Original Research Paper

Image-based dietary assessment skills of undergraduate nutrition and dietetics students in a multicultural developing country

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Abstract

Background: Image-based dietary assessment is a digital method relatively new in nutrition education. We aimed to evaluate the nutrient estimation skills of nutrition and dietetics students in Malaysia using image-based dietary assessment, and develop a tool to assess their image-based dietary assessment skills. **Methods:** The study was performed among undergraduate nutrition and dietetics students in two phases. Phase One (n=75) was conducted in four steps: 1) photography of food/beverage at two angles (45° and 90°) with and without a fiducial marker (ruler/dessert spoon); 2) study tool establishment; 3) pre-testing; and 4) conduct of the study. Incorporating changes from Phase One, 55 students participated in Phase Two. Participants were evaluated on their accuracy in recognizing and estimating portions and nutrients of a food/beverage. Data analysis included response frequency and percentages, and statistical differences (Wilcoxon Signed Rank test) in estimating nutrient content. **Results:** In both phases, the participants scored above 80% for the correct identification of most food items. Participants scored the lowest when estimating nutrient content in local snacks [median (IQR): Phase One, 12.5% (25.0); Phase Two, 16.7% (16.7)]. Participants in Phase One showed better nutrient estimation skills with both fiducial markers, however, no significant difference was observed in Phase Two [without: 21.1% (7.9%); with the dessert spoon: 19.0% (13.8%), p=0.197]. Participants' knowledge, skills, and food images were the main barriers to accurate nutrient estimation. **Conclusion:** Our study found poor nutrient estimation skills among Malaysian undergraduate nutrition and dietetics students**.** These key findings warrant urgent attention to address this through innovative dietary assessment training on food and portion size from images.

Keywords: Dietary assessment, dietetics, health professions education, fiducial marker, Malaysia, students

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Introduction

Dietary assessment is the evaluation of food and beverage consumption to monitor an individual's nutritional status[1] and is used to advise, validate, and review dietary outcomes in nutrition interventions, to possibly reduce disease occurrence, and develop prophylactic interventions for chronic diseases.[2-4] Traditional dietary assessment methods, including 24-hour diet recall, food frequency questionnaires, and weighed food records, are taught and practiced by dietitians and nutrition (DN) professionals globally. These methods have several drawbacks, such as reliance

on participant reporting,[1] food knowledge,[2-4] recall bias,[1-5] and burden on participants.[2-6]

Image-based dietary assessment (IBDA) is an approach to estimate dietary intake based on images taken either actively or passively by the participants,[7] and subsequently, used by DN professionals to analyze the nutrient intake.[8] The active mode involves capturing food images via mobile or digital cameras whereas, in the passive mode, food images are captured automatically by camera devices worn by the participants, such as SenseCam[9] and eButton.[10] With the IBDA method gaining in popularity, the accuracy of interpreting the nutrient content through food images becomes crucial.[11-13]

IBDA usage was evaluated and compared.[14] Food images enhance self-reporting by revealing unreported foods and identifying misreporting errors not captured by traditional methods alone.[9,15,16] In some studies, when used as a primary record of dietary intake, food images can provide valid estimates of energy intake.[17,18] However, a recent meta-analysis and systematic review showed IBDA greatly underestimated energy intake when compared to doubly labelled water.[19] Due to the complexity and diversity of foods, IBDA is likely to underestimate energy intake if incorrect procedures are followed and images are unsatisfactory.[18,20,21]

Malaysian diets are considerably complex with a variety of foods, especially composite foods, and communal eating practices,[22,23] which may increase measurement errors, and pose challenges for in-depth investigations using food images.[22,23] In most scenarios when interpreting the nutrient content through food images, a fiducial marker is placed next to the food, acting as a reference point or a measure. Spoons, rulers, checkerboard cards, and credit card-sized reference cards have been reported, yet evidence of their validity is limited.[3,11,24] Similarly, data on the interpretation of nutrient content through food images and fiducial markers among nutrition professionals are scarce.

Only a few studies have been performed globally among nutrition professionals and undergraduate students with inconsistent outcomes and small sample sizes, ranging from 12 to 114 participants.[11,16,25-27] To our knowledge, there is no formal training program in Malaysia on IBDA skills, and given the increasing accessibility of mobile technology, this study aimed to determine food identification and nutrient estimation skills using food images among undergraduate DN students, and to develop a tool to assess their IBDA skills. Factors affecting IBDA skills were identified.

