]	162 (116; 243)	167 (103; 230)	253 (145; 385)
Zinc [mg/d]	139 (98.5; 176)	162 (108; 223)	89.2 (41.7; 142) †
Fat-soluble Vitamins			
Vitamin A [µg/d]	48.5 (31.1; 106) †††	54.1 (28.5; 117) ††	38.8 (15.7; 104) †††
Vitamin D [µg/d]	77.9 (9.86; 206) †	135 (20.6; 211)	26.7 (0.74; 98.5) †††
Vitamin E [mg/d]	82.2 (53.8; 121) †	94.5 (54.2; 157) †	102 (54.2; 152)
Water-soluble Vitamins			
Thiamin [mg/d]	114 (84.7; 155)	101 (70.1; 149)	86.4 (57.6; 138) †
Riboflavin [mg/d]	69.1 (47.7; 90.8) ††	67.4 (46.1; 94.5) ††	64.2 (32.4; 101) ††
Niacin [mg/d]	118 (87.7; 150)	112 (80.6; 153)	86.1 (41.2; 133) †
Pyridoxine [mg/d]	177 (130; 252)	152 (110; 215)	138 (88.2; 236)
Folate [µg/d]	73.6 (52.6; 99.2) ††	62.1 (42.2; 89.1) ††	61.3 (29.0; 104) ††
Cobalamin [µg/d]	105 (46.6; 234)	162 (56.8; 203)	68.8 (2.24; 183) ††
Ascorbic Acid [mg/d]	352 (197; 469)	254 (151; 393)	151 (68.8; 263)

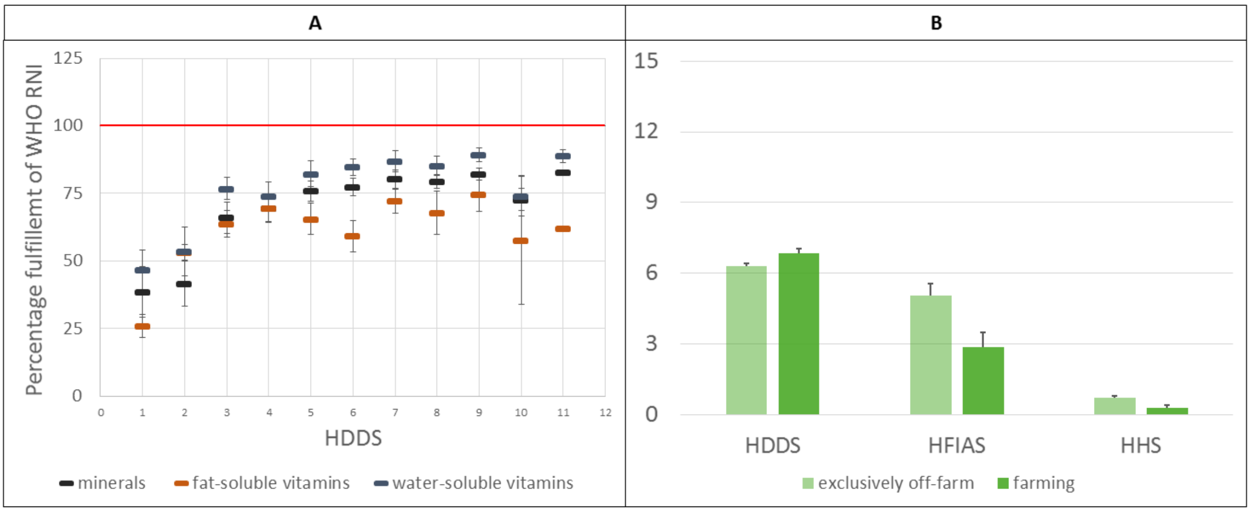

Fig. 2: Percentage fulfilment of dietary mineral, fat- and water-soluble vitamin intakes for men (19-65y) from Brong Ahafo, Central and Eastern region (n=166) versus HDDS (A). Comparison of HDDS, HFIAS and HHS of (part-time) farmers (n=64) and non-farmers (n=183) in respective regions. Graphs show the standard deviation of the mean.

