

SUPPLEMENTARY FILE 1

DETAILS OF THE SUB-STUDIES

Sub-study 1:



Bean bags as portion size estimation aids in the elderly

BACKGROUND

In the increasing elderly population, good nutritional status is important for optimal health. This requires accurate portion size estimation as part of dietary assessment. The performance of portion size estimation aids (PSEAs) may be influenced by the type and quantity of food. Beans bags are generic, three-dimensional, malleable PSEAs of known volumes, yet their estimation accuracy is unknown.

AIM

To determine the accuracy of bean bags as portion size estimation aids of a fixed amount of different food types in the elderly.

METHODS

Design: Cross-sectional study
Setting: Old age home/retirement village in Pretoria, South Africa
Sampling: Convenience
Data collection: In a standardised and pre-tested interviewer-administered approach, participants were presented with a random order of 3 sets of plated foods, consisting of 2 example foods (all $\frac{3}{4}$ cup) of 4 food types (amorphous masses, amorphous pieces, solids and liquids) from the breakfast menu (Table 1). Six round, beige-coloured bean bags of various known volumes were presented in a random arrangement after each set of food and participants estimated the portion sizes of each food using the bean bags.
Data analysis: Estimation accuracy classes were determined based on agreement between chosen bean bag volume and example food volume (Table 2).

Table 1: Perfect and almost perfect estimation accuracy of food types (N=30)

Food volume	Example foods	n (%) Perfect & almost perfect accuracy	Food type	Perfect & almost perfect accuracy
$\frac{3}{4}$ cup	Porridge	26 (86.7%)	Amorphous masses	73.3%
	Scrambled eggs	18 (60%)		
	Diced apple	25 (83.3%)	Amorphous pieces	81.7%
	Grapes	24 (80.0%)		
	Bread	21 (70%)	Solids	80.0%
	Whole apple	27 (90%)		
	Fruit juice	24 (80%)	Liquids	76.7%
	Tea	22 (73.3%)		



RESULTS

Sample: 30 elderly residents (mean age: 80.1y; 87% female)

Estimation accuracy:

- Limited perfect accuracy (Agreement range: 22% for amorphous masses and solids, to 37% for amorphous pieces)
- Perfect and almost perfect accuracy combined: Performance increased to 73% to 82%: little difference between food types (Table 1)
- For solids and amorphous masses: within-food type differences in accuracy (Table 1)
- A tendency of overall underestimation of solids and liquids was noted, and an overestimation of amorphous masses

Table 2: Estimation accuracy classes

Bean bag volumes	Estimation accuracy classes
$\frac{1}{8}$ cup	Overall underestimation
$\frac{1}{4}$ cup	
$\frac{3}{4}$ cup	Perfect accuracy
1 cup	Overall overestimation
1½ cups	
2 cups	

CONCLUSIONS

Perfect accuracy of bean bags as portion size estimation aids was limited and not apparently related to food types in the quantification of a $\frac{3}{4}$ cup of food by elderly participants. Where less accuracy is acceptable, bean bags may have some potential, but more research is needed to unravel the complexities of portion size estimation, particularly with bean bags, in this target group.

Sub-study 2:



Ability of female adults to estimate portion sizes of 3-D printed amorphous foods with bean bags

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BACKGROUND

Bean bags are commonly used as portion size estimation aids (PSEAs) in South Africa. There is limited literature regarding the accuracy of bean bags as PSEAs and about potentially related factors, such as body weight, energy density and perceived healthfulness of foods.

AIM

To determine female adults' ability to estimate the portion size of 3-D printed amorphous food models using bean bags. In addition, portion size estimation ability was evaluated taking individuals' body mass index (BMI), as well as the energy density and perceived healthfulness of foods into account.

METHODS

Design: Cross-sectional study.

Participants and setting: Female staff members from three private schools in Gauteng/South Africa.

Sampling: Convenience sampling.

Data collection: Using bean bags (test objects), participants recorded the estimated volume of 12 different 3-D printed food models (reference objects) presented in individual booths. Food and bean bag volumes included $\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$, 1, $1\frac{1}{2}$ and 2 cups. Reliability was determined by repeat assessments of three food models. Six models represented higher energy dense foods (>200 kcal/cup). Seven foods represented amorphous masses and five amorphous pieces. Healthfulness of foods was rated on a 5-point attitudinal scale

Data analysis: BMI was categorized as <25.0 kg/m², 25.0-29.9 kg/m² and ≥ 30 kg/m². Estimations were evaluated as **perfect** or **acceptable**, as well as gross under- or overestimations by more than one bean bag.

