British Journal of Nutrition (2021), 126, 92–100 doi:10.1017/S0007114520003864

British Journal of Nutrition

EAT–*Lancet* diet score requires minimum intake values to predict higher micronutrient adequacy of diets in rural women of reproductive age from five low- and middle-income countries

Giles T. Hanley-Cook[1]*, Alemayehu A. Argaw[1,2], Brenda P. de Kok[1], Katrien W. Vanslambrouck[1], Laeticia C. Toe[1,3,4], Patrick W. Kolsteren[1], Andrew D. Jones[5] and Carl K. Lachat[1]

[1]*Department of Food Technology, Safety and Health, Faculty of Bioscience Engineering, Ghent University, 9000 Ghent, Belgium*
[2]*Department of Population and Family Health, Institute of Health, Jimma University, PO Box 378 Jimma, Ethiopia*
[3]*Center for Microbial Ecology and Technology, Faculty of Bioscience Engineering, Ghent University, 9000 Ghent, Belgium*
[4]*Unité Nutrition et Maladies Métaboliques, Institut de Recherche en Sciences de la Santé, 01 BP 2779 Bobo-Dioulasso, Burkina Faso*
[5]*Department of Nutritional Sciences, School of Public Health, University of Michigan, Ann Arbor, MI 48109-2029, USA*

(Submitted 12 February 2020 – Final revision received 10 August 2020 – Accepted 23 September 2020 – First published online 30 September 2020)

Abstract

The EAT–*Lancet* Commission promulgated a universal reference diet. Subsequently, researchers constructed an EAT–*Lancet* diet score (0–14 points), with minimum intake values for various dietary components set at 0 g/d, and reported inverse associations with risks of major health outcomes in a high-income population. We assessed associations between EAT–*Lancet* diet scores, without or with lower bound values, and the mean probability of micronutrient adequacy (MPA) among nutrition-insecure women of reproductive age (WRA) from low- and middle-income countries (LMIC). We analysed single 24-h diet recall data (n 1950) from studies in rural DRC, Ecuador, Kenya, Sri Lanka and Vietnam. Associations between EAT–*Lancet* diet scores and MPA were assessed by fitting linear mixed-effects models. Mean EAT–*Lancet* diet scores were 8·8 (SD 1·3) and 1·9 (SD 1·1) without or with minimum intake values, respectively. Pooled MPA was 0·58 (SD 0·22) and energy intake was 10·5 (SD 4·6) MJ/d. A one-point increase in the EAT–*Lancet* diet score, without minimum intake values, was associated with a 2·6 (SD 0·7) percentage points decrease in MPA ($P < 0·001$). In contrast, the EAT–*Lancet* diet score, with minimum intake values, was associated with a 2·4 (SD 1·3) percentage points increase in MPA ($P = 0·07$). Further analysis indicated positive associations between EAT–*Lancet* diet scores and MPA adjusted for energy intake ($P < 0·05$). Our findings indicate that the EAT–*Lancet* diet score requires minimum intake values for nutrient-dense dietary components to avoid positively scoring non-consumption of food groups and subsequently predicting lower MPA of diets, when applied to rural WRA in LMIC.

Key words: Diet quality: 24-h diet recall: Low- and middle-income countries: Nutrient adequacy: Micronutrient deficiency: Sustainable healthy diets: Women of reproductive age

Ensuring food systems deliver improved human and planetary health is among the most pressing global challenges of the 21st century(1). Global food production threatens climate stability and ecosystem resilience and constitutes the single largest driver of environmental degradation and transgression of planetary boundaries(2). Furthermore, low-quality diets are responsible for the greatest burden of disease worldwide(3), affecting countries and population groups at all levels of socio-economic development(4). To facilitate reversing these detrimental global trends, the EAT–*Lancet* Commission drew on state-of-the-art nutritional and environmental science as a yardstick for healthy diets from sustainable food systems(1). The report thus defined a 'flexitarian' universal reference diet and advocated a *Great Food Transformation* from business as usual towards win–win environmental sustainability and human health outcomes by the year 2050.

At present, academics and public health professionals are calling for accurate, robust and cross-cutting metrics (and data) to track diet quality and environmental sustainability goals at global, country and regional levels(5,6). Accordingly, Knuppel

---

Abbreviations: EAR, estimated average requirement; LMIC, low- and middle-income countries; MPA, mean probability of adequacy; WRA, women of reproductive age.

* **Corresponding author:** Giles T. Hanley-Cook, email giles.hanleycook@ugent.be

et al.(7) constructed a novel EAT–*Lancet* diet score (0–14 points) and reported its inverse associations with risks of major health outcomes in a high-income adult population. EAT–*Lancet* diet score might proxy diet quality, which is one guiding principle of healthy sustainable diet indicators(8,9). Furthermore, in contrast to other diet quality scores, for example, Healthy Eating Index-2015(10), Alternate Healthy Eating Index-2010(11) and Mediterranean Diet Score(12,13), the EAT–*Lancet* diet score is designed for global application and therefore aims to make meaningful comparisons across countries, populations and cultures. Moreover, the EAT–*Lancet* diet score extends previous universal diet quality metrics, based on adherence to WHO global nutrition guidelines, that is, Healthy Diet Indicators(14,15), by incorporating environmental health considerations(1) and simplifying food composition data requirements (no cholesterol, *n*-3 or *n*-6 PUFA components, etc.) to assess adherence to universal dietary recommendations in the Global South(16).

This being said, in the EAT–*Lancet* Commission's report, nutrient adequacy of the universal reference diet was calculated by assuming consumption (i.e. mean value of the proposed intake ranges) from each of the fourteen recommended dietary components and used food composition data primarily from US sources(1). Surprisingly, however, the healthy reference diet developed by Willett *et al.*(1) and the subsequent EAT–*Lancet* diet score by Knuppel *et al.*(7) set minimum intake values for multiple nutrient-dense food groups at 0 g/d. *A priori*, the authors of this research acknowledged these intake/scoring ranges as a potential pitfall of the EAT–*Lancet* diet score in food and nutrition insecure low- and middle-income countries (LMIC). Lawrence *et al.*(17) also argued for further development of the EAT–*Lancet* universal reference diet narrative, which must specifically clarify the inclusion of zero consumption recommendations (i.e. no minimum intake values) for various nutrient-dense dietary components. In particular, women of reproductive age (WRA) remain more susceptible than men to malnutrition and food insecurity, that is, higher prevalence of non-consumption of dietary components (0 g/d), across every continent(18), but most notably in resource-poor settings(19,20). Hence, women's nutrition and health in LMIC have received increased global political attention and resource allocation during the Millennium and Sustainable Development Goals Era(21–23). At present, the United Nations Decade of Action on Nutrition 2016–2025 and the 2030 Agenda for Sustainable Development provide global and national stimuli to monitor and address global malnutrition outcomes, with specific targets for women.

