



Validation of the Updated Korean Calcium Assessment Tool

Joowon Jin, Yunjung Lee, Yongsoon Park

Department of Food and Nutrition, Hanyang University, Seoul, Korea

Corresponding author

Yongsoon Park
Department of Food and Nutrition, Hanyang University, 222 Wangsimni-ro, Seongdong-gu, Seoul 04763, Korea
Tel: +82-2-2220-1205
Fax: +82-2-2220-1856
E-mail: yongsoon@hanyang.ac.kr

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Background: We previously developed the Korean Calcium Assessment Tool (KCAT) for assessing the intake of calcium and vitamin D in Korean women. However, based on the Korea National Health and Nutrition Examination Survey (KNHANES) VI and VII (2013–2018), major food sources for calcium and vitamin D have changed, and the National Standard Food Composition database was updated. Therefore, the present study aimed to update the KCAT and validate the Updated KCAT. **Methods:** A total of 285 women aged > 19 years were asked to complete questionnaires of the KCAT and the Updated KCAT. **Results:** Calcium intake did not differ significantly between the KCAT (566 ± 245 mg/day) and the Updated KCAT (569 ± 248 mg/day; $P=0.343$). A correlation coefficient of 0.99 indicated a positive correlation on calcium intake between the KCAT and the Updated KCAT, with an almost perfect agreement by Cohen's κ coefficients (0.95). Vitamin D intake assessed by the Updated KCAT was significantly higher than that assessed by the KCAT, which was positively correlated with a moderate agreement measured by Cohen's κ coefficients (0.41). **Conclusions:** The present study demonstrated that the Updated KCAT was a valid tool for the rapid evaluation of calcium and vitamin D intake for Korean women.

Key Words: Calcium · Calcium, dietary · Diet surveys · Vitamin D

INTRODUCTION

Osteoporosis is characterized by decreased bone density with consequence increases in bone fragility and has become a serious health problem.[1] An osteoporosis prevalence of 32.6% has been reported in Korean adult women,[2] and older postmenopausal women are particularly affected by the disease.[3] The Korea National Health and Nutrition Examination Survey (KNHANES) indicated that the osteoporosis prevalence rate is 6 times higher in women than men and increases with age.[2]

Sufficient nutrition, particularly adequate intake of calcium plays an important role in prevention and treatment of osteoporosis.[4-6] However, only 27.4% Korean women satisfied calcium intake up to the level of the dietary reference intakes for Koreans (KDRI).[7] Vitamin D is also an essential nutrient for bone health in terms of optimal calcium absorption,[8] but the intake is low at all ages in Korean compared with KDRI.[7]

Food frequency questionnaires (FFQ), 24-hr recall, and dietary records are used

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for the assessment of all the nutrient intakes, but it takes a long time to complete. Simple calcium questionnaires called the Calcium Calculator™ [9,10] is available to assess the calcium intake in a western country, where people's main source of calcium is dairy products. However, our previous study showed that Korean women consumed only 1/3 of their calcium intake from dairy products, and vegetables were substantial source of calcium.[11] Dark green vegetables were a practical source of dietary calcium for Korean women, although calcium in vegetables has low bioavailability compared to the calcium in dairy products.[12,13] Thus, we previously developed the Korean Calcium Assessment Tool (KCAT) to assess the calcium and vitamin D intake for Korean women in 2013.[14] However, KNHANES VI and VII conducted during 2013 to 2018 showed that major food sources of calcium and vitamin D have been changed. [15-20] In addition, the National Standard Food Composition Table was updated in 2020,[21] and Computer Aided Nutritional analysis Program (CAN-Pro; Korean Nutrition Society, Seoul, Korea) was upgraded from version 4.0 to version 5.0 in 2021. Therefore, major food sources and amount of calcium and vitamin D in the KCAT are needed to update, and the Updated KCAT is needed to validate by comparing with the original KCAT.

METHODS

1. Participants

The study was conducted in accordance with the Declaration of Helsinki, and all procedures involving human participants were approved by the Institutional Review Board (IRB) of Hanyang University (HYUIRB-202103-021). Informed consent were obtained from all participants. Korean women with > 19 years old were recruited and excluded if they were pregnant or breastfeeding. Participants were recruited Hanyang University, Seoul, Korea. Two hundred and eighty-5 Korean women completed both the KCAT and Updated KCAT were included in the analysis.

2. Assessment of dietary calcium and vitamin D intake

Participants' information on age, height, weight was obtained through a survey. Participants were asked to complete 2 questionnaires, the KCAT and the Updated KCAT. The dietary intake of calcium and vitamin D for the past 1

year was assessed.

Based on the KNHANES VI and VII (2013-2018), food sources of calcium and vitamin D in original KCAT were modified. [15-20] Regarding calcium sources, shrimp, crab, pollack, croaