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Development and validation of a digital photographic food atlas of Malaysian foods

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ABSTRACT

Introduction: Portion size estimation elements (PSEE), such as food atlas, are utilised to improve portion size estimation accuracy in dietary assessments. Digital food atlases offer advantages like high accuracy, convenience, and portability. This study aimed to develop and validate a digital food atlas comprising commonly consumed Malaysian foods. **Methods:** Foods were selected based on national food consumption data. Photographs were taken at 45-degree angle under standard lighting conditions. During validation study, 41 Malaysian university staff and students (mean age 25±9 years) were recruited to estimate the portion of 33 pre-weighted foods using the atlas. Validity of the atlas was determined by comparing actual versus estimated weight of test foods using Wilcoxon signed-rank test. Subsequently, a usability questionnaire evaluated the atlas's usefulness. **Results:** In total, 91 foods were included in the atlas. Significant differences were present in 23 food items tested in validation study, ranging from 54.9% underestimation to 95.1% overestimation. The digital food atlas received high usability scores, with an average of 3.2/4 for carbohydrate foods, and 3.3/4 for protein and fruit/vegetable sections. **Conclusion**: This study developed and validated a digital food atlas of commonly consumed local foods, potentially improving accuracy of portion size estimation in dietary assessments. Further modification by including wider range of foods and validation among diverse ethnic and age groups is warranted before its widespread use. Integration into clinical practice, research, and public health initiatives could further support dietary assessment and portion size education.

Keywords: dietary assessment, digital food atlas, portion size estimation

INTRODUCTION

Malaysia faces the double burden of malnutrition. Undernutrition remains prevalent, especially among the elderly population, where data estimated that one-third of older adults are either malnourished or at risk of malnutrition (Ahmad *et al.*, 2021). Concurrently, Malaysians are also burdened by diseases related to overnutrition, mainly obesity (20.1%), type 2 diabetes (14.4%), and heart diseases (17.7%) (Akhtar *et al.*, 2022). Diet plays a crucial role in addressing these issues.

Portion size estimation is one of the most crucial components of dietary assessment. Misreporting food volumes may lead to inaccurate nutrient intake assessments and misinterpretation of diet-health relationships (Ravelli

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& Schoellar, 2020). To address this, portion size estimation elements (PSEE) have been proposed as solutions.

A photographic food atlas is a compilation of pictures depicting commonly consumed local foods in various portion sizes (Wong & Wong, 2020). Compared to other PSEE, food atlases are inexpensive, portable, and easy to use (Shinozaki *et al.*, 2022). Food atlas should be adapted to the local context using national food consumption data (Shinozaki *et al.*, 2022; Ali *et al.*, 2018). Given Malaysia's rich culinary diversity, a culturally inclusive atlas that features a range of commonly consumed Malaysian dishes is essential for accurate portion estimation across different dietary patterns.

Although several Malaysian food atlases have been developed (Wong & Wong, 2020; Zainal Badari *et al.,* 2015; Abdul Ghaffar *et al.,* 2011; Suzana Shahar *et al.,* 2015), many face limitations in public accessibility (Wong & Wong, 2020; Zainal Badari *et al.,* 2015) and lack of validation (Wong & Wong, 2020; Abdul Ghaffar *et al.,* 2011; Suzana Shahar *et al.,* 2015), raising concerns about their accuracy and usability. In addition, inconsistencies in photographic methods, such as varying camera angles, distances, and lighting conditions, further compromise the precision of portion size estimation (Abdul Ghaffar *et al.*, 2011; Suzana Shahar *et al.,* 2015). These methodological gaps highlight the need for a standardised photographic protocol, including the use of fiducial markers, to improve visual consistency and measurement accuracy. Moreover, rigorous validation procedures are essential to ensure the reliability and applicability of food atlases in dietary assessment (Ding *et al.,* 2020; Harris-Fry *et al.,* 2016; Jayawardena & Herath, 2017; Shinozaki & Murakami, 2022).

