frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 16 August 2024
DOI 10.3389/fsufs.2024.1432057

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OPEN ACCESS

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RECEIVED 13 May 2024
ACCEPTED 23 July 2024
PUBLISHED 16 August 2024

CITATION
Hilary S, Safi S, Sabir R, Numan AB, Zidan S and Platat C (2024) Development and validation of a tool to assess knowledge, attitudes, and practices toward diet sustainability.
Front. Sustain. Food Syst. 8:1432057.
doi: 10.3389/fsufs.2024.1432057

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Development and validation of a tool to assess knowledge, attitudes, and practices toward diet sustainability

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This study aimed to develop and validate an instrument, the Sustainable Diets Questionnaire (SDQ), to assess the knowledge, attitude, and practice of sustainable diets in adult populations. A panel of four nutritionists identified 63 items through a literature review and refined them to a 54-item model for validation across four domains: Knowledge domain (K, eight items), Attitude domain (A, 18 items), Practice domain (P, 16 items) and Consumption Habits domain (D, 12 items). The validation process consisted of a pilot with 86 individuals (Phase 1) and a larger study with 389 participants (Phase 2). Confirmatory Factor Analysis (CFA) was conducted in both phases to verify model fit. In Phase 1, the initial four-factor model did not converge, indicating a need for item modification and a revised three-factor model (K domain, eight items; A domain, 18 items; new P domain, 28 items). In Phase 2, the new model showed improvement in fit indices with a Scaled Chi-Square of 2.415, Comparative Fit Index (CFI) of 0.863, Goodness of Fit Index (GFI) of 0.747, Tucker-Lewis Index (TLI) of 0.851 and the Root Mean Square Error (RMSE) was 0.066, although some indices fell below the 0.9 threshold. The Cronbach's α for the Knowledge, Attitude, and Practice domains were 0.9, 0.96, and 0.897, respectively, with an overall α of 0.959. There was no significant difference between the first and second attempts of the SDQ model, indicating good test–retest reliability. There was also a significant positive correlation between the response scores of K, A, and P domains (K vs. A, $r = 0.575$, $p < 0.001$; K vs. P, $r = 0.496$, $p \leq 0.001$ and A vs. P, $r = 0.665$, $p \leq 0.001$). The study concludes that the three-factor model of SDQ is a valid and reliable tool for understanding the knowledge, attitudes, and practices of sustainable diets among adults.

KEYWORDS

knowledge, attitudes, practice, sustainable diets, sustainable nutrition, questionnaire, validity, reliability

1 Introduction

The global food system is at a critical juncture, with the dual challenges of ensuring food security for a growing population and mitigating the environmental impacts of food production and consumption (Hallström et al., 2015). The food system is responsible for more than one-third of global greenhouse gas emissions, with the consumption of meat and animal

products being significant contributors (von Koerber et al., 2017). In contrast, plant-based foods generate much lower emissions and are associated with numerous health benefits (von Koerber et al., 2017; Zurek et al., 2022). WHO (2003) has identified poor diet as a significant risk factor for chronic diseases. Overnutrition is the scourge of modern societies, leading to diseases like obesity, hypertension, and diabetes. Nutrition education programs to combat the global rise in obesity are launched to decrease the dietary intake of energy, the consumption of some nutrients, especially those associated with metabolic dysfunctions, like sodium, sugar and trans fats, and to increase the proportion of nutrients beneficial to health such as fiber, protein, vitamins, and minerals. The situation in the United Arab Emirates (UAE) is no different, with an estimated 44.2% of adult women and 30.9% of adult men living with obesity (GNR, 2021). UAE's obesity prevalence is higher than the regional average of 10.3% for women and 7.5% for men. Similarly, diabetes is estimated to affect 17.4% of adult women and 17.3% of adult men in the population (GNR, 2021).

Empirical evidence suggests that adopting healthy and sustainable diets and transitioning to a sustainable food system is urgently needed to counteract the double burden of non-communicable diseases and climate change (Willett et al., 2019). Sustainable diets has emerged as a viable solution to these challenges. The idea of a sustainable diet was introduced by Gussow and Clancy (1986), who looked at foods from the nutritional perspective and also considered their environmental impact. More recently, the Food and Agriculture Organization has defined sustainable diets as diets protective and respectful of biodiversity and ecosystems, culturally acceptable, accessible, economically fair, and affordable; nutritionally adequate, safe, and healthy while optimizing natural and human resources (Allès et al., 2017; Drewnowski et al., 2020). The transition toward sustainable diets warrants strategies that address the entire food chain, from sustainable land and water use to efficient handling of food waste, responsible logistics, food processing, consumption, and packaging practices (Willett et al., 2019). Many vital strategies have been proposed to promote diet sustainability (Lawrence et al., 2015; Hyland et al., 2017; de Boer and Aiking, 2019; Reyes et al., 2021; Barbour et al., 2022). An example of the most common initiative is reducing food waste throughout the food chain (Conrad et al., 2018).

The EAT-Lancet Commission, in 2019, published its report on healthy diets from sustainable food systems, which outlined a dietary model that can help meet the scientific targets for healthy and sustainable diets (Willett et al., 2019). This model, also known as the planetary health diet or the EAT-Lancet diet, was proposed to meet the health requirements of humans without exceeding planetary boundaries. The EAT-Lancet Commission proposed a global dietary shift, including a significant reduction in the consumption of animal proteins and starchy vegetables and increasing the consumption of legumes, whole grains, and nuts to achieve Sustainable Development Goals (SDGs) laid out by the United Nations (UN) and reign in climate change. Diet sustainability is, therefore, at the forefront of nutrition research, and it is vital to understand its awareness, attitude, and practices across populations. Consumer attitudes and demand for food, including sustainable diet consumption, differ widely across countries (Pucci et al., 2022). Some studies were reported in this regard and they mainly focus on the willingness of consumers to pay for sustainable food products, increase their plant-based protein, vegetable or fruit consumption, and how different age groups perceive diet sustainability (Barosh et al., 2014; Faber et al., 2020; Szczebyło et al., 2020; Baur et al., 2022; Curi-Quinto et al., 2022). Some studies assess food sustainability knowledge and perception among specific populations, such as healthcare professionals and those pursuing higher education (Fresán et al., 2023; Irazusta-Garmendia et al., 2023). It is important to note that most of these studies were also conducted in European countries (Pucci et al., 2022; Kenny et al., 2023). The broader takeaway from all of these studies is that a broader range of initiatives is required to educate consumers on diet sustainability practices and target the general unawareness of the population concerning diet sustainability behaviors.

