Development and Validation of a Brief Instrument to Measure Knowledge about the Energy

Content of Meals

Research Brief

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ABSTRACT

Objective: To develop and validate a brief scale to assess knowledge about the energy content of meals for adults in Switzerland.

Methods: Based on a random sample, the scale was developed using a Rasch model approach. To assess validity and reliability, the model was replicated, the scores compared to another nutrition knowledge measure and to dietitian trainees' scores. A test-retest was performed.

Results: The survey studies included each 477, 505 and 136 participants from the general population and 59 nutrition experts. The Rasch scale consisted of 11 multiple-choice items ranging from easy to difficult and correlated with general nutrition knowledge $r = 0.47$, $P < .001$, $r^2 = 0.22$. Dietitian trainees achieved higher scores $P < .001$, $d = 2.17$ than people from the general population and the test-retest reliability was $r = 0.73$, $P < .001$, $r^2 = 0.53$.

Conclusions and Implications: The results show that the scale is efficient, valid and reliable for use in the general population in Switzerland.

Keywords: practical nutrition knowledge, energy content of meals, Rasch scale, questionnaire

INTRODUCTION

In developed countries, people have continuous access to a huge supply of affordable, highly processed foods (e.g., burgers, frozen pizza, cereal bars, crisps, sweets, sugared drinks) that are high in fat, added sugar and salt, whereas the proportion of fresh foods has declined.^{1,2} The consumption of such foods and the increased consumption of foods and beverages out of home (e.g., ready-to-eat meals) have been associated with a higher energy intake and a lower diet quality, resulting in a higher risk of obesity.^{3,4} To meet dietary recommendations in such a food environment, consumers need specific knowledge and skills to make healthy food choices, particularly when eating away from home.⁵ For example, consumers should have knowledge regarding the energy content of meals to choose a low-energy-dense diet, as recommended by current dietary guidelines for maintaining or achieving a healthy body weight.⁶ However, a recent systematic review concluded that nutrition knowledge and food intake are only weakly correlated, and the specific role of nutrition knowledge in healthy eating is not yet fully understood.⁷ One reason might be that many studies do not measure nutrition knowledge and food intake with the same degree of specificity.⁸ More precisely, most of the existing nutrition knowledge questionnaires assess general knowledge, which might not be appropriate for predicting specific behaviors such as choosing low-energy food.^{7,9-12} In addition, general nutrition knowledge questionnaires, such as the widely used questionnaire of Parmenter and Wardle,¹³ are very time-consuming and contain several items of questionable relevance. To better explore the impact of nutrition knowledge on food intake, reliable and valid questionnaires are thus required to measure a specific (unidimensional) and relevant type of nutrition knowledge.^{7,8,14} The authors concluded that a reliable and valid questionnaire for assessing knowledge about the energy content of meals is needed, as previous studies using ad hoc measures revealed that consumers know little about the energy content of different foods.¹⁴⁻¹⁶ In addition, knowledge about the energy content of meals might be more relevant than knowledge about the energy content of single food

items, as most foods are eaten together as a meal. A lack of such knowledge might be a risk factor for a higher energy intake.¹⁷⁻¹⁹ Therefore, this study aimed to develop and validate a brief scale called “practical knowledge about meal calories” (PKM-11), intended to measure practical knowledge about the energy content of meals and meal components among an adult Swiss population, which can be further used to investigate the association with energy intake.

METHODS

Study Design

The development and validation of the PKM-11 scale encompassed 3 cross-sectional studies and 1 test-retest study. The newly developed items were included in the same surveys and tested in the same samples as an already published scale.²⁰ This scale, called the PKB-7 scale, has been developed and validated for assessing knowledge about balanced meals.²⁰ This knowledge is assumed to be important for choosing a balanced diet, which is conceptually a different type of knowledge than the energy content of meals.¹⁴ However, both nutrition knowledge types might be required for adopting a diet in line with the dietary guidelines.

The studies included people from the general population, nutrition experts and dietitian trainees. Respondents under the age of 18 and over 75 years were excluded. None of the respondents received monetary compensation. All studies received approval from the ETH Ethics Committee, Zurich, Switzerland.

52 **Item Generation**

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54 A panel of nutrition experts and psychologists generated a large pool of items ($n = 93$)
 55 related to the energy content of meals (including fat and added sugar content). They focused on
 56 practical knowledge in the form of meal choices (e.g., “Which meal contains less
 57 energy/sugar/fat...?”) based on common eating patterns in Switzerland. They used simple
 58 vocabulary without technical terms and included pictures of meals if necessary. The item generation
 59 followed Haladyna’s guidelines for multiple-choice test construction.²¹ To check for content
 60 validity, 4 nutrition experts reviewed all the newly developed items. They evaluated each item to
 61 determine whether it measured relevant knowledge about the energy content of meals or meal
 62 components, its level of difficulty and any technical ambiguity. Additionally, 2 nutrition experts
 63 conducted thinking-aloud interviews with laypeople differing in age, gender, education and native
 64 language until comments began to repeat ($n = 10$). They were instructed to express their thoughts
 65 aloud while answering the items to qualitatively assess the comprehensibility, difficulty and
 66 ambiguity of the items.^{22,23} The participants were also asked what they thought that the items were
 67 measuring. Based on the experts' and laypeople's comments and suggestions, ambiguous items were
 68 revised and modified (e.g., wording and poor distractors) and irrelevant items were removed.
 69 Subsequently, a group of nutrition experts and psychologists reviewed and discussed all items and
 70 selected the 34 most appropriate ones for further testing in a larger survey sample.

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72 **Participants and Survey**

73 The first of the 4 conducted studies concerned item testing in a random sample of
 74 participants and scale development. In the second and third studies, the scale was validated using
 75 another sample from the general population and dietitian trainees. The fourth study assessed the
 76 test-retest reliability of the scale. Table 1 presents a description of the samples.

77 In Study 1 (n = 447 adults from the general population), a survey including the 34 developed
 78 items and questions related to health and socio-demographic characteristics was mailed to a random
 79 sample of 1,200 households in the German-speaking part of Switzerland to achieve a target sample
 80 size of about 500 individuals.²⁴ The researchers randomly selected addresses from the telephone
 81 directory. The household member over the age of 18, whose birthday was closest to the date when
 82 the survey was received, was asked to complete the questionnaire. One reminder letter was sent to
 83 nonresponders; the final response rate was 46%.

84 Study 2 used the same recruitment and survey administration as described in Study 1, with
 85 500 participants (42% response rate). The survey was mailed to a random sample of 1,500 German-
 86 speaking Swiss households and included the new PKM-11 scale, the GNKQ with 3 subscales
 87 (*awareness of dietary recommendations, food sources of nutrients and choosing foods for a healthy*
 88 *diet*),^{11,13} a nutrition-related health interest scale,²⁵ and personal questions.

89 In Study 3, 59 dietitian trainees (44% response rate) completed an online survey consisting
 90 of the PKM-11 items. They were recruited by sending an email to all advanced bachelor students of
 91 nutrition and dietetics in the German-speaking part of Switzerland.

92 Study 4 included a convenience sample of adults from the general population (n = 136, 73%
 93 response rate), derived from an Internet panel. The participants of this Internet panel were randomly
 94 chosen volunteers from the general population who were asked to regularly participate in
 95 thematically different online studies. They completed an online version of the PKM-11 scale twice
 96 within 2 weeks, which is the time span recommended for a test-retest.²²

97 - Insert Table 1 here -

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99 **Scale Development**

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101 Based on the tested 34 items in Study 1, a Rasch analysis was conducted to build the final
 102 scale by eliminating nonfunctioning items stepwise.^{26,27} The researchers used this scaling method

because the Rasch model tests whether dichotomous multiple-choice items fit the requirements of a mathematical measurement model rather than merely testing the psychometric properties of given items.²⁸ Correct responses were scored as 1, while incorrect and “don’t know” answers were scored as 0. Higher scores indicated higher levels of knowledge.

