An Experimental Study On Influence Of Plate Size On Actual And Perceived Energy Intake Among Undergraduates In A Public University, Malaysia.

Siti Amirah Shaheera Binti Shalihin, B.Sc.
Department of Nutrition and Dietetics, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, Serdang 43400, Malaysia.
shaheerashalihin@gmail.com

***Rosita Jamaluddin, P.hD**
Department of Nutrition and Dietetics, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, Serdang 43400, Malaysia.
rositaj@upm.edu.my

Cheah Khang Jin, B.Sc.
Department of Nutrition and Dietetics, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, Serdang 43400, Malaysia.
jincheah06@gmail.com

Najihah Mohamad, B.Sc.
Department of Nutrition and Dietetics, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, Serdang 43400, Malaysia.
najihahmohamad15@gmail.com

***Corresponding author:** Rosita Jamaluddin, rositaj@upm.edu.my

Article History:
Received on October 26, 2020
Accepted on April 6, 2021
Published on June 10, 2021

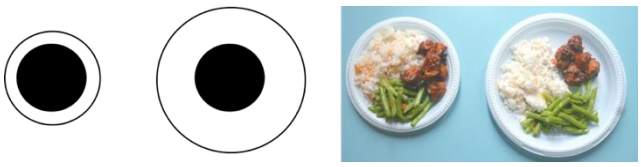
Abstract:

Background: A within-subjects experimental study design was conducted to determine the influence of plate sizes on the actual compared to the perceived energy consumed.
Materials and Methods: Fifty-eight participants (45 female, 13 male) were selected from a faculty in a public university. On separate experimental days, they were invited to a lunch buffet dishes in which white rice, a chicken dish and stir-fried vegetables were self-served using small (7-inch/18cm) and large (9-inch/23cm) diameter plates. Anthropometric measurements, perceived energy intake, actual energy intake and socio-demographic information were analyzed. The weight of each food was used to calculate the actual energy consumed.
Result: On the 7-inch/18cm plate size, the perceived dietary intake was significantly higher than the actual dietary intake (p<0.01). While on the 9-inch/23cm plate size, participants perceived a significantly lower dietary intake compared to the actual dietary intake (p<0.01). There were significant differences in actual and perceived dietary intake between the 2 plate sizes (p<0.001).
Conclusion: Participants underestimated their dietary intake on a large plate and overestimated their dietary intake on a small plate. It can be concluded that plate size has an influence on dietary intake and could be considered as part of weight loss interventions.

Keywords: Delboeuf illusion; eating behavior; meal energy; obesity; plate size; portion size

Introduction:

The prevalence of obesity has increased substantially over the past 40 years (Gómez, et al., 2017). Despite obesity has long been identified as one of the top five global risk factors contributing to and reducing life expectancy, it has not been adequately explored in the formulation of national policies for reducing obesity rates (Roberto, et al., 2015; Stanaway, et al., 2018). Obesity is a complex disease resulting from multiple factors including genetic, behavior and environment. The environmental factors such as food portion size and food containers are thought to play a role in the development of obesity (Kleef, et al., 2012; English, et al., 2015). Based on available data, the average size of a dinner plate nowadays is 36% larger compared to its size in the past three decades, which is in concurrent with the rise in obesity rates (Wansink, 2006). A larger food container allows for more food to be served resulting in an increase in energy intake. This plate-size phenomenon happens because the ability to estimate the regular portion size of a meal served is impaired by visual illusion (Young & Nestle, 2002).
People tend to use perception cues in determining their food consumption volume. When the same amount of food is presented on a small plate, individuals tend to overestimate the quantity or conversely underestimate it on a large plate. This plate-size-effect is attributed to a visual illusion called Delboeuf illusion. This illusion is opposite when the gap between both circles is large. In this situation, the plated food is perceived as a separate component from the plate leading to the food appearing smaller in portion (Sobal & Wansink, 2007; Ittersum & Wansink, 2012). In other words, the same amount of foods appear larger when served on a small plate but smaller when served on a larger plate. Figure 1 below shows the Delboeuf illusion with concentric circle and actual dishes.



