Evaluation of a food frequency questionnaire for assessing of calcium, protein and phosphorus intakes in children and adolescents

By Christian Mølgaard, Brittmarie Sandström and Kim Fleischer Michaelsen

Received: November 13, 1997; Accepted: December 30, 1997

Abstract

The aim of the study was to assess validity and reproducibility of a self-administered quantitative food frequency questionnaire (FFQ) designed to assess calcium, protein and phosphorus intakes, and to be used in a semilongitudinal study on bone mineralisation in children and adolescents. Validation study: 23 children aged 13-14 years filled in the questionnaire and kept 3-day weighed food records. Reproducibility study: 293 children aged 5-19 years completed the questionnaire twice with a half year interval.

Spearman rank correlations between nutrient intake values from the questionnaire and weighed food records were 0.56-0.62 (mean 0.60). There were no significant differences in intake estimated by FFQ and weighed record for either calcium ($p=0.07$) or protein ($p=0.61$), while phosphorus intake estimated by FFQ was 10% higher than phosphorus intake estimated by weighed record ($p=0.04$). On average regarding calcium, protein, and phosphorus intake, 43% of the subjects were classified in the same quartile in the questionnaire and the record, and 1% in the opposite quartile. Spearman rank correlation between nutrient intake from the two questionnaires was 0.72-0.73, with no significant difference between the measurements. It is concluded that this questionnaire is able to rank children according to their intakes of calcium, protein, and phosphorus and to give a reasonable estimate of the quantity of the nutrients in groups of children.

Introduction

It is generally accepted that peak bone mass obtained in early adulthood is related to the risk of osteoporosis in later life (1,2). It is therefore important to study how nutrients affect bone mass in childhood and adolescence. It has been suggested that intake of calcium, protein and phosphorus has an influence on bone mass in childhood and adolescence (3-5). Until now research has focused mainly on calcium intake, but there is no consensus on how much calcium children need. Some studies have found a positive association between calcium intake and bone mass in childhood and adolescence (6,7) while others could not confirm such an association (8-10). Lack of agreement on how much calcium children need to obtain the genetically determined peak bone mass is reflected in the great differences between recommendations around the world (11-13). Reliable registration of calcium, protein and phosphorus intakes is needed in research in which the relation between food intake and bone mass is being examined.

The aim of the present study was to evaluate a quantitative food frequency questionnaire (FFQ) for registration of calcium, protein and phosphorus intakes. The questionnaire was developed for use in a semilongitudinal study on the relation between diet and bone mass in healthy children and adolescents (14,15).

Methods

Food frequency questionnaire

The quantitative FFQ was designed to measure the "usual" intake of calcium, protein and phosphorus during the previous month. It included questions about the intake of 88 food items. A list of the food items included in the questionnaire is given in Table 1. Questions concerning foods with a high calcium content such as dairy products were most detailed. Frequency of consumption was given as times per day, times per week, less than once per week or never, depending on the food item. Portion sizes were presented in household units e.g. glass, cups, spoonful etc. Children below 13-14 years answered the FFQ together with their parents. Single copies of the FFQ, which is in Danish, may be obtained from the authors for use in other studies.

Relative validity

Diet record (DR) by weighing was used as a reference because this method is regarded as one of the most accurate methods for

measuring food intake (16,17). Twenty-three school children (8 boys and 15 girls) aged 13-14 years (7th grade) participated. They all answered the FFQ as instructed by a dietician. Thereafter weighed diet record was performed. The children completed a 3-day record (two weekdays, one Saturday). Participants were provided with a notebook and a digital balance with a precision of ± 1 g and a maximum of 1000 g, and were given practical and written instructions. The FFQ was filled in at home.

Reproducibility

Reproducibility was studied in a group of children and adolescents participating in a study on bone mineralisation during growth. Diet was assessed by FFQ two times with a half year interval between each completion in 293 healthy school children (163 females, 130 males) aged 5-19 years, (median age 13.0 years). Each individual or their parents was given instruction on how to answer the FFQ.