Scale Validation

Study 2 reproduced the same Rasch measurement model as in Study 1 to examine its construct validity. The PKM-11 scores were also compared with those of the widely used GNKQ, which measures broad nutrition knowledge, nutrition-related health interest, dieting experience, and demographic characteristics such as gender and education. The PKM-11 scores were expected to correlate moderately with general nutrition knowledge but only weakly with other nutrition-related variables. In line with previous research, female and higher educated individuals and those with dieting experience were expected to achieve higher PKM-11 scores.^{7,14,18} To further validate the scale, the PKM-11 scores were compared between dietitian trainees and laypeople, which is a common method used in previous scale validations.⁹⁻¹³ In Study 4, the reliability was examined using a test-retest, which was expected to achieve a minimum recommended value of $r = 0.70$ for a good test.²⁹

Statistical Analysis

The researchers conducted a Rasch analysis in the statistical software R (R Foundation for Statistical Computing, Vienna, Austria, 2014) using the extended Rasch modeling (eRm) package,³⁰ guided by the recommendations of Koller, Alexandrowicz and Hatzinger.³¹ The item parameters were estimated by applying the conditional maximum likelihood (CML) method. The model fit of the items was examined using chi-square fit statistics, with infit and outfit mean-squared residuals

129 between 0.8 and 1.2 regarded as appropriate.²⁸ The overall model fit was tested using the global
 130 Andersen's likelihood ratio test,³² which requires the absence of significant differences in item
 131 difficulties between higher and lower nutrition-literate respondents. Further, Andersen's likelihood
 132 ratio tests were performed for gender, age and education to check for differential item functioning
 133 (DIF). The unidimensionality of the scale was tested with the Martin-Löf test.³³ Andersen's
 134 likelihood ratio tests using selected items as split criteria determined the local independence of the
 135 items. For model acceptance, all tests were expected to be non-significant on a Bonferroni-adjusted
 136 significance level.³¹ A more detailed description is provided in a previous scale development
 137 paper.²⁰

138 With the exception of the Rasch modeling, the researchers performed statistical analyses
 139 using SPSS statistical software (version 22, IBM Corp., Armonk, NY, 2013), tested at a 5%
 140 significance level. The associations between the variables of interest were determined by Pearson
 141 correlation coefficients, and two-tailed *t*-tests for independent samples identified the differences
 142 between 2 groups. For significant results, the effect size, Cohen's *d*, is reported.

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145 **RESULTS**

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148 Following the stepwise item selection by the Rasch analysis in Study 1, a final scale
 149 consisting of 11 multiple-choice items was built (Table 2). Some items had to be removed because
 150 they showed poor item discrimination between participants with high and low nutrition knowledge,
 151 indicated DIF among age and gender, or did not measure the intended unidimensional construct
 152 (showed poor item fit values). An example item for age DIF was: "Which of the following meals
 153 contains fewer calories?" Answer options: a large portion of pasta Bolognese with a small green
 154 salad; a small portion of pasta Bolognese with a slice of bread (correct answer); both similar; don't

