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Original Research Article

Cross-context equivalence and agreement of healthy diet metrics for national and global monitoring: a multicountry analysis of cross-sectional quantitative 24-hour dietary intake studies

Giles T Hanley-Cook *, Simone M Gie, Juan Pablo Parraguez, Sara Hoogerwerf, Victoria Padula de Quadros, Agnieszka Balcerzak, Lynnette M Neufeld, Bridget A Holmes

Food and Nutrition Division (ESN), Food and Agriculture Organization of the United Nations (FAO), Rome, Italy

A B S T R A C T

Background: Despite national and global commitments to improve nutrition, there are no universally accepted indicators for at-scale monitoring of diets. Several metrics have been proposed and used, but they vary in their comprehensiveness and validity in capturing the properties of healthy diets and, potentially, their interpretability across contexts.

Objective: The objective of this study was to assess the cross-context equivalence and agreement of healthy diet metrics.

Design: Quantitative 24-h dietary intake data from 57,456 nonpregnant females (15–49 y) in 21 countries were used to construct the food group diversity score (FGDS) and Minimum Dietary Diversity for Women indicator; the Global Diet Quality Score (GDQS) and its submetrics: GDQS+ and GDQS−; the Global Dietary Recommendations (GDR) score and its submetrics: noncommunicable disease (NCD)-Protect and NCD-Risk scores; and the All-5 indicator. Associations between (standardized) measures and indicators were quantified by fitting linear and logistic mixed-effect models across World Bank country income classifications, respectively. The levels of agreement between measures were assessed using Bland–Altman plots of z-scores, whereas rank correlations were assessed using Spearman's ρ.

Results: The consumption of healthy food groups was positively associated with concurrent intakes of unhealthy food groups, in particular in high-income countries. Hence, metrics constructed using both healthy and unhealthy food groups (i.e., GDR score and GDQS) showed relatively less discriminatory capacity across country income classifications than their respective submetrics or FGDS. Standardized metrics of healthy (e.g., FGDS and GDQS+) and unhealthy food group consumption (i.e., NCD-Risk and GDQS−) exhibited strong agreement and correlations.

Conclusion: Composite metrics weighting both healthy and unhealthy food groups have limited cross-context equivalence, because a wide range of diets can theoretically return similar scores. Healthy food group (sub)metrics performed comparably, likely indicating strong underlying construct validity (i.e., dietary diversity and nutrient adequacy). For national and global monitoring, refinement and validation of unhealthy food group metrics (i.e., moderation) is recommended to complement healthy food group metrics.

Keywords: FAO/WHO GIFT, 24-h recall, food diary, dietary diversity, nutrient adequacy, moderation

Introduction

The impacts of diets on public health are well recognized, yet most countries do not have surveillance systems for monitoring diets at scale. This is constrained, in part, by the lack of universally accepted healthy diet metrics [1,2]. Timely national dietary intake data are crucial to assess more immediate progress toward international initiatives' indicators, identify within-country disparities, permit valid cross-country comparisons, and inform high-level decisions on nutrition-specific and nutrition-sensitive actions [3].

Quantitative individual-level dietary assessments, such as 24-h recalls or food diaries (24-HRs), provide estimates of mean intake of foods and nutrients, whereas repeated measurements among a subsample allow for an estimate of usual intake. However, for monitoring

Abbreviations: DQQ, Diet Quality Questionnaire; FAO, Food and Agriculture Organization of the United Nations; FGDS, food group diversity score; GIFT, Global Individual Food consumption data Tool; GDQS, Global Diet Quality Score; GDQS+, Global Diet Quality Score Positive Submetric; GDQS−, Global Diet Quality Score Negative Submetric; GDR, Global Dietary Recommendations; 24-HR, 24-h recall or food diary; LOA, level of agreement; MDD-W, Minimum Dietary Diversity for Women; NCD, noncommunicable disease; UPF, ultraprocessed foods.

* Corresponding author.
E-mail address: giles.hanleycook@fao.org (G.T. Hanley-Cook).

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at national scale, these methods are too time-consuming and expensive, require significant technical capacity, and therefore remain out of reach for most countries. Moreover, when conducted, quantitative national dietary surveys are often carried out too infrequently to meet the needs for short- and medium-term monitoring of dietary changes over time [4–6].

Consequently, qualitative and semiquantitative food group-based metrics have been developed and validated as proxies for reference metrics of dietary intake. They require limited enumerator capacity, entail shorter data collection and analysis phases, and are suitable for integration into existing, large-scale multitopic surveys.

However, although the concept of healthy diets comprises multiple properties, such as dietary diversity, nutrient adequacy, macronutrient balance, and moderation [7,8], food group-based metrics often aim to capture only 1 or a limited number of these properties [9]. In contrast, quantitative dietary metrics, such as the Healthy Eating Index, attempt to measure adherence to "favorable dietary patterns" more generally [9].

In 2023, a suitability report [9] identified Minimum Dietary Diversity for Women (MDD-W) [4], Global Diet Quality Score (GDQS) [5], and the Global Dietary Recommendations (GDR) score [6] as the most promising population-level food group-based metrics for at-scale monitoring and evaluation of healthy diets. The Nova score for the consumption of ultraprocessed foods was also identified in this report [10]; however, it is not discussed in this article because the metric is not based on food groups, but subgroups of ultraprocessed foods.

Although the 3 priority metrics aim to function as proxies for reference metrics of dietary intake, they are constructed differently (i.e., number and weighting of food groups), vary in their complexity (i.e., minimum food group intake quantities or not), and differ in their comprehensiveness in capturing the properties of a healthy diet [9].

Previous studies have evaluated the comparative performance of GDQS and MDD-W against (bio)markers of dietary intake, nutritional status, and health outcomes [11–19] and assessed the performance of GDR score and MDD-W against a measure of adherence to GDR [6]. The current study examined the mutual relationships and agreement between healthy diet metrics across country income levels. Subsequently, these exploratory analyses aim to evaluate whether a metric's score can be interpreted analogously across contexts [20] and gauge the potential complementarity (or redundancy) of healthy diet metrics for national and global monitoring.

Methods

Our research is reported using the STROBE-nut checklist [21].

Data sources

We used secondary cross-sectional data from nonpregnant females aged 15–49 y, because this is the broadest population group for which validation studies have been conducted for all 3 healthy diet metrics [9]. Open access data were downloaded on 3 April 2023 from FAO/WHO Global Individual Food consumption data Tool (GIFT) [22]. FAO/WHO GIFT is an online platform aiming to provide access to existing quantitative 24-HRs from national and subnational surveys. Our statistical analyses included 1989 females from 5 low-income (6 surveys [23–28]), 17,759 from 9 lower middle income (14 surveys [29–41]), 36,242 from 5 upper middle-income (6 surveys [42–47]), and 1466 from 2 high-income countries (3 surveys [48–50]) (Supplemental Table 1). Further details on these 29 surveys, including their sampling framework, timing and method of data collection, and dietary assessment methodology, are available on the FAO/WHO GIFT website, https://www.fao.org/gift-individual-food-consumption/data/en. We used dietary intake data from the first day only (n = 57,456; Figure 1). One individual with missing data on sex was excluded. Previously, food and drink items reported in the available surveys on FAO/WHO GIFT had been coded with 1857 unique European Food Safety Authority FoodEx2 base term codes [51]. Subsequently, we assigned each FoodEx2 code to the 17, 25, and 27 distinct food (sub)groups used to construct the 10-point food group diversity score (FGDS) and dichotomous MDD-W indicator, the 49-point GDQS, and the 18-point GDR score, and dichotomous All-5 indicator, respectively (Supplemental Table 2).