Nutrient calculation

Daily intakes of calcium, protein and phosphorus were calculated by the statistical programme SPSS/PC+ using a national food database (*Levnedsmiddeltabeller* 1989, LST) containing data on Danish food.

Statistical methods

Data from the dietary assessment methods were analysed using the statistical programmes SAS (Version 6.11) and SPSS

Christian Mølgaard*, MD, PhD, Brittmarie Sandström, Prof, Phil dr, Kim Fleischer Michaelsen, Dr Med, Associate Professor in Paediatric Nutrition. All authors are affiliated to Research Department of Human Nutrition and Centre for Advanced Food Studies, The Royal Veterinary and Agricultural University, Rolighedsvej 30, DK-1958 Frederiksberg C, Denmark.

* Correspondence: E-mail: CM@kv1.dk

(Version 7.0/7.5 for windows). Non-parametric statistics were used since some of the nutrient intake distributions were skewed towards higher values. The sample medians, 25th and 75th percentiles were computed. The 10th, 25th, 50th, 75th and 90th percentiles of the individual differences between the two measurements of nutrient intakes were computed and the differences were tested by Wilcoxon matched-pairs signed rank test. The number of persons with a difference between the two registrations in measured intakes of less than 20% was calculated to make comparison with another Scandinavian study possible (16). Bland-Altman plots were used to illustrate the magnitude of disagreement between two registrations (18). Spearman rank correlations were used to compare values from two measurements. As recommended by *Garrow* (19) agreement on the category level between FFQ and diet record was examined by classification of intakes into quartiles. In the reproducibility study multiple regression was used to analyse whether the difference in intakes estimated by FFQ with a half year interval were related to age and sex.

Results

Relative validity

Table 2 shows the daily intake of calcium, protein and phosphorus determined by FFQ and by diet records. There were no significant differences between FFQ and diet record estimated protein intake ($p=0.61$). FFQ estimated calcium intake was borderline significantly higher (19%, $p=0.07$) and phosphorus intake significantly higher (10%, $p=0.04$) than diet record estimated intakes. The number of persons with a difference in estimated intake between the two methods below 20% of diet record estimate was 8, 11 and 8 for calcium, protein and phosphorus intake, respectively (Table 2). Table 3 shows the distribution of individual differences between the FFQ and the diet record estimates. There was a large individual variation in differences between the absolute values of FFQ and diet record measurements. In general, the difference increased with intakes for calcium, protein and phosphorus, as shown in Figure 1. Spearman rank correlation coefficient between pairs measurements by FFQ and diet record was 0.56-0.62. (Table 2). The extent to which the FFQ and diet record classified individuals in the same quartile and misclassified to the opposite quartile is shown in Table 4.

Reproducibility

The differences between the two FFQ estimates with a half year interval were not

related to age and sex for either calcium (age: $p=0.34$, sex: $p=0.40$), protein (age: $p=0.19$, sex: $p=0.44$) or phosphorus (age: $p=0.33$, sex: $p=0.31$). Table 5 shows the daily intakes of calcium, protein and phosphorus determined by 2 FFQ measurements with a half year interval. There was no significant difference between the two measurements for calcium, protein or phosphorus. The number of individuals with a difference between the two measurements below 20% of the first measurement were 141, 163, and 154 for calcium, protein and phosphorus intakes respectively. Table 6 shows the distribution of individual differences between the two measurements for calcium, protein and phosphorus intakes. There was a large individual variation in differences between the two measurements. In general, the individual difference increased with intakes for calcium, protein and phosphorus (Figure 2). The Spearman rank correlations between pairs measurements was 0.72-0.73 (Table 5).