155 know. This item was more difficult for older people than younger people. Another example item for
 156 gender DIF was: "Which of the following salads contains more fat?" Answer options: a green salad
 157 with egg and French dressing; a tomato mozzarella salad with Italian dressing (correct answer);
 158 both similar; don't know. This item was more difficult for men than for women. The mean score
 159 was 5.8 (SD = 1.9), ranging from 0 to 10 (possible range of 0–11), which indicated a nearly normal
 160 distribution (Appendix A). The item difficulties ranged from very easy to very difficult (93.1%–
 161 7.1% of correct answers). Chi-square item fit statistics were non-significant and showed infit and
 162 outfit values close to 1, indicating that the empirical data fit the model's expectations (for details of
 163 item difficulties and fit values see Appendix B).²⁸ The global Andersen's likelihood ratio test (χ^2
 164 (10) = 10.81; $P = .37$) determined the overall model fit. Andersen's likelihood ratio tests, which
 165 control for DIF, showed that the items functioned equally well among the subgroups of age, gender
 166 and education (Appendix C). Furthermore, non-significant Andersen's likelihood ratio tests using
 167 selected items as split criteria showed that the items were locally independent of each other.
 168 Moreover, according to the Martin-Löf test (χ^2 (29) = 25.93; $P = .63$), the 11 items were
 169 homogeneous and measured a unidimensional latent trait.

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171 *- Insert Table 2 here -*

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173 The Rasch model replication of Study 2 also showed a good model fit (global Andersen's
 174 likelihood ratio test [χ^2 (10) = 12.06; $P = .28$]), and the items ranged from very easy to very difficult
 175 (92.4%–13.8% of correct answers). The estimated item difficulties, as well as the infit values, were
 176 similar to those in Study 1 (Appendix B). The participants' raw scores were again nearly normally
 177 distributed and ranged from 1 to 11 (possible range of 0–11), with a mean score of 5.8 (SD = 1.8).

178 The Martin-Löf test and Andersen's likelihood ratio tests, using the same split criteria as in
 179 Study 1, showed no Bonferroni-adjusted significant values for the items (Appendix C).

Further results of the scale validation in Study 2 showed that the PKM-11 scores were substantially correlated with those of the GNKQ, which measured general nutrition knowledge, but were only modestly correlated with nutrition-related health interest (Table 3). Moreover, the respondents with dieting experience (mean = 6.5, SD = 1.7) scored 1 point higher than those without dieting experience (mean = 5.5, SD = 1.8) ($t [473] = 5.40$; $P < .001$, $d = 0.55$). Women (mean = 6.2, SD = 1.8) scored 1 point higher than men (mean = 5.2, SD = 1.8) ($t (476) = 6.00$; $P < .001$).

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- Insert Table 3 here -

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The results of Study 3 showed that the dietitian trainees (mean = 9.2, SD = 1.3, range of 7–11) scored significantly higher than the respondents from Study 2 (mean = 5.8, SD = 1.8, range of 0–10) ($t [90] = 18.36$; $P < .001$, $d = 2.17$). Study 4 showed no significant difference ($t [135] = 0.84$; $P = .40$) between the PKM-11 scores in the first survey (mean = 6.1, SD = 1.9) and the second survey (mean = 6.2, SD = 2.0). The correlation of the scale scores between the first and the second surveys was $r = 0.73$ ($P < .001$, $r^2 = 0.53$).

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DISCUSSION

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The results of the 4 studies showed that the new PKM-11 scale was a valid and reliable Rasch-based instrument for briefly assessing the practical knowledge about the energy content of meals among adults from the general population in Switzerland. More precisely, both nutrition experts and laypeople in the pretests attested that the final items measured relevant knowledge regarding the energy content of meals, indicating content validity. Further construct validity was

206 shown by the replication of the Rasch measurement model in a second, independent sample and by
 207 the result that dietitian trainees achieved significantly higher scores than laypeople. Differences
 208 between high and lower nutrition-literate individuals have also been reported in many previous
 209 validation studies.⁹⁻¹³ The PKM-11 scale correlated moderately with the GNKQ, confirming that
 210 both measure nutrition knowledge, although not exactly the same nutrition knowledge type.
 211 Additionally, the weak correlation between the PKM-11, the GNKQ, and nutrition-related health
 212 interest confirmed that interest and knowledge are different constructs. In line with the previous
 213 literature suggesting gender and education as consistent predictors of nutrition knowledge,^{7,22}
 214 women and more educated individuals achieved higher PKM-11 scores. Additionally, the test-retest
 215 reliability was good.²⁹