In the UAE, the reliance on food imports and the preference for resource-intensive food items exacerbate environmental impacts. This situation uniquely challenges balancing nutritional needs, food security, and environmental sustainability. Many opportunities can be explored to reshape the food system to ensure it produces healthy and safe food with a limited environmental impact. Actionable initiatives for sustainable nutrition/diet are critical in the UAE, as the Global Nutrition Report of 2021 for UAE has underscored that the country has shown limited progress toward achieving the diet-related non-communicable disease (NCD) targets (GNR, 2021). The report also indicated that the planetary impact of the food system is unsustainable on all levels. Therefore, to achieve a successful transformation toward a more sustainable food system, a remarkable shift in dietary practice is warranted. To accomplish this shift, it is crucial to comprehend the knowledge, attitudes, and practices in this population regarding sustainable diets which benefit both the health and the environment (Andrade et al., 2020; Ahmed et al., 2021). This understanding provides essential insights that can empower researchers with the necessary information to design targeted interventions to facilitate behavioral modification that best aligns with the UN's SDGs (Andrade et al., 2020). In light of these challenges, there is a pressing need for a valid tool to assess the knowledge, attitudes, and behaviors related to sustainable diets in adult populations. This study aims to develop and validate a questionnaire to address the lack of a validated tool.

2 Methodology

2.1 Study design and ethics approval

The study was conducted at the United Arab Emirates University among the university staff and student community. The ethics approval for the study was obtained from the United Arab Emirates University's Social Sciences Research Ethics Committee (approval number: ERSC_2024_4357). Informed consent was obtained from all participants after providing detailed information about the study's purpose, risks, and benefits. Participants were assured that their participation was voluntary and that they could withdraw without penalty.

All participants were also provided instructions on how to access and complete the questionnaire. The tool development and validation process of items for the SDQ was undertaken in two phases, as illustrated in Figure 1. Phase 1 involved developing items that align with the study purpose by reviewing the relevant literature and pilot testing in a subpopulation for modification. Phase 2 validated the instrument in a larger population using factor analysis, determining

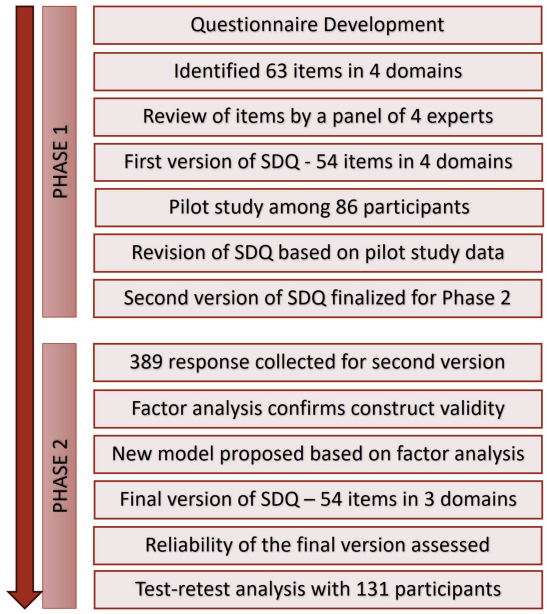

FIGURE 1
Illustration of the study design.

the construct validity and reliability of the final version of the questionnaire.

2.2 Study participants and data collection

In Phase 1 of the study, SDQ was pilot-tested among 86 participants for questionnaire modification and Phase 2 involved data collection from 389 participants to validate the final SDQ. The sample size for Phase 2 was determined using Cochran's formula with a 95% confidence interval, 5% significance level (0.05) and marginal error of 0.05 (Woolson et al., 1986). Participants aged 18 years and above who are part of the university community were approached in person or invited via email, social media, and other online platforms to complete the survey. Participants were asked to provide basic sociodemographic information, such as their gender, age, nationality, place of residence, educational background, and income level. Moreover, self-reported weight and height were collected for body mass index calculation.

2.3 Questionnaire development and modification

To define the constructs of the questionnaire, a thorough literature review was conducted in PubMed, Google Scholar, Science Direct, and Scopus to define the domains of interest and their respective items for developing the initial questionnaire. Selective keywords such as "sustainable diets," "sustainable nutrition," "sustainability," "perceptions," "attitude," "knowledge," "practice," "adherence," and "willingness" were used to search the databases. Several studies were identified, including two most relevant studies to our research objective (Culliford and Bradbury, 2020; García-González et al., 2020). A panel of four nutritionists initially identified 63 items in four proposed domains: knowledge (K), attitude (A), practice (P) and consumption habits (D) and later revised the questionnaire to list 54 items in the four domains to build the first version of the questionnaire for the UAE population. This first version of SDQ was pilot-tested (Phase 1), and revisions were made to several items to improve comprehension and develop the final version of SDQ for validation in a larger population in Phase 2.

2.4 Statistical analyses

Statistical analyses for the experiments were performed using SPSS® version 29 (IBM Corporation, Armonk, NY, United States) and R statistical package. Descriptive statistics (Mean ± SD) were used to describe continuous variables, and categorical variables were expressed as counts and percentages (*N*, %). Kaiser-Meyer-Olkin (KMO) and Bartlett's Sphericity test were used in phases 1 and 2 to test the suitability of data for factor analysis. Confirmatory Factor Analysis (CFA) was carried out to verify the factorial structure of the model and confirm the construct validity in phases 1 and 2. For Phase 2 data, factor loadings and item-to-total correlations were calculated to test the validity of the SDQ. Cronbach's-α was used to determine the internal consistency of SDQ and test–retest reliability was analyzed by conducting a *T*-test of the two attempts and Bland–Altman analysis. Correlation tests were also used to find the association between the domains and the domain response scores to the various sociodemographic characteristics of the participants. A $p < 0.05$ was considered statistically significant.