Discussion

In the present study we have evaluated a newly developed food frequency questionnaire used in a study on the influence of calcium, protein and phosphorus intakes on bone mineralisation in healthy children and adolescents. The questionnaire can be used in assessment of calcium, protein and phosphorus intakes in large groups of children and adolescents, because it is cheap and easily used by children and adolescents. It took about 30 minutes for the children/parents to complete the FFQ. A small database containing

Table 1. Food questionnaire. Number of items (n=88) and portion sizes listed in their order of appearance in the questionnaire. Frequency of consumption was given as times per day, times per week, less than once per week or never, depending on the food item.

Groups of Food items	Portion size	No. of items
Milk:	Glasses	4
Breakfast	Glasses	4
Lunch weekday	Glasses	4
Lunch weekends	Glasses	4
Afternoon	Glasses	4
Dinner	Glasses	4
Evening	Glasses	4
Cacao milk	Glasses	1
Curtle milk	Decilitres	9
Cereals	Decilitres	6
Bread	Slices	3
Cheese*	Slices of bread	5
Egg	4 portion sizes	1
Vegetables	No portion size	12
Dry beans	No portion size	4
Dry fruit	Spoons	3
Nuts	Handfuls	5
Chocolate	Number	8
Ice cream	Number / slices	1
Fresh fruits	4 portion sizes	10
Juice	Glasses	4
Soft drinks	Glasses	3
Coffee	Cups	1
Snacks	Handfuls / gram	3
Dinner with meat	4 portion sizes	AI
Dinner with fish	4 portion sizes	AI
Slices cold meats	Slices of bread	AI
Slices of cold smoked fish	Slices of bread	AI
Vegetarian dinner	No portion size	AI

* On bread only; AI=All included

Table 2. Validation study: Daily intake of nutrients based on questionnaire (FFQ) and diet records (DR) (n=23).

		FFQ Median (P_{25} , P_{75}) ^a	DR Median (P_{25} , P_{75}) ^a	n ^b	P ^c	R ^d
Calcium	mg	1102 (931,1339)	924 (727, 1145)	8	0.07	0.62
Protein	g	63.1 (47.6, 80.1)	63.8 (53.3, 80.7)	11	0.61	0.62
Phosphorus	mg	1191 (1027, 1538)	1081 (799, 1360)	8	0.04	0.56

^a P_{25} , P_{75} = 25th, 75th percentile. ^b Number of persons with a difference in measured intakes between FFQ and DR <20% of DR. ^c Wilcoxon match-pair signed rank test. ^d All $p < 0.006$.

Table 3. Validation study: Distribution of individual differences in daily nutrient intake based on food frequency questionnaire and diet records (n=23).

		P ₁₀	P ₂₅	P ₅₀	P ₇₅	P ₉₀
Calcium	mg	-360	-121	168	447	960
Protein	g	-16.0	-13.0	3.3	12.6	26.4
Phosphorus	mg	-232	-105	238	439	1095

P₁₀, P₂₅, P₅₀, P₇₅, P₉₀ are 10th, 25th, 50th, 75th and 90th percentile.

the nutrient content of the 88 food items is easy to construct. The coding of the questions is quick compared to the processing of diet record, which requires qualified personnel. The coding of foods and calculation of nutrients is quick and easy using a database containing data on food items together with the FFQ.

A weakness in the validation study was the relatively small number of participants, and because of that sex differences were not examined. In spite of a possible day to day variation that could influence the results we used only a 3 day weighed record as reference because in practice it is difficult to get reliable data on children from 7 day record. Figure 1 shows 3, 1 and 1 outliers for calcium, protein and phosphorus, respectively. The outliers were all due to a very high FFQ registration compared to diet record, and may be due to an overestimation by FFQ. However the median individual differences between FFQ and diet record in our study (Table 3) were lower than observed in a recently published Norwegian study with 18-year-old individuals, where median difference was 355 mg/day and 22 g/day for calcium and protein intakes respectively (16). The proportion of individuals with a difference below 20% of the diet record was higher for both calcium and protein intakes in our study than in the Norwegian study (Table 2). Phosphorus intake was not measured in

the Norwegian study. Furthermore, in the Norwegian study intakes of calcium and protein based on FFQ were significantly higher than intakes based on diet records. In our study we found the same pattern for phosphorus intake, while there were no significant difference between calcium and protein intakes estimated by FFQ and diet record (Table 2).