To the authors' knowledge, no previous study has assessed the association between the EAT–*Lancet* diet score and the (micro) nutrient adequacy of diets for rural WRA in LMIC. Thus, the EAT–*Lancet* diet score's potential application to monitor and evaluate global adherence to healthy and sustainable food consumption in the Anthropocene is currently unknown (i.e. cross-cutting metric for Sustainable Development Goals and Paris Agreement targets). Therefore, the present study used local food composition tables and evaluated EAT–*Lancet* diet scores(7), without or with (>0 g/d) minimum intake values for nutrient-dense dietary components, as a potential predictor of higher Mean Probability of Micronutrient Adequacy (MPA) of diets in rural WRA from five LMIC across Africa, Asia and Latin America.

Methods

Data sources

Cross-sectional secondary data from five LMIC were used in the present study (online Supplementary Table S1). Dietary intake data of non-pregnant non-lactating WRA (15–49 years) were collected using a quantitative and comparable single multiple-pass 24-h dietary recall method that identified food and drinks to at least the species level(24). Dietary intake data during the wet (lean) season were obtained from rural areas in the Democratic Republic of Congo (*n* 375(25)), Ecuador (*n* 201(26)), Kenya (*n* 361(27)), Sri Lanka (*n* 20) and Vietnam (*n* 262). Dietary intake data from the dry (plenty) season were also available from Kenya (*n* 362(27)) and Vietnam (*n* 369). All studies considered agricultural and wild sources of food and drinks, without assessment of dietary supplement intake. All data were collected between July 2009 and April 2015, and samples were representative of the village-level populations. Food composition data for Ca (mg), folate (µg), Fe (mg), vitamin A (µg retinol equivalents), vitamin C (mg) and Zn (mg), available for all five LMIC, were mostly sourced from national food composition tables, to capture the substantial variations in content and density of essential micronutrients between- and within-food species(5,28,29). In the event, food composition data were missing and best-matching values were obtained from similar settings, countries, or food and drinks (online Supplementary Table S1).

Ethics

Anonymised individual-level data and protocols are available at https://dataverse.harvard.edu/dataverse/DietarySpeciesRichness. All studies were approved by an ethics committee, except in Sri Lanka where the protocol was exempted from clearance. The present analysis was approved by the Ethics Committee of Ghent University Hospital (NR B670201422403). Our research was reported using the STROBE-nut checklist (online Supplementary Text 1(30)).

EAT–*Lancet* diet scores

First, using data from the 24-h dietary recall method (*n* 1950), we calculated the EAT–*Lancet* diet score(7) based on fourteen key recommendations in Willett *et al.*(1) (Table 1). The EAT–*Lancet* universal reference diet corresponds to the average energy needs (10·5 MJ/d or 2500 kcal/d) of a 30-year-old woman weighing 60 kg and whose physical activity level is between moderate and high (1·7–2·0). The serving ranges for each food group were derived from state-of-the-art scientific evidence with regard to human and planetary health impacts of foods in the Anthropocene(1). As recommended in Knuppel *et al.*(7), diets were assigned one point for meeting the amount of dietary intake (g/d) and proportion of energy (MJ/d) for whole grains, recommended for each dietary component, resulting in a possible score ranging from 0 to 14 points.

Table 1. Construction of the EAT–*Lancet* diet score without or with minimum intake values

	Criteria for scoring one point based on the planetary health diet(1)†	
Dietary component*	Without minimum intake values‡	With minimum intake values§
Whole grains		
Rice, wheat, maize and other	Total grains 0–60 % of food energy (MJ/d) and ≤464 g/d‖	Total grains 32–60 % of food energy (MJ/d) and 232–464 g/d‖
Tubers and starchy staples		
Potatoes and cassava	≤100 g/d	50–100 g/d
Vegetables		
All vegetables	200–600 g/d	200–600 g/d
Fruits		
All fruits	100–300 g/d	100–300 g/d
Dairy foods		
Whole milk or derivative equivalents	≤500 g/d	250–500 g/d
Protein sources		
Beef, lamb and pork	≤28 g/d	14–28 g/d
Chicken and other poultry	≤58 g/d	29–58 g/d
Eggs	≤25 g/d	13–25 g/d
Fish	≤100 g/d	28–100 g/d
Legumes		
Dry beans, lentils and peas	≤100 g/d¶	50–100 g/d¶
Soya foods	≤50 g/d	25–50 g/d
Peanuts and tree nuts	25–100 g/d	25–100 g/d
Added fats		
Palm oil, unsaturated oils, dairy fats (included in milk), lard or tallow	20–91·8 g/d	20–91·8 g/d
Added sugars		
All sweeteners	≤31 g/d	≤31 g/d

* Each dietary component contributed 0 or 1 point resulting in a total score ranging from 0 to 14 points.

† Food species consumed per food group are described in Lachat *et al.*(5) (online Supplementary Table S5).

‡ Recommendations used for the associations with ischaemic heart disease, stroke, diabetes and all-cause mortality in Knuppel *et al.*(7) (online Supplementary Table S1).

§ Intake values used for the assessment of nutrient adequacy in Willett *et al.*(1) (online Supplementary Table S4).

‖ Reference diet refers to dry, raw weight. Equivalent dry weights assigned based on the third supplement to McCance & Widdowson's *The Composition of Foods*, 4th edition (1988)(31).

¶ Reference diet refers to dry, raw weight. Equivalent dry weights assigned based on the fifth supplement to McCance & Widdowson's *The Composition of Foods*, 4th edition (1991)(32).

Nevertheless, as previously described, nutrient adequacy of the 'flexitarian' universal reference diet was calculated by assuming consumption (mean value of the proposed intake ranges, e.g. 29 g/d of chicken and other poultry; Table 1) from each of the fourteen recommended dietary components(1). However, the healthy reference diet promulgated by Willett *et al.*(1) set lower bound intake values for multiple nutrient-dense food groups at 0 g/d. *A priori*, we acknowledged the absence of minimum intake requirements for tubers and starchy staples (dietary component no. 2), dairy foods (no. 5) and protein sources (nos. 6–11), as a potential pitfall of the EAT–*Lancet* diet score for vulnerable populations in food and nutrition insecure settings. To illustrate, WRA consuming a monotonous diet composed of 436 g/d whole-grain hard red spring wheat (±5·9 MJ/d), 91 g/d added rapeseed oil (±3·4 MJ/d) and 30 g/d added granulated sugar (±0·5 MJ/d) would counterintuitively score 11 points from a maximum of 14.