Technological advancements have facilitated the digitalisation of food atlases (Shinozaki *et al.*, 2022; Flax *et al.*, 2019). Compared to the traditional version, digital atlases are easily distributed, inexpensive, and practical, making them a valuable tool for large-scale epidemiological studies (Nichelle *et al.*, 2019). Additionally, they enable real-time updates and improve interactivity (e.g., zoom functionality). Importantly, validation studies that compare digital and physical food atlases found no statistical difference in portion size estimation accuracy (Nichelle *et al.,* 2019). This study aimed to develop a comprehensive digital food atlas consisting of commonly consumed Malaysian foods and assess its validity and usability among the public.

MATERIALS AND METHODS

Development of the food atlas

Sequential design was used in the development and validation of the food atlas. Food selection was based on consumption frequency and nutritional relevance. A comprehensive list was compiled from a published dietary survey (IPH, 2014), Malaysian Dietary Guidelines (MDG) (NCCFN, 2021), an existing food atlas (Abdul Ghaffar *et al.*, 2011), and menus of popular local restaurants (Badrasawi *et al.*, 2023; Tueni *et al.*, 2012).

Food photographs were presented as a series or guide (Figures 1 & 2). Foods commonly served without predetermined portion (e.g., rice, vegetables) were shown in 4-6 images with increasing portion sizes, providing a sufficient range without overwhelming the users (Subar *et al.,* 2010). Recommended portions from the MDG (NCCFN, 2021) and *Album Makanan Malaysia* (AMM) (Abdul Ghaffar *et al.*, 2011) were used as references. Conversely, guide photographs depicted single-unit foods (e.g., fried chicken, orange) with portion sizes reflecting market availability. The categorisation

P4. Fried *tenggiri*

115g 85g 68g 50g

P4-1

Figure 1. Guide photographs in the atlas

P3: Beef *rendang*

43g

P3-1

85g

P3-2

128g

P3-3

170g

P3-4

Figure 2. Series photograph in the atlas

of series and guide photographs aligns with previous studies conducted in Japan and Sri Lanka (Jayawardena & Herath, 2017; Shinozaki *et al.*, 2022).

Food items were sourced from various local eateries, then weighed using a Tanita KD321 (Tokyo, Japan) kitchen scale with precision of 1g to obtain the weight of every portion of food. Standard white plates (23 cm in diameter) and white bowls (17.5 cm in diameter) were used to present the food items to enhance visibility.

Foods on plates were photographed at a 45-degree angle, while foods in bowls used a 30-degree angle to ensure clear depth and surface area visibility, aligning with studies in Nepal and Sri Lanka (Jayawardena & Herath, 2017; Harris-Fry *et al.*, 2016). The angles were kept consistent by mounting a digital single-lens reflex (DSLR) camera, the Canon EOS 850D (Tokyo, Japan), on a tripod with an angle indicator. Lighting was provided by the Godox TT685 flash (Shenzhen, Guangdong, China) mounted on a softbox for consistency. Standard camera settings (1/11s, F10, ISO400) were used to keep lighting consistent with strategic light filling, using a whiteboard for even illumination.

A white tile backdrop was used. Fiducial markers, which included a dessert fork (18.5cm), dessert spoon (18.5cm), and a standard credit card (54mm x 85.5mm), were photographed alongside food items for scale. Each image was uniquely coded and compiled into a PDF for accessibility.

Validation of the developed atlas

A validation study was conducted to gauge the accuracy of the developed atlas. Given the impracticality of validating all food items due to potential cognitive fatigue, 33 items were selected for evaluation, with portion sizes assigned randomly, aligning with a previous study done in Japan (Shinozaki *et al.,* 2022).

Ethical approval was obtained from the IMU Joint Committee on Research and Ethics [Project ID of BDN 1-2023 (07)]. The Declaration of Helsinki was followed. Written consent was obtained from subjects before participation.

Sample size was calculated using an online calculator (Ristl, n.d.) based on the mean and standard deviation from a Japanese study (Shinozaki *et al.*, 2022). Accounting for a 20% drop-out rate, 41 Malaysian participants (aged 18-65 years), who frequently consumed Malaysian foods, were recruited from a local university via convenience sampling. Exclusion criteria included individuals with nutrition or dietetics background, those on special diets, and those with severe neurological and visual deficits or severe allergies.