(a) **(b)**

Figure 1. (a) The Delboeuf illusion shown with concentric circles (b) Delboeuf illusion shown with actual dishes (white rice, spicy chicken and stir-fried vegetables)

The Delboeuf illusion has been demonstrated in studies which found that larger food containers influenced adults to serve themselves larger amounts of food (Wansink, 2004; Wansink & Johnson, 2014). However, there is still no consensus agreement regarding the effect of plate size on meal portion size and dietary intake. (Robinson, et al, 2014). Therefore, it is important to establish an evidence-based data to suggest whether using small plate is useful for reducing food intake. With current inconsistent outcomes from these studies, hence the recommendation of using smaller plate size to reduce food intake needs more research. So far too little attention has been given in investigating people's perception of their own calories consumption when self-served using different plate sizes. Moreover, research regarding the effect of plate sizes on food intake is scarce in Malaysia. This study aimed to assess (1) the difference in actual and perceived energy and (2) the accuracy of energy estimation level from lunch dishes consisted of carbohydrate (rice), protein (chicken) and vegetable intake between two different plate sizes: 7-inch/18cm and 9-inch/23cm.

Materials and Methods:

This within-subjects experimental study design with one week wash-out period was established based on previous studies (Rolls et al., 2007; Zuraikat et al., 2016). The independent variables were 7-inch/18cm and 9-inch/23cm plate sizes. The primary outcome variables were perceived and actual energy on each lunch dishes' intake. Fifty-eight participants of both sexes and all ethnic groups were recruited from Universiti Putra Malaysia (UPM) poster and flyer advertisements. The participants were screened before being recruited into the study. Undergraduate students aged 18 to 25 years were included. Pregnant students, those on medications known to affect appetite and weight regulation, those with a history of food allergies, students on a special diet, physically disabled students, and those majoring in nutrition or dietetics were excluded.

On the experimental days, all participants were instructed to maintain their normal breakfast intake and physical activity level to avoid their appetite from being affected. The study was carried out in the dietetic laboratory during the lunch hour. Free flow lunch buffet was provided, comprising of common local dishes menu of white rice, spicy chicken (small chunk of breast part) and stir-fried vegetables. They were allowed to eat an unlimited amount of food during the one-hour duration of study (12:00 PM to 1:00 PM). Each food consumed was weighed including the gravy of spicy chicken, and all the readings were recorded before participants were allowed to sit freely in the lab. Participants were instructed to record their estimated energy intake in

the form provided before eating and each time after they have additional food from the buffet. The procedure of weighing meal was repeated for any additional food taken. All participants had lunch dishes using a 7-inch/18cm plate and after one week, the same participants had lunch dishes with the same menu using a 9-inch/23cm plate. To avoid the participants being bias and conscious of the study objective, the participants had not been informed that this study was conducted to study the energy intake of students during lunch time. This study received ethical approval from the Ethics Committee for Research Involving Human Subjects of the university (JKEUPM 1.4.18.2).

A self-administered questionnaire was used to gather information on socio-demographic factors of participants, namely sex, age, race and monthly food expenses. Participants' body weight was measured before the lunch buffet on the first experimental day using TANITA digital weighing scale HD-306 (Tanita Corporation, Tokyo, Japan) and their height was measured using Seca 213 Portable Stadiometer (Seca GmbH & Co. KG, Hamburg, Germany). The BMI was calculated by using the formula of body weight (kg) divided by height in meters squared (m^2). Both plates used in this study were disposable, eco-friendly and featured with the international symbol for "food safe" logo. The sizes of the plate were 7-inch/18cm and 9-inch/23cm.

The weight of each food consumed by participants was determined using the SJ Series Compact Bench Scale (A&D Company Limited, Tokyo, Japan) with reading to the nearest of 0.1gram. Any left-over of each food was also weighed and adjusted to calculate the weight of food consumed. This procedure was conducted by enumerators and the readings were recorded in a master sheet. Using the quantity of ingredients from the recipes of each dish and the Nutritionist Pro software version 2005 (Axxya Systems LLC, Redmon, WA, USA), the actual amount of calories on each food consumed was determined. The perceived energy intake was recorded by participants based on what they had eaten during the experiment lunch period. The energy intake estimated was based on their knowledge nevertheless no assessment was done among participants to test their knowledge level on the calorie of the food. The accuracy of energy estimation for each dish on both plates was computed using the formula of (perceived energy consumed / actual energy consumed) X 100 and then further categorized into underestimation (<80% accuracy), accurate estimation (80-120% accuracy) and overestimation (>120%) (Balzo, et al., n.d.).