216 Overall, the studies revealed that a substantial segment of the people from the general
 217 population in Switzerland had little knowledge about the energy content of meals, a result also
 218 found in previous studies using ad hoc measures.¹⁴⁻¹⁹ Furthermore, this research showed that age
 219 was negatively correlated with the PKM-11, corresponding to previous findings that knowledge
 220 about the energy content of meals decreases with age.¹⁴ In addition to younger individuals, those
 221 with dieting experience also achieved higher PKM-11 scores, which might indicate an increased
 222 interest in knowledge about the energy content of food in order to reduce weight.¹⁸

223 In comparison to most other nutrition knowledge questionnaires, this study used a Rasch
 224 analysis to build the final scale, which provided unique advantages for scale construction.^{26,27} For
 225 example, the Rasch model required testing whether the items were equally difficult for specific
 226 subgroups (e.g., men vs. women, less educated vs. more educated). This model assumption of DIF
 227 might be especially relevant for the development of new nutrition knowledge questionnaires, as
 228 demographics were consistently correlated with nutrition knowledge.⁷ This means that for many
 229 other nutrition knowledge questionnaires, it cannot be determined whether people with less
 230 education answered an item differently because they lacked nutrition knowledge or did not
 231 understand a specific technical term in the question (e.g., protein).

This study had some limitations that should be addressed. First, the development and validation studies were conducted in the German-speaking part of Switzerland, which limits the usage of the scale. Second, despite the randomized survey administration, there might be a self-selection bias toward people who were more interested in the topic of nutrition. Additionally, although the participants were asked not to use any external sources to answer the questions, the survey format did not control for this. Third, the mean age of the random samples was slightly higher than that of the Swiss population, corresponding to those of other survey studies based on addresses from the telephone directory.^{11,20} However, the samples covered the full range of age and other demographic levels.

IMPLICATIONS FOR RESEARCH AND PRACTICE

The newly developed PKM-11 scale has been shown to be valid and reliable in adults from the general population in Switzerland. As a brief instrument comprising only 11 items, this scale can quickly identify knowledge gaps about the energy content of meals, for instance, during nutrition counseling or weight-loss interventions. The possibility to assess this type of knowledge in a reliable and valid way is important since a substantial proportion of people lack knowledge about the energy content of food, which might be associated with higher energy intake.¹⁷ As this scale measures specific (unidimensional) and practical nutrition knowledge, it might be more relevant for choosing a low-energy-dense diet than the abstract and more general nutrition knowledge assessed by most previous questionnaires.⁷ However, additional studies are needed to investigate to what extent higher PKM-11 scores might be helpful for choosing a low-energy-dense diet and controlling body weight. In addition, future studies are required to examine whether the proposed scale can be used in other populations.

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Table 1 Characteristics of the Four Survey Samples in the Development and Validation of the PKM-11 Scale
(Practical Knowledge about Meal Calories)

	Study 1	Study 2	Study 3	Study 4
	Development	Validation	Validation	Test-retest
	% (n = 447)	% (n = 505)	% (n = 59 nutrition experts)	% (n matched =136)
Female	58	57	93	44
Age				
18–35 years	11	10	98	6
36–50 years	32	27	2	21
51–75 years	57	63	0	73
Last finished school				
Primary and lower secondary school	7	5	0	-
Vocational education	41	46	0	-
Upper secondary university preparation school	6	7	0	-
Higher vocational education	24	23	0	-
University	22	19	100	-
Body mass index (BMI)				
< 18.5	2	2	-	-
18.5–24.9	58	55	-	-
25.0–29.9	28	32	-	-
> 30.0	12	11	-	-
Having dieting experience	26	30	-	-

Table 2 Final Items of the Translated Version of the PKM-11 Scale (Practical Knowledge about Meal Calories)

The following questions are about the caloric content of meals. Please indicate the answer that is correct in your opinion (instruction).