The validation session was conducted in the university's nutrition and dietetics laboratory. Foods to be validated were weighed and presented using identical plates and bowls from the food atlas. Participants validated the 33 test foods in 3 rounds (10-12 foods each round) to minimise fatigue. They were given a 30-second time limit to validate each food, with a 3-minute break between rounds. Participants observed pre-weighted foods, selected the image with the portion closest to the test food and recorded their choice, noting any foods they found difficult to estimate.

After the validation session, participants completed a usability questionnaire and evaluated individual sections (carbohydrates, proteins, and fruits and vegetables) using a bilingual questionnaire adapted from three validated evaluation tools (Kaphingst *et al.*, 2012; Clayton, 2009; Agency for Healthcare Research and Quality, n.d.). The questionnaire assessed content, layout and design, portrayal of food, and overall suitability. Additional feedback was recorded at the end of the questionnaire.

Statistical analysis

Statistical analysis was conducted using IBM SPSS Statistics for Windows version 29.0 (IBM Corporation, Armonk, New York, United States). Participants' characteristics and sociodemographic data were presented as frequency and percentage. Absolute differences (in grams) between estimated and actual portion sizes were analysed using Wilcoxon's signed-rank test. Furthermore, relative difference (in percentage) was computed using the formula below:

Relative difference (%) = (Estimated portion size – actual portion size) / actual portion size * 100%.

Mann-Whitney U test was used to compute the relative difference between estimation error and participants' characteristics, including age, gender, ethnicity, body mass index (BMI), occupation, and cooking frequency. A *p*-value less than 0.05 was considered statistically significant.

The usability questionnaire was analysed using descriptive analysis to compute mean scores for each domain and the overall mean score. Frequency (%) was used to analyse the proportion of participants who agreed or disagreed with each question.

RESULTS

Development of the food atlas

In total, 91 food items were photographed, with 19 foods depicted as guides and 72 as series. For ease of navigation, the atlas was divided into four sections: composite foods, carbohydrate foods, protein foods, and fruits and vegetables. Additionally, food items photographed as a series were condensed into a single page to streamline navigation. Food names were displayed at the top of every page, with Malay and English versions included for accessibility. The weight of all portions was labelled at the bottom of the images.

Participants' characteristics

Table 1 presents the sociodemographic characteristics of the research participants. Among 63 participants who signed up for the study, five did not meet the inclusion criteria and 18 did not attend the session. Consequently, 41 participants with mean age of 25±9 years and mean BMI of 22.4±4.2 kg/m^2 were included in the analysis. The majority were between 18-25 years old (80.5%), females (56.1%), of Chinese ethnicity (73.2%), and university students (73.2%). The education level of this cohort was relatively high, with all participants having attained tertiary-level education. More than two-thirds of the participants either never cooked or were cooking less than twice weekly.

Accuracy and correctness of portion size estimation

Table 2 shows the difference between the actual and estimated weight of test foods validated. Of the 33 foods validated, significant differences were observed in 23 items, with relative differences ranging from a 54.9% underestimation for oats to a 95.1% overestimation for tuna. Foods that had the smallest estimation errors included beef rendang (-1.2%), tempeh *goreng kicap* (-1.2%), and jackfruit (1.7%), while tuna had the largest error (95.1%). The average relative difference between estimated and actual portion size across all items was 1.9%.

Table 3 shows the overall correctness of the validated foods. In total, 1353 estimations were made for validated foods, with more than half (54.2%) of the responses correct (selection of image with the correct portion size). Food items were more frequently underestimated (30%) than overestimated (15.8%).