RESULTS

Sample: N=72 females

Age: 44.5 \pm 12.3 years; BMI: 22.5 \pm 4.6 kg/m²

Estimation accuracy:

Of a total 864 portion size estimations (Table):

- **28.6% : Perfect**
- **73.4% : Acceptable**
- Overestimation: Largest proportion of acceptable estimations.
- Amorphous masses: More accurately estimated than pieces.
- Food models tended to be overestimated, regardless of BMI category, energy density, or perceived healthfulness.



Table: Estimation accuracy of food models by volume

3-D Food models & volumes	Bean bag volume						n*
	$\frac{1}{4}$ c	$\frac{1}{2}$ c	$\frac{3}{4}$ c	1 c	$1\frac{1}{2}$ c	2 c	
	n (%)	n (%)	n (%)	n (%)	n (%)	n (%)	
$\frac{1}{4}$ c							
Peas and corn, boiled	27 (18.8)	45 (31.3)	43 (29.9)	20 (13.9)	7 (4.9)	2 (1.4)	144
Candy							
$\frac{1}{2}$ c							
Peanuts, roasted	7 (4.9)	22 (15.3)	37 (25.7)	49 (34.0)	24 (16.7)	5 (3.5)	144
Grapes							
$\frac{3}{4}$ c							
Spinach, boiled (plain)	2 (1.4)	9 (6.3)	31 (21.5)	89 (61.8)	12 (8.3)	1 (0.7)	144
Scrambled eggs							
1 c							
Rice, white	0 (0.0)	4 (2.8)	1 (0.7)	27 (18.8)	70 (48.6)	42 (29.2)	144
Minced meat							
$1\frac{1}{2}$ c							
Stiff porridge	0 (0.0)	0 (0.0)	2 (1.4)	10 (6.9)	48 (33.3)	84 (58.3)	144
Oats porridge							
2 c							
Potato salad, with mayonnaise	2 (1.4)	2 (1.4)	3 (2.1)	10 (6.9)	35 (24.3)	92 (63.9)	144
Popcorn, oil popped							

*n = number of estimations (2x food models per volume; 72 participants x 2)

Green = Perfect estimation

Pink = Acceptable estimation (over- or underestimation by 1 bean bag)

CONCLUSION

- Female teachers from private schools in Gauteng can estimate portion sizes of 3-D printed, amorphous foods with **acceptable accuracy**.
- Slight overestimations predominated.
- Links to BMI categories, energy density and perceived healthfulness were inconclusive.



The ability of adolescents (13–19 years) to estimate amorphous food portions from food photographs using bean bags

BACKGROUND

Dietary assessment needs to be quantified, particularly in adolescents, in order to be useful to dietetic professionals during individualised nutrition care. There is a lack of validated, easily accessible and affordable portion size estimation aids. Beans bags are used in practice, specifically for amorphous foods, but they have not been systematically investigated in South Africa in this target group.

AIM

To determine the ability of adolescents (aged 13-19 years) to match food photographs of known volumes of amorphous foods to corresponding bean bags.

METHODS

Design: Cross-sectional study.

Participants and setting: Adolescent learners, 13-19 years, in the middle and high school of a private, co-educational school (N=59) in Pretoria, South Africa.

Data collection: Nine different amorphous ready-to-eat foods (familiar and less common) of different, but known volumes (¼ to 2½ cups) were each photographed twice (aerial and 45°). In a random order (see ppt show) both versions were simultaneously displayed for 30 seconds on a projector to the six classes (grades 7-12; group size range: 4-12). Learners had to match the portion displayed on the screen with one of six coded bean bags (also ¼ to 2½ cups) randomly placed on a desk beside them. Frequency of consumption of each food was also asked. A total of twenty slides were displayed, three of which were repetitions to test for intra-rater, test-retest reliability. The process was standardised following pilot testing.

Data analysis: Responses were scored: perfect accuracy was assigned 0. Under-estimation and overestimation respectively got negative and positive values; absolute 1 was almost perfect, with increasing values indicating increasing inaccuracy.

RESULTS

Sample: All 51 eligible learners present on days of data collection were included (response rate: 86.4%; middle school: n=25 (51.0%); male: n=32 (62.7%).)