3 Results

3.1 Sociodemographic characteristics of participants

The sociodemographic characteristics of participants from phases 1 and 2 of the study are listed in Table 1. The study population mainly comprised young adults with a mean age of 28.9 in phase 1 and 25 years in phase 2. The average BMI of the respondents of Phase 1 and Phase 2 was 25.6 and 24.7 kg/m^2, respectively. Most of our respondents were UAE nationals, 62.8% in Phase 1 and 68.9% in Phase 2, and the rest were expatriate residents from over 25 different countries. We had a significantly higher number of female respondents (80.2% in Phase 1 and 80.7% in Phase 2). The number of male participants in the study was limited to 17 (19.8%) in Phase 1 and 75 (19.3%) in Phase 2. Most of the participants were also single, 64% in Phase 1 and 76.3% in Phase 2; however, the more significant proportion of the respondents came from large households with five or more members, 66.3% in Phase 1 and 71.1% in Phase 2. The participants in the study were mostly educated since it was conducted in a university community, and all respondents had at least a high school degree or higher. Since the student body represented most of our respondents, the number of those who identified as unemployed or students was higher (62.8% in Phase 1 and 76.9% in Phase 2). Similarly, most participants indicated their income as less than 5,000 AED, 52.3% in Phase 1 and 73.8% in Phase 2. Only a very small proportion belonged to the high-income groups in our study, 12.8 and 8% in Phases 1 and 2, respectively. Regarding nutrition knowledge and training, more than half of the

TABLE 1 Sociodemographic characteristics of study participants.

	Phase 1 (*N* = 86)	Phase 2 (*N* = 389)
Age (years)*	28.9 ± 11.8	25.0 ± 9.7
BMI (kg/m^2)*	25.6 ± 5.9	24.7 ± 4.9
Nationality		
UAE	54 (62.8)	268 (68.9)
Others	32 (37.2)	121 (31.1)
Gender		
Female	69 (80.2)	314 (80.7)
Male	17 (19.8)	75 (19.3)
Marital status		
Single	55 (64)	297 (76.3)
Married	31 (36)	92 (23.7)
Family size		
1–2 members	8 (9.3)	25 (6.4)
3–4 members	21 (24.4)	85 (21.9)
5 or more members	57 (66.3)	279 (71.7)
Education		
High school	34 (39.5)	210 (54.0)
Bachelor	24 (27.9)	104 (26.7)
Masters	14 (16.3)	45 (11.6)
Doctorate	14 (16.3)	30 (7.7)
Employment		
Employed	32 (37.2)	90 (23.1)
Unemployed/student	54 (62.8)	299 (76.9)
Income		
<5,000 AED	45 (52.3)	287 (73.8)
5,000 AED–20,000 AED	30 (34.9)	71 (18.3)
20,000 AED and above	11 (12.8)	31 (8.0)
Diet counseling		
Yes	34 (39.5)	136 (35.0)
No	52 (60.5)	253 (65.0)
Formal nutrition education		
Yes	48 (55.8)	213 (54.8)
No	38 (44.2)	176 (45.2)
Knowledge of nutrition guidelines		
I have never heard of them	2 (2.3)	28 (7.2)
I have heard of them but know very little	22 (25.6)	75 (19.3)
I know a fair amount	39 (45.3)	185 (47.6)
I know a lot	23 (26.7)	101 (26.0)

*Age and BMI data presented as Means ± s.d. All other data in the table presented as *N* (%).

participants indicated that they have had some form of formal training in nutrition, 55.8% in Phase 1 and 54.8% in Phase 2. Moreover, a more significant number of respondents also indicated that they have a fair amount of knowledge regarding nutrition guidelines (45.3% in Phase 1 and 47.6% in Phase 2). In light of these numbers, it is interesting to note that the percentage of respondents who have consulted with dieticians or nutritionists is low (39.5% in Phase 1 and 35% in Phase 2).

3.2 Sustainable diet questionnaire

The proposed SDQ consisted of 54 items in 4 domains: K, A, P, and D. The final version of the SDQ is provided in Supplementary File. The K domain assesses the knowledge level of the respondent regarding seven common sustainability terms (items K1–K7) such as "*ecological footprint*," "*carbon footprint*," "*food sustainability*," "*environmental impact*," "*biodiversity*," "*locally produced foods*," "*greenhouse gas emissions*". The responses are coded from 0 to 4 using statements indicative of knowledge such as "*No, I have not heard the term*"; "*I have heard the term, but I do not know what it means*"; "*I have a vague understanding of the term*"; "*I have heard the term and know what it means*"; "*I have a clear understanding of the term*". This domain also includes an 8th item (item K8), "Do you believe that healthy and sustainable diets mean the same?" The response is coded using a 5-point Likert scale of agreement. The A domain assesses respondents' attitudes by asking how important a set of statements contributes to sustainable diets. The response is coded using a 5-point Likert scale of importance. The list includes 17 statements (items A1–A17). Some examples include "*Organic food production*," "*Diet with plenty of fresh products*," "*Diet rich in vegetables and fruits*," and "*Diet with traditional foods from own culture*". Item A18 ("*How important is it for you that the products you consume are produced sustainably?*") is a stand-alone question in the A domain that codes the response in a 5-point Likert scale of importance. Like domain A, domain P includes a list of 15 behaviors (items P1–P15) that assess the extent to which the respondents practice those behaviors. The responses are coded from 0 to 4 using the following statements: "*I'm not interested in doing this at the moment*"; "*I'm thinking about this, but I need more information*"; "*I would like to do this, but other things are stopping me*"; "*I have started to do this some of the time*"; "*I'm doing this confidently most of the time*". Item P16 asks the respondents about their willingness to pay higher prices for food products that are produced sustainably using a 5-point Likert scale of willingness. In domain D, which assesses the respondents' weekly consumption habits, a list of 12 foods (items D1-D12) is presented with five intake frequencies (0 times, 1–2 times, 3–4 times, 5–6 times, seven or more times). The responses are codes from 0–4 for all items in the domain except D2, D4, and D6, which are reverse-coded.

3.3 Factorial structure of SDQ: phase 1

Data from the Phase 1 study of SDQ is provided in Tables 2–4. The data suitability was assessed using the measure of sampling adequacy. The KMO and Bartlett's Test of Sphericity are shown in Table 2. The KMO measure of sampling adequacy was 0.852, 0.835, 0.835, and 0.72 for domains K, A, P, and D, respectively. The KMO values for all domains were higher than 0.5; hence, the factor analysis was appropriate for this data. Bartlett's test was highly significant for all domains ($p < 0.001$), indicating that the data was suitable for CFA. The details of the different models from factor analysis are presented in Table 3. The factor structure of the four-factor model failed to converge with the proposed 54 items in Phase 1 of the study. This

TABLE 2 Kaiser–Meyer–Olkin's and Bartlett's tests.

