Pictogram-based Method of Visualizing Dietary Intake*

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Summary
Background: Pictograms have been shown by many studies to be an effective way of conveying information. An easy-to-understand pictorial description is essential for communication of dietary intake in the computer era.

Objectives: We proposed a novel approach that represents textual descriptions of dietary intake into a pictorial representation with the concept of pictograms. The computational implementation in terms of a web-based tool was investigated on how well the pictograms carry their intended message.

Methods: 1) We investigated how well the pictograms are comprehended in terms of subjects’ accuracy rate and response time. In the study (n = 90), pictorial variants with three types of food images (black-and-white sketch, colored sketch, and colored photograph) were tested. 2) We also investigated how well subjects were able to select the standard food size among various food portions with the use of the tool. A comparison was made against the current standard of an educational session taught by a registered dietitian. We recruited 86 university students who were asked to select a standard size out of five different size categories. Three types of shapes were used. The bowl is the container that is widely used in the participants’ country. The pork strip was to represent foods with elliptical cross-section. The apple was used to represent a baseball-like size and shape.

Results: Two pictograms with black-and-white food image were low of less than 50% in accuracy rate. The rest of the twenty-seven pictograms derived from portions of the nine foods were well understood with high accuracy rates (above 85%). Participants in using the tool without the dietitian’s session was better than participants in the dietitian education session in selecting a standard portion size of an apple (p < 0.0001; p = 0.0009 after adjustment for gender and age). The rate of correct bowl and pork strip size estimates were similar between the two conditions (p > 0.05).

Conclusion: The development of pictograms could be used as a computational visual aid for comprehending and identifying dietary intake. Broader investigation is required for considering the effectiveness of the pictograms on recall, measurement, or estimation as well as for further evaluation in the clinical practice.

1. Introduction

With the trend of digitalization, websites, mobile and remote devices can be used as a means for providing tailored dietary advice, and could function like personal counseling [1–3]. There is growing evidence that technology-enhancement interventions can be effective [4]. Dietary intake are becoming increasingly important in clinical practice as the prevalence of obesity and chronic disease increases globally. According to prior research [5, 6], visual cues of portion size influence caloric intake. Since people may unknowingly eat more or less food when served a biased food portion, having accurate visual cues is crucial in preventing unintentional caloric miscalculation. Thus, it is important to developing enhanced aids for the identification of a “what” and “how much” dietary intake.

Recently, novel approaches of visualizing health information have been emphasized and developed [7–9]. To build up a pictorial representation of dietary intake information, a broad range of functional and cognitive elements for visualization are required for design and evaluation. In this paper, a method of visualizing dietary intake is proposed. Generally, pictorial illustrations are helpful [10, 11], which sometimes be effective substitutes for words when the conveyed information is visual [12]. Despite the availability of traditional visual aids, e.g., photographs, three dimensional models, utensils and volume measures, drawings, and plastic food replicas used [13, 14], the research is limited into the effect of visualization as an aid to communicate food portion.

The purpose of this research is to propose a systematic approach to represent descriptions of food portion size (FPS) with
2. Background

2.1 The Pictogram-based Method

We adopted the format of a pictogram from U.S. Pharmacopoeia, Drug Information (USP-DI) [15]. USP-DI has been widely used as a communication tool to provide comprehensible information related to drug instructions, prevention and warning messages [16, 17]. Combinatorial sum of standard black-white iconic elements developed in USP-DI has shown improving comprehension from special communities such as the elderly and people with low levels of education [18, 19]. However, iconic elements developed so far do not include the elements in use of nutrition education.

A pictogram in this article is defined as pictorial elements in a framed and sequential layout (Figure 1a). There are three components: frame, pictorial elements, and the layout. Each pictogram has two overlapping frames: a larger frame placed in the center and a smaller frame placed in the upper left-hand corner. Pictorial elements are combined to form an illustration of a food or a food portion. The layout extends from the upper left to the middle. Variants of the pictogram were generated in three steps: 1) separating each food portion into elements of food intake, 2) translating pictorial elements into illustrations, and 3) combining pictorial elements into pictogram variants.