The data collected was analyzed by using the standard statistical software package, IBM SPSS 23.0 for Windows (SPSS Inc., Chicago, IL, USA). Paired t-test was conducted to compare the mean values of actual and perceived energy intakes as well as accuracy of energy estimation on each dish between both plates. All the statistical analysis was conducted at 95% confidence interval or p-value <0.01.

Results:

A total of 58 undergraduate students consented to participate in this study. The mean age was 21.6 years. Majority of the participants were female (78%) as compared to males in this study and majority of the participants were Malay (95%) and of normal weight (71%). Table 1 shows the characteristics of participants based on socio-demographic and anthropometric data collected.

Table 1. Characteristics of participants

Characteristics	n (%)	Mean ± SD
Sex		
Male	13 (22)	
Female	45 (78)	
Age		21.6 ± 0.5
Ethnicity		
Malay	55 (95)	
Others	3 (5)	
Weight (kg)		
Male		72.0 ± 22.3
Female		50.6 ± 6.9
BMI (kg/m^2)		
Male		25.0 ± 6.7
Female		21.1 ± 2.4
BMI Classification (kg/m^2)		
Underweight	9 (16)	
Normal	41 (71)	
Overweight/obese	8 (13)	

Table 2 shows differences between actual and perceived energy intake on respective plates. When using the 7-inch/18cm plate, the mean of perceived energy consumed was higher compared to the mean of actual dishes intake for rice, chicken and vegetables. However, participants perceived less energy consumed when using the 9-inch/23cm plate. Results obtained from paired t-test showed a significant difference between the actual and perceived lunch dishes energy values using this plate size as well.

Further analysis was carried out to compare the difference of actual as well as perceived lunch dishes intake between the two plates (Table 3). The mean of actual energy consumed using the 7-inch/18cm plate was significantly lower for all types

Table 2. Comparisons between actual and perceived lunch dishes energy values using 7-inch/18cm plates and 9-inch/23cm plates.

Foods	Mean ± *SD* (kcal)		*t*-value	*p*-value	*df*
	Actual energy consumed	Perceived energy consumed			
7-inch/18cm plates					
Rice	242 ± 54	282 ± 65	5.778	0.001*	57
Chicken	157 ± 42	183 ± 42	8.426	0.001*	57
Vegetable	26 ± 11	62 ± 24	14.671	0.001*	57
9-inch/23cm plate					
Rice	304 ± 54	204 ± 65	11.290	0.001*	57
Chicken	204 ± 54	151 ± 55	9.188	0.001*	57
Vegetable	38 ± 14	32 ± 11	7.204	0.00*	57

*Variables differed significantly as assessed by t-test, p<0.01

Table 3. Comparisons between 7-inch/18cm and 9-inch/23cm plates on actual and perceived lunch dishes energy value.

Foods	Mean ± *SD* (kcal)		*t*-value	*p*-value	*df*
	7-inch/18cm plate	9-inch/23cm plate			
Actual energy intake					
Rice	242 ± 54	304 ± 54	11.817	0.001*	57
Chicken	157 ± 42	204 ± 54	-12.746	0.001*	57
Vegetable	26 ± 11	38 ± 14	-13.296	0.001*	57
Perceived energy intake					
Rice	282 ± 65	204 ± 65	8.162	0.001*	57
Chicken	183 ± 42	151 ± 55	4.944	0.001*	57
Vegetable	63 ± 24	31 ± 11	11.997	0.001*	57

*Variables differed significantly as assessed by t-test, p<0.01

Table 4. Energy estimation comparison for lunch dishes between 7-inch/18cm and 9-inch/23cm plates.