Therefore, we re-calculated the EAT–*Lancet* diet score (Table 1) with minimum intake values (i.e. mean value of the proposed intake ranges, as used for the nutrient adequacy calculations in online Supplementary Table S4 of the EAT–*Lancet* Commission's report(1)), to avoid assigning zero consumption (0 g/d) of a dietary component as one point.

Mean probability of nutrient adequacy

As a measure of the micronutrient adequacy of diets, we calculated the probability of adequacy (PA) for Ca, folate, Fe, vitamin A, vitamin C and Zn and the MPA for each WRA over a 24-h period using the probability approach(33). We used the estimated average requirements (EAR) and CV from the FAO & WHO(34). For Fe requirements, which are known to be skewed for non-pregnant, non-lactating women, we used the IOM's reference tables(35), but adjusted for absorption of 10 % on the basis of diet patterns, according to FAO and WHO guidance(34). For Zn, we use the International Zinc Nutrition Consultative Group's EAR and CV(36), assuming low absorption (25 %). The EAR used for each micronutrient are reported in online Supplementary Table S3. MPA was calculated as the mean of the PA of the six individual micronutrients. In parallel to micronutrient PA, the MPA has a possible range of 0–1. In addition, as a measure of the micronutrient density of diets, we calculated energy-adjusted MPA (MPA/total energy intake (MJ/d)) for each WRA.

Statistical analysis

Data management and statistical analysis were conducted in Stata version 15.1(37). A two-sided significance level of $P < 0·05$ was applied for all analyses. WRA were considered equally representative; therefore, overall summary statistics (mean values and standard deviations; %) were calculated averages for WRA per country and across countries. We compared EAT–*Lancet* diet scores and MPA between seasons (i.e. Kenya and Vietnam only) using Welch's independent-samples *t* test.

To assess the associations between EAT–*Lancet* diet scores, without or with minimum intake values, and MPA (or energy-adjusted MPA), linear mixed effects models (*mixed*; random intercept: country; random slope: varying association by country) were fitted, assuming an unstructured covariance matrix.

To examine any differences in EAT–*Lancet* diet scores, without or with minimum intake values, by season and total energy intake, we tested exploratory interaction terms between EAT–*Lancet* diet scores and season and total energy intake as a binary variable (i.e. 0 for <10·5 MJ/d and 1 for ≥10·5 MJ/d underpowered for the latter group in Ecuador and Sri Lanka). Furthermore, we repeated the analyses, for EAT–*Lancet* diet scores with each individual recommendation adjusted for the score (minus itself) to investigate whether one or more dietary recommendations were responsible for our associations(38). Moreover, EAT–*Lancet* diet scores were potentially associated with total energy intake (MJ/d)(39). Therefore, to evaluate the micronutrient density of the diet, we tested associations between EAT–*Lancet* diet scores, without or with minimum intake values, and standardised energy-adjusted MPA (percentage points/MJ; SD).

Results

Sample characteristics

24-h Dietary recall method data were obtained for 1219 (62·5 %) WRA in the wet and 731 WRA in the dry season (mean age 28·5 (SD 7·8) years). The difference between EAT–*Lancet* diet scores, without or with minimum intake values (mean 6·8 (SD 1·1) points), ranged between 6·0 (SD 1·1) in Ecuador and 7·5 (SD 0·8) in the Kenya. MPA (mean 0·58 (SD 0·22)) ranged between 0·45 (SD 0·18) in Sri Lanka and 0·64 (SD 0·18) in Vietnam (Table 2). Diets were particularly non-adhering to the EAT–*Lancet* diet score, without minimum intake values, with regard to whole grains (43·2 %), vegetables (28·8 %), fruits (16·5 %), nuts (3·3 %) and added fats (20·9 %) (online Supplementary Table S2). In contrast, diets were non-adhering to the EAT–*Lancet* diet score, with minimum intake values, for all key dietary components (<50 %), except added sugar (63·6 %) (online Supplementary Table S4). Diets were particularly inadequate for Ca (mean PA 0·12 (SD 0·30)) and folate (mean PA 0·31 (SD 0·43); online Supplementary Table S3). The EAT–*Lancet* diet score, without minimum intake values, was higher in the wet (lean) season ($P = 0·030$), whereas the EAT–*Lancet* diet score, with minimum intake values, was higher in the dry (plenty) season ($P = 0·024$). MPA was lower ($P < 0·001$) in the wet (lean) season, and thus dietary variables were not comparable across seasons when only countries with data for both seasons were used (i.e. Kenya and Vietnam; *n* 1354; Table 2).

*Associations between EAT–*Lancet* diet scores and MPA*

The EAT–*Lancet* diet score, without minimum intake values, was consistently inversely associated with MPA across countries (Fig. 1; online Supplementary Fig. S1). Each one-point increase in the EAT–*Lancet* diet score, without minimum intake values, was associated with a 2·6 (SD 0·7) percentage points decrease in MPA ($P < 0·001$) (Table 3). The associations were not explained

Table 2. EAT–*Lancet* diet scores, without or with minimum intake values, and mean probability of adequacy in women of reproductive age by country and season
(Mean values and standard deviations)

	Democratic Republic of Congo		Ecuador		Kenya						Sri Lanka		Vietnam						All					
Season	Wet (*n* 375)		Wet (*n* 201)		Wet (*n* 361)		Dry (*n* 362)		Combined (*n* 723)		Wet (*n* 20)		Wet (*n* 262)		Dry (*n* 369)		Combined (*n* 631)		Wet (*n* 1219)		Dry (*n* 731)		Combined (*n* 1950)	
Indicators	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
EAT–*Lancet* diet score, without minimum intake values (0–14 points)	9·3	1·2	8·5	1·3	8·9	1·0	9·1	1·2	9·0*	1·1	7·8	1·4	8·5	1·2	8·2	1·2	8·3*	1·2	8·9	1·2	8·6	1·3	8·8	1·3
EAT–*Lancet* diet score, with minimum intake values (0–14 points)	2·2	1·1	2·6	1·2	1·3	1·0	1·7	1·1	1·5*	1·1	1·8	1·2	2·3	1·0	1·9	0·9	2·1*	1·0	2·0	1·2	1·8	1·0	1·9	1·1
Mean probability of adequacy (0–1)	0·537	0·228	0·487	0·229	0·505	0·218	0·663	0·236	0·584*	0·241	0·448	0·183	0·648	0·174	0·638	0·185	0·642	0·181	0·542	0·222	0·651	0·212	0·583	0·224
Energy (MJ/d)	8·9	4·3	6·2	2·0	10·9	5·0	11·4	5·0	11·2	5·0	8·9	3·9	12·0	3·5	12·5	3·7	12·3	3·6	9·7	4·5	11·9	4·4	10·6	4·6

* Two-sided Welch's independent-samples *t* test significant by season at the 5 % level.