2.1.1 Separating the Food Portion into Elements (Step 1)

The portion of a particular food is divided into food items and portion size as shown in Figure 1b. In this study, portion size was given a fractional value. The fractional value was represented by images of serving containers or images of the food items. For example, 1/3 of a bowl, glass, or plate to indicate one-third portion or one piece of a food item to indicate a full portion. A measurement aid was also used to interpret the size of a portion. Common objects of known size were used to give a sense of scale.

2.1.2 Translating Pictorial Elements into Illustrations (Step 2)

The next step was to translate elements (i.e., food item, portion size, and measurement aid) of the food portion into pictorial illustrations. For each food item, many types of images are possible. We selected three commonly used types, i.e., black-white sketches (B/W), color sketches (CS), or color photographs (CP). However, other types of images can be used to depict food items. Following the style of the USP-DI, simplified line drawings were used as B/W pictograms of food items. Colors were added to the B/W pictograms to convert them to CS pictograms. Photographs of real food items were taken from above or at an angle, under regular lighting, so as to display their original colors. Background items and other unwanted details were excluded from the photograph.

The container or food shape is depicted by abstract symbols and generic structures. These elements include household measures, or mound of a food, or the shape of a food. These elements are presented in B/W. An apple (taken as an example) is symbolized by a circle. The shapes of a bowl and cup are recognizable, so they are presented in profile two-dimensionally. Where measures, such as a spoon or mound are not easy to recognize in profile, an angled view is presented.

Measurement aids are depicted as B/Ws or CSs. Objects used to aid measurement include a credit card, a tennis ball, a finger, a palm, or a fist. For example, in this research, a sketched right hand was used to estimate the size of a portion. The hand is presented fully open, while the food of a given portion size is placed in front of the fingers, straight in line with the right and the bottom sides of the palm. Innovative or culturally appropriate aids can be included. The presentation of visual measurement aids help evaluate portion volume or size of a food item.

![Figure 1](image-url)

Figure 1
Decomposing the pictogram-based method. a) Pictogram-based approach: deriving pictorial representations from textural descriptions. b) Decomposing into food and portion size elements, as well as decompose portion size into sub-elements.
2.1.3 Combining Elements into Pictorial Variants (Step 3)

Pictorial variants are recombinants of representing images (▶Figure 2a), different layouts (▶Figure 2b), and measurement aids (▶Figure 2c). Combination of different variants is also possible. For example, six pictorial variants result from using a B/W, CS, or CP in an upper-left or middle layout to show a "1/4 medium size apple."

2.2 The Web-based Visual Aid Tool

The tool was developed under a three-tier type of client/server architecture. In the current version, the tool was developed as described to be able to build a dietary plan (▶Figure 3). Three meals per day are considered as a baseline, divided into three sections. Pictogram representation of each meal is shown in the tool, which allowed participants to understand the type and amount of food. The user’s own left hand was used as a comparative reference for estimating portion size. A credit card, a baseball, or kitchen utensils could be used as a comparative reference. The two dimensional graphics (e.g. a circle, or an ellipse) were used to represent what the portion looks like.

To continue using the tool, each user’s left hand had to be placed on the screen to modify the reference hand to represent as closely as possible that of the user. A size adjustment was done through adding or reducing (+ or –, respectively) the scale. The 1:1 diagram was visually displayed on the screen in front of the user (▶Figure 4). Each user was shown how to access each food portion to remember the correct size in reference to his or her hand.

3. Methods

In this study, comprehensibility of the pictograms were evaluated in answering the following two questions: 1) How well the pictogram variants are understood by the subjects? 2) How well subjects are able to select the standard food size among different food portions in using the tool? Two experiments were proposed to test each question. The samples of students were overlapping and the two experiments were conducted separately. The study was approved by the Institutional Review Board (IRB no.98-3694B) of Chang Gung Medical Foundation, Tao-Yuan, Taiwan. All participated students completed the experiment. A desktop computer with a 22-inch monitor was used for displaying the pictograms. All statistical analysis was conducted with SAS software Version 9.2.