Foods	Rice n (%)		Chicken n(%)		Vegetables n(%)	
	7-inch /18cm plate	9-inch /23cm plate	7-inch /18cm plate	9-inch /23cm plate	7-inch /18cm plate	9-inch /23cm plate
Underestimation	5 (9)	45 (78)	1 (2)	37 (64)	1 (2)	29 (50)
Accurate	28 (48)	13 (22)	13 (22)	20 (35)	1 (2)	23 (40)
Overestimation	24 (41)	0 (0)	44 (76)	1 (2)	54 (91)	2 (5)

of food compared to the mean of actual energy consumed using the 9-inch/23cm plate. These data confirmed that more food was consumed when participants served themselves using the larger plate. The largest contrast of actual energy consumed was attributed to rice dish intake which showed a difference of 62kcal (242 ± 54 kcal versus 304 ± 54kcal, p<0.01). Conversely, the mean of perceived energy intakes using 7-inch/18cm plate was significantly higher compared to the 9-inch/23cm for all the three types of food.

The energy estimation level for each type of food consumed on both plate sizes is shown in Table 4. For chicken (n=44, 76%) and vegetable (n=54, 91%) estimations on 7-inch/18cm plate, more than half of the participants overestimated the energy value. The data revealed most of the participants underestimated the energy value for all types of food while using 9-inch/23cm plate.

Discussion:

Findings from this study showed that plate size influenced the actual and perceived lunch dishes intake among university students in a self-serve buffet setting. It is interesting to note that participants overestimated the dishes, by 17% of carbohydrate intake, 17% of protein intake and 138% of fiber more

when they served themselves using the 7-inch/18cm plate. When using 9 inch/23cm plate, they underestimated the energy value from carbohydrate, protein and fiber by 49%, 35% and 19% respectively. Our results revealed that the plate-size-effect influenced the perceived energy value. In other words, they consumed bigger portion of the dishes while perceiving a lower energy value when using the 9-inch/23cm plate.

Our findings demonstrate the role of the Delboeuf illusion in food intake through platescapes. This illusion makes the identical food quantities appearing smaller when served on a relatively large plate causing underestimation of perceived energy intake (Ittersum & Wansink, 2012). Visual cues are easily influenced by other norms that are present in the environment and this can impact on food-related estimation and consumption behavior (Wansink, 2014). An increasing size of the dining plate and the misperception that bigger portion sizes should be served on bigger plates make people's judgement less accurate when estimating how much calories has been consumed (Libotte, et al., 2014; Lim, et al., 2018). Specifically, larger dishware decreases the perceived food portion size and consequently reduces the ability to monitor food intake, which ultimately increases the amount of food eaten during a single eating occasion (Pratt, Croager & Rosenberg, 2012; Wansink & Johnson, 2014).

The present findings supported a previous study conducted among 405 trained dietitians which reported that people tend to underestimate the energy value on a larger plate due to visual cues (Chandon & Wansink, 2007). With regards to the actual food intake, the energy intake from respective dishes from 9-inch/23cm plate led to an addition total average ingestion of 122kcal or 23% compared to eating with 7-inch/18cm plate. This result is consistent with previous findings which reported that the use of large food containers promotes higher food intake (Kleef, et al., 2012; Wansink & Johnson, 2014; Wansink & Kim, 2005; Marchiori, et al., 2012). However, most of the significant findings were from studies using bowl as the food container and high energy dense snacks as the food. The effect of plate size on energy intake is yet controversial and much disputed (Libotte, et al., 2014; Rolls, et al., 2007; Yip, et al., 2013; Wansink & Ittersum, 2013; Hollands, et al., 2015). Thus, the present results showed increases in self-served dishes with larger plate.

The finding of this study is in contradiction with a controlled experiment using a fake food buffet which showed that participants' food intake was not influenced by plate size in a buffet setting (Robinson, et al., 2014). Nevertheless, results from a recent meta-analysis revealed that plate size had a positive effect the amount of food consumed if the participants were unaware that they were involved in a food study and the effect was stronger if the food was self-served (Holden, et al., 2016). This is in line with our result that showed participants consumed higher actual energy intake for each type of food when using the 9-inch/23cm plate compared to the 7-inch/18cm plate as the participants were unaware of the study objective and were self-served.