The Spearman rank correlation coefficient between the paired measurements was (Table 2) higher than or at a similar level as other studies (16,17,20-22). In the Norwegian study Spearman rank correlation coefficients between pairs measurements with FFQ and diet record were 0.48 for protein intake and 0.54 for calcium intake (16). *Cumming* et al. found a similar correlation between a food frequency questionnaire using household units and a seven-day diet record (22). When nutrients are categorised in quartiles the chance expectation is 25% in the same quartile and 12.5% in the opposite quartile (19). The ability of our FFQ to rank individuals by nutrient intake in the same/opposite quartiles (Table 4) was similar to results reported by *Frost Andersen* et al. (16) for calcium (43%/4%) and protein intakes (39%/6%). *Bingham* et al. (21) compared two different food frequency questionnaires named Oxford FFQ and Cambridge FFQ with a 16 day diet record method. For the Oxford FFQ the per-

centage in the same quartile/opposite quartile was 46%/6% for calcium intake and 39%/4% for protein intake, and for the Cambridge FFQ it was 27%/4% for calcium intake and 30%/9% for protein intake. In summary, the ability of our FFQ to rank subjects or to categorise individuals in quartiles according to calcium intake is as good as other food frequency questionnaires, and regarding protein intake somewhat better.

The reproducibility of the FFQ was evaluated by registration with a 0.5 year interval. This long interval reduces the risk that children or parents remember what their responses to the first questionnaire was 0.5 year ago. On the other hand, a 0.5 year interval increases the possibility of a real dietary change. Thus, the differences between the two measurements consisted of a real difference in dietary intake combined with a methodological error. It is not possible to estimate the magnitude of each of these components. However, there were no significant differences between the two measurements for the amount of either calcium, protein or phosphorus intakes, and the differences were related to neither age nor sex. With only a 6 week interval between two measurements with FFQ, *Frost Andersen* et al. found, the second measurement of intake was significantly lower for both calcium and protein (16). As shown in Table 6 the

Figure 1. The differences in intakes measured with the food frequency questionnaire and diet record, plotted against the mean of the intakes measured with the two methods, for calcium, protein and phosphorus intake respectively (n=23). Method: *Bland and Altman* (18).

Figure 2. The differences in intakes measured with the food frequency questionnaire repeated with a half year interval, plotted against the mean of the intakes measured with the two questionnaires for calcium, protein and phosphorus intake respectively (n=293). Method: *Bland and Altman* (18).

individual difference with a 0.5 year interval between the questionnaires could be large, which is in agreement with the findings by *Frost Andersen et al.* with a 6 weeks interval (16). However, about half of the individuals had a difference below 20% of the first measurement for calcium, protein and phosphorus intakes (Table 5). In the Norwegian study with an interval of only 6 weeks between the two FFQ measurements 58 of 103 individuals had a difference in calcium intake, and 72 of 103 had a difference in protein intake below 20% of the first registration (16). The Spearman rank correlation coefficients between the two measurements with a 0.5 year interval was good (0.72-0.73) for all three nutrients. This is similar to or even better than, previously reported for food frequency questionnaires in adults (23-25), adolescents (16) and children (26).

In conclusion, we have shown that the used food frequency questionnaire was able to rank 13-14-year-old children adequately according to their intakes of calcium, protein and phosphorus, and we believe that it is also a valuable method for other ages during childhood and adolescence. The method may be useful in epidemiological studies of children and adolescents. Furthermore, this method may be used to determine the average intakes of calcium, protein and phosphorus in groups of children and adolescents.