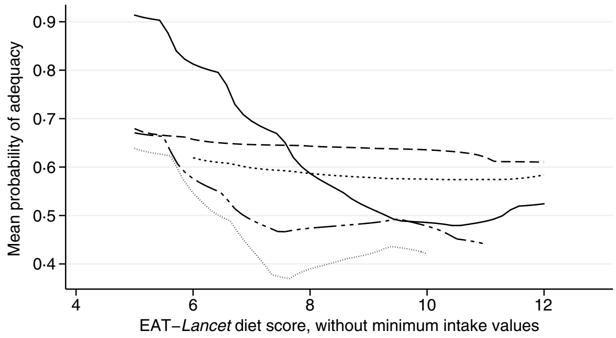

Fig. 1. Associations between mean probability of adequacy and EAT–*Lancet* diet score, without minimum intake values, in 1950 women of reproductive in five low- and middle-income countries. Kernel-weighted local polynomial smoothing plot. ——, Democratic Republic of Congo; ——, Sri Lanka; -----, Vietnam; –··–, Ecuador; ·········, Kenya.

by one single dietary recommendation (non-consumption included in criteria for scoring one point), suggesting a negative cumulative effect of the EAT–*Lancet* diet score's dietary components without minimum intake values (online Supplementary Table S6). However, 1923 (98·6 %) WRA achieved the recommendations (including 0 g/d) for dairy foods, 1724 (88·4 %) for eggs, 1773 (90·9 %) for fish, 1761 (90·3 %) for dry beans, lentils and peas, 1948 (99·9 %) and only 64 (3·3 %) for peanuts and tree nuts, suggesting that a subset of the recommendations contributed to the lower MPA associated with better adherence to the EAT–*Lancet* diet score without minimum intake values. The interaction term between the EAT–*Lancet* diet score, without minimum intake values, and season was significant in Kenya and Vietnam ($P < 0·05$). Nevertheless, the direction of the modified association between the EAT–*Lancet* diet score and MPA remained unchanged. Furthermore, the interaction term between the EAT–*Lancet* diet score, without minimum intake values, and total energy intake (<10·5 or ≥10·5 MJ/d) was also significant ($P = 0·003$), although associations between the EAT–*Lancet* diet score and MPA were non-significant (online Supplementary Table S5).

In contrast, the EAT–*Lancet* diet score, with minimum intake values, was positively associated with MPA (Fig. 2; online Supplementary Fig. S2). Each one-point increase in the EAT–*Lancet* diet score, with minimum intake values, was non-significantly associated with a 2·4 (SD 1·3) percentage points increase in MPA ($P = 0·07$; Table 3). The associations were not explained by one single dietary recommendation, suggesting a positive cumulative effect (e.g. all vegetables, dairy products, and peanuts and tree nuts) of the EAT–*Lancet* diet score's dietary components with minimum intake values (online Supplementary Table S6). The interaction term between the EAT–*Lancet* diet score, with minimum intake values, and season was significant in Vietnam only ($P = 0·003$), but did not change the positive associations between the EAT–*Lancet* diet score, with minimum intake values, and MPA across both seasons. Moreover, the interaction term between the EAT–*Lancet* diet score, without minimum intake values, and total energy intake (<10·5 or ≥10·5 MJ/d) was significant ($P = 0·018$), although the positive association between the EAT–*Lancet* diet score and MPA was significant in the <10·5 MJ/d group only ($P = 0·001$; online Supplementary Table S5).

Table 3. Associations between EAT–*Lancet* diet scores, with or without minimum intake values, and mean probability of adequacy in women of reproductive age by country and season
(β Values with their standard errors)

	Mean probability of adequacy (0–1)																							
Country	Democratic Republic of Congo		Ecuador		Kenya						Sri Lanka		Vietnam						All†					
Season	Wet (*n* 375)		Wet (*n* 201)		Wet (*n* 361)		Dry (*n* 362)		Combined (*n* 723)		Wet (*n* 20)		Wet (*n* 262)		Dry (*n* 369)		Combined (*n* 631)		Wet (*n* 1219)		Dry (*n* 731)		Combined (*n* 1950)	
Indicator	β	SE	β	SE	β	SE	β	SE	β	SE	β	SE	β	SE	β	SE	β	SE	β	SE	β	SE	β	SE
EAT–*Lancet* diet score without minimum intake values (per one-point increase)	−0·057***	0·009	−0·027*	0·012	−0·034**	0·011	−0·004	0·010	−0·011	0·008	−0·050	0·029	−0·028***	0·009	0·0	0·008	−0·011	0·006	−0·039***	0·006	0·0	0·006	−0·026***	0·007
EAT–*Lancet* diet score with minimum intake values (per one-point increase)	−0·007	0·011	0·029*	0·013	0·041***	0·011	0·054***	0·011	0·061***	0·008	−0·032	0·036	0·017	0·010	0·061***	0·011	0·039***	0·007	0·016	0·010	0·057***	0·008	0·024	0·013

* $P < 0·05$, ** $P < 0·01$, *** $P < 0·001$.
† Mixed effects linear regression model random intercept: country; random slope: association between EAT–*Lancet* diet score and MPA by country.

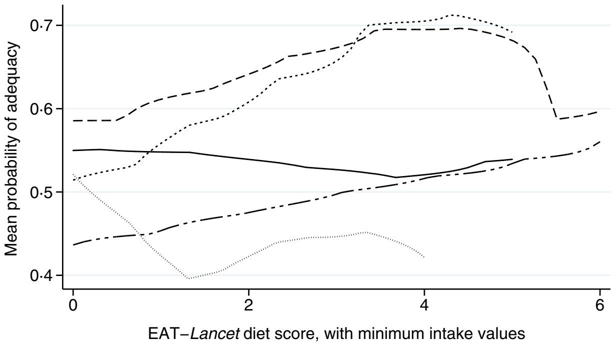

Fig. 2. Associations between mean probability of adequacy and EAT–*Lancet* diet score, with minimum intake values, in 1950 women of reproductive in five low- and middle-income countries. Kernel-weighted local polynomial smoothing plot. ——, Democratic Republic of Congo; ——, Sri Lanka; ----, Vietnam; –··–, Ecuador; ·········, Kenya.