3.1 Evaluating Pictogram Variants

3.1.1 Participants and Setting

We recruited 90 students at Chang Gung University in Taiwan, 47 males and 43 females between the ages of 18 and 24 years old, allocated into group A, B, C (30 subjects each). None had taken a college level nutrition course. The purpose of the study was to assess the effect of pictorial variants in food item using three different types of images: B/W, CS, CP. Therefore, a specific
portion of the food derived three pictorial variants. To include common food items and ensure sufficient variety of food items, nine foods exemplifying irregularly shaped/soft foods (vegetables, milk, tea, noodle), single-unit foods (Chinese sausage), small pieces (peanuts, glutinous rice balls, rice), and regularly shaped foods (apple) were selected. The container was represented by images of a “bowl,” “glass,” or “spoon”; the fractional value by “one,” “1/2,” “3/4,” or “1/4”; measurement aid by a sketched right hand. The foods, containers, portions, and measurement aids were culturally appropriate and familiar to the study group. Each subject in the group was given nine pictograms with the food item in B/W, CS, or CP.

3.1.2 Data Collection and Analysis

In the test of food portions, all subjects were informed regarding the purpose and procedure of the test. Each subject was trained with an example (i.e., “1/4 bowl of potato”) on how to recognize and read the pictogram for 2–4 minutes. Having understood the purpose and procedure, and completed the training, each subject was asked to answer questions. For each group, the pictorial representation of a specific food portion was presented on the computer screen one at a time and in the same order for all subjects. The subjects were asked to describe what he/she saw in the format of food portions (e.g., 1/4 bowl of potatoes”), while the questions did not provide any suggestions related to the food item or portion. The results were divided into “correct” and “incorrect” for each pictorial variant. The accuracy rate of a pictorial variant was defined as ((total participating subjects – total “incorrect” subjects) /total participating subjects) ´ 100. The “incorrect” subject was defined as 1) the subject who answered wrong food title and/or wrong portion size, or 2) the subject who didn’t answer. We used relative frequencies with a defined threshold to compare the distribution of correct versus incorrect answers with independent subjects.

3.2 Evaluating Standard Size Selection

3.2.1 Participant and Setting

A total of 86 students with ages ranging from 18–23 years completed the experiment. Forty-four students (22 males and 22 females) participated in the dietitian-based intervention, meanwhile 42 students (11 males and 31 females) participated in the web-based intervention (both W and D). Subjects were selected to participate in one of two groups to select a standard size from five different sizes. At least two aspects are considered to be important for identification of a standard food portion. Firstly, as people may not be aware if a large or small food portion was consumed, they may unintentionally overeat or not eat enough. Secondly, a biased food portion may further exaggerate estimation errors. For example, caloric underestimation has been observed to be related to meal size [5]. Furthermore, studies suggest that large portions tend to underestimated meanwhile small ones are overestimated [6].

In the dietitian-based group, each subject was interviewed by the registered community dietitian, who provided individual education on the six food groups, food servings and standard portions. The dietitian was experienced at showing students how to approximate the size of a bowl, pork strip, and an apple. The dietitian used nutrition teaching aids (i.e., food replicas) to aid the students in understanding accurate portion sizing. Each subject was instructed to hold the food replicas. Additionally,
standard portion sizes were compared to each subject’s hand size as a reference for improved recall. For example, a standard-sized portion of one serving of meat, using a pork strip as an example, was explained as the equivalent in width to three female or two male fingers.

Directly after the completion of the education session, subjects were asked to select the standard size from the five different sizes available for each food item. After ensuring that the procedure was well understood, each subject was separately tested. Subjects were encouraged to follow the dietitian’s instructions, to hold each size and compare to his/her hand for measurement. The sequence of the test was as follows: bowl, pork strip, and apple. The selected category size was recorded.