FGDS and the MDD-W indicator

For FGDS, the 17 food subgroups were aggregated into the following 10 predefined food groups [52]: *1*) starchy staple foods; *2*) beans, peas, and lentils; *3*) nuts and seeds; *4*) dairy products (milk, yogurt, and cheese); *5*) flesh foods (meat, fish and seafood, poultry, and liver or organ meats); *6*) eggs; *7*) dark-green leafy vegetables; *8*) vitamin A-rich fruits and vegetables; *9*) other vegetables; and *10*) other fruits. The FGDS (0–10 points) was constructed by summing the number of food groups consumed in ≥15 g/d. Reaching MDD-W was defined – according to the previously validated threshold [52] – as a female consuming ≥5 food groups above the minimum intake threshold.

Other food items (i.e., their respective FoodEx2 codes) were assigned to the following 13 additional food groups also enumerated through MDD-W survey modules, but not used in the indicator's construction (collection of food groups i–vii is recommended and viii–xiii is optional) [52]: *1*) packaged salty snacks, *2*) deep fried snacks, *3*) instant noodles, *4*) fast food restaurant foods, *5*) sweet foods, *6*) sugar-sweetened beverages, *7*) sweetened infusions, *8*) insects and small protein foods, *9*) wild plants, *10*) red palm oil, *11*) other oils and fats, *12*) condiments and seasonings, and *13*) other beverages and foods.

GDQS and its cutoffs, GDQS+, and GDQS−

For GDQS, the 25 food groups are as follows [5]: *1*) citrus fruits, *2*) deep-orange fruits, *3*) other fruits, *4*) dark-green leafy vegetables, *5*) cruciferous vegetables, *6*) deep-orange vegetables, *7*) other vegetables, *8*) legumes, *9*) deep-orange tubers, *10*) nuts and seeds, *11*) whole grains, *12*) liquid oils, *13*) fish and shellfish, *14*) poultry and game meat, *15*) low-fat dairy, *16*) eggs, *17*) high-fat dairy (in milk equivalents), *18*) red meat, *19*) processed meat, *20*) refined grains and baked goods, *21*) sweets and ice cream, *22*) sugar-sweetened beverages, *23*) juice, *24*) white roots and tubers, and *25*) purchased deep fried foods (which are double classified). Points were assigned based on 3 or 4 categories of consumed amounts (defined in g/d) specific to each food group. In brief, food groups 1–16 were defined as healthy (scored by giving more points for higher g/d intake), food groups 17 and 18 were classified as unhealthy when consumed in excessive amounts (increasing points are given until specific amounts have been consumed, after which no points are given), and food groups 19–25 were defined as unhealthy (more points for lower g/d intake) [5]. GDQS was obtained by summing points across all of the 25 food groups and ranges from 0 to 49 points. GDQS scores ≥23 are defined as high, ≥15 and <23 scores are moderate, whereas <15 indicates a low score [5]. Moreover, the GDQS Positive Submetric (GDQS+; 0–32 points) and GDQS Negative Submetric (GDQS−; 0–17 points) are calculated by summing food groups 1–16 and 17–25 (i.e., lower score when more and larger amounts of unhealthy food groups are consumed), respectively.

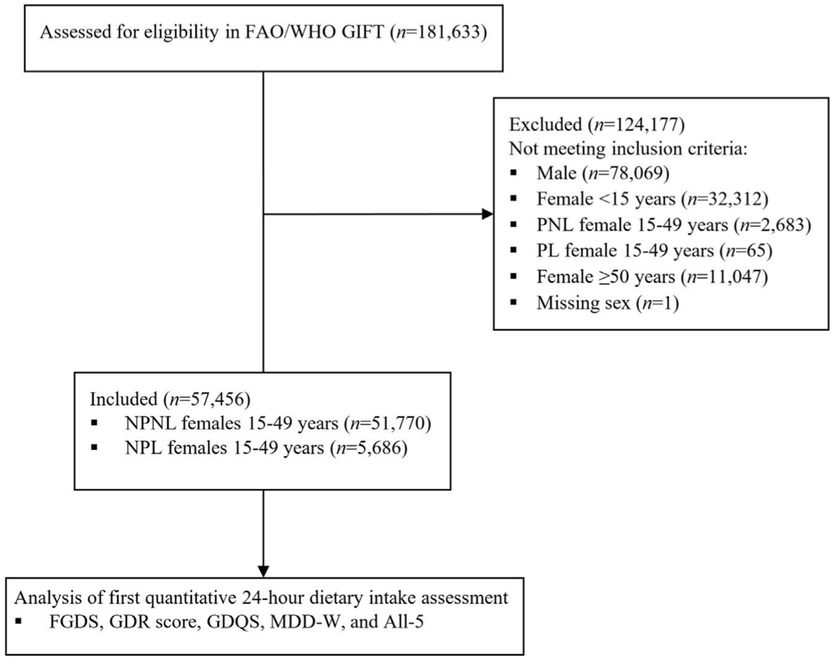

FIGURE 1. Study flowchart. FAO, Food and Agriculture Organization of the United Nations; FGDS, food group diversity score; GDQS, Global Diet Quality Score; GDR, Global Dietary Recommendations; GIFT, Global Individual Food consumption data Tool; MDD-W, Minimum Dietary Diversity for Women; NPL; nonpregnant and lactating; NPNL, nonpregnant nonlactating; PL, pregnant and lactating; PNL, pregnant nonlactating; WHO, World Health Organization.

GDR score and its cutoff, Noncummunicable Disease-Protect and Noncommunicable Disease-Risk scores, and the All-5 indicator

For GDR score, 19 food subgroups were aggregated into the following 17 predefined food groups [6]: *1*) whole grains, *2*) pulses, *3*) nuts and seeds, *4*) vitamin A-rich orange vegetables, *5*) dark-green leafy vegetables, *6*) other vegetables, *7*) vitamin A-rich fruits, *8*) citrus, *9*) other fruits, *10*) sugar-sweetened beverages, *11*) baked/grain-based sweets, *12*) other sweets, *13*) processed meat, *14*) unprocessed red meat, *15*) deep fried foods, *16*) fast foods and instant noodles, and *17*) packaged ultraprocessed salty snacks. The intake of food groups 1–9 in >0 g/d quantities scores 1 point each, whereas the consumption of food groups 10–17 scores −1 point each (except food group 13, which scores −2 points). The GDR score is obtained by summing points across all the 17 food groups and adding 9 points, therefore ranging from 0 to 18 points. The GDR cutoff was defined – according to the previously validated threshold [6] – as a GDR score ≥10. Furthermore, the noncommunicable disease (NCD)-Protect and NCD-Risk scores (both 0–9 points) are calculated by summing food groups 1–9 and 10–17 (i.e., higher score when a greater number of unhealthy food groups are consumed), respectively. As a sensitivity analysis, we recalculated the GDR score and its submetrics excluding food items consumed in quantities <15 g/d.