Our findings suggest that smaller plate size might reduce dishes intake through perception on overestimated self-served portion size. Therefore, smaller plate size could be used as a strategy in controlling food intake and weight management. However, special attention should be given on vegetable intake as our results also showed people overestimated their vegetable intake when eating with smaller (7inch/18cm) plate and lead to low actual fiber intake. Encouragement on fiber intake is important when using smaller plate in weight management strategy as fiber intake may reduce energy intake indirectly (Hervik & Svihus, 2019).

One of the strengths of this study was the within-subject design which has greater statistical power and the effect of confounding factors is minimal. Moreover, participants also were not aware of the main objective of the study to avoid any bias in their food intake behavior. They were allowed to seat freely either alone or with friends, mimicking the real dining setting. The actual and perceived dishes intake was determined through a common lunch menu instead of a fake food buffet which can also influence and fake participants' food intake behavior. Nonetheless, there are several limitations in the present study. First, there were no assessments carried out on fullness or hunger level before starting the lunch buffet.

However, the participants were instructed to maintain similar food intake a day before each experiment and to eat the same breakfast meal during both experimental days. These food intakes were not monitored and standardized. This could have possibly affected food intake of participants during the two lunch buffets and control for this effect is warranted. The influence of socio-demographic and socio-economic factors on the effect of plate size upon actual and perceived dishes energy intake were not investigated in this study, which can be addressed in future studies.

Conclusion:

The current study found that there was an influence of plate size on the actual and perceived dishes intake. Participants underestimated the energy intake on the

larger plate and therefore tended to consume more foods using this kind of plate. The small plate size influenced the participants to consume a smaller amount of foods because they overestimated the amount of food in relation to the lesser empty space on the small plate. The present findings could be beneficial in weight management programs whereby the use of smaller plates could reduce food and subsequently energy consumption over time.

References:

Balzo V, Scanu A, Dernini S, Palmieri O, Cannella C. . "Mediterranean lifestyle: nutritional education on-line." (n.d.): 565-73.

Chandon, P., & Wansink, B. (2007). Is obesity caused by calorie underestimation? A psychophysical model of meal size estimation. *Journal of Marketing Research, 44*(1), 84-99. doi: 10.1509/jmkr.44.1.84

English, L., Lasschuijt, M., & Keller, K. L. (2015). Mechanisms of the portion size effect. What is known and where do we go from here? *Appetite, 88*, 39–49. doi:10.1016/j.appet.2014.11.004

Hervik, A. K., & Svihus, B. (2019). The Role of Fiber in Energy Balance. *Journal of Nutrition and Metabolism, 2019*, 1–11. doi:10.1155/2019/4983657

Holden, S. S., Zlatevska, N., & Dubelaar, C. (2016). Whether smaller plates reduce consumption depends on who's serving and who's looking: a meta-analysis. Journal of the *Association for Consumer Research, 1*(1), 134-146. doi: 10.1086/684441

Hollands, G. J., Shemilt, I., Marteau, T. M., Jebb, S. A., Lewis, H. B., Wei, Y., … Ogilvie, D. (2015). Portion, package or tableware size for changing selection and consumption of food, alcohol and tobacco. *The Cochrane database of systematic reviews, 2015*(9), CD011045. doi:10.1002/14651858.CD011045.pub2

Ittersum, K., & Wansink, B. (2012). Plate Size and Color Suggestibility: The Delboeuf Illusion's Bias on Serving and Eating Behavior. *Journal of Consumer Research, 39*(2), 215–228. doi:10.1086/662615

Kleef, E., Shimizu, M., & Wansink, B. (2012). Serving bowl selection biases the amount of food served. *Journal of Nutrition Education and Behavior, 44*, 66–70.

Libotte, E., Siegrist, M., & Bucher, T. (2014). The influence of plate size on meal composition. Literature review and experiment. *Appetite, 82*, 91-96.