Table 1. Participant characteristics

Variables	Values	
	Mean±SD	*n (%)*
Gender		
Male		18 (43.9)
Female		23 (56.1)
Ethnicity		
Malay		7 (17.1)
Chinese		30 (73.2)
Indian		4 (9.7)
Age (years)	25±9	
Body height (cm)	165.4±13.8	
Body weight (kg)	61.3±9.6	
Body mass index (kg/m^2)†		
Underweight (<18.5)		4 (9.8)
Normal (18.5 - 22.9)		24 (58.5)
Overweight & obese (>22.9)		13 (31.7)
Education		
Tertiary level education		38 (92.7)
Higher level education		3 (7.3)
Income level‡		
RM 0 - RM 5250		33 (80.5)
RM 5251 - RM 11819		4 (9.8)
RM 11820 and above		1 (7.3)
Cooking frequency (days per week)		
Never		15 (36.5)
1 - 2		10 (24.4)
3 - 4		8 (19.5)
5 - 6		4 (9.8)
Everyday		4 (9.8)
Occupation		
Student		30 (73.2)
Staff		11 (26.8)

†Body mass index categorisation from Pan WH & Yeh WT (2018). How to define obesity? Evidence-based multiple action points for public awareness, screening, and treatment: an extension of Asian-Pacific recommendations. *Asia Pac J Clin Nutr* 17(3):370–374.
‡Income categorised according to Malaysian income groups

Individual food items exhibited varying degrees of correctness. Sambal tofu garnered the highest number of correct estimations, where 40 out of 41 estimations were correct. This is likely because participants can visually discern the number of tofu pieces in the actual food and compare it with corresponding photographs from the digital atlas. In contrast, no correct estimations were made for curry chicken and fried *tenggiri*; all responses were underestimations. The curry chicken used during validation had larger pieces compared to those in the pictures and might be influenced by the 'unit size effect' (Scisco *et al.,* 2012). From participants' feedback, the size differences in *ikan tenggiri* were not distinct enough to aid accurate portion size estimation.

Table 2. Overall validation results

Food items	*Actual weight (g)*	*Mean estimated weight (g)±SD*	*p-value*	*Mean absolute difference (g) ±SD*[†]	*Mean relative difference (%)±SD*[‡]
White rice	75	58±15	<0.001***	-17.1±15.2	-22.8±20.3
Cornflake	16	12±7	<0.001***	-4.3±7.0	-26.8±43.4
Plain porridge	332	306±54	0.006**	-26.4±54.0	-8.0±16.3
Oat	40	18±11	<0.001***	-22.0±11.0	-54.9±27.5
Kuey teow	100	109±29	0.076	8.54±28.8	8.5±28.8
Spaghetti	38	44±25	0.102	6.37±24.9	16.8±65.5
Instant noodle	125	104±23	<0.001***	-21.3±22.7	-17.1±18.2
French fries	55	60±16	0.038*	5.2±16.2	9.5±29.5
Curry chicken	193	104±21	<0.001***	-88.8±21.2	-46.0±11.0
Fried squid	50	54.±11	0.034*	3.66±10.5	7.3±21.1
Beef *rendang*	95	84±15	0.679	-0.98±15.0	-1.2±17.6
Fried *tenggiri*	90	73±13	<0.001***	-17.29±13.3	-19.2±14.8
Tempeh *goreng kicap*	60	148±12	0.527	-1.46±14.9	-1.2±7.8
Sambal tofu	150	59±15	0.317	-1.83±11.7	-2.4±24.9
Tuna	40	83±26	<0.001***	38.05±17.8	95.1±44.4
Roasted chicken	88	99±34	0.197	-5.37±26.4	-6.1±30.0
Dal	90	78±18	0.102	8.78±33.7	9.8±37.4
Water Spinach	10	13±11	0.066	3.2±11.3	31.7±112.8
French Bean	63	59±11	0.001**	-3.9±11.3	-6.2±17.9
Carrot	60	54±13	0.005**	-5.2±12.5	-10.4±20.9
Cauliflower	25	24±8	0.621	-1.0±8.8	-4.1±35.2
Tomato	84	66±18	<0.001***	-21.4±17.9	-22.0±21.3
Watermelon	250	232±45	0.014*	-18.3±44.7	-7.3±17.0
Banana	26	47±25	<0.001***	21.1±25.4	81.0±97.6
Apple	182	289±78	<0.001***	49.8±77.9	20.8±32.6
Grapes	239	159±23	<0.001***	-23.1±22.9	-12.7±12.6
Pineapple	150	179±60	0.005**	29.3±60.2	19.5±40.1
Dates	8	10±2	<0.001***	2.0±2.0	24.4±24.4
Mangosteen	81	74±31	0.002**	-6.8±31.8	-8.3±39.2
Raisin	40	32±7	<0.001***	-7.6±7.0	-18.9±17.5
Jackfruit	259	264±33	<0.001***	4.5±32.8	1.7±12.7
Papaya	55	67±36	0.041*	12.1±35.9	22.0±65.2