Estimation accuracy

The table shows:

- Test-retest reliability was acceptable.
- The majority of learners estimated 90-95% of food photographs with perfect or almost perfect accuracy.
- Food portions of ¼ cup and 1 cup were more often accurately estimated than other portion sizes.
- Meat dishes (minced meat and curry) were underestimated by most learners.

High school participants had a 5% higher perfect to almost perfect accuracy rating compared to middle school learners. Males had a 10% higher perfect to almost perfect accuracy score rate, than females.

No association between consumption frequency and estimation accuracy was observable.

Table: Estimation accuracy of different portion sizes for different foods, relative to food photographs (N=51)

Example foods	Portion size (cup)	Bean bag	n	Score: n (%)										
				-5	-4	-3	-2	-1	0	1	2	3	4	5
Mixed vegetables	¼		50						27(54)	17(34)	3(6)	3(6)	0(0)	0(0)
Rice	¼		50						11(22)	27(54)	8(16)	2(4)	1(2)	0(0)
Egg plant	¼		47						29(62)	14(30)	2(4)	0(0)	2(4)	0(0)
Egg plant (repeat)	¼		49						32(65)	14(29)	1(2)	0(0)	2(4)	0(0)
Kivi	½		48					2(4)	19(40)	23(48)	3(6)	0(0)	1(2)	
Kivi (repeat)	½		49					4(8)	13(27)	25(51)	6(12)	0(0)	1(2)	
Cereal	½		50						4(8)	16(32)	2(2)	1(1)	11(22)	4(8)
Yoghurt	½		51						4(8)	5(10)	30(59)	9(18)	1(2)	2(4)
Rice	1		50					3(6)	5(10)	26(52)	13(26)	3(6)	0(0)	
Curry	1		51					1(2)	7(14)	30(59)	10(20)	3(6)	0(0)	
Curry (repeat)	1		50					1(2)	6(12)	30(60)	13(26)	0(0)	0(0)	
Egg plant	1		48					4(8)	6(13)	22(46)	12(25)	4(8)	0(0)	
Spagetti	1½		49			0(0)	1(2)	9(18)	17(35)	17(35)	5(10)			
Mixed vegetables	1½		50			3(6)	3(6)	14(28)	23(46)	5(10)	2(4)			
Minced meat	1½		50			1(2)	3(6)	28(54)	15(30)	3(6)	0(0)			
Cereal	2		51			4(8)	2(4)	2(4)	5(10)	12(24)	26(51)			
Yoghurt	2		50			3(6)	1(2)	3(6)	5(10)	20(40)	18(36)			
Curry	2½		50	1(2)	6(12)	7(14)	16(30)	16(30)	4(8)					
Minced meat	2½		51	1(2)	2(4)	12(24)	23(45)	11(22)	2(4)					
Spagetti	2½		49	0(0)	1(2)	4(8)	7(14)	12(24)	25(51)					

Shaded cells = mode score: perfect accuracy, off by 1 (almost perfect accuracy), off by 2



To view the interactive presentation, download *Aurasma* and scan the rice image.

CONCLUSION

Adolescents of a mid-to-high socioeconomic status have the ability to estimate amorphous food portions from food photographs using bean bags with perfect or almost perfect accuracy. There may be a relation to their phase in the school (middle or high school), their gender and the portion size, but not to their consumption frequency and the type of food.



The effect of PLATE CHARACTERISTICS on university students' ESTIMATION ACCURACY of a FIXED SIZE BEANBAG



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Introduction

Portion size estimation is critical in quantitative dietary assessment. Plates are popular portion size estimation aids, yet plate characteristics may influence clients' ability to estimate the (food) quantity displayed on the plate.

Aim

"To determine the effect of four plate characteristics (**size**, **colour**, **pattern**, and **presence of a rim**) on the accuracy of portion size estimation of a fixed volume beanbag (as standardised proxy for amorphous food) by university students."

Methods



Design: Quasi-experimental study.



Population: Students enrolled at the University of Pretoria.
Sampling: Convenience.



Data collection: Participants recorded their response to the stimulus "What is the size of the beanbag on the plate?" at 13 randomly presented stations each displaying a 250mL beige-coloured bean bag on plates with different characteristics

- Size: 6 plate pairs: 20 vs 25cm diameter
 - Colour: 4 plate pairs: white vs navy
 - Pattern: 2 plate pairs: navy ornaments on white
 - Rim: 4 plate pairs: presence or absence of rim
- Five distractor bean bag volumes (125-500mL; also beige) were randomly added, as well as a test-retest station for reliability assessment.