		Domain K	Domain A	Domain P	Domain D
Phase 1	KMO measure of sampling adequacy	0.852	0.835	0.835	0.72
	Bartlett's test of Sphericity				
	Approx. chi-square	479.887	790.101	622.989	364.422
	p-value	<0.001	<0.001	<0.001	<0.001
Phase 2	KMO measure of sampling adequacy	0.905	0.953	0.948	0.821
	Bartlett's test of Sphericity				
	Approx. chi-square	2156.434	5977.542	4346.34	1609.558
	p-value	<0.001	<0.001	<0.001	<0.001

Data from Phase 1 ($N = 86$) and Phase 2 ($N = 389$) are presented. K, knowledge; A, attitude; P, practice; D, consumption habit. Statistical significance is set at $p \leq 0.05$.

TABLE 3 Summary of fit indices of SDQ.

	Model 1 ($N = 86$)	Model 2 ($N = 86$)	Model 3 ($N = 389$)	Model 4 ($N = 389$)
No. of domains	Four domains	Four domains	Four domains	Three domains
No. of items	52 items	51 items	54 items	54 items
Scaled chi-squared	1.655	1.646	2.415	2.415
Comparative fit index (CFI)	0.693	0.705	0.882	0.863
Goodness of fit index (GFI)	0.571	0.577	0.761	0.747
Tucker–Lewis index (TLI)	0.675	0.687	0.871	0.851
Root mean square error (RMSE)	0.088	0.087	0.061	0.066

Fit indices of the various models from factor analysis of the SDQ in Phase 1 and 2. Model 1 and 2 fit data from Phase 1. Model 3 and 4 displays fit indices of data from Phase 2 of the study. Model 1 converges with the deletion of items D2 and D6, Model 2 with the deletion of items D2, D6, and K8. Model 4 combines items from Practice and consumption habits into a single domain. The factor structure figure of each model is available in Supplementary File.

indicated that the data from the pilot study could not uniquely estimate model parameters, making it difficult to assess the model's fit to the data. However, we were able to converge two models (Model 1 and 2) with the deletion of specific items. Model 1 converged with the deletion of items D2 and D6 in the D domain, and model 2 with the deletion of items D2 and D6 in the D domain and K8 from the K domain, but the fit indices of both models were not satisfactory. The comparative fit index (CFI) was 0.693 and 0.705, the Tucker and Lewis index (TLI) was 0.675 and 0.687, the goodness of fit index (GFI) was 0.571 and 0.577, and the Root Mean Square Error (RMSE) was 0.088 and 0.087, for model 1 and 2, respectively. The factor structure figures are provided in Supplementary File.

3.4 Validity of SDQ: phase 1

Table 4 shows the factor loadings for the four-factor domain of SDQ in Phase 1. The first factor, the domain K, accounted for 60.4% of the total variance and comprised eight items, of which item K4 ranked the highest (0.897) and item K8 ranked the lowest (0.067). The second factor in the model was domain A, which accounted for 39.4% of the total variance and comprised 18 items. The factor loadings in domain A ranged between 0.267 (item A18) and 0.747 (items A9 and A16). In the P domain with 39.8% variance, the factorial weights ranged between 0.407 (item P16) and 0.77 (item P3). The fourth factor in the model was domain D, which accounted for 32.9% of the total variance and comprised 12 items. There was high variability in the factorial weights in this domain, with a minimum value of 0.12 and a maximum value of 0.8. The internal consistency of the K, A and P domains was high in Phase 1, with Cronbach's α values of 0.89, 0.903 and 0.896, respectively. The Cronbach's α value of the domain D was low and below the acceptable range (0.462).

3.5 Factorial structure of SDQ: phase 2

Based on the data from Phase 1, the questionnaire was revised further to incorporate minor changes to the language and the modified version of SDQ was again administered to the UAE University community. The response collection was continued until the target sample size was attained. The factor structure of the revised SDQ was then tested using the data from 389 respondents of Phase 2. The data suitability was assessed again for the 389 respondents using the measures of sampling adequacy (Table 2). With the increase in the sample size from Phase 1, the KMO measure of sampling adequacy improved to 0.905, 0.953, 0.948, and 0.821 for domains K, A, P, and D, respectively. Bartlett's test was also highly significant for all domains ($p < 0.001$), indicating that the data was appropriate for CFA. The factor structure of the four-factor model (model 3) converged with all 54 items in Phase 2 of the study (Table 3). There was an overall improvement in the fit indices for model 3. The CFI was 0.882, the TLI was 0.871, the GFI was 0.761, and the RMSE was 0.061 for model 3. Based on the validity data from Phase 1 of the study and the nature of the items in domain D, a new three-factor model (model 4) was proposed, which combines the 16 items in the P domain with the 12 items in domain D for a new practice domain (P + D) with 28 items.

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TABLE 4 Factorial weights for items from study phase 1 ($N = 86$).

Domain K		Domain A		Domain P		Domain D	
Cronbach's $\alpha = 0.890$		Cronbach's $\alpha = 0.903$		Cronbach's $\alpha = 0.896$		Cronbach's $\alpha = 0.462$	
Variance = 60.4%		Variance = 39.4%		Variance = 39.8%		Variance = 32.9%	
Item	Factor loadings	Item	Factor loadings	Item	Factor loadings	Item	Factor loadings
K1	0.761	A1	0.579	P1	0.701	D1	0.557
K2	0.804	A2	0.665	P2	0.678	D2	0.119
K3	0.846	A3	0.505	P3	0.77	D3	0.748
K4	0.897	A4	0.448	P4	0.649	D4	0.495
K5	0.862	A5	0.668	P5	0.564	D5	0.724
K6	0.826	A6	0.587	P6	0.696	D6	0.234
K7	0.812	A7	0.597	P7	0.658	D7	0.706
K8	0.067	A8	0.665	P8	0.568	D8	0.573
		A9	0.747	P9	0.673	D9	0.319
		A10	0.56	P10	0.768	D10	0.276
		A11	0.571	P11	0.612	D11	0.8
		A12	0.736	P12	0.588	D12	0.774
		A13	0.678	P13	0.505		
		A14	0.673	P14	0.604		
		A15	0.673	P15	0.545		
		A16	0.747	P16	0.407		
		A17	0.732				
		A18	0.267				

K, knowledge; A, attitude; P, practice; D, consumption habits.