[†]Absolute difference (g) = estimated weight (g) - actual weight (g)
[‡]Relative difference (g) = [estimated weight (g) - actual weight (g)]/actual weight (g) × 100
P-value tested using Wilcoxon signed-rank test. $p<0.05$ is considered statistically significant; *$p<0.05$, ***$p<0.01$, ****$p<0.001$

Associations between participants' characteristics and estimation error

Before conducting the analysis, some sociodemographic factors were re-categorised to achieve a more balanced distribution. Ethnicity was regrouped into Chinese and Malay/Indian due to the small number of participants in the latter category, while cooking frequency was reclassified as low (cooking <3 times per week) and high (cooking ≥3 times per week). Additionally, age and BMI were categorised based on their median values: age was grouped into younger

Table 3. Overall correctness of the validated food items

Food Item	*Value*		
	Underestimate, n (%)	*Correct, n (%)*	*Overestimate, n (%)*
White rice	27 (65.9)	13 (31.7)	1 (2.4)
Cornflake	28 (68.4)	11 (26.8)	2 (4.9)
Plain porridge	9 (22.0)	32 (78.0)	0 (0)
Oat	38 (92.9)	1 (2.4)	2 (4.9)
Kuey teow	11 (26.8)	7 (17.1)	23 (56.1)
Spaghetti	0 (0)	38 (92.7)	3 (7.3)
Instant noodle	27 (65.9)	12 (29.3)	2 (4.9)
French fries	0 (0)	36 (87.8)	5 (12.2)
Rice noodle	13 (31.7)	22 (53.7)	6 (14.6)
Fried squid	-	36 (87.8)	5 (12.2)
Curry chicken	41 (100)	-	-
Beef *rendang*	3 (7.3)	36 (87.8)	2 (4.9)
Fried *tenggiri*	41 (100)	-	-
Tempeh *goreng kicap*	6 (14.6)	31 (75.6)	4 (9.8)
Sambal tofu	1 (2.4)	40 (97.6)	-
Tuna	-	5 (12.2)	36 (87.8)
Roasted chicken	10 (24.4)	26 (63.4)	5 (12.2)
Dal	-	37 (90.2)	4 (9.8)
Water Spinach	0 (0)	37 (90.2)	4 (9.8)
French Bean	15 (36.6)	19 (46.3)	7 (17.1)
Carrot	19 (46.3)	18 (43.9)	4 (9.8)
Cauliflower	9 (22.0)	29 (70.7)	3 (7.3)
Tomato	28 (68.3)	12 (29.3)	1 (2.4)
Watermelon	6 (14.6)	35 (85.4)	0 (0)
Banana	0 (0)	24 (58.5)	17 (41.5)
Apple	4 (9.7)	22 (53.7)	15 (36.6)
Grapes	20 (48.8)	21 (51.2)	0 (0)
Pineapple	6 (14.6)	15 (36.6)	20 (48.8)
Dates	0 (0)	9 (22.0)	32 (78.0)
Mangosteen	16 (39.0)	20 (48.8)	5 (12.2)
Raisin	26 (63.4)	15 (36.6)	0 (0)
Jackfruit	2 (4.9)	38 (92.7)	1 (2.4)
Papaya	0 (0)	36 (87.8)	5 (12.2)
Average	406 (30.0)	733 (54.2)	214 (15.8)

adults (18–21 years) and older adults (22–61 years), while BMI was classified as lower (<23.0 kg/m²) or higher (≥23.0 kg/m²).