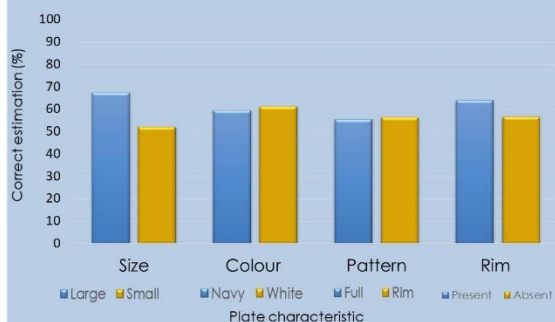
Description of sample



n = 184
Mean age: 20 ± 1.69 years
Male = 89 (48%)
Female = 95 (52%)

Results

Percentage of accurate size estimations by plate characteristic



Plates with least and most accurate size estimations by plate characteristic

Plate Characteristic	Least accurate (%)	Most accurate (%)
Size (6 plate pairs)	Small, white, non-rimmed plate (43)	Large, navy, rimmed plate (74)
Colour (4 plate pairs)	Small, white, non-rimmed plate (43)	Large, navy, rimmed plate (74)
Pattern (2 plate pairs)	Large, fully-patterned plate (55)	Large, rim-patterned plate (66)
Rim (4 plate pairs)	Small, white, non-rimmed plate (43)	Large, navy, rimmed plate (74)

Conclusion

- The **size** of the presentation plate affected university students' accuracy of portion size estimations of a fixed volume beanbag.
 - **Large plates** → **more accurate volume estimation**
- No obvious effect of the other characteristics on portion size estimation were seen.



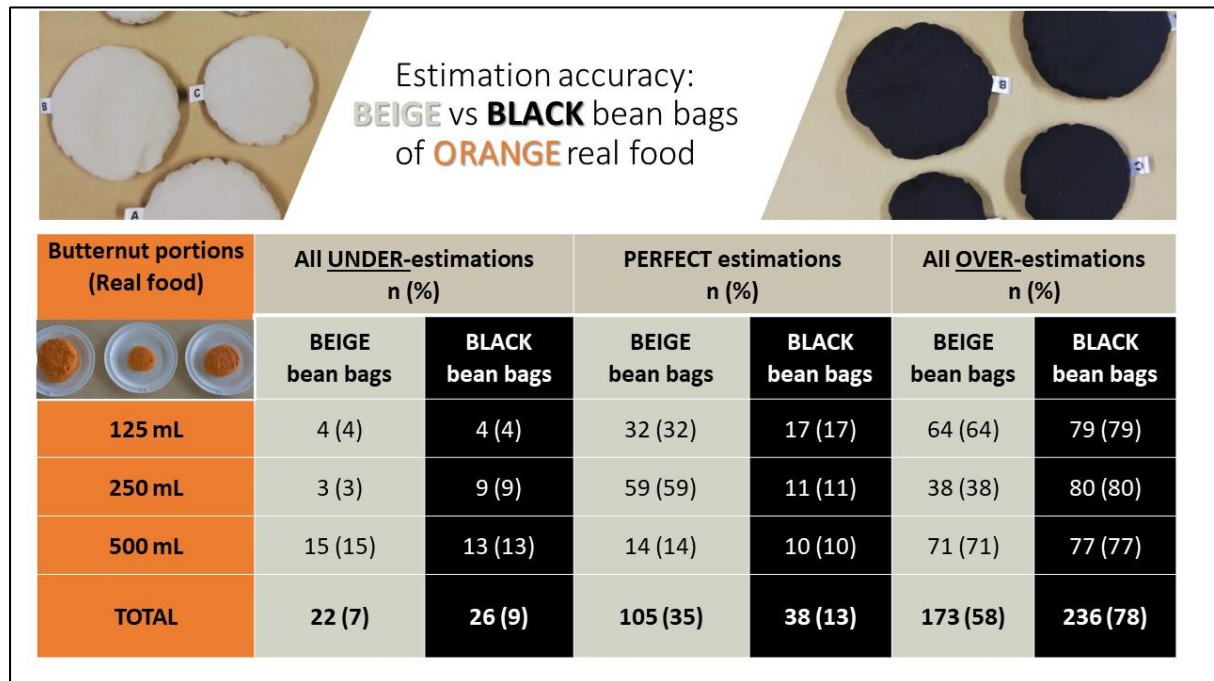
For full reference list & images of data collection set-up.