The confirmatory factor analysis was repeated for model 4 (Table 3). The model converged all 54 items in the three domains, and fit indices did not vary from model 3. The CFI was 0.863, the TLI was 0.851, the GFI was 0.747, and the RMSE was 0.066 for the new model. The factor structure figures are found in the Supplementary File.

3.6 Validity of SDQ: phase 2

The factor loadings improved in model 3 of Phase 2 (Table 5). Domain K recorded 62.6% of the variance, with factor loading between 0.828 and 0.899, except for K8, which again had the lowest factor loading (0.043), showing no improvement in the item value from Phase 1 to Phase 2. The variance in domain A improved to 60.3% in Phase 2 with factor loadings between 0.607 and 0.863, except for item A18 (0.315). Similarly, the variance increased to 55.5% in the P domain, and the factorial weights ranged between 0.676 and 0.835 for all items except P16 (0.288). There was no noticeable difference in variance for Domain D, which was 33.9% in Phase 2. However, overall, the factor loadings of the 12 items in the domain showed improvement with the revised questionnaire and a higher number of respondents. The factor loadings now ranged between 0.4 and 0.7 in this domain. After merging the practice and consumption habits domain, we tabulated the item-total correlations of individual items in model 4 of SDQ (Table 6). In domain K, all items had high correlations between 0.7 and 0.8 except for item K8, which had the lowest correlation coefficient of 0.034. Similarly, in domain A, all items except A18 had a high correlation between 0.5 and 0.8, except A18 (0.286). In the P + D domain of SDQ with 28 items, the correlation coefficients were above 0.5 in all cases except for the following nine items: P16, D1, D2, D4, D5, D6, D8, D9, and D10.

3.7 Internal consistency and test–retest reliability of SDQ

The overall model of SDQ had very high consistency in Phase 2 of the study with Cronbach's α of 0.959 (Table 7). The Cronbach's α values for the K, A, P, and D domains were 0.9, 0.96, 0.944, and 0.359, respectively. The results indicate good internal consistency for K, A, and P domains. The reliability of the D domain was below the acceptable range. Upon combining the items from P and D into a new practice domain (P + D) with 28 items, the internal consistency values improved drastically with Cronbach's α value of 0.897, which is well above the acceptable threshold of 0.7. The strategy also justified model 4 with the three-factor domain. The test–retest reliability of model 4 of the SDQ demonstrated the reproducibility of the questionnaire when nearly one-third of participants attempted the questionnaire a second time after 2–3 weeks from the first attempt. There was no significant difference in the response scores between the two attempts in the overall model or when individual domain scores were compared using the Mann–Whitney U-test (Table 7). The Bland–Altman plots

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TABLE 5 Factorial weights for items from study phase 2 (model 3) ($N = 389$).

Domain K		Domain A		Domain P		Domain D	
Variance = 62.6%		Variance = 60.3%		Variance = 55.5%		Variance = 33.9%	
Item	Factor loadings	Item	Factor loadings	Item	Factor loadings	Item	Factor loadings
K1	0.778	A1	0.771	P1	0.744	D1	0.531
K2	0.812	A2	0.812	P2	0.747	D2	0.53
K3	0.868	A3	0.742	P3	0.802	D3	0.693
K4	0.899	A4	0.607	P4	0.708	D4	0.583
K5	0.876	A5	0.832	P5	0.758	D5	0.632
K6	0.828	A6	0.813	P6	0.826	D6	0.382
K7	0.852	A7	0.829	P7	0.801	D7	0.704
K8	0.043	A8	0.776	P8	0.727	D8	0.589
		A9	0.852	P9	0.809	D9	0.47
		A10	0.78	P10	0.835	D10	0.406
		A11	0.744	P11	0.741	D11	0.667
		A12	0.846	P12	0.79	D12	0.683
		A13	0.787	P13	0.676		
		A14	0.832	P14	0.752		
		A15	0.781	P15	0.757		
		A16	0.817	P16	0.288		
		A17	0.863				
		A18	0.315				

TABLE 6 Item to total correlations of study phase 2 (model 4) ($N = 389$).

Domain K		Domain A		Domain P + D			
Item	*r*	Item	*r*	Item	*r*	Item	*r*
K1	0.704	A1	0.735	P1	0.656	D1	0.41
K2	0.735	A2	0.786	P2	0.649	D2	0.267
K3	0.807	A3	0.711	P3	0.695	D3	0.522
K4	0.843	A4	0.569	P4	0.639	D4	0.225
K5	0.814	A5	0.804	P5	0.664	D5	0.326
K6	0.741	A6	0.783	P6	0.734	D6	0.037
K7	0.785	A7	0.803	P7	0.701	D7	0.522
K8	0.034	A8	0.744	P8	0.643	D8	0.287
		A9	0.829	P9	0.69	D9	0.122
		A10	0.751	P10	0.741	D10	0.159
		A11	0.71	P11	0.654	D11	0.57
		A12	0.817	P12	0.701	D12	0.576
		A13	0.752	P13	0.587		
		A14	0.802	P14	0.661		
		A15	0.753	P15	0.669		
		A16	0.789	P16	0.274		
		A17	0.835				
		A18	0.286				

for the three domains and the overall model clearly highlight that both response scores were within the limits of agreement between the first and second attempts (Figure 2). The results confirm the agreement between the two attempts and no proportional bias.

3.8 Correlation between the domain response and sociodemographic variables

There was a positive association between the three domains of model 4 of the SDQ (Table 8). The knowledge domain was highly correlated with the attitude domain ($r = 0.575$, $p < 0.001$), while the coefficient was lower when associated with the practice domain ($r = 0.496$, $p < 0.001$). Interestingly, the attitude domain's association with the practice domain was higher than the knowledge domain ($r = 0.665$, $p < 0.001$). The correlation of domain response scores to the participants' sociodemographic characteristics also revealed interesting relationships (Table 9). Overall, all significant correlations between the domain response scores and the sociodemographic variables were weak and ranged between 0.06 and 0.35. There was a significant positive association between the age of the respondents and the response score of all three domains of SDQ. The result indicates that with increasing age, there is an increase in the population's knowledge, attitude, and practice concerning sustainable diets. The BMI of the participants was also significantly associated with attitudes and practice domain, but the correlations were weak, $r = 0.149$ and 0.131 for the A and P domains, respectively. Gender was significantly

TABLE 7 Internal consistency and test–retest reliability of SDQ.