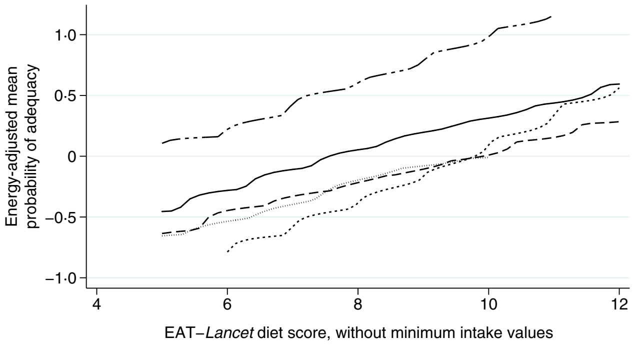

Fig. 3. Associations between standardised energy-adjusted mean probability of adequacy and EAT–*Lancet* diet score, without minimum intake values, in 1950 women of reproductive in five low- and middle-income countries. Kernel-weighted local polynomial smoothing plot. ——, Democratic Republic of Congo; ——, Sri Lanka; ----, Vietnam; –··–, Ecuador; ·········, Kenya.

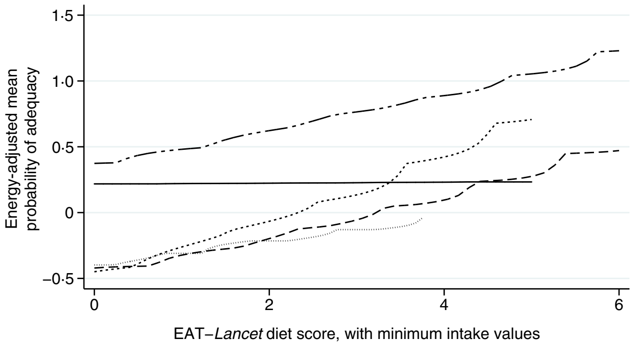

Fig. 4. Associations between standardised energy-adjusted mean probability of adequacy and EAT–*Lancet* diet score, with minimum intake values, in 1950 women of reproductive in five low- and middle-income countries. Kernel-weighted local polynomial smoothing plot. ——, Democratic Republic of Congo; ——, Sri Lanka; ----, Vietnam; –··–, Ecuador; ·········, Kenya.

Further analysis indicated consistent positive associations between EAT–*Lancet* diet scores, without or with (except the Democratic Republic of Congo) minimum intake values, and standardised energy-adjusted MPA across countries (Figs. 3 and 4). Each one-point increase in the EAT–*Lancet* diet score, without minimum intake values, was associated with an increase of 0·20 (SD 0·03) in energy-adjusted MPA ($P < 0·001$; online Supplementary Table S7 and Fig. S3). In parallel, a one-point increase in the EAT–*Lancet* diet score, with minimum intake values, was associated with an increase of 0·16 (SD 0·06) in energy-adjusted MPA ($P = 0·011$; online Supplementary Fig. S4).

Discussion

The EAT–*Lancet* diet score, without minimum intake values for all nutrient-dense dietary components, was consistently negatively associated with MPA in all five countries. In contrast, the EAT–*Lancet* diet score, with minimum intake values, was positively associated with MPA in all countries, except in the underpowered sample from Sri Lanka (which only included twenty WRA). Therefore, our findings advocate minimum intake values (>0 g/d), to avoid the EAT–*Lancet* diet score predicting non-consumption of nutrient-dense dietary components and subsequent lower micronutrient adequacy of diets in resource-poor settings. In parallel to our findings, Willett *et al.*(1) also noted that the universal reference diet's dietary recommendations might need to be adapted/flexible to the local culture, geographic, social or economic circumstances, as a strict global adoption of the EAT–*Lancet* diet might not be an optimal (ethical or equitable) choice for all(17,40,41).

Our results are in contrast to research by Knuppel *et al.*(7), which indicated that a similar EAT–*Lancet* diet score, without minimum intake values for multiple nutrient-dense food groups, was associated with lower risks of major health outcomes, such as ischaemic heart disease and diabetes (but was not associated with stroke or mortality), in adults of the EPIC-Oxford cohort. However, we argue that analyses of the EAT–*Lancet* diet score, without minimum intake values, and nutritional outcomes in high-income countries characterised by overconsumption(3), are unlikely to suffer from the same limitations as in LMIC, that is, capturing non-consumption of nutrient-dense food groups (0 g/d) and subsequent lower micronutrient adequacy of diets in populations crippled by the triple burden of malnutrition(42). To illustrate, our findings indicate that diets were micronutrient inadequate (MPA < 0·60) in the study population of rural WRA in the Democratic Republic of Congo, Ecuador, Kenya and Sri Lanka (excluding Vietnam). Furthermore, in parallel to previous research on country-level adherence to dietary guidelines(43,44), the proportion of WRA meeting the fourteen key dietary recommendations, with minimum intake values, was low. Therefore, future nutrition and environmental research might apply the EAT–*Lancet* diet scores, with minimum intake values, in prospective cohort studies in LMIC (e.g. Prospective Urban Rural Epidemiology study(45)) and model better adherence to multiple environmental impacts at national or regional scales(46). This research shows that the EAT–*Lancet* diet score, with minimum intake values, might potentially serve as a cross-cutting sustainable healthy diet indicator, to facilitate monitoring and evaluation of women's dietary (and environmental, not assessed in this study) risk factors, rather than detrimental outcomes alone (e.g. prevalence of anaemia in WRA).

Furthermore, EAT–*Lancet* diet scores, without minimum intake values, and MPA were significantly different between wet (lean) and dry (plenty) seasons in Kenya and Vietnam. Our results might be attributable to the seasonal changes in local production systems, increased food availability and micronutrient density of food species associated with the plenty season(40). These findings are distinct from Lachat *et al.*(5), although expected considering previous systematic reviews reported considerable intra-annual variation in nutritional quality of adult's diets in highly biodiverse areas(47,48). Indeed, we report higher intake (g/d) of beef, lamb, pork, chicken, other poultry and eggs in the dry season (results available on request). Moreover, the EAT–*Lancet* diet score, with minimum intake values, was more positively associated with MPA in the dry season, suggesting that it might be easier to increase micronutrient adequacy of diets in the plenty season. Our findings are potentially attributed to the observed higher prevalence of WRA reaching the EAT–*Lancet* diet score's recommendations, with minimum intake values, for vegetables, dairy foods and fish in the dry season.