Methods

The research was conducted in two phases. In Phase One, we developed and piloted an assessment tool on nutrient estimation skills of undergraduate students using food images. Following the pilot test, the developed tool was revised and tested in Phase Two among undergraduate students from different universities in Malaysia. This study was conducted according to the Declaration of Helsinki and all procedures involving human subjects were approved by the ethics committee [BDNI-2020 (19) & BDNI-2021 (08)].

Four data collection steps were implemented in Phase One, from January 2021 to May 2021: 1) development of food images; 2) establishment of the study tool; 3) pre-testing of the study tool; and 4) conduct of the study.

Development of food images

A list of foods, local snacks *(kuih)*, fruits, beverages, and assembled meals was developed. These items were representative of main Malay, Indian, Chinese, and Western meals and snacks in Malaysia. The assembled meals were combinations of one food and one beverage with either one snack or one fruit. Before imaging, all items were weighed (in grams). The measurements were used to determine the nutrient values [energy (kcal), carbohydrate (g), protein (g), and fat (g)] based on Nutritionist Pro™ Diet Analysis (Axxya Systems, Washington, United States of America) referenced against two national food composition databases from Malaysia[28] and Singapore.[29] The reliability testing revealed a Cronbach-alpha of 0.76.

During photography, a lightbox was set up for clear food images, and markings were done. A 16-megapixel rear phone camera was placed on tripod stands at two fixed angles of 45° and 90°. The height, distance, and degree of zoom between the food and the camera were fixed and all images were taken in portrait orientation. The images were repeated for all items alone and with a fiducial marker (dessert spoon/ruler), placed on the right-hand side of the food.

Establishment of study tools

The study tool comprised four sections: (1) socio-demography, food identification, and portion size estimation; (2) nutrient estimation without a fiducial

marker; (3) nutrient estimation with a fiducial marker (dessert spoon/ruler); and (4) factors affecting IBDA skills.

In section 1, participants were required to name the food items referring to the food images. They identified the corresponding portion size as either small, regular, or large. A small portion was defined as less than 40% of the serving, 90-110% of the serving as regular, and more than 160% of the serving size as large. In sections 2 and 3, participants were asked to estimate the nutrient values for each item. They were provided six answer options, ranging between 10% and 120% of the correct answer. The correct answers of the nutrients were based on local food composition tables,[28,29] and previous similar studies.[11,30]

For section 4, eleven questions were developed[17] to explore factors affecting IBDA. There were seven close-ended questions on the angle of the food image, the usefulness and challenges of using fiducial markers in estimating portion size and nutrients, and participants' willingness to use the IBDA method in future practice. Open-ended questions (n=4) covered facilitating and hindering factors in performing nutrient estimation, suggestions for other fiducial markers, preference for the IBDA method, and recommendations.

Pre-testing of the study tool

Six participants completed the pre-testing via the online platform [SurveyMonkey (SVMK Inc.)]. The pre-testing was done on three separate weekdays. A one-day interval was set to avoid bias in question order due to a similar flow of questions and answer options. Section 1 was completed on day 1, followed by Section 2 on day 2, and both Sections 3 and 4 on the third day of the research.

Conduct of the study

The sample size was calculated using a 95% confidence interval and a 5% level of significance based on Howes *et al* [25] (margin of error was 0.8), and the final required sample accounting for 20% of dropouts was 132. The data collection was conducted via an online platform during the COVID-19 pandemic. The convenience sampling method was used as main method for recruitment to address the imposed movement control that restricted face-to-face contacts. In total, 75 participants joined Phase One (57% of response rate). This study recruited current undergraduate DN students in Malaysia who had completed the topics on dietary assessment methods. Students who did not meet the study eligibility and/or did not complete the questionnaire were excluded.

Considering findings from Phase One, several changes were made in Phase Two to the food images and study tool. Firstly, the category of beverages was removed due to the misrepresentation of the beverages based on their color (Cola, Pepsi, Sarsi, or coffee) which could affect the results of nutrient estimation.[11] Secondly, common food items available in Malaysia but not included in study 1 (n=5) were added, including curry laksa noodles, chicken rice, *thosai* (fermented rice and lentil pancake), brownies, and papaya. To account for composite food intakes, two popular rice dishes, known as mixed rice, were incorporated. Mixed rice 1 represented the Chinese-style consisting of rice, fried chicken, stir-fried long bean, and *choy sum* (mustard green leaf); whereas rice, snake gourd stir-fried with carrots, and fried mackerel with chilli represented Malay-style mixed rice 2.