	Cronbach's α[1]	Test–retest reliability[2]		
		Response 1	Response 2	*p*-value
Domain K	0.900	257.04	270.76	0.3660
Domain A	0.960	260.07	261.77	0.9108
Domain P	0.944	256.92	271.13	0.3490
Domain D	0.359	261.33	258.05	0.8285
Domain P + D	0.897	258.28	267.08	0.5621
Overall model	0.959	258.73	265.77	0.6429

[1]Data from Phase 2 of the study with 389 participants presented. [2]Mean rank for respective domains and overall model presented in columns Response 1 ($N = 389$) and Response 2 ($N = 131$). Response 1 and 2 compared using Mann–Whitney *U*-test. Statistical significance set at $p \leq 0.05$. K, knowledge; A, attitude; P, practice; D, consumption habit. Domain P + D combines items from practice and consumption habits (domain D). The overall model includes all 54 items of SDQ.

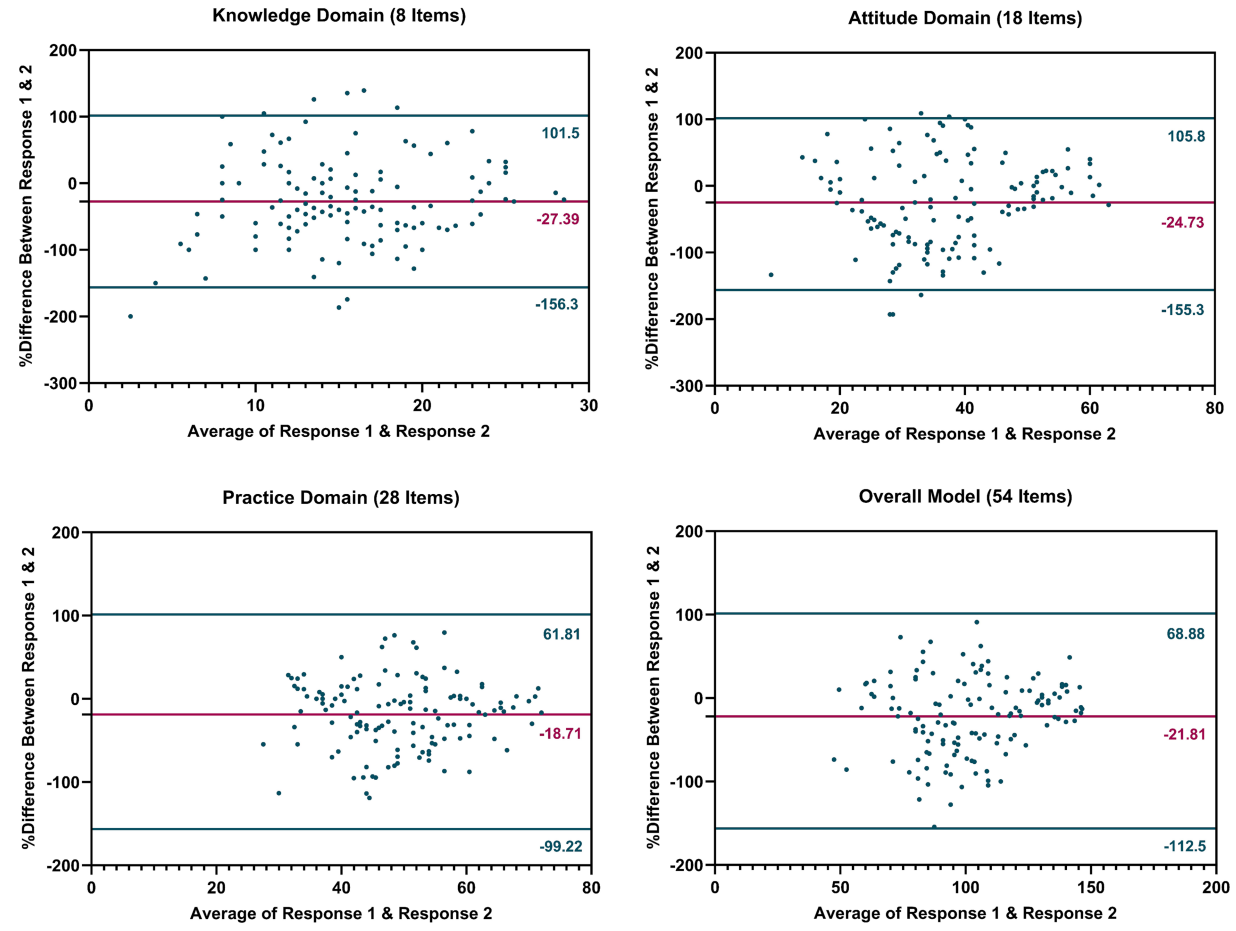

FIGURE 2
Bland–Altman plots of SDQ. Data of test–retest reliability using Bland–Altman analysis. Response 1 ($N = 389$) compared with response 2 ($N = 131$). % Difference calculated as (Response 1-Response 2)/Average of response 1&2 × 100. Practice domain (P + D).

TABLE 8 Correlation between the domains of SDQ.

	Domain K	*p*-value[1]	Domain A	*p*-value[1]
Domain K				
Domain A	0.575	<0.001		
Domain P + D	0.496	<0.001	0.665	<0.001

[1]Statistical significance set at $p \leq 0.05$. K, knowledge; A, attitude; P, practice; D, consumption habit. Domain P + D combines items from practice and consumption habits (domain D).

correlated only with the knowledge domain, $r = 0.129$ ($p = 0.011$). Interestingly, the respondents' nationality also correlated significantly with all three domains of SDQ. The marital status of the respondents was positively associated with all three domains, indicating that older married respondents had higher scores for the questionnaire. Family size was negatively correlated with SDQ, indicating that smaller households have better knowledge, attitudes, and practices regarding sustainable diets. The respondents' income and employment status

positively correlate with the three domains. Similarly, the results indicate that in our population, with a higher educational status and nutrition knowledge along with formal nutrition education, the knowledge, attitude, and practice of sustainability also increases.