In addition to the 3 previously described priority healthy diet metrics, the All-5 indicator was included in the analysis, as binary indicators are particularly useful for advocacy and cross-sectoral communication [4]. In brief, 19 food groups (of which 11 overlap with GDR score) were aggregated into its 5 predefined food groups: *1*) starchy staples; *2*) vegetables; *3*) fruits; *4*) pulses, nuts, and seeds; and *5*) animal-source foods. Reaching All-5 was defined as nonpregnant females consuming all 5 food groups.

Other food items that were assigned to 2 food groups were also enumerated through the Diet Quality Questionnaire (DQQ) [6]: *1*) sweet tea/coffee/cocoa and *2*) fruit juice and flavored drinks.

Statistical analysis

Data management and statistical analysis were conducted in Stata (16.1, StataCorp LLC) [53]. All analyses reported were conducted for the pooled sample and by World Bank country income classification (i.e., low, lower middle, upper middle, and high income) [54]. Descriptive data are presented as means ± SD and median (P^{25} and P^{75}) or frequency (percentages). Relationships between (pseudo-) continuous measures (i.e., FGDS, GDR score, GDQS, and their submetrics) were visualized using local polynomial smoothing plots, whereas relationships between binary indicators (i.e., MDD-W, GDR cutoff, and All-5) against measures were visualized using violin plots. In addition, binary MDD-W, GDR cutoff, and All-5 were compared with one another by 2 × 2 contingency tables to quantify the percentage of agreement.

To assess the concurrent positioning of individuals on each healthy diet metrics' scoring distributions (e.g., does a 90th percentile FGDS equate with a 90th percentile GDQS+), the measurement agreement between mean-standardized measures was visually inspected using Bland–Altman plots, with coordinates graphically weighted by (nonproportional) bubbles [55]. To clarify, we graphed the difference between *z*-scores against the average of *z*-scores (e.g., normalized FGDS as compared with normalized GDQS+). The upper and lower levels of agreement (LOAs) were defined as mean ± 1.96 × SD. In addition, we visualized the differences between GDR and GDQS *z*-scores, as compared with FGDS *z*-score using kernel density plots. For analyses of measurement agreement by World Bank income classification, the within-sample mean was used for standardization, rather than the pooled sample mean. In addition, we examined the Spearman's rank correlations coefficient (ρ) between healthy diet (sub)metrics.

To assess the direction and magnitude of associations between (standardized) FGDS, GDR score, GDQS, and their submetrics, and the differences in GDR score and GDQS between MDD-W, GDR cutoff, and All-5 achievers and nonachievers, we fitted multilevel linear regression models (random intercept for survey). The normality of residuals was assessed by visual inspection of normal probability and quantile–normal plots. If the normality assumption was violated, measures were transformed (e.g., log, square, and cubic) or quantile regression models were fitted. To assess relationships between MDD-W, GDQS cutoffs (i.e., low, moderate, and high), GDR cutoff, and All-5, we used multilevel logistic regression (random intercept for survey). As robustness checks, regression analyses were repeated including weights based on the inverse of each survey's sample size and country's total population size, respectively, and excluding large, nationally representative surveys from Brazil and India.

Our exploratory analyses did not correct for multiple comparisons to avoid inflating type II errors (i.e., false negatives) [56]. Two-sided *P* values of <0.05 were considered significant for all statistical tests.

Ethical approval

All FAO/WHO GIFT data providers signed a License to Redistribute Contribution in which they warrant that: "The data included in any datasets have been collected and compiled in compliance with any legal or regulatory requirements as applicable to the Contributor" and "The data contained in the dataset(s) were collected in full informed consent of the data subject(s)." The current study did not include any interaction or intervention with human subjects or include any access to nonanonymized data; hence, no approval was required from an institutional review board.

Results

Sample characteristics

On average, the prevalence of females achieving MDD-W (i.e., reaching the ≥5 food group cutoff) was lowest (19.3%) in lower middle-income countries (i.e., <15% consumed "nuts and seeds," "eggs," and "vitamin A-rich fruit and vegetables" in ≥15 g/d) and highest (77%) in high-income countries (Table 1, Supplemental Table 3).

In contrast, the mean GDR score was lowest (8.0 ± 1.9 points) in upper middle and highest (11.2 ± 1.5 points) in low-income countries (i.e., except for "other sweets," <10% consumed NCD-Risk food groups in >0 g/d). Excluding food items consumed in quantities <15 g/day did not change our main findings (data not shown). Moreover, in the pooled sample, only 15.7% of nonpregnant females reached All-5, as <25% and <15% consumed "fruits" and "pulses, nuts, and seeds" in lower middle and high-income countries, respectively (Table 1, Supplemental Table 3).

Similarly, the mean GDQS was lowest (14.8 ± 3.7 points) in upper middle and highest (18.3 ± 3.5 points) in low-income countries (i.e., >70% consumed low or moderate amounts of GDQS− food groups, except for "refined grains and baked goods") (Table 1, Supplemental Table 3).

Measurement agreement between FGDS, GDR score, GDQS, and their submetrics

The LOA between standardized FGDS and GDR score (–2.7, 2.7 *z*-scores) was wider as compared with the LOA between FGDS and GDQS− (–2.2, 2.2 *z*-scores). Furthermore, due to the lower scoring heterogeneity of composite metrics, the LOA between GDQS and GDR score (–1.5, 1.5 *z*-scores) was the narrowest (Supplemental Figure 1; Figure 2).

Likewise, the LOAs among the healthy food group (sub)metric FGDS, NCD-Protect score, and GDQS+ were narrow (–2, 2 *z*-scores in all cases) and the mean difference was 0 *z*-score, indicating strong measurement agreement (Figure 3).