In the web-based group, none of the subjects had prior experience with the educational tool. To use the tool, each subject was instructed to place their left hand on the screen to modify the reference hand to be as close as possible in dimension to his or her hand. The instructor sat near the student to ensure the alignment was appropriate. The subject was taken to the webpage that demonstrated how the tool was used. The 1:1 diagram was visually displayed on the screen in front of the subject. Each subject was shown how to assess each food portion size in relation to his or her hand. After being able to operate the system, the subjects had five minutes to practice remembering the appropriate heights and widths of each portion in correspondence with their hand.

### 3.2.2 Data Collection and Analysis

The students were instructed that they would be tested by having to choose one among the five sizes that best reflect the desired one. The five different size categories are mini, standard, medium, large, and super large of various food containers or food replica. Three different shapes were used in the experiment: a bowl, a pork strip, and an apple. The bowl was used due to its wide use for measurement of food portion in the participants’ country. The pork strip was to represent foods with elliptical cross-section. A pork strip represents one common amorphous shape for the meat and alternatives group. The selection of an apple is used to represent a baseball-like size and shape. In our tool, the shape of an apple, an orange, or other round foods were abstracted and represented to be a spherical object.

Five different sizes of bowls, made by the same manufacturer, with the same appearance and material were selected from the market. Pork strips were formed of modeling clay into an ellipse shape with a thickness of 1 cm. The radius of the major and minor axes for each incremental size category differed by 1 cm. Samples of apples were selected by the dietitian from the food market, based on the following criteria: round and symmetric in shape, and visually distinguishable based on differences in size. The variation of each size category within the three items was shown in ▶ Appendix 1. The results were divided
into “correct” and “incorrect” for each selection from five different size categories. We examined the effect of the web-based intervention (W) in comparison to the dietitian-based intervention (D). We used the Chi-square test to compare the distribution of correct versus incorrect answers with independent subjects. We also conducted the multiple logistic regression for multivariable analysis to evaluate the intervention effect after adjustment for age and gender.

4. Results
4.1 Pictogram Variant
4.1.1 Overall Evaluation of the Derived Pictograms
In Table 1, high accuracy rates (above 85%) were shown regardless of B/W, CS, or CP. Considering each pictogram, only three of the 27 pictograms were considered to be ineffective compared to the comprehension criterion of at least 67% correct, for pictorial symbols, specified in ISO 3864 [20]. These are “1 piece of Chinese sausage” and “1/2 bowl glutinous rice ball” with B/W that were extremely low of less than 50%, and “1/2 bowl glutinous rice ball” with CS (66.7%). The rest of the pictograms were effective with accuracy rates between 80% and 100%.

4.2 Standard Size Selection
4.2.1 Evaluation of Different Portion Size Selection
Frequencies of correct size estimates were summarized by group for each of the three food types. As shown in Table 2, the rate of correct bowl and pork strip size estimates were similar between the W and D conditions (p > 0.05). However, the rate of correct apple size estimates was significantly higher in the W versus the D condition.

5. Discussion
5.1 Representing Pictograms
Limited studies investigate types of representation (B/W, CS, CP) in digital images to be mostly comprehensible. However, how good the pictorial illustrations convey may impact the system’s usefulness. Below is a discussion of the three types.

5.1.1 B/W vs. CS
Research has shown that color drawings more than black and white drawings improve comprehension [21]. In the present study, the accuracy rates associated with the CS and CP pictograms were higher than the ones associated with the B/W pictogram. Numerous food varieties with similar appearance can be confusing. Adding distinguishing colors to the pictogram remove some of this confusion. On the other hand, differences can be adequately discerned from B/Ws using dots, lines, or planes to describe specific pharmaceutical categories [20], where the use of B/W is sufficient to distinguish the differences. B/W pictograms are effective for some food items if the characteristics of the food are clearly presented.