Overall, sociodemographic factors did not significantly influence estimation error for most foods. However, significant differences were found between genders and estimations for curry chicken (p=0.030), French beans (p=0.030), carrots (p=0.001), and watermelon (p=0.037). Significant differences were also observed between the sexes for estimations of fried squid and cooking frequency (p=0.045).

Usability questionnaire

Overall, more than 90% of the responses were positive, with participants rating the questions either as 'totally agree' or 'agree'. This yielded an average mean score of 3.24 for the carbohydrate section, 3.29 for the protein section, and 3.30 for the fruits/vegetables section, with the highest possible score being 4.00. The similarity in scores suggested that participants found all sections of the food atlas equally useful. Among all domains across all food groups, "portrayal of foods" scored the lowest, with scores ranging from 2.96 to 3.10. In contrast, the domain "overall suitability" scored the highest across all food groups, with scores ranging from 3.43 to 3.50, indicating that participants found the current atlas suitable to be used in the local context, as common cultural names were used in the naming of food items.

Comments were mostly centred around the portrayal of foods, specifically on the visual differences in portion sizes. It was highlighted that certain food items, such as fried *tenggiri*, mixed rice, and tuna, were hard to quantify due to the similarity in appearance across different portion sizes shown in the photographs. It was also harder to differentiate between portion sizes for food items white in colour, such as oats and *mee hoon*, as they were visually blended into the white plate, therefore lowering contrast.

DISCUSSION

This digital atlas is one of the most comprehensively developed in Malaysia, containing 91 foods representing an array of dishes, comparable with a previously published food atlas in Sri Lanka (Jayawardena & Herath, 2017). It offers several advantages, including photos depicted in multiple portion sizes from very small to very large with standardised photography, inclusion of irregularly shaped foods, and foods with different textures (Shinozaki *et al.*, 2022; Nelson & Haealdsdottir, 1998).

Out of the 33 foods validated, 23 presented with significant differences, with a mean relative error of 1.9%. To date, the acceptable accuracy for portion size measurements has not been formally established. However, previous studies suggested that a relative error within 25% was considered to be acceptable (Shinozaki & Murakami, 2022). Furthermore, more than half of the estimates were correct, with a higher tendency for underestimation than overestimation, aligning with previous findings (Naska *et al.*, 2016; Ali *et al.,* 2018; Badrasawi *et al.*, 2023). However, there was a large variation in estimation error, ranging from a 54.9% underestimation to a 95.1% overestimation. Previous studies reported estimation errors ranging from -13% to 40% in Sri Lanka (Harris-Fry *et al.*, 2016), -29.8% to 34% in Japan (Shinozaki & Murakami, 2022), and -0.09 to 39% in Brazil (Nichelle *et al.*, 2019). One possible reason for the considerable variation in estimation error might be the low cooking frequency among recruited participants. More than two-thirds (61%) of the participants cooked less than three times per week and only four out of the 41 participants reported cooking daily. Additionally, as most participants were of Chinese ethnicity, they likely engaged in communal eating, where the main dishes are placed in the middle of the table for everyone to share (Ma, 2015). This style of eating might make quantifying food amounts challenging (Burrows *et al.*, 2019).

It was suggested that the physical characteristics of foods, such as shape and texture, influence the accuracy of portion size estimation, with estimating amorphous foods without a defined shape being more challenging compared to estimating single-unit foods (Nichelle *et al.*, 2019; Flax *et al.*, 2019). However, no clear association between food characteristics and estimation accuracy was observed in this study. Although some amorphous foods, such as tuna and plain porridge, were poorly estimated, others (such as dal) were well estimated. Tuna is rarely consumed on its own but as a spread; thus, it might have been more appropriate to photograph it on a dessert spoon rather than on a plate (Subar *et al.,* 2010). Plain porridge was portrayed in a white bowl; the low visual contrast made it challenging to differentiate between different portion sizes. On the other hand, dal is commonly served in bowls locally; this familiar presentation may have facilitated a more accurate portion size selection. Notably, all foods depicted as guides presented substantial differences between the estimated and actual portion sizes, and this finding aligns with the validation study conducted in Japan. This suggests that the type of photographs might affect portion size estimation accuracy (Shinozaki & Murakami, 2022). Despite these observations, conclusions on food characteristics, photography type, and estimation accuracy cannot be made due to the small number of foods in each category.