Lastly, the LOA for standardized GDQS− and the complement of the NCD-Risk score (i.e., to ensure that higher values of both metrics reflected lower unhealthy food group consumption) was narrow at

TABLE 1
Sample characteristics by World Bank income classification[1]

	Total (n = 57,456)	Low income (n =1989)	Lower middle income (n = 17,759)	Upper middle income (n = 36,242)	High income (n = 1466)
Age (y)	25 ± 10	28 ± 9	30 ± 9	22 ± 10	33 ± 10
	21 (16, 33)	28 (20, 35)	30 (23, 37)	17 (16, 26)	35 (25, 42)
Lactating, *n* (%)	5,686 (9.90)	826 (41.5)	3,918 (22.1)	932 (2.57)	10 (0.68)
FGDS (0–10 points)	4.1 ± 1.3	4.0 ± 1.4	3.6 ± 1.1	4.4 ± 1.3	5.3 ± 1.2
	4 (3, 5)	4 (3, 5)	4 (3, 4)	4 (3, 5)	5 (5, 6)
MDD-W, *n* (%)	21,755 (37.9)	696 (35.0)	3427 (19.3)	16,505 (45.5)	1127 (76.9)
GDR score (0–18 points)	9.0 ± 2.2	11.2 ± 1.5	10.9 ± 1.3	8.0 ± 1.9	8.8 ± 1.8
	9 (7, 11)	11 (10, 12)	11 (10, 12)	8 (7, 9)	9 (8, 10)
NCD-Protect (0–9 points)	2.3 ± 1.2	2.9 ± 1.4	2.8 ± 1.2	2.0 ± 1.2	2.7 ± 1.1
	2 (1, 3)	3 (2, 4)	3 (2, 4)	2 (1, 3)	3 (2, 3)
NCD-Risk (0–9 points)	2.3 ± 1.7	0.7 ± 0.8	1.0 ± 0.7	3.0 ± 1.6	2.9 ± 1.5
	2 (1, 3)	1 (0, 1)	1 (1, 1)	3 (2, 4)	3 (3, 4)
GDR cutoff, *n* (%)	25,518 (44.4)	1756 (88.3)	15,273 (86.0)	7986 (22.0)	503 (34.3)
All-5, *n* (%)	8997 (15.7)	213 (10.7)	2,520 (14.2)	6,105 (16.9)	159 (10.9)
GDQS (0–49 points)	15.9 ± 3.8	18.3 ± 3.5	17.7 ± 3.2	14.8 ± 3.7	16.9 ± 3.5
	16 (13.25, 18.25)	18.25 (16, 20.5)	17.5 (15.5, 20)	15 (12.25, 17.25)	16.75 (14.5, 19.25)
Low, *n* (%)	21,623 (37.6)	358 (18.0)	3322 (18.7)	17,531 (48.4)	412 (28.1)
Moderate, *n* (%)	33,972 (59.1)	1440 (72.4)	13,343 (75.1)	18,214 (50.3)	975 (66.5)
High, *n* (%)	1861 (3.24)	191 (9.60)	1094 (6.16)	497 (6.16)	79 (5.39)
GDQS+ (0–32 points)	5.9 ± 2.9	7.5 ± 3.4	6.0 ± 2.9	5.7 ± 3.0	7.0 ± 2.9
	6 (4, 8)	7.25 (5, 9.5)	6 (4.25, 8)	6 (4, 8)	6.75 (4.75, 8.75)
GDQS− (0–17 points)	10.0 ± 2.5	10.8 ± 1.5	11.7 ± 1.4	9.1 ± 2.4	9.9 ± 2.1
	10 (8, 12)	11 (10, 12)	12 (11, 13)	9 (8, 11)	10 (9, 11)

Abbreviations: FGDS, food group diversity score, GDQS, Global Diet Quality Score; GDQS+, Global Diet Quality Score Positive Submetric; GDQS−; Global Diet Quality Score Negative Submetric; GDR, Global Dietary Recommendations; NCD, noncommunicable disease.

[1] Data are mean ± SD and median (interquartile ranges) unless otherwise stated.

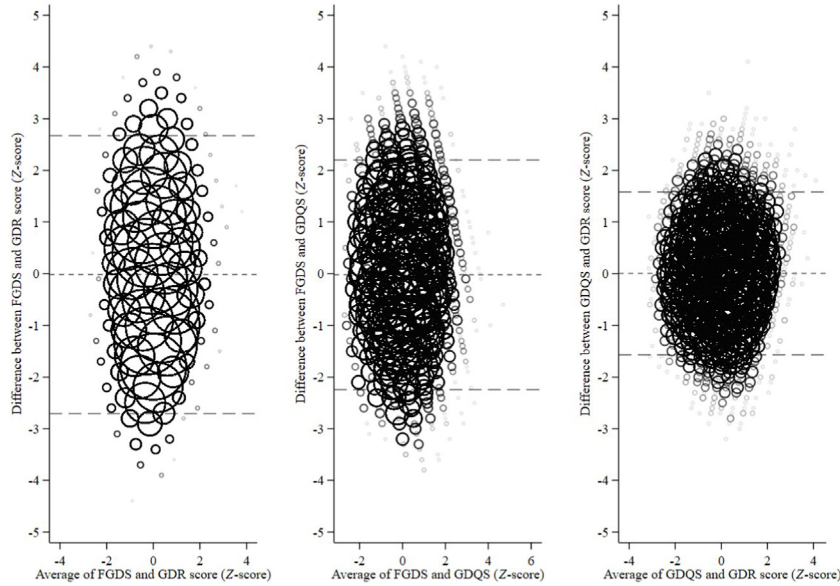

FIGURE 2. Bland–Altman plot of mean-standardized food group diversity score (FGDS), Global Diet Recommendations (GDR), and Global Diet Quality Score (GDQS) (n = 57,456). The short dashed line is the mean difference, whereas the 2 dashed lines are the upper and lower levels of agreement (mean ± 1.96 × SD).

−1.6 to 1.5 z-scores (Figure 4). This finding should be interpreted with caution, as unhealthy food group consumption was low across FAO/WHO GIFT surveys (i.e., low variability in unhealthy food group submetrics).

The magnitudes of our findings were relatively stable across all World Bank country income classifications (Supplemental Figures 2–29).

Measurement agreement between MDD-W, GDR cutoff, and All-5 indicators

The binary MDD-W and All-5 indicators showed ≥70% agreement (i.e., the proportion of nonpregnant females achieving or failing to achieve both food group cutoffs) in low, lower- and upper middle-income countries, whereas only a 34% agreement in high-income countries, due to the low prevalence of females achieving All-5 (Supplemental Table 4). Low agreement was observed between the GDR cutoff and both MDD-W (i.e., 30–60% across World Bank income classifications) and the All-5 indicator (i.e., <30% in low and lower middle-income countries) (Supplemental Tables 5 and 6). The higher agreement (i.e., >65%) between the GDR cutoff and All-5 indicator in upper middle and high-income countries is almost exclusively attributable to true negatives (i.e., ~90% of females failed to reach both indicator cutoffs).

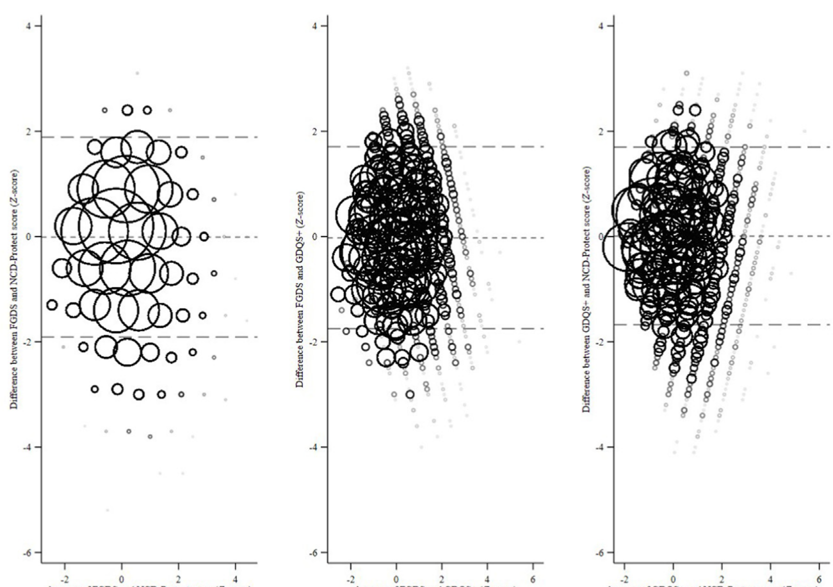

FIGURE 3. Bland–Altman plot of mean-standardized food group diversity score (FGDS), NCD-Protect score, and Global Diet Quality Score Positive Submetric (GDQS+) (n = 57,456). The short dashed line is the mean difference, whereas the 2 dashed lines are the upper and lower levels of agreement (mean ± 1.96 × SD). NCD, noncommunicable disease.