Advocating global adherence to a 'flexitarian' EAT–*Lancet* diet (with lower bound intake values for animal-source food groups set at 0 g/d) has generated mixed responses and criticism within the global research and development community(17). The state-of-the-art scientific basis for a predominately plant-based (or low animal-source food) universal reference diet(1), focused on promoting a diversity of whole grains, vegetables, fruits, legumes, nuts and unsaturated oils, low-to-moderate amounts of seafood and poultry, and no or low quantities of red meat, processed meat, added sugar, refined grains and starchy vegetables, is controversial(38,45,49–51), socially polarised(17,52) and has been questioned for vulnerable population groups in LMIC(41,53–55). To illustrate, increased intakes of nutrient-dense foods, such as animal-source foods, are known to provide vital nutritional benefits, including protein and essential micronutrients (e.g. Fe, Zn and B-vitamins) to WRA in LMIC(56–61). To add to the intricacies/wicked problem of healthy sustainable diets, Hirvonen *et al.*(62) reported that adherence to the EAT–*Lancet* Commission's universal reference diet, with minimum intake values (MJ/d), requires relatively larger quantities of higher-cost food groups, such as dairy products, eggs, meat, fish, fruits and vegetables than near-subsistence diets (or alternative diets with minimally adequate levels of essential nutrients), rendering the diet unaffordable for approximately 1·5 billion people, mostly in sub-Saharan Africa and South Asia. Therefore, in order to address global diet-related inequities(63) and improve adherence to sustainable healthy diets(41,62), we argue that more dedicated and comprehensive multi-sectoral nutrition-sensitive and nutrition-specific policies and programmes are required.

Although there is a need to develop simple *a priori* global indicators for healthy sustainable diets, to ensure policymakers and consumers understand how such diets improve individual and population health and conserve natural resources(64), using crude scores, for example, the EAT–*Lancet* diet score has inherent statistical limitations, including subjective selection of components and cut-offs, single dietary components considered as independent (i.e. correlated structure or substitution effects (e.g. vegetal and animal protein sources) not considered) and assumptions of linear additive effects(65). Moreover, given the complexity of the magnitudes of impact dietary components has on human and planetary health(66), sustainable healthy diet indices might be more informative when composed of a suite of nutritional and environmental metrics(46,67,68).

As was the case with previous studies(5,26,27,69), the first limitation of the present research was a lack of nutrient composition data of certain foods consumed (limiting analysis to six micronutrients available across all five countries). The composition of various indigenous, wild, neglected and underutilised food species was often not available and was substituted with nutrient values from similar foods. Second, we were unable to use a cut-off for fibre intake to accommodate for the emphasis of the universal reference diet on whole grains. Third, we used only a single multiple-pass 24-h dietary recall method per WRA. Although this method is appropriate to estimate population average dietary intakes, it does not allow accounting for intra-person variability(70) and thus estimation of usual intake(33). Fourth, analyses of EAT–*Lancet* diet scores pertain only to a reference WRA, and recommendations differ among women depending on their height, weight, physical activity, pregnancy and lactation status. Further assessments of the applicability of EAT–*Lancet* diet scores in diets with a higher contribution of foods obtained from (peri-) urban markets or processed foods and diverse population groups are warranted.

Although the EAT–*Lancet* Commission's dietary recommendations provide a valuable roadmap for healthy sustainable diets, which can be used to tailor (inter)national food-based dietary guidelines, the EAT–*Lancet* diet score requires minimum intake values, for all nutrient-dense food groups, to avoid positively scoring non-consumption (i.e. 0 g/d) of dietary components and subsequently predicting lower micronutrient adequacy of diets in rural WRA from LMIC across Africa, Asia and Latin America.

Acknowledgements

Celine Termote and Patrick Van Damme contributed data from the Democratic Republic of Congo; Daniela Penafiel and Patrick Van Damme contributed data from Ecuador; Francis Oduor Odhiambo and Celine Termote contributed data from Kenya; Kaat Verzelen, Danny Hunter and Disna Ratnasekera contributed data from Sri Lanka; Jessica E. Raneri, Hoang The Ky and Gina Kennedy contributed data from Vietnam.

The following sources funded studies from which the data were used; Democratic Republic of Congo: Flemish Interuniversity Council, Leopold III fund for Nature Exploration and Conservation, and Stichting Roeping; Ecuador: Flemish Interuniversity Council; Kenya and Vietnam: Humidtropics and Agriculture for Nutrition and Health CGIAR Research Group; Sri Lanka: Global Environment Facility, United Nations Environmental Programme, Food and Agriculture Organisation of the United Nations, and Bioversity International. The funders of the studies had no role in study design, data collection, analysis, interpretation or writing of the manuscript. The corresponding author has full access to all of the data in the study and had the final responsibility for deciding to submit the manuscript for publication.

The authors' contributions were as follows. G. T. H.-C., A. A. A. and C. K. L. designed the research; G. T. H.-C. developed the first draft and revised the manuscript; G. T. H.-C. and A. A. A. analysed the data; P. W. K., A. D. J. and C. K. L. advised on statistical analyses. B. P. K., L. C. T., K. W. V. and A. D. J. critically reviewed and revised the manuscript. All authors read and approved the final manuscript.

The authors declare that there are no conflicts of interest.

Supplementary material

For supplementary material referred to in this article, please visit https://doi.org/10.1017/S0007114520003864