4 Discussion

The primary objective of our study was to develop and validate a scale to assess the KAP related to sustainable diets, and it highlights that the SDQ model with three domains and 54 items is valid. Our results demonstrate that this newly developed scale is a valid and reliable tool to evaluate KAP on sustainable diets for educated adults. The objective to generate a validated SDQ was achieved by conducting the study in two phases: Phase 1, which tested the first version of SDQ among 86 respondents and Phase 2, which tested the validity of the revised and modified SDQ among 389 respondents. The SDQ was tested in Phase 1 of the study by conducting factor analysis, which assessed the model's fitness. The model's failure to converge with all 54 items and fit indices indicated that the sample size could be insufficient to determine the model's fitness. This phase of the study also highlighted several items within the questionnaire, such as K8, A18, D2, D6, D9, and D10 for modification. Moreover, we found that the internal consistency within the D domain was below the acceptable range. Hence, in Phase 2, the revised SDQ was readministered in a larger population and the factor analysis was repeated. With the increase in the sample size, the four-factor model converged with all 54 items, generating model 3 with acceptable fit indices.

We also looked at a new three-factor model (model 4) by combining the items from the P and D domains into a single domain. This strategy was adopted after considering the nature of items in both domains P and D, and also the low internal consistency and highly variable factor loadings of the Phase 1 data of domain D. The items to assess the weekly consumption habit were included in SDQ to provide a qualitative measure of the diet quality and its adherence to sustainable diets. These items can, therefore, be grouped with the items of the practice domain to get an overall qualitative measure of the respondent's diet sustainability practices. When we compared models 3 and 4, there was no significant variation in the fit indices and Cronbach's α value for the two practice domains (P with 16 items and P with 28 items). For evaluating the model fit of CFA, it is crucial to consider the thresholds of various model fit indices (Goretzko et al., 2023). RMSE values less than 0.05 are deemed excellent, and values ranging from 0.05 to 0.08 are considered acceptable (Fabrigar et al., 1999). Consequently, our model's RMSE value of 0.066 signifies a satisfactory fit. The GFI value of 0.75, although below the preferred threshold of 0.90, is still relevant given that GFI is known to be influenced by sample size (Mulaik et al., 1989). The CFI and TLI values above 0.90 suggest optimal fit (Bentler, 1990). In our study, their values slightly fall short of this threshold but are closer to 0.9.

The improvement in the SDQ model in Phase 2 was also evident in the factor loadings. The factor loading represents the association between an item and its corresponding factor; typically, a factor loading exceeding 0.30 suggests a moderate relationship between the item and the factor (Tavakol and Wetzel, 2020). However, the literature suggests different cut-off points for factor loadings between 0.4, 0.5, and 0.7 for accepting a model's construct validity (Posner and Kouzes, 1988; Schaufeli et al., 2006; Cheung et al., 2023). Our results indicate that 50 items in SDQ satisfied the established criteria for factor loadings. Four items, including K8, A18, P16, and D6, have factor loadings below 0.4. To validate the SDQ model, we further generated the item-to-total correlations for all items in three domains. Item-to-total correlation is another measure of construct validity (LoBiondo-Wood and Haber, 2013). These values depict the correlation between a given item and the total score of all other items within a domain. A score above 0.5 is widely considered the benchmark for validity, while a score between 0.3 and 0.5 is considered acceptable (Raharjanti et al., 2022). The observations were similar to factor loading data, with low correlation values for K8, A18, P16, and seven more items related to consumption habits in the new practice domain (items D1, D2, D4, D6, D8, D9, and D10).

It is important to note that the items K8 (*Do you believe that healthy and sustainable diets mean the same?*), A18 (*How important is it for you that the products you consume are produced sustainably?*) and P16 (*To what extent are you willing to pay more money for food and drinks that are produced in a sustainable way?*) are questions that are intended to assess knowledge, attitude and practice, respectively,

TABLE 9 Correlations between domain response and sociodemographic characteristics.

	Domain K (8 items)		Domain A (18 items)		Domain P + D (28 items)	
	Spearman Rho	p-value[1]	Spearman Rho	p-value[1]	Spearman Rho	p-value[1]
Age	0.288	<0.001	0.334	<0.001	0.353	<0.001
BMI	0.098	0.053	0.149	0.003	0.131	<0.010
Gender	0.129	0.011	0.143	0.005	0.137	0.007
Nationality	0.249	<0.001	0.172	<0.001	0.227	<0.001
Marital status	0.163	0.001	0.235	<0.001	0.241	<0.001
Family size	−0.164	0.001	−0.155	0.002	−0.231	<0.001
Education	0.176	<0.001	0.217	<0.001	0.253	<0.001
Employment	0.183	<0.001	0.193	<0.001	0.219	<0.001
Income	0.157	0.002	0.178	<0.001	0.199	<0.001
Nutrition training	0.204	<0.001	0.18	<0.001	0.105	0.039
Nutrition knowledge	0.259	<0.001	0.243	<0.001	0.224	<0.001

[1]Statistical significance set at $p \leq 0.05$.

they are also different in nature to the other items in their respective domain. Hence, the low factor loadings could be attributed to the nature of the items. However, for contextual relevance, these items are essential elements of SDQ. Item K8 assesses whether an individual knows to distinguish between healthy food and sustainable food because what is healthy may not always be sustainable (Lindgren et al., 2018; Willett et al., 2019). Similarly, it is also essential to understand if sustainability motivates an individual's food choice and whether price is a potential barrier to diet sustainability practice, which items A18 and P16 gauge. Items D1 to D12 in the practice domain assess the consumption frequency of various foods. Measuring accurate patterns of food consumption is significantly hindered by the tendency of individuals to under-report or over-report certain foods considered unhealthy or healthy, respectively, when using self-reported measures (Asbeck et al., 2002; Hopkins et al., 2021). A variety of psychological, personality, and social characteristics have been proposed as potential indicators of misreporting intake measures in respondents, including dietary restraint (Asbeck et al., 2002), social desirability and approval (Hebert et al., 1997), as well as socioeconomic status and educational level (Pryer et al., 1997). The unsatisfactory indices in our result for items related to consumption habits could be attributed to measurement errors. Despite the errors associated with self-reported intakes, a substantial body of evidence indicates that dietary intake data can effectively inform nutritional guidelines and public health policies (Subar et al., 2015). The scientific rationale for including items related to consumption habit was to get a qualitative measure of sustainable consumption of the population in correlation with their knowledge, and attitudes. In this context, self-reported consumption data could be valuable in answering a number of key sustainability-related questions. These include characterizing the types of foods consumed by individuals and its frequency with higher knowledge score and positive attitude compared with those with low knowledge score and negative attitude to sustainability. Hence, all of these items are relevant to the conceptual framework of the SDQ.