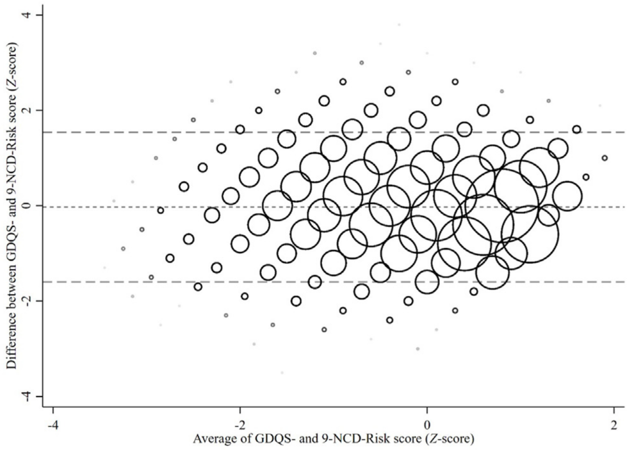

FIGURE 4. Bland–Altman plot of mean-standardized Global Diet Quality Score Positive Submetric (GDQS+) and 9–NCD-Risk score (n = 57,456). The short dashed line is the mean difference, whereas the 2 dashed lines are the upper and lower levels of agreement (mean ± 1.96 × SD). NCD-Risk scores were subtracted from 9 to ensure that higher values of both metrics reflected lower unhealthy food group consumption. NCD, non-communicable disease.

Associations between healthy diet metrics

The normality assumption was met; hence untransformed (standardized) data were modeled.

Overall, a unit increase in FGDS was associated with a slightly higher GDR score (95% CI: 0.5, 0.5 points; 0.30, 0.31 z-scores). Our findings were similar across most World Bank county income classifications, although slightly lower in high-income countries (95% CI: 0.2, 0.3 points; 0.11, 0.20 z-scores) (Figure 5). The observed relationships were predominantly driven by the strong association between FGDS and NCD-Protect score (95% CI: 0.6, 0.6 points; 0.67, 0.68 z-scores). Nonetheless, in high-income countries, a unit increase in FGDS was also associated with a higher NCD-Risk score (95% CI: 0.3, 0.4 points; 0.21, 0.30 z-scores), reflecting the concurrent greater consumption of healthy and unhealthy food groups (Figure 6).

Furthermore, a unit increase in FGDS was related to a relatively higher GDQS, as compared to the GDR score (95% CI: 1.5, 1.6 points; 0.54, 0.56 z-scores). These relationships were stable across World Bank income groups, but highest in low-income countries (95% CI: 1.9, 2.1 points; 0.66, 0.73 z-scores) (Figure 5). The observed association is a consequence of the strong relationship between FGDS and GDQS+ (95% CI: 1.6, 1.6 points; 0.68, 0.69 z-scores). In high-income countries, in particular, higher FGDS was associated with a decrease in GDQS− (95% CI: −0.3, −0.1 points; −0.14, −0.04 z-scores), also indicating healthy food group consumption occurs simultaneously with higher intakes of unhealthy food groups (Figure 7).

Moreover, a unit increase in GDR score was associated with a higher GDQS (95% CI: 1.3, 1.3 points; 0.75, 0.76 z-scores). However, results were somewhat higher in low-income (95% CI: 1.6, 1.8 points; 0.94, 1.0 z-scores) and lower in high-income countries (95% CI: 1.1, 1.2 points; 0.61, 0.70 z-scores) (Figure 5). In addition, higher NCD-Protect scores were associated with greater GDQS+ (95% CI: 1.6, 1.6 points; 0.69, 0.70 z-scores), whereas a unit increase in NCD-Risk score was associated with lower GDQS− (95% CI: –0.9, –0.8 points; −0.59, −0.58 z-scores).

The Spearman's rank correlation coefficients between composite metrics (i.e., GDQS and GDR score) were moderate across all World Bank country income classifications (range ρ: 0.51–0.65). Furthermore, the healthy food group submetrics, FGDS, GDQS+, and NCD-Protect score, exhibited moderate to high correlations across settings

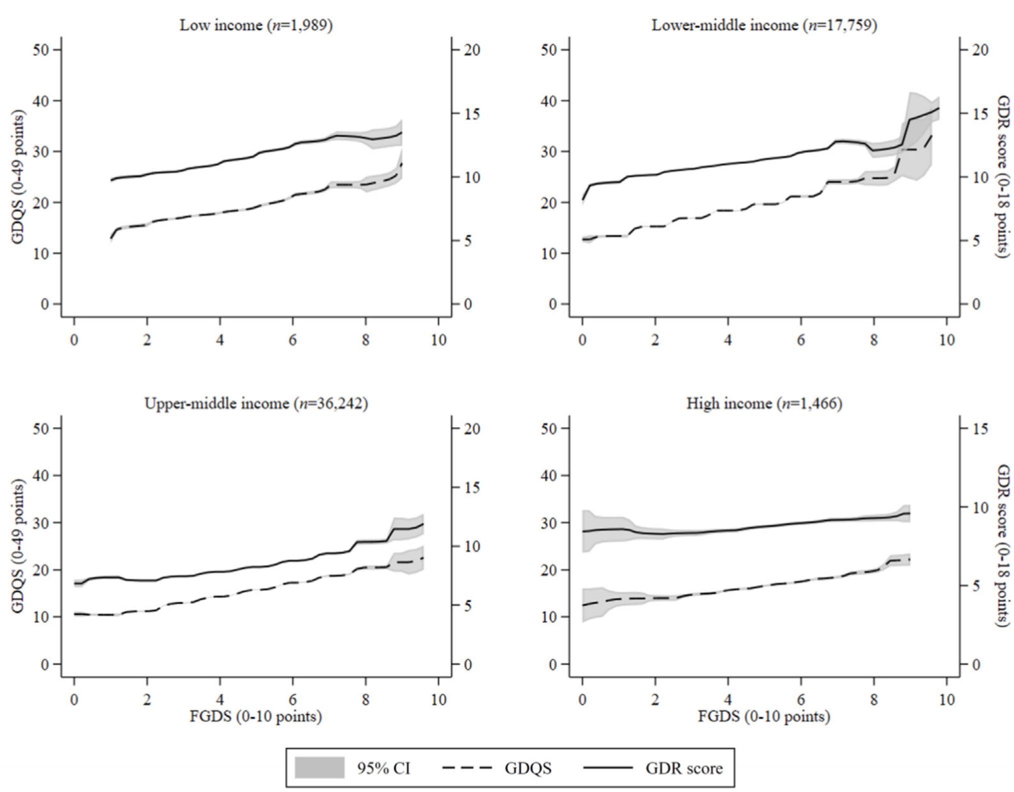

FIGURE 5. Relationships between food group diversity score (FGDS), Global Diet Quality Score (GDQS), and Global Dietary Recommendations (GDR) score, by World Bank income classification. The solid and dashed lines represent the local polynomial smoothing predictions with 95% confidence intervals.