References

1. Willett WC, Rockström J, Loken B, *et al.* (2019) Food in the anthropocene: the EAT–*Lancet* Commission on healthy diets from sustainable food systems. *Lancet* **6736**, 3–49.
2. Steffen W, Richardson K, Rockström J, *et al.* (2015) Planetary boundaries: guiding human development on a changing planet. *Science* **347**, e1259855.
3. Afshin A, Sur PJ, Fay KA, *et al.* (2019) Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet* **393**, 1958–1972.
4. Swinburn BA, Kraak VI, Allender S, *et al.* (2019) The global syndemic of obesity, undernutrition, and climate change: the Lancet Commission report. *Lancet* **393**, 791–846.
5. Lachat C, Raneri JE, Smith KW, *et al.* (2018) Dietary species richness as a measure of food biodiversity and nutritional quality of diets. *Proc Natl Acad Sci U S A* **115**, 127–132.
6. Development Initiatives (2017) *Global Nutrition Report 2017: Nourishing the SDGs*. Bristol: Development Initiatives Poverty Research Ltd.
7. Knuppel A, Papier K, Key TJ, *et al.* (2019) EAT-Lancet score and major health outcomes: the EPIC-Oxford study. *Lancet* **6736**, 1–2
8. Food and Agriculture Organization of the United Nations & World Health Organization (2019) *Sustainable Healthy Diets – Guiding Principles*, 1st ed. Rome: FAO and WHO.
9. Jones AD, Hoey L, Blesh J, *et al.* (2016) A systematic review of the measurement of sustainable diets. *Adv Nutr An Int Rev J* **7**, 641–664.
10. Krebs-Smith SM, Pannucci TRE, Subar AF, *et al.* (2018) Update of the Healthy Eating Index: HEI-2015. *J Acad Nutr Diet* **118**, 1591–1602.
11. Chiuve SE, Fung TT, Rimm EB, *et al.* (2012) Alternative dietary indices both strongly predict risk of chronic disease. *J Nutr* **142**, 1009–1018.
12. Trichopoulou A, Costacou T, Bamia C, *et al.* (2003) Adherence to a Mediterranean diet and survival in a Greek population. *N Engl J Med* **348**, 2599–2608.
13. Estruch R, Ros E, Salas-Salvadó J, *et al.* (2018) Primary prevention of cardiovascular disease with a Mediterranean diet supplemented with extra-virgin olive oil or nuts. *N Engl J Med* **378**, e34.
14. Kanauchi M & Kanauchi K (2015) Diet quality and adherence to a healthy diet in Japanese male workers with untreated hypertension. *BMJ Open* **5**, e008404.
15. Jankovic N, Geelen A, Streppel MT, *et al.* (2014) Adherence to a healthy diet according to the World Health Organization guidelines and all-cause mortality in elderly adults from Europe and the United States. *Am J Epidemiol* **180**, 978–988.
16. Micha R, Coates J, Leclercq C, *et al.* (2018) Global dietary surveillance: data gaps and challenges. *Food Nutr Bull* **39**, 175–205.
17. Lawrence MA, Baker PI, Pulker CE, *et al.* (2019) Sustainable, resilient food systems for healthy diets: the transformation agenda. *Public Health Nutr* **22**, 2916–2920.
18. Food and Agriculture Organization of the United Nations (FAO), International Fund for Agricultural Development (IFAD), United Nations Children's Fund (Unicef), *et al.* (2019) *The State of Food Security and Nutrition in the World 2019. Safeguarding Against Economic Slowdowns*. Rome: FAO.
19. Torheim LE, Ferguson EL, Penrose K, *et al.* (2010) Women in resource-poor settings are at risk of inadequate intakes of multiple micronutrients. *J Nutr* **140**, 2051S–2058S.
20. Arimond M, Wiesmann D, Becquey E, *et al.* (2010) Simple food group diversity indicators predict micronutrient adequacy of women's diets in 5 diverse, resource-poor settings. *J Nutr* **140**, 2059S–2069S.
21. Baker P, Hawkes C, Wingrove K, *et al.* (2018) What drives political commitment for nutrition? A review and framework synthesis to inform the United Nations Decade of Action on Nutrition. *BMJ Glob Health* **3**, e000485.
22. Langer A, Meleis A, Knaul FM, *et al.* (2015) Women and health: the key for sustainable development. *Lancet* **386**, 1165–1210.
23. Fox EL, Davis C, Downs SM, *et al.* (2019) Who is the woman in women's nutrition? A narrative review of evidence and actions to support women's nutrition throughout life. *Curr Dev Nutr* **3**, nzy076.
24. Gibson RS, Charrondiere UR & Bell W (2017) Measurement errors in dietary assessment using self-reported 24-hour recalls in low-income countries and strategies for their prevention. *Adv Nutr An Int Rev J* **8**, 980–991.
25. Termote C, Bwama Meyi M, Dhed'a Djailo B, *et al.* (2012) A biodiverse rich environment does not contribute to a better diet: a case study from DR Congo. *PLOS ONE* **7**, e30533.
26. Penafiel D, Cevallos-Valdiviezo H, Espinel R, *et al.* (2019) Local traditional foods contribute to diversity and species richness of rural women's diet in Ecuador. *Public Health Nutr* **22**, 2962–2971.
27. Oduor FO, Boedecker J, Kennedy G, *et al.* (2019) Exploring agrobiodiversity for nutrition: household on-farm agrobiodiversity is associated with improved quality of diet of young children in Vihiga, Kenya. *PLOS ONE* **14**, e0219680.
28. Lutaladio N, Burlingame B, Crews J (2010) Horticulture, biodiversity and nutrition. *J Food Compos Anal* **23**, 481–664.
29. Burlingame B, Mouillé B, Charrondière R (2009) Nutrients, bioactive non-nutrients and anti-nutrients in potatoes. *J Food Compos Anal* **22**, 494–502.
30. Lachat C, Hawwash D, Ocké MC, *et al.* (2016) Strengthening the Reporting of Observational Studies in Epidemiology – Nutritional Epidemiology (STROBE-nut): an extension of the STROBE statement. *PLoS Med* **13**, e1002036.
31. Holland B, Unwin ID & Buss DH (1988) *Cereals and Cereal Products. The Third Supplement to McCance and Widdowson's The Composition of Foods*, 4th ed. Cambridge: Royal Society of Chemistry.
32. Holland B, Widdowson EM, Unwin ID, *et al.* (1991) *Vegetables, Herbs and Spices: The Fifth Supplement to McCance and Widdowson's The Composition of Foods*, 4th ed. Cambridge: Royal Society of Chemistry.
33. Institute of Medicine (IOM) (2000) *Dietary Reference Intakes: Applications in Dietary Assessment*. Washington, DC: National Academies Press.
34. Food and Agriculture Organization of the United Nations (FAO) & World Health Organization (WHO) (2004) *Vitamin and*

Mineral Requirements in Human Nutrition, 2nd ed. Geneva: FAO and WHO.