Moreover, our findings underscore the reliability of all three domains of the SDQ. In many studies, Cronbach's alpha is the most frequently reported reliability coefficient (Tavakol and Dennick, 2011; Cho, 2016). This coefficient, a measure of internal consistency, is generally deemed reliable when values exceed 0.7 (Tavakol and Dennick, 2011). At the same time, others have highlighted a reliability standard of 0.8, indicating that reliability of 0.7 implies only modest reliability (Lance et al., 2006). Schmitt (1996) suggests that there is no universally accepted threshold for α coefficients and that instruments with even lower α values can still be helpful in specific contexts. Nevertheless, the Cronbach's α value for the three domains in our study was above 0.8 and 0.959 for the whole model. Another statistical method for scale validation is test–retest reliability (Woolson et al., 1986), for which the SDQ model demonstrated excellent reliability. When 131 participants completed the questionnaire a second time after an interval of 2–3 weeks, there was no significant change in the domain scores, suggesting that the responses were stable over time.

We also analyzed the association between the three domains of SDQ. Knowledge of sustainable diets was highly correlated with both attitudes and practices. However, the practice of sustainable diets had a higher association with the population's attitude than their knowledge. It is important to note that efforts to promote sustainable food consumption compete with other contextual influences on people's food choices (Leng et al., 2017; Cairns, 2019). Changing food habits is difficult because they are deeply ingrained in people's lifestyles and sociocultural surroundings (Caso and Vecchio, 2022). Food choices are also influenced by the marketing strategies of food companies (Booth et al., 2001), which have led to shifts in dietary norms and the cultural values that guide food behaviors (Roudsari et al., 2017). The nature of food-related decisions renders them vulnerable to a wide array of social, cognitive, emotional, and environmental factors. Hence, individuals can know and express environmental concerns but do not consistently act on them. Numerous studies also report this type of gap between awareness and practice regarding healthy food choices (Brown et al., 2000; Abdelhafez et al., 2020; Liu et al., 2022). It is also important to note that people may follow a sustainable diet without sustainability being the primary reason for their practice. For example, many individuals across the globe follow a vegetarian diet for religious reasons, and plant-based diets are considered the healthiest and most planet-friendly.

Our study findings indicate that in this population, older adults who are employed with higher educational status and belong to the higher income bracket have higher levels of knowledge, attitude, and practice related to sustainable diets. Although the strength of these correlations was weak, it is important to consider them because, in such population studies, the direction of the correlation is of greater interest than the strength of the association (Mohammadi et al., 2018; Alhebshi et al., 2023). Gender and nationality were also significantly correlated to all three domains in our population, but this might be a factor of the sample itself because we had a considerably higher proportion of females and UAE nationals among our respondents. Interestingly, there was also a significant positive correlation between the domain scores with nutrition knowledge and formal nutrition education in the population. This observation indicates that with proper nutrition education, the population can practice the elements of sustainable diets, such as incorporating more plant-based proteins, fruits and vegetables. In addition, we found that household size was negatively correlated with domain response scores. This observation is not unique; a study by Hong et al. (2020) reported that the number of household members significantly affects the expenditure on unhealthy food. For each increase in the number of household members, the amount of unhealthy food expenditure increased by 0.6510 in this study (Hong et al., 2020). BMI was positively correlated with higher domain scores. A critical association to consider is the positive correlation of BMI with the practice domain. It is reported that individuals with higher BMI can practice dietary restraints to control their weight (Johnson et al., 2012; Alhebshi et al., 2023). There is also the tendency to misreport the intake of unhealthy foods in these higher BMI groups (Hopkins et al., 2021), which could influence this association independently of sustainability concerns. Our study is not without limitations, including a predominance of young adults and individuals with higher educational backgrounds, reflecting the university setting of the research. Moreover, SDQ is an English tool that requires translation and validation in Arabic before being used among the wider UAE population. Additionally, the self-reported nature of consumption habits may introduce response bias, necessitating caution when extrapolating the findings to the general population.

5 Conclusion

The study demonstrated that the newly developed SDQ is a reliable and valid instrument for evaluating knowledge, attitudes, and practices concerning sustainable diets among adults, as evidenced by the scale's construct validity. Our diverse sample, encompassing respondents from 30 countries, underscores the tool's applicability across various demographic groups. Consequently, the SDQ is instrumental in assessing knowledge, attitudes, and practices, thereby aiding the formulation of effective strategies to promote sustainable behaviors. This knowledge can enable researchers to design targeted behavioral change interventions aligned with the United Nations' SDGs. However, since the SDQ was validated among people with at least a high school degree, its use among the general population must be cautiously approached. An Arabic version of the tool is also warranted for broader use among the UAE population and the Arabic-speaking region. Despite these limitations, the SDQ remains valuable for advancing research and interventions in sustainable dietary practices among educated adults.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving humans were approved by the Social Sciences Research Ethics Committee at United Arab Emirates University. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their informed consent to participate in this study.

Author contributions

SH: Data curation, Formal analysis, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing. SS: Data curation, Formal analysis, Investigation, Methodology, Software, Writing – review & editing, Writing – original draft. RS: Formal analysis, Methodology, Supervision, Writing – review & editing, Writing – original draft. AN: Data curation, Investigation, Writing – original draft, Writing – review & editing. SZ: Data curation, Investigation, Writing – original draft, Writing – review & editing. CP: Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Writing – review & editing, Writing – original draft.

Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This research was supported by ASPIRE, the technology program management pillar of Abu Dhabi's Advanced Technology Research Council (ATRC), via the ASPIRE VRI (Virtual Research Institute) Award (fund code ARIFSID 21R097).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2024.1432057/full#supplementary-material

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