Department of Human Nutrition, 2019



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Sub-study 5 Results



Sub-study 6:



UNIVERSITY STUDENTS' ABILITY TO ESTIMATE PORTION SIZES OF MAIZE MEAL PORRIDGE: COMPARISON OF TWO PORTION SIZE ESTIMATION AIDS

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BACKGROUND

Previous studies have established the accuracy of various portion size estimation aids (PSEAs) in different populations and age groups. However, evidence regarding bean bags as PSEAs is very limited. Therefore, this study aimed to determine the usefulness of bean bags as PSEAs in South Africa when compared to food photographs in the quantification of a local staple food.

AIM

To determine university students' ability to estimate two portion sizes of three forms of maize meal porridge (soft, stiff and phuthu porridge) using bean bags and food photographs as PSEAs.

METHODS

Study design: Cross-sectional, comparative.

Participants and setting: 104 University of Pretoria full time students dining at the Groenkloof dining hall.

Sampling: Convenience.

Data collection: In 12 separate stations participants had to match small (250 mL) or large (500 mL) portions of three forms of maize meal porridge dished up on enamel dishes to either a set of bean bags (625 mL, 500 mL, 375 mL, 250 mL, 190 mL and 125 mL) or to life size, colour photographs of the same volumes on the same dishes, in random order. Three test-retest assessments were added to the battery. Body weight (SECA 874 digital scale) and height (SECA 217 height meter) were obtained.

Data analysis: Estimations were scored by difference: a perfect accuracy was assigned 0, underestimation got negative values, and overestimation positive values. BMI (body weight[kg]/height[m]²) was calculated.

RESULTS

Sample: N=104. Age: 20.9±1.97; 58(56.3%): females; BMI: 18(17%) underweight, 5(5%) obese.

Estimation accuracy:

From a total of 1243 estimations (Table):

- ♣ 37.0% were perfect
- ♣ 26.7% were underestimations
- ♣ 36.2% were overestimations
- ♣ General estimation trend
 - ◆ soft and phuthu: overestimation
 - ◆ stiff porridge: underestimation
- ♣ Bean bags overestimated both portion sizes of all three forms of maize meal porridge
- ♣ Test-retest reliability was acceptable

Table: Overall estimation accuracy for the three forms of maize meal porridge with either bean bags or food photographs (N=104)

PSEA	Portion Size	Participant Responses							
		Score: n (%)							
		-4	-3	-2	-1	0	+1	+2	+3
← Underestimation				Perfect Accuracy	→ Overestimation				
☉	L	2 (2)	2 (2)	3 (3)	19 (18)	29 (28)	49 (47)		
	S			1 (1)	24 (23)	57 (55)	22 (21)		
☉	L			4 (4)	14 (14)	51 (50)	27 (27)	4 (4)	1 (1)
	S			7 (7)	40 (38)	48 (46)	9 (9)		
☉	L			7 (7)	10 (10)	36 (35)	37 (36)	9 (9)	5 (5)
	S	2 (2)	3 (3)	11 (11)	15 (14)	24 (23)	49 (47)		
☉	L			20 (19)	41 (40)	34 (33)	4 (4)	2 (2)	2 (2)
	S			7 (7)	6 (6)	26 (25)	34 (33)	23 (22)	8 (8)
☉	L			2 (2)	15 (14)	39 (38)	36 (35)	7 (7)	5 (5)
	S	1 (1)	1 (1)	1 (1)	37 (36)	44 (42)	20 (19)		
☉	L	2 (2)	1 (1)	6 (6)	10 (10)	19 (18)	66 (63)		
	S			7 (7)	11 (11)	54 (52)	26 (25)	2 (2)	3 (3)
Total	n(%)	332 (26.7)			461 (37)	450 (36.2)			

S: Small (250mL)
 L: Large (500mL)

CONCLUSION

- ♣ University students tended to overestimate portion sizes of three forms of maize meal porridge when using bean bags.
- ♣ Life-size food photographs of identical real foods outperformed the bean bags with a tendency towards underestimation.

University of Pretoria Research Ethics Approval: 567/2017