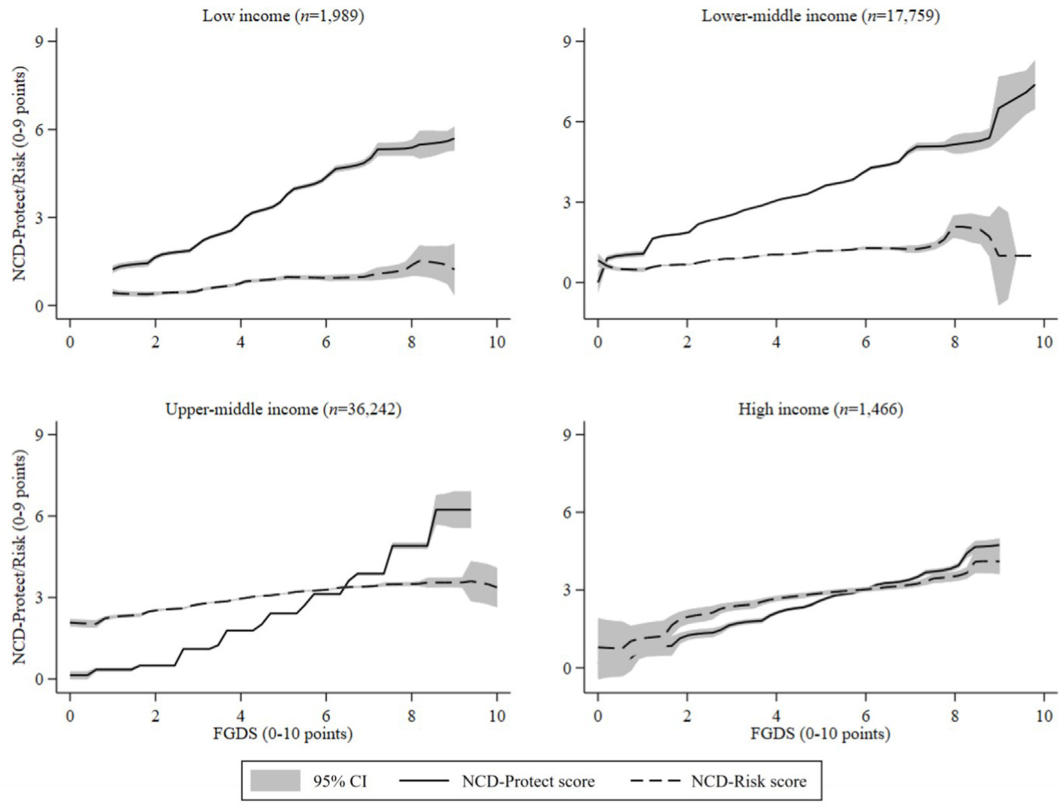

FIGURE 6. Relationships between food group diversity score (FGDS), NCD-Protect score, and NCD-Risk score, by World Bank income classification. Top left, top right, bottom left, and bottom right are low, lower middle, upper middle, and high-income countries, respectively. The solid and dashed lines represent the local polynomial smoothing predictions with 95% confidence intervals. NCD, noncommunicable disease.

(range ρ: 0.54–0.77), whereas the unhealthy food group submetrics, GDQS− and the complement of the NCD-Risk, the score showed only low to moderate correlations (range ρ: 0.15–0.69). Healthy food group submetrics were negatively correlated with GDQS− and the complement of the NCD-Risk score in low, upper middle, and high-income countries (Supplemental Tables 7–10).

Unsurprisingly, reaching the GDR cutoff was most strongly associated with a higher GDQS and its cutoffs (i.e., both are derived from composite metrics). However reaching MDD-W was more strongly associated with a greater GDQS and its cutoffs, as compared with All-5, while achieving All-5 was more strongly associated with a higher GDR score (Supplemental Text 1; Supplemental Figures 30–32). The All-5 indicator and GDR score computation use 8 overlapping food groups. Lastly, the comparative advantage of MDD-W and the All-5 indicator to capture healthy food group consumption, as compared with the GDR cutoff, was confirmed by their greater associations with FGDS, GDQS+, and NCD-Protect score (Supplemental Text 1; Supplemental Figures 33 and 34).

Sensitivity analyses confirmed the strength and direction of our main findings (results not shown).

Discussion

In this multicountry study, healthy food group (sub)metrics showed relatively strong agreement and moderate to high correlations. Similarly, in most contexts, the unhealthy food group submetrics were moderately correlated and indicated relatively strong concordance. In contrast, our analyses indicated relatively poor agreement and low to moderate correlations between food group (sub)metrics and composite healthy diet metrics. These findings are explained by higher intakes of healthy food groups often occurring in parallel to greater intakes of unhealthy food groups, leading to lower scoring heterogeneity. Unhealthy food group consumption was generally low in our study, likely because most surveys included in the analyses were conducted over a decade ago in rural areas of low- and middle-income countries.

Overall, composite metrics demonstrated poor cross-context equivalence, as similar scores can be achieved in myriad ways, masking the underlying nature of diets. For instance, the "cancelling-out" effect of NCD-Protect and NCD-Risk scores means that identical GDR scores can be achieved by drastically different diets, from not consuming any food groups to consuming all food groups.

The lack of cross-context equivalence of composite metrics can be further illustrated using recently published findings. Similar GDQS were reported among adults in rural Ethiopia (19.8 points) [13] and urban China (20.8 points) [11]. In Ethiopia, moderate GDQS was attributable to low intakes of unhealthy foods (i.e., signaled by a relatively high mean GDQS− of 12.5) and concurrent low intake of healthy food groups (i.e., relatively low mean GDQS+ of 7.2) [13]. This finding was confirmed by 2 other studies of GDQS in Ethiopia [14,57]. Unfortunately, disaggregated descriptive statistics on GDQS+ or GDQS− were not published for urban China [11]; however, a credible explanation for the moderate GDQS might be higher intakes of both healthy and unhealthy foods groups. In any case, the similarities in GDQS between urban China and rural Ethiopia – but also rural villages in Malawi, Nigeria, and Uganda (i.e., GDQS ranged between 20.2 and 20.7 points) [13] – are unexpected given their distinct nutrition landscapes [58]. Furthermore, the average global GDR scores did not vary significantly by education level or whether individuals had enough