No associations were observed between participants' characteristics and accuracy of estimates for most foods. This finding aligns with previously published literature, where no associations were found between age (Harris-Fry *et al.*, 2016), BMI (Ali *et al.*, 2018; Shinozaki & Murakami, 2022), education level (Flax *et al.*, 2019; Harris-Fry *et al.*, 2016), and accuracy of portion size estimations using image-based PSEE. Therefore, significant findings found between sex, age, cooking frequency, and estimation accuracy of some foods in this study might be simply due to their photographic presentation and low statistical power of the study (Shinozaki & Murakami, 2022).

Overall, participants rated the atlas highly usable through the usability questionnaire. However, participants noted challenges in distinguishing between portion sizes for some food items, particularly those with low contrast between the food and plate. Moreover, portion size differences were not always visually discernible. Future development should enhance contrast and ensure clearer portion size differentiation.

This study had several strengths. Firstly, this was the first digital food atlas developed for Malaysian adults. A digital version offers several advantages over traditional atlases, including enhanced accessibility, ease of sharing, and portability. Furthermore, the content of this atlas has been validated and a usability questionnaire was administered to gauge the public's acceptance of the atlas as a PSEE.

Several limitations must also be acknowledged. Firstly, the food atlas might not fully capture Malaysia's diverse cuisine, as it mainly features dishes from the three primary ethnicities (Malay, Chinese, and Indian) and staple foods like rice and porridge. Further studies expanding this food atlas should include dishes from East Malaysia and the indigenous population to enhance its comprehensiveness. Additionally, the absence of studies on commonly consumed portion sizes among Malaysians could affect the accuracy of portion size representation in the atlas. It is important to note that the design of this validation study allowed for the identification of perception errors but not errors related to conceptualisation or memory, as participants estimated portion sizes without a lapse of time. Previous studies have reported inconsistent results on the effects of memory and conceptualisation (Tueni *et al.*, 2012; Ali *et al.*, 2018). Moreover, the sociodemographic characteristics of the participants (majority below the age of 25, university staff and students, highly educated, and Chinese) did not represent the Malaysian population as a whole, thus reducing the generalisability of the results. Lastly, as the validation was conducted in a highly controlled setting, participants might have paid more attention than usual to the amount of food presented. Future validation studies with a more purposeful sampling design and multi-centre recruitment in real-life settings with varying lighting may be more helpful to accurately assess the validity of the atlas.

CONCLUSION

In conclusion, a digital food atlas comprising 91 foods for Malaysians was developed. Each stage in the development process was supported by previous research, with detailed explanations and justifications provided for every protocol. A validation study was also conducted to assess the accuracy of estimating a pre-weighted amount of food using the developed digital food atlas. It was observed that 24 of the 33 foods resulted in significant estimation errors between the estimated weight and actual weight of the pre-weighted food. Nevertheless, most participants deemed the food atlas helpful in portion size estimation.

The developed digital food atlas can potentially serve as a useful alternative to the traditional atlas. It is easily portable, making it more convenient for researchers and nutrition practitioners. Moreover, it can support nutrition assessments such as the 24-hour diet recall by enhancing portion size estimation accuracy. However, further development, refinement, and validation of the atlas are necessary before it can be used widely in clinical or research settings.

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Authors' contributions

Jim MS, designed the study, collected and analysed the results, and prepared the manuscript; Chang CYH and Chong WT, assisted with data collection, and drafting and reviewing of the manuscript; Lee YY, assisted with the conceptualisation and design of the study, and supervised the data collection process; Chong PN, principle investigator, designed the study, supervised the data collection process, assisted in drafting of the manuscript, and reviewed the manuscript.

Conflict of interest

The authors declare no conflict of interest.

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