As shown in Table 1, seven of the nine pictograms were associated with high accuracy rates. Research has suggested that comprehension of the information conveyed by sketches was affected by the explicitness of the information and the clarity of the details [23]. In this research, the CS was generated from the B/W by adding color. This increased comprehensibility for certain pictograms. However, a color representation that highlights the major characteristics of the foods’ outward appearance is not always feasible. Compared with CS pictograms of other food items in the present study, the CS pictogram of “a piece of Chinese sausage” was associated with a relatively lower accuracy rate of 80%. Further improvement could be achieved through repeated revision of the sketches with testing in the target population to assess improvement. And, this could be resolved by following related studies such as those conducted by Dowse and Ehlers [24] and Basara and Jenkins [25] that their design of sketches was repeatedly modified and tested with the involvement of target population to make the sketches better understood. However, if this is still not possible, including the name of the food under the sketch or photo, such as “Chinese sausage” would be necessary.

5.1.2 Photograph vs. Sketch
Whether the information should be presented with photographs or sketches, previous studies showed different perspectives. Some research showed that simple sketches are most effective in facilitating comprehension. Many drug instructions are based on sketch mode that used cartoon-style and abstract lines.
26, 27]. Readance and Moore [21] explored the level of understanding and suggested that line sketches seem to help readers’ comprehension more than shaded sketches or photographs. Moll [22] found that cartoon-style sketch achieved the highest understanding level, followed by line sketches, with photographs having the worst effect. This article showed that comparing use of pictograms with CS or CP, the results have no statistical difference. This article showed that comparing each pictogram of CS food item and with each pictogram of CP food item, the results are similar, except that the food portion of “1 piece of Chinese sausage” and “1/2 bowl glutinous rice ball”. In the food portion of “1 piece of Chinese sausage”, the pictogram with CP food item is better than the pictogram with CS food item. However, in the food portion of “1/2 bowl glutinous rice ball”, the result is reverse. It is unable to decide which type of the representations is better.

In this study, evaluation was made only the variations on the three types of food items. Extended evaluation on pictograms considering the variations of layout, visuals of portion, and visuals of measurement aid can be included. Currently, this research was conducted on the understanding level of the food portion information. It was also suggested that various aspects be included in the future, including estimation, and recall. Further studies with different sociodemographic, age, gender, and cultural groups are also required.

### 5.2 The Pictogram-based Method and the Tool

In terms of the explicit presentation of information as a dietary aid, the food items’ appearance was the key feature. Dimensions vary among foods and these various should be considered for inclusion in terms of the proposed pictorial representations. This information could be provided through the addition of a two-dimensional figure (representing an appropriate view) that compares the thickness of the food with a scale drawing of a comparison object, e.g., a hand. However, some information such as the food items’ nutritional content, such as “low-fat milk”, stressing its characteristic of being “low-fat”, are hard to portray using outward appearance. Nutritional attributes, such as protein and fat, are hard to recognize if presented in the form of chemical compositions. To resolve this, training may be used as a strategy to enhance understanding of an unfamiliar pictorial illustration.

In this study, we also evaluated the utility of a web-based visual tool that supports the selection of an appropriate size of a container or food items. The key feature of this tool is the use of an adjustable hand size to represent portion size that is in alignment with abstract geometry (e.g., circular, ellipse). We compared the rate of correct size estimates after use of this web-based tool to that after an interactive educational nutrition session with a community dietitian. The two methods are similar in that both use the individual’s hand to aid in the accuracy of measurement. However, while the method used by the dietitian represents a serving size in terms of a person’s hand, the proposed web-based method used generic two-dimensional visuals (e.g. circle, rectangle, etc) in comparison to the hand.

The method proposed in this research has the following characteristics. First, the method allowed students to visualize the size and shapes of food; a key consideration given that visualization is one of the primary strategies used to recall food intake. Second, the generic shapes were used to represent the average size of a certain food or food container. For example, a circle could be used to represent the size of an apple, orange, or other round fruit or vegetables. Therefore, a limited number of shapes were able to represent a broad range of foods. Third, since the measurement of a standard size relies on the use of an individual’s hand, food portion estimates were not limited by food models or three-dimensional measurement aids (e.g. baseball, golf ball, etc.). Thus, the measurement can be made at home, in the office, or other locations as long as computing devices, such as a computer or smart phone, are available. And, this could help to resolve a large amount of shapes required to develop so as to represent all kinds of foods. Fourth, since the individual’s actual hand size was used as the reference, he or she did not need to remember how to convert his/her hand size into a standard size. In contrast, a typical nutrition education session uses a physical model with the support of a hand and fingers as the reference. However, this is limited by the variability in hand size between individuals. Thus, the dietitian is required to convert each student’s hand size to a standard size. For example, when showing each student how to measure a serving of meat, the typical size of three finger widths had to be converted to the specific finger widths of the student. Finally, unlike previous research [22, 25], initial pictograms were commonly developed by medical artists based on their experience. FPS developed in this study was divided into reusable primitives, and thus systematic combination of the reusable primitives makes it possible to fit into various FPSs.