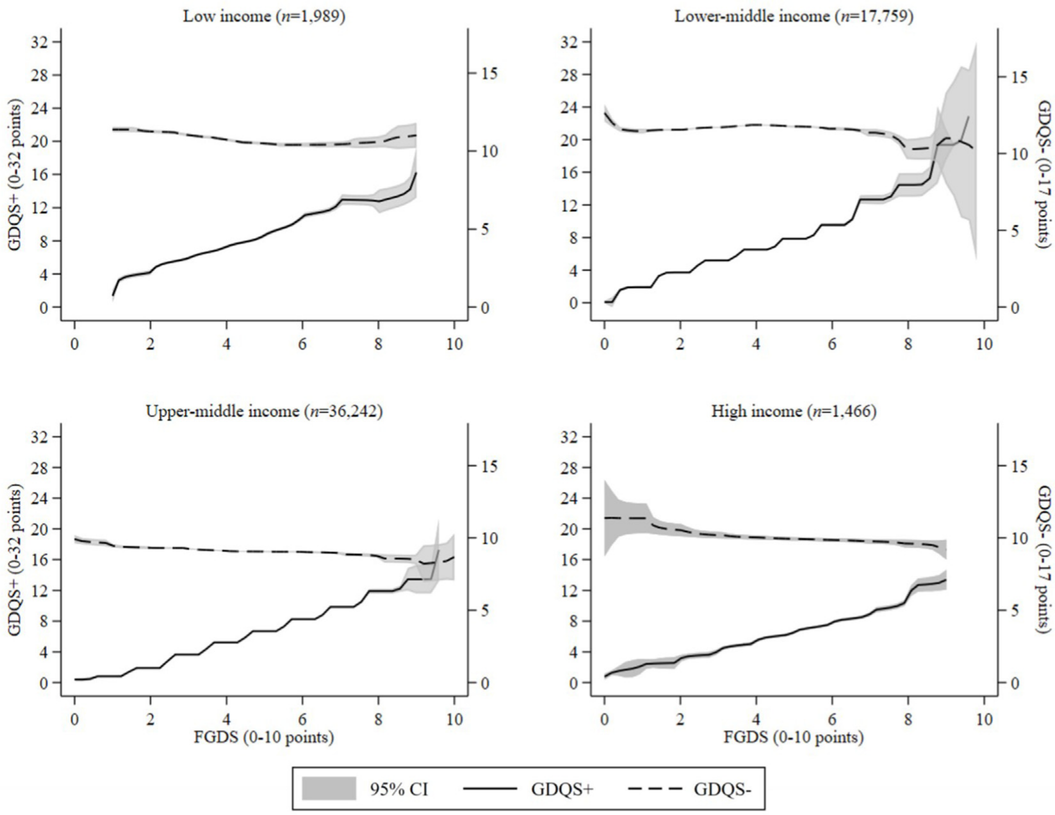

FIGURE 7. Relationships between food group diversity score (FGDS), Global Diet Quality Score Positive and Negative (GDQS+ and GDQS−) submetrics, by World Bank income classification. Top left, top right, bottom left, and bottom right are low, lower middle, upper middle, and high-income countries, respectively. The solid and dashed lines represent the local polynomial smoothing predictions with 95% confidence intervals.

money to purchase food (i.e., ~10–11 points) [59]. These unintuitive findings are attributable to the composite GDR score obscuring that population groups with higher educational attainment or income had higher NCD-Protect scores, as well as higher NCD-Risk scores [59]. Moreover, although at the national level, Bolivia and India had comparable GDR scores (i.e., 11.0 and 10.9 points), their NCD-Protect (4.7 as compared with 3.3 points) and NCD-Risk scores (2.7 as compared with 1.5 points) were rather dissimilar [59]. These studies support our finding that ambiguous composite metrics, such as GDQS and GDR score, have limited cross-context equivalence and are therefore not appropriate for informing program targets and monitoring healthy diets.

Nevertheless, complementary submetrics, such as GDQS+ and GDQS−, have synergistic and superior descriptive utility for monitoring diets. For example, a similar average GDQS in urban Ethiopia [60] and the United States [17] (i.e., 20.0 and 21.6 points) can be explained by assessing the heterogeneity in GDQS+ (i.e., 8.8 as compared with 13.0 points) and GDQS− (i.e., 11.2 as compared with 8.6 points). Relatedly, the slightly higher mean GDQS of 23.0 points in India, as compared with the United States [17], was attributable to the former's higher GDQS− [12], whereas the lower average GDQS of 15.8 points in Mexico was attributable to lower GDQS+ [15]. In contrast to findings in India, Fung et al. [18] reported that increments across GDQS (quintiles) were determined primarily by increasing GDQS+ among females in the United States.

To facilitate interpretation, food group (sub)metrics reflecting only a single subconstruct of a healthy diet, such as MDD-W, are recommended. However, in isolation, they also obscure essential information for monitoring. To illustrate, among pregnant females in rural Tanzania, low FGDS of 2.9 points failed to reflect the concurrent high intakes of unhealthy food groups, as revealed by the very low GDQS of 2.4 points, which unequivocally indicates low GDQS− [61]. Moreover, identical NCD-Protect scores in Israel and Kenya (i.e., 4.0 points) can only be meaningfully interpreted with their complementary NCD-Risk scores (i.e., 3.0 as compared with 1.6 points), revealing higher unhealthy food group consumption in Israel despite a similar healthy food group consumption to Kenya [59]. Arguably, single construct (sub)metrics might also reflect dissimilar dietary patterns. To illustrate, MDD-W can be achieved by diverse vegetarian and omnivorous diets [62,63]. However, improvement in such food group (sub)metrics can only be achieved by either increasing healthy food group diversity (e.g., FGDS) or decreasing unhealthy food group consumption (e.g., GDQS−), not an abstruse combination of both.

There is a large body of evidence indicating the validity of FGDS and MDD-W to signal better micronutrient adequacy [4,62,64–69]. Meanwhile, other studies have also shown that healthy food group submetrics, such as MDD-W, are poorly associated with the intake of nutrients to limit and rates of diet-related NCDs [70]. Therefore, increased attention should be paid to refining measures of unhealthy food group consumption and subsequently validating indicator thresholds. To illustrate, Herforth et al. [6] showed that an FGDS of 4.0 in Brazil and 4.5 points in the United States failed to reflect the low proportion of the population adhering to WHO's recommendations for free sugar, sodium, and processed meat intakes. Furthermore, Angulo et al. [16] and Fung et al. [17] reported that lower GDQS− was more strongly associated with 2- and 4-y weight gain than FGDS among adults in Mexico and the United States, respectively, whereas higher GDQS− was associated with lower waist circumference and serum triglycerides in China [11] and lower diastolic blood pressure in Ethiopia [14]. Moreover, FGDS was not associated with type II diabetes [18] or ischemic heart disease rates in multiple United States cohorts [71], whereas higher GDQS− (but not GDQS+) was associated with lower rates of diabetes in the United States [18]. However, GDQS− tended to correlate weakly or even negatively with nutrient intakes and adequacy, once again highlighting the public health relevance of monitoring both healthy and unhealthy food group submetrics [5].