After weighing each food item and calculating nutrient values,[28,29] all food images were re-taken without, and with only one, fiducial marker (dessert spoon), keeping the height and distance between food and camera constant at 45° and 90° angles. To improve the quality of food images, a tripod, and a 24 megapixels camera (Nikon Digital Single-Lens Reflex) were used. For Phase 2, 15 food items and 76 food images were included and met the acceptable reliability index, Cronbach-alpha of 0.612.[31] The subsections on portion size estimation and questions on the ruler as the fiducial marker in Phase One were eliminated. The study tool was revised from four to three sections and was allowed to be completed on two separate weekdays to reduce questionnaire fatigue.

The survey for Phase Two was administered online via Google Forms between December 2021 and April 2022. Undergraduate students from Malaysian universities offering nutrition and/or dietetics programs were invited, and 55 participated.

Data Analysis

The responses for food identification and nutrient estimation without, and with, a fiducial marker(s) were classified as either 'accurate' or 'inaccurate'. For food identification, the response was considered 'accurate' if it was consistent with the correct answer. Conversely, the response was recorded as 'inaccurate' if it was incorrect, or if it did not match the images. In terms of nutrient estimation, the

response was recorded as 'accurate' if matching the standard answer; otherwise, it was considered 'inaccurate'.

Statistical analysis was performed using Statistical Package for Social Sciences Version 26 (IBM® SPSS Statistics, United States of America), with a *p*-value of less than 0.05 indicating statistical significance. Categorical data on sociodemographic characteristics were expressed as frequencies and percentages. Median and interquartile ranges (IQR) were used to present descriptive statistics while the Wilcoxon Signed Rank test was performed to compare the percentage of nutrients correctly estimated with and without a fiducial marker. For the open-ended questions, the responses were analyzed based on content analysis where they were coded and counted using Microsoft Excel Version 26 (Microsoft Corporation, Kuala Lumpur, Malaysia).

Results

Participant characteristics

In Phase One, 75 participants completed the survey while 55 participated in Phase Two. In both phases, most participants were Malaysian Chinese females studying in semester 6 of the undergraduate program. About 36% of the participants rarely cooked and more than 80% of the participants either never, or rarely, used measuring tools when cooking. Those reporting experience with IBDA were 65.1% and 61.8%, respectively in Phase One and Two.

Skills in food identification and nutrient estimation

Accuracy of food identification skills in percentages was identified. In both studies, the participants scored correctly above 80% for most of the food items including *nasi lemak*, *char kuey tiao,* fish and chips, *kuih lapis*, curry puff, guava, and watermelon. Similarly, the additional food items in Phase Two scored above 80%, except for *thosai* (74.5%). Banana leaf meal was commonly misinterpreted (Phase One: 37.3%; Phase Two: 29.1%) as *nasi kandar* (white rice served on a plate with an assortment of meat and vegetables, covered in thick curry sauce), while cola drink was misinterpreted as *cincau* or herbal drink. For portion size estimation, out of four items, the fish and chips dish was most correctly estimated (65.3%) while curry puff had the most inaccurate responses (53.3%).

Accuracy of nutrient estimation skills based on various categories of food images (all combined, individual food items, main meals, *kuih*, fruits, and assembled meals) was determined. In both studies, participants scored the highest when estimating fat content in fruits irrespective of without, and with, fiducial markers [median (IQR): 100% (0.00), 66.7% (0.00), respectively], and the lowest (score of 'zero') for *kuih* in Phase One (all nutrients), and Phase Two (energy and carbohydrate).

The correct answers (in percentage) for nutrient estimation were generally higher in Phase One when fiducial markers (ruler and dessert spoon) were provided in the food images as opposed to Phase Two. Specifically, the use of a ruler or dessert spoon as a fiducial marker in Phase One significantly improved participants' estimation skills for assembled meals (18.8% versus 12.5%, $p=0.006$; 18.8% versus 12.5%, $p<0.001$) and for all categories combined (21.4% versus 19.6%, $p=0.002$; 21.4% versus 19.6%, $p<0.001$). However, in Phase Two, there were no significant differences for energy and nutrients across all food items (n=15) and assembled meals (n=4) ($p>0.05$).

Facilitators and barriers to IBDA skills

The main facilitators and barriers to IBDA skills were similar in both phases. Phase Two participants stated that the use of fiducial markers and serving equipment was the most important facilitator (n=25, 33.3%). The lack of good quality food images, appropriate angle, and quality was ranked as the top barrier in Phase One (n=25, 33.3%). In Phase Two, participants provided the same number of responses (n=3, 5.5%) for the identified three categories of facilitators: 1) fiducial markers and serving equipment; 2) familiarity, experience, and knowledge; and 3) food images. In Phase Two, the participants' lack of familiarity, experience, and knowledge were the main hindering factors (n=20, 36.4%) toward nutrient estimation skills.