<table>
<thead>
<tr>
<th>Model</th>
<th>Items</th>
<th>Variable</th>
<th>Web-based</th>
<th>Dietitian-based</th>
<th>p-value</th>
<th>Adjusted p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>W vs. D</td>
<td>Bowl</td>
<td>Corrected</td>
<td>21 (50.0%)</td>
<td>21 (47.7%)</td>
<td>0.8331</td>
<td>0.7318</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Uncorrected</td>
<td>21 (50.0%)</td>
<td>23 (52.3%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pork</td>
<td>Corrected</td>
<td>25 (59.5%)</td>
<td>29 (65.9%)</td>
<td>0.5403</td>
<td>0.5749</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Uncorrected</td>
<td>17 (40.5%)</td>
<td>15 (34.1%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Apple</td>
<td>Corrected</td>
<td>27 (64.3%)</td>
<td>9 (20.4%)</td>
<td>&lt;0.0001</td>
<td>0.0009</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Uncorrected</td>
<td>15 (35.7%)</td>
<td>35 (79.6%)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: W: stands for the effect of web-based intervention; D: stands for the effect of dietitian-based intervention; * after adjustment for age and gender
As illustrated in Table 2, a significant difference was shown in the accuracy of estimating the size of an apple, in which the shape was abstracted in the web-based tool as a ball. Typically, ball-shape objects are used as a visual aid to help estimate the portion size of various specific foods within the six food groups. Thus, the ability to identify the appropriate portion size of a spherical food item is particularly important. Our results also showed that the rate of correctly selecting the right size of an apple after the dietitian-led session was very low (~20%). In other words, most students in the dietitian-based group were unable to correctly choose the standard portion of the five available options. One potential reason of the low selection is that the use of the analogy of “about the size of a fist” to describe the size of a food item did not allow students to make the right selection in this experiment. However, most the participants (over 77%) selected the size category, mini that is one level smaller than the standard. This would indicate that the dietitian’s training method is valid, but causes subjects to slightly underestimate standard sizes. On the other hand, a relatively high rate (over 60%) of correctly selecting the right apple size was observed for the students in the web-based group.

In the dietitian group, up to 65% of students correctly estimated the standard size of a pork strip by using the “three finger width” analogy. The fact that a pork strip is similar in shape to a two-dimensional sheet can explain why the rates of correct estimates of pork strip size are higher than those of the bowl and apple. However, further investigation is necessary before any conclusions can be made.

Our results also suggested that size estimating accuracy differs based on the type of container or food shape. For example, in the dietitian group, the highest rate of correct size estimates was observed for the pork strip, followed by the bowl, and finally, the apple. Specifically, the accuracy for the different shapes was shown to differ greatly between the items evaluated, ranging from 20% to 65% for the dietitian-based group.

6. Conclusion

The study proposed a novel method representing dietary intake. This approach could be used to generate pictograms in a consistent manner, facilitating their comprehension, and to build pictograms from a wide range of FPS, simply from primitives. An investigation was conducted to see if this representation is appropriate for conveying its intended meaning as well as for selecting from different food portions. This research indicated that pictograms systematically derived from the approach have the potential to be used as a computational dietary aid in health informatics. The idea of pictograms for communicating dietary information has yet to be explored completely. Currently, this research was conducted merely on the comprehension level of the FPS information. This research served a role to support the visualization of dietary intake in health care informatics to be used for further evaluation in the clinical practice of nutrition education, and to introduce a generic representation of dietary information using pictograms.

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