At present, there are limited studies to which we can equate our agreement analyses of standardized healthy diet metrics. Nonetheless, similar to our findings, Baye and Yaregal [57] reported that FGDS was more strongly correlated with GDQS+ than with composite GDQS among nonpregnant Ethiopian females ($\rho = 0.53$ as compared with $\rho = 0.34$). Furthermore, FGDS was strongly correlated with GDQS+ ($\rho = 0.76$) and negatively associated with GDQS− ($\rho = -0.29$) in India [12]. Likewise to our results, in India, GDQS and GDQS+ were also negatively correlated with GDQS− ($\rho = -0.08$ and $\rho = -0.39$, respectively) [12]. Moreover, analogous to our regression coefficients, a one-point increase in FGDS was associated with a 1.5 points increase in GDQS (95% CI: 1.3, 1.8) in Ethiopia, which was almost exclusively driven by the significantly stronger relationship with GDQS+ (95% CI: 1.3, 1.8 points) [57].

Because FGDS, GDQS+, and NCD-Protect scores are all healthy food group (sub)metrics, including many of the same broad food groups, collecting data and reporting statistics on each is likely redundant for monitoring. To clarify, FGDS was comparable (or outperformed) GDQS+ for overall nutrient adequacy, for which nutrient intakes and anthropometric and clinical (bio)markers of undernutrition served as proxies in sub-Saharan African countries, Mexico, China, India, and Brazil [5,11–15,19]. In addition, the Spearman rank correlation coefficients between FGDS and NCD-Protect were high (i.e., $\rho > 0.75$) in Brazil and the United States, although the NCD-Protect score was a slightly stronger metric for adherence to more than half of WHO's dietary recommendations (i.e., ≥6 of 11) [6]. To guide and expedite indicator refinement and selection, the reference metrics of dietary intake against which healthy diet metrics should be validated must be established through independent expert consultations, such as the Healthy Diets Monitoring Initiative [72].

For global monitoring of healthy diets, a critical argument in favor of nonquantitative food group modules is that they have proven to be feasible to integrate into multitopic surveys, such as the DQQ as part of the Gallup World Poll [59]. The available GDR score and MDD-W modules do not rely on standalone technology-assisted applications for data collection. In contrast, the GDQS application – with 10 accompanying 3D cubes to estimate semiquantitative food group intakes – likely has implications for large-scale and repeated data collection in terms of accessibility, practicality, cost, and the need for additional (time-consuming) probing by enumerators [73].

Similar to our descriptive statistics, a lower prevalence of females achieved All-5, as compared with MDD-Win the Gallup World Poll (e.g., 28% and 75% in Senegal, respectively) [59]. Similar to our results in lower middle and high-income countries, the food groups most commonly lacking across 41 countries were "pulses, nuts, or seeds," followed by "fruits'' [59]. Due to its strict attainment criteria, All-5 is likely to be insensitive to dietary improvements in contexts where large shares of the population have a vegan or vegetarian diet (i.e., animal-source food must be consumed). Moreover, in our study, the lowest prevalence of females reaching All-5 was observed in high-income countries (i.e., 10.9%) due exclusively to the poor consumption of "pulses, nuts, or seeds" (<15%). Therefore, the All-5 indicator did not reflect that the other 4 food groups were consumed by >75% of females. Lastly, the highly aggregated food groups used to construct All-5 further obscure potential substitutions occurring between more disaggregated food subgroups over time and across contexts (e.g., meat and seafood substituted for eggs). Hence, All-5 is not recommended for global monitoring of healthy diets.

The variability reported in magnitudes of correlation coefficients between healthy diet (sub)metrics is in line with previous research. To illustrate, 3 comparative studies among adults [74] and pregnant females from Lebanon [75], and males and females from Spain [76] indicated that 5 validated Mediterranean diet scores generally showed moderate to high Spearman's rank correlation coefficients (range ρ: 0.35–0.75) and percentage agreement when using 50th percentile dichotomous thresholds (range: 64–75%) [74,75]. Likewise, a study contrasting 4 established Dietary Approached to Stop Hypertension metrics indicated Spearman's rank correlation coefficients ranging between 0.37 and 0.75 [77].

Our study has several limitations. First, quantitative 24-HR data on FAO/WHO GIFT are heterogeneous in terms of year and season of data collection, sample sizes and weighting, national representativeness, 24-HR methodology, and prevalence of over- and underreporting. Hence, our pooled estimates by World Bank country income classifications – presented for didactic simplicity – should be interpreted with caution (e.g., India accounts for ~70% of the sample size from lower middle income countries). Nonetheless, weighted regression analyses confirmed the main research findings. Second, our study included only a few surveys from high-income countries and was restricted to nonpregnant females. However, repeating our analyses including males aged 15–49 y strengthened our main conclusions (data not shown). Third, no standalone MDD-W, DQQ, or GDQS questionnaires were used to measure food group consumption, resulting in the best-case scenario to discover relationships and concordance between healthy diet metrics. To clarify, in most studies, the prevalence of food group consumption is assessed using simpler methods such as non- or semiquantitative open 24-HRs for FGDS and GDQS [52,73], respectively, or (sentinel) list-based questionnaires for FGDS and GDR score [6,52]. Previous research has indicated that simpler and more scalable data collection methods to assess food group intakes result in misreporting, compared with quantitative dietary assessments considered as reference methods [62,65,78,79].

Our study also has several important strengths. First, all datasets on FAO/WHO GIFT were harmonized with European Food Safety Authority's FoodEx2 food classification and description system. This harmonization was aimed at enhancing the consistency and reliability of dietary assessments across contexts [80]. Second, the recoding of FoodEx2 base terms to the metrics' food subgroups was conducted independently by 4 dietary assessment experts at FAO, resulting in a high level of coding accuracy. Third, our multicountry analyses covered a large sample of nonpregnant females' diets across all World Bank country income classifications.

In conclusion, composite metrics weighting both healthy and unhealthy food groups have limited cross-context equivalence, as a wide range of often opposing dietary patterns theoretically return similar scores. Furthermore, (sub)metrics constructed using only healthy food groups showed strong measurement agreement and moderate to high correlations, likely indicating acceptable underlying construct validity (e.g., dietary diversity, and nutrient adequacy). For surveillance systems to effectively monitor diets in the context of the ongoing nutrition transition, a suite of healthy diet submetrics is recommended. However, multicountry analyses should be undertaken to (further) refine and validate unhealthy food group metrics, such as GDQS− and NCD-Protect.

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Author contributions

The authors' responsibilities were as follows – GTH-C: designed research and analyzed data and performed statistical analysis; GTH-C, SMG, JPP, SH, VPdQ, AB: curated and managed data; GTH-C, SMG: wrote the paper; GTH-C, LMN, BAH: have primary responsibility for final content; and all authors: read, edited, and approved the final manuscript.

Conflict of interest

The authors report no conflicts of interest.

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Data availability

All data supporting the reported results are publicly available on the FAO/WHO Global Individual Food consumption data Tool (FAO/WHO GIFT), and can be accessed with https://www.fao.org/gift-individual-food-consumption/data/en.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ajcnut.2024.07.010.

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