Lim, Y. J., Jamaluddin, R., & Er, Y. T. (2018). Association between Platescapes, Foodscapes, and Meal Energy Intake in Government Employees from Muar, Johor, Malaysia. Nutrients, 10(7), 819. doi:10.3390/nu10070819

Marchiori, D. R., Corneille, O., & Klein, O. (2012). Container size influences snack food intake independently of portion size. *Appetite, 58*(3), 814-817. https://doi.org/10.1016/j.appet.2012.01.015

Marchiori, D., Corneille, O., & Klein, O. (2012). Container size influences snack food intake independently of portion size. *Appetite, 58*(3), 814-817. doi: 10.1016/j.appet.2012.01.015

Pratt, I. S., Croager, E. J., & Rosenberg, M. (2012). The mathematical relationship between dishware size and portion size. *Appetite, 58*(1), 299–302. doi:10.1016/j.appet.2011.10.010

Roberto, C. A., Swinburn, B., Hawkes, C., Huang, T. T., Costa, S. A., Ashe, M., ... & Brownell, K. D. (2015). Patchy progress on obesity prevention: emerging examples, entrenched barriers, and new thinking. *The Lancet, 385* (9985), 2400-2409.

Robinson, E., Nolan, S., Tudur-Smith, C., Boyland, E. J., Harrold, J. A., Hardman, C. A., & Halford, J. C. G. (2014). Will smaller plates lead to smaller waists? A systematic review and meta-analysis of the effect that experimental manipulation of dishware size has on energy consumption. *Obesity Reviews, 15*(10), 812–821. doi:10.1111/obr.12200

Rolls, B. J., Roe, L. S., Halverson, K. H., & Meengs, J. S. (2007). Using a smaller plate did not reduce energy intake at meals. *Appetite, 49*(3), 652–660. doi:10.1016/j.appet.2007.04.005

Rolls, B. J., Roe, L. S., Halverson, K. H., & Meengs, J. S. (2007). Using a smaller plate did not reduce energy intake at meals. *Appetite, 49*(3), 652–660. doi:10.1016/j.appet.2007.04.005

Sobal, J., & Wansink, B. (2007). Kitchenscapes, Tablescapes, Platescapes, and Foodscapes. *Environment and Behavior, 39*(1), 124–142. doi:10.1177/0013916506295574

Stanaway, J. D., Afshin, A., Gakidou, E., Lim, S. S., Abate, D., Abate, K. H., ... & Abdela, J. (2018). Global, regional, and national comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990–2017: A systematic analysis for

the Global Burden of Disease Study 2017. *The Lancet, 392*(10159), 1923-1994.

Wansink B. Mindless Eating: Why We Eat More Than We Think. Bantam Dell: New York, NY, USA, 2006.

Wansink, B. (2004). Environmental factors that increase the food intake and consumption volume of unknowing consumers. *Annual Review of Nutrition, 24*, 455–479.

Wansink, B., & Johnson, K. A. (2014). The clean plate club: about 92% of self-served food is eaten. *International Journal of Obesity, 39*(2), 371–374. doi:10.1038/ijo.2014.104

Wansink, B., & Kim, J. (2005). Bad popcorn in big buckets: Portion size can influence intake as much as taste. *Journal of nutrition education and behavior, 37*(5), 242-245. doi: 10.1016/s1499-4046(06)60278-9

Wansink, B., & Van Ittersum, K. (2013). Portion size me: Plate-size induced consumption norms and win-win solutions for reducing food intake and waste. *Journal of Experimental Psychology: Applied, 19*(4), 320-332. doi: 10.1037/a0035053

Yip, W., Wiessing, K. R., Budgett, S., & Poppitt, S. D. (2013). Using a smaller dining plate does not suppress food intake from a buffet lunch meal in overweight, unrestrained women. *Appetite, 69*, 102–107. doi:10.1016/j.appet.2013.05.017

Young, L. R., & Nestle, M. (2002). The contribution of expanding portion sizes to the US obesity epidemic. *American journal of public health, 92*(2), 246–249. doi:10.2105/ajph.92.2.246

Zuraikat, F. M., Roe, L. S., Privitera, G. J., & Rolls, B. J. (2016). Increasing the size of portion options affects intake but not portion selection at a meal. *Appetite, 98*, 95–100. https://doi.org/10.1016/j.appet.2015.12.023