Discussion

To our knowledge, our results are the first to quantitatively measure IBDA skills among undergraduate DN students in Malaysia. Findings from our study extend previous literature examining dietary assessment skills amongst the community in Malaysia.[3,11] The results suggest the need to implement training on IBDA methods for students to improve the estimation of food portions and nutrients, and serve as evidence to strengthen the nutrition and dietetics curriculum design and

delivery, by applying educational theories such as constructivism and social constructivism.[32]

The ability to identify individual food and beverage in the present study was consistent with studies done locally[11] and internationally.[25] These studies used commonly consumed food/beverage images, which are more likely to be encountered by undergraduates and professionals in their training and practice. Inadequate knowledge and skills were cited as the main barrier to IBDA nutrient estimation skills in the present study, similar to those reported in the literature.[14] Traditional dietary assessment methods are taught at the initial phase of the curriculum, and IBDA is being slowly adopted formally for up-to-date knowledge and hands-on skills.[25,27] Students' competency and familiarity with digital food photography must be developed alongside rapid technological development.[26,33]

Most participants in our study were unable to correctly identify two types of Indian cuisines: banana leaf meal and *thosai*. A key reason for this is that most participants were of Chinese ethnicity. Hence, the lack of familiarity with other ethnic-specific cuisines aside from one's own culture could explain our findings. Multi-ethnic diets are considerably complex.[22,23]

Another explanation for poor skills was the challenge of differentiating items with similar appearances from the images. The inability to differentiate foods due to the similarities in their physical appearances had been published elsewhere.[3] Food items being wrongly identified include mistaking whole wheat bread as rye bread, and ham luncheon meat as fresh ham.[25] A Japanese study amongst adults concluded that including additional text descriptions of the food images might improve the image analysis to address the complex and traditional Japanese dishes,[23] which can be explored in a future study.

The overall median scores for nutrient estimation without, and with, fiducial markers were around 20% reflecting a poor ability to correctly estimate the nutrients from the food images. Such poor performance could be related to unfamiliarity with the fiducial marker aside from the lack of knowledge and skills. Participants in Phase One cited better nutrient estimation skills when using household measurements and hand-based methods such as the food exchange list[34] and hand jive.[35] The exchange list consists of information on serving sizes for each food under specific food groups[34] while the hand jive was invented as a measurement tool for appropriate portion sizes of carbohydrates, fats, protein, and vegetables.[35] These approaches are developed in a user-friendly manner to assist patients requiring specific dietary management, especially those with diabetes.[36] The students also find these more useful and easier as a reference, especially when they have low knowledge and skills in food preparation and household measurements. Such practical skills can be transferable to patients and public to improve their food portion and dietary intake management. With increasing lifespan and chronic diseases, proper nutrition and physical activity are highly important to maintain health.

Poor image quality posed major challenges in other studies among professionals,[11,21] and the public.[18,20,21] The estimation of nutrients relied heavily upon the photographs including zoom factor, angle, and distance. This is further complicated by hidden ingredients (e.g., butter, oil, and sugar) that even trained nutrition professionals may have trouble identifying and quantifying.[11,25] These challenges are well-reflected in our study as some of the popular food items from different cultures had the lowest correct scores because they are prepared either using a large amount of sugar (*kuih lapis)* or oil (curry puff), hence having higher energy and macronutrients. IBDA alone may not provide accurate analysis and must be supported by additional dietary information provided by the users to achieve optimal accuracy.[17,20,21]

The strengths of this study include food images captured from two angles and all images being prepared under the standardized protocol. The inclusion of the participants' open feedback supplemented and strengthened the quantitative findings. The small sample size for both phases can introduce bias and limits the generalizability of the study, however, the current findings provide a valuable insight into the status of the undergraduate nutrition and dietetics education in Malaysia.

The studies were conducted online during the movement restrictions imposed for COVID-19 pandemic, the participants answered the questionnaires independently without supervision, therefore, there may be a possibility of respondent bias, and a low response rate. Challenges in identifying beverages in Phase One could be inherent to IBDA suggesting additional information would be essential, aside from food images alone, instead of omission of the items.

Our study was the first to measure IBDA skills among undergraduate nutrition and dietetics students in a multicultural developing country**.** Despite the ability to correctly identify food items, participants demonstrated poor nutrient estimation skills. Considering the importance of DN professionals' ability to perform IBDA, the accuracy, and skills of nutrient estimation could be further improved with better food photography, innovative technology-based training and enhanced access to multicultural food databases. With advances in technology, IBDA will become more common in the future training of DN professionals in this vital skill. This provides opportunities for curriculum development in IBDA that could potentially change the landscape of nutrition education in Malaysia and beyond.

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