Q1. Which potato side dish contains the smallest amount of fat?

- ☐ Potato salad
- ☐ Mashed potatoes
- ☒ Baked potatoes
- ☐ Don't know

Q2. Which of the following cheese sandwiches has the lowest fat content?

- ☐ Sandwich with cream cheese
- ☐ Sandwich with hard cheese
- ☒ Sandwich with cottage cheese
- ☐ Don't know

Q3. Which of these sandwiches is lower in calories?

- ☒ Ham sandwich
- ☐ Schnitzel sandwich
- ☐ Both similar
- ☐ Don't know

Q4. Which of the following meals contains the fewest calories for equal portion sizes?

- ☒ Trout fillet with boiled potatoes and broccoli
- ☐ Breaded vegetarian schnitzel with pasta and peas
- ☐ Both similar
- ☐ Don't know

Q5. Which of the following wraps (sandwich made with a soft flatbread) has the lowest fat content?

- ☐ Chicken wrap with salad and guacamole (avocado cream)
- ☒ Chicken wrap with salad and tomato salsa
- ☐ Chicken wrap with sour cream
- ☐ Don't know

Q6. Which snack contains the smallest amount of fat for equal portion sizes?

- ☐ Puff pastry
- ☐ Tortilla (corn) chips
- ☒ Salted pretzel sticks
- ☐ Don't know

Q7. Which dessert contains the smallest amount of fat?

- ☐ Chocolate mousse
- ☐ Mixed berry tiramisu
- ☒ Caramel pudding
- ☐ Don't know

Q8. Which dessert contains the smallest amount of calories for equal portion sizes?

- ☐ Fresh raspberries with mascarpone
- ☒ Fresh raspberries with whipped cream
- ☐ Both similar
- ☐ Don't know

Q9. Which of the following beverages contains less sugar for equal portion sizes?

- ☐ Energy drink
- ☐ Orange juice
- ☒ Both similar
- ☐ Don't know

Q10. Which of the following meals is lower in calories?

- ☐ Fish, rice and green beans

- ☒ Chicken, pasta and carrots

- ☐ Both similar
- ☐ Don't know

Q11. Which meat dish contains the smallest amount of fat?

- ☐ Lamb chops with roasted potatoes and broccoli
- ☐ Minced beef with roasted potatoes and broccoli
- ☒ Pork medallion (not breaded) with roasted potatoes and broccoli
- ☐ Don't know

Note: Correct answers are marked. Items are listed from easy to difficult.

Table 3 Correlation Coefficients (r^2) Between PKM-11 Scores (Practical Knowledge about Meal Calories) and Other Nutrition-Related and Demographic Variables (n = 505)

	1	2	3	4	5	6	7
(1) PKM-11	-						
(2) GNKQ Total	0.47** (0.22)	-					
(3) Health interest	0.22** (0.05)	0.27** (0.07)	-				
(4) Gender ^a	0.26** (0.07)	0.20** (0.04)	0.31** (0.10)	-			
(5) Age	-0.16** (0.03)	-0.06 (0.00)	0.12** (0.01)	-0.12** (0.01)	-		
(6) Education ^b	0.13** (0.02)	0.23** (0.05)	0.05 (0.00)	-0.15* (0.02)	-0.05 (0.00)	-	
(7) Dieting experience ^c	-0.24** (0.06)	-0.14* (0.02)	-0.06 (0.00)	-0.24** (0.06)	0.11* (0.00)	0.11 (0.01)	-
Mean	5.8	51.9	4.8	57 ^d	54.1	3.1	30 ^d
SD	1.8	8.4	1.1	-	13.5	1.3	-
Number of items	11	84	8	-	-	-	-

^a(0) male, (1) female. ^b(1–5) low to high education. ^c(0) diet experience, (1) no diet experience. ^dValues as a percentage.

Significant by Pearson's correlation or Phi coefficient analysis (* $P < .05$, ** $P < .01$).