more or less a plateau, if six or more different food categories were consumed (Fig. 2A). Interestingly, a DDS ≥6 appears to be an equally critical value in childhood development where normal body weight and growth was only achieved, if at least six different food groups were consumed (Steyn et al., 2006). Besides the DDS, other indicators were applied to measure household hunger in food insecure areas. The Household Food Insecurity Access Scale (HFIAS; Coates et al., 2007) and the Household Hunger Scale (HSS; Ballard et al., 2011) represent other tools that capture and quantify food insecurity by summarizing respective results in a scale. Having compared with the above-mentioned proxy indicators, it is evident, that (part-time) farmers are generally having a more diverse diet and feel less anxious and less uncertain about the household's food supply than people working exclusively in the non-agricultural sector.

Conclusion

CIMI represents a fast and precise IT-based approach for dietary assessments on individual level and was adapted, validated and applied within a Ghanaian setting. Dietary micronutrient intakes of men, women and children were analyzed and compared to WHO RNIs. The program is a first step towards the collection of large-scale datasets on individual dietary intakes that will serve as a valid basis for stakeholders to recommend appropriate intervention strategies to address potential dietary gaps.

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References

Ballard, T., Coates, J., Swindale, A., Deitchler, M., 2011. Household Hunger Scale: Indicator Definition and Measurement Guide. Version 1, FANTA.

Biesalski, H.K., 2013. Hidden Hunger, English Edition. ed. Springer.

Coates, J., Swindale, A., Bilinsky, P., 2007. Household Food Insecurity Access Scale (HFIAS) for Measurement of Food Access: Indicator Guide. Version 3, FANTA.

FAO, 2012. West African Food Composition Table. Food and Agriculture Organization of the United States, Rome, Italy.

FAO, IFAD, UNICEF, WFP and WHO, 2017. The State of Food Security and Nutrition in the World 2017. Building resilience for peace and food security. Rome, FAO.

Jati, I.R., Widmer, C., Purwestri, R.C. et al., 2014. Design and validation of a program to identify inadequate intake of iron, zinc, and vitamin A. Nutrition, 30, 1310-1317.

Pisa, P.T., Landais, E., Margetts, B. et al., 2018. Inventory on the dietary assessment tools available and needed in africa: a prerequisite for setting up a common methodological research infrastructure for nutritional surveillance, research, and prevention of diet-related non-communicable diseases. Critical Reviews in Food Science and Nutrition, 58, 37-61.

Ritchie, H., Roser, M., 2018. Micronutrient Deficiency. Published online at OurWorldInData.org. Retrieved from: https://ourworldindata.org/micronutrient-deficiency

Ruel, 2002. Is Dietary Diversity an Indicator of Food Security or Diet Quality? A Review of Measurement Issues and Research Needs; International Food Policy Research Institute: Washington, DC, USA.

Souci, S.W., Fachmann, W., Kraut, H., 2016. Food Composition and Nutrition Tables, 8th revised and completed edition, MedPharm Scientific Publishers.

Steyn, N.P., Nel, J.H., Nantel, G. et al., 2006. Food variety and dietary diversity scores in children: are they good indicators of dietary adequacy? Public Health Nutrition, 9, 644-650.

Swindale, A., Bilinsky, P., 2006. Household Dietary Diversity Score (HDDS) for Measurement of Household Food Access: Indicator Guide. Version 2, FANTA.

USDA Food Composition Databases. https://ndb.nal.usda.gov/ndb/ accessed on 20.02.2018.

Wald, J.P., Nohr, D., Biesalski, H.K., 2018. Rapid and easy carotenoid quantification in Ghanaian starchy staples using RP-HPLC-PDA. Journal of Food Composition and Analysis, 67, 119-127.

WHO/FAO, 2004. Vitamin and mineral requirements in human nutrition, Second Edition.