35. Institute of Medicine (IOM) (2001) *Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc*. Washington, DC: National Academies Press.
36. Brown KH, Rivera JA, Bhutta Z, *et al.* (2004) International Zinc Nutrition Consultative Group (IZiNCG) technical document #1. Assessment of the risk of zinc deficiency in populations and options for its control. *Food Nutr Bull Bull* **25**, Suppl. 2, S99–S203.
37. StataCorp LLC (2017) *Stata Statistical Software: Release 15*. College Station, TX: StataCorp.
38. Akbaraly TN, Sabia S, Shipley MJ, *et al.* (2013) Adherence to healthy dietary guidelines and future depressive symptoms: evidence for sex differentials in the Whitehall II study. *Am J Clin Nutr* **97**, 419–427.
39. Willett WC, Howe GR & Kushi LH (1997) Adjustment for total energy intake in epidemiologic studies. *Am J Clin Nutr* **65**, Suppl. 4, 1220S–1231S.
40. Tuomisto HL (2019) The complexity of sustainable diets. *Nat Ecol Evol* **3**, 720–721.
41. Milner J & Green R (2018) Sustainable diets are context specific but are they realistic? *Lancet Planet Health* **2**, E425–E426.
42. Development Initiatives (2018) *Global Nutrition Report 2018: Shining a Light to Spur Action on Nutrition*. Bristol: Development Initiatives Poverty Research Ltd.
43. Biesbroek S, Verschuren WMM, Boer JMA, *et al.* (2017) Does a better adherence to dietary guidelines reduce mortality risk and environmental impact in the Dutch sub-cohort of the European Prospective Investigation into Cancer and Nutrition? *Br J Nutr* **118**, 69–80.
44. Batis C, Aburto TC, Sánchez-Pimienta TG, *et al.* (2016) Adherence to dietary recommendations for food group intakes is low in the Mexican population. *J Nutr* **146**, 1897S–1906S.
45. Dehghan M, Mente A, Zhang X, *et al.* (2017) Associations of fats and carbohydrate intake with cardiovascular disease and mortality in 18 countries from five continents (PURE): a prospective cohort study. *Lancet* **390**, 2050–2062.
46. Clark MA, Springmann M, Hill J, *et al.* (2019) Multiple health and environmental impacts of foods. *Proc Natl Acad Sci U S A* **116**, 23357–23362.
47. Penafiel D, Lachat C, Espinel R, *et al.* (2011) A systematic review on the contributions of edible plant and animal biodiversity to human diets. *Ecohealth* **8**, 381–399.
48. Phalkey RK, Aranda-Jan C, Marx S, *et al.* (2015) Systematic review of current efforts to quantify the impacts of climate change on undernutrition. *Proc Natl Acad Sci U S A* **112**, E4522–E4529.
49. Johnston BC, Zeraatkar D, Han MA, *et al.* (2019) Unprocessed red meat and processed meat consumption: dietary guideline recommendations from the NutriRECS consortium. *Ann Intern Med* **171**, 756–764.
50. Zheng Y, Li Y, Satija A, *et al.* (2019) Association of changes in red meat consumption with total and cause specific mortality among US women and men: two prospective cohort studies. *BMJ* **365**, l2110.
51. Guasch-Ferré M, Satija A, Blondin SA, *et al.* (2019) Meta-analysis of randomized controlled trials of red meat consumption in comparison with various comparison diets on cardiovascular risk factors. *Circulation* **139**, 1825–1845.
52. Garcia D, Galaz V, Daume S (2019) EATLancet vs yes2meat: the digital backlash to the planetary health diet. *Lancet* **394**, 2153–2154.
53. Torjesen I (2019) WHO pulls support from initiative promoting global move to plant based foods. *BMJ* **365**, 1700.
54. Zagmutt FJ, Pouzou JG, Costard S (2019) The EAT–Lancet Commission: a flawed approach? *Lancet* **394**, 1140–1141.
55. Adesogan AT, Havelaar AH, McKune SL, *et al.* (2020) Animal source foods: sustainability problem or malnutrition and sustainability solution? Perspective matters. *Glob Food Sec* **25**, 100325.
56. Enahoro D, Lannerstad M, Pfeifer C, *et al.* (2018) Contributions of livestock-derived foods to nutrient supply under changing demand in low- and middle-income countries. *Glob Food Sec* **19**, 1–10.
57. Murphy SP & Allen LH (2003) Nutritional importance of animal source foods. *J Nutr* **133**, 3932–3935.
58. Grace D, Dominguez-Salas P, Alonso S, *et al.* (2018) The influence of livestock-derived foods on nutrition during the first 1,000 days of life. Nairobi. ILRI Policy Brief 25. Nairobi, Kenya: ILRI. https://cgspace.cgiar.org/handle/10568/92907 (accessed November 2019).
59. Hall AG, Ngu T, Nga HT, *et al.* (2017) An animal-source food supplement increases micronutrient intakes and iron status among reproductive-age women in rural Vietnam. *J Nutr* **147**, 1200–1207.
60. Nguyen PH, Huybregts L, Sanghvi TG, *et al.* (2018) Dietary diversity predicts the adequacy of micronutrient intake in pregnant adolescent girls and women in Bangladesh, but use of the 5-group Cutoff Poorly identifies individuals with inadequate intake. *J Nutr* **148**, 790–797.
61. Martin-Prevel Y, Arimond M, Allemand P, *et al.* (2017) Development of a dichotomous indicator for population-level assessment of dietary diversity in women of reproductive age. *Curr Dev Nutr* **1**, e001701.
62. Hirvonen K, Bai Y, Headey D, *et al.* (2020) Affordability of the EAT-Lancet reference diet: a global analysis. *Lancet Glob Health* **8**, E59–E66.
63. Perez-Escamilla R, Bermudez O, Buccini GS, *et al.* (2018) Nutrition disparities and the global burden of malnutrition. *BMJ* **361**, k2252.
64. Johnston JL, Fanzo JC & Cogill B (2014) Understanding sustainable diets: a descriptive analysis of the determinants and processes that influence diets and their impact on health, food security, and environmental sustainability. *Adv Nutr* **5**, 418–429.
65. Schulze MB, Martínez-González MA, Fung TT, *et al.* (2018) Food based dietary patterns and chronic disease prevention. *BMJ* **361**, k2396.
66. Springmann M, Wiebe K, Mason-D'Croz D, *et al.* (2018) Health and nutritional aspects of sustainable diet strategies and their association with environmental impacts: a global modelling analysis with country-level detail. *Lancet Planet Health* **2**, e451–e461.
67. Chaudhary A, Gustafson D & Mathys A (2018) Multi-indicator sustainability assessment of global food systems. *Nat Commun* **9**, 848.
68. Poore J & Nemecek T (2018) Reducing food's environmental impacts through producers and consumers. *Science* **360**, 987–992.
69. Boedecker J, Odhiambo Odour F, Lachat C, *et al.* (2019) Participatory farm diversification and nutrition education increase dietary diversity in Western Kenya. *Matern Child Nutr* **15**, e12803.
70. Beaton GH (1994) Approaches to analysis of dietary data: relationship between planned analyses and choice of methodology. *Am J Clin Nutr* **59**, 253S–261S.