Acknowledgement

This study was financed by the Food Technology Research and Development Programme (FØTEK) and the Danish Dairy Research Foundation. We are grateful to *Birgitte Hermansen, Pia Saver Larsen* and *Marianne Soerensen* for valuable assistance with the collection and the computation of nutrient data.

References

- Anonymous: Consensus development conference: diagnosis, prophylaxis, and treatment of osteoporosis. *Am J Med* 1993;94:646-50.
- Hansen MA, Overgaard K, Riis BJ, Christiansen C: Role of peak bone mass and bone loss in postmenopausal osteoporosis: 12 year study. *BMJ* 1991;303:961-4.
- Matkovic V, Ilich JZ, Andon MB, Hsieh LC, Tzagournis MA, Langer BJ, Goel PK: Urinary calcium, sodium, and bone mass of young females. *Am J Clin Nutr* 1995;62:417-25.
- Metz JA, Anderson JJ, Gallagher PN, Jr: Intakes of calcium, phosphorus, and protein, and physical-activity level are related to radial bone mass in young adult women. *Am J Clin Nutr* 1993;58:537-42.
- Wyshak G, Frisch RE: Carbonated beverages, dietary calcium, the dietary calcium/phosphorus ratio, and bone fractures in girls and boys. *J Adolesc Health* 1994;15(3):210-5.
- Chan GM: Dietary calcium and bone mineral status of children and adolescents. *Am J Dis Child* 1991;145:631-4.
- Lee WT, Leung SS, Ng MY, Wang SF, Xu YC, Zeng WP, Lau J: Bone mineral content of two populations of Chinese children with different calcium intakes. *Bone Miner* 1993;23:195-206.
- Henderson NK, Price RI, Cole JH, Gutteridge DH, Bhagat CI: Bone density in young women is associated with body weight and muscle strength but not dietary intakes. *J Bone Miner Res* 1995;10:384-93.
- Young D, Hopper JL, Nowson CA, Green RM,

Table 4. Percentage of subjects classified into the same quartile and percentage of subjects misclassified into extreme quartiles of calculated nutrient intake based on the diet record and the questionnaire methods (n=23).

	Classified into same quartile	Misclassified into opposite quartile
Calcium	39%	0%
Protein	52%	4%
Phosphorus	39%	0%

Table 5. Reproducibility of the quantitative food frequency questionnaire repeated with a 0.5 year interval (n=293).

		FFQ A Median (P ₂₅ , P ₇₅) ^a	FFQ B Median (P ₂₅ , P ₇₅)	n ^b	P ^c	R ^d
Calcium	mg	1019 (750, 1534)	1117 (737, 1458)	141	0.69	0.73
Protein	g	63.6 (50.9, 84.2)	62.3 (49.3, 82.5)	163	0.09	0.73
Phosphorus	mg	1266 (985, 1739)	1261 (934, 1639)	154	0.11	0.72

^a P₂₅, P₇₅ = 25th, 75th percentile. ^b Number of persons with a difference in measured intakes between first and second questionnaire <20% of the first questionnaire.

^c Wilcoxon match-pair signed rank test. ^d All p<0.0001.

Table 6. Reproducibility study: Distribution of individual differences in daily nutrient intake between the first and second questionnaire (n=293).

		P ₁₀	P ₂₅	P ₅₀	P ₇₅	P ₉₀
Calcium	mg	-552	-248	30	209	524
Protein	g	-24.6	-9.4	2.0	13.3	22.4
Phosphorus	mg	-524	-189	42	252	567

P₁₀, P₂₅, P₅₀, P₇₅, P₉₀ are 10th, 25th, 50th, 75th and 90th percentile.

- Sherwin AJ, Kaymakci B, Smid M, Guest CS, Larkins RG, Wark JD: Determinants of bone mass in 10- to 26-year-old females: a twin study. *J Bone Miner Res* 1995;10:558-67.
- Glastra C, Braillon P, David L, Cochat P, Meunier PJ, Delmas PD: Measurement of bone mineral content of the lumbar spine by dual energy x-ray absorptiometry in normal children: correlations with growth parameters. *J Clin Endocrinol Metab* 1990;70:1330-3.
- Lyhne N, Stubgaard K: Næringsstofanbefalinger, begrundelser, baggrund, brug og begrænsninger. 2nd ed. København: Levnedsmiddelstyrelsen; 1992. (*In Danish*)
- Anonymous: Calcium. The report of the British Nutrition Foundation's task force. London: The British Nutrition Foundation; 1989.
- Anonymous: NIH Consensus conference. Optimal calcium intake. NIH Consensus Development Panel on Optimal Calcium Intake. *Jama* 1994;272:1942-8.
- Mølgaard C, Sandström B, Michaelsen KF: Whole body bone mineral content (BMC) and calcium intake in healthy children. *J Pediatr Gastroenterol Nutr* 1996;22:436.
- Mølgaard C, Thomsen BL, Prentice A, Cole TJ, Michaelsen KF: Whole body bone mineral content in healthy children and adolescents. *Arch Dis Child* 1997;76:9-15.
- Frost Andersen L, Nes M, Lillegaard IT, Sandstad B, Bjørneboe G-EA, Dreven CA: Evaluation of a quantitative food frequency questionnaire used in a group of Norwegian adolescents. *Eur J Clin Nutr* 1995;49:543-54.
- Tjønneland A, Overvad K, Haraldsdottir J, Bang S, Ewertz M, Jensen OM: Validation of a semiquantitative food frequency questionnaire developed in Denmark. *Int J Epidemiol* 1991;20:906-12.
- Bland JM, Altman DG: Statistical methods for

assessing agreement between two methods of clinical measurement. *Lancet* 1986;1:307-10.

- Garrow JS: Validation of methods for estimating habitual diet: proposed guidelines. *Eur J Clin Nutr* 1995;49:231-2.
- Johansson I, Hallmans G, Eriksson S, Hagman U, Bruce Å, Wikman Å, Kaaks R, Riboli E: Evaluation of the accuracy of a dietary questionnaire aimed for the Västerbotten study. *Scand J Nutr/Näringsforskning* 1994;38:50-5.
- Bingham SA, Gill C, Welch A, Day K, Cassidy A, Khaw KT, Sneyd MJ, Key TJA, Roe L, Day NE: Comparison of dietary assessment methods in nutritional epidemiology: weighed records v. 24 h recalls, food-frequency questionnaires and estimated-diet records. *Br J Nutr* 1994;72:619-43.
- Cummings SR, Block G, McHenry K, Baron RB: Evaluation of two food frequency methods of measuring dietary calcium intake. *Am J Epidemiol* 1987;126:796-802.
- Munger RG, Folsom AR, Kushi LH, Kaye SA, Sellers TA: Dietary assessment of older Iowa women with a food frequency questionnaire: nutrient intake, reproducibility, and comparison with 24-hour dietary recall interviews. *Am J Epidemiol* 1992;136:192-200.
- Goldbohm RA, van't Veer P, van den Brandt PA, van't Hof MA, Brants HAM, Sturmans F, Hermus RJJ: Reproducibility of a food frequency questionnaire and stability of dietary habits determined from five annually repeated measurements. *Eur J Clin Nutr* 1995;49:420-9.
- Brown JL, Griebler R: Reliability of a short and long version of the block food frequency form for assessing changes in calcium intake. *J Am Diet Assoc* 1993;93:784-9.
- Rockett HRH, Wolf AM, Colditz GA: Development and reproducibility of a food frequency questionnaire to assess diets of older children and adolescents. *J Am Diet Assoc* 1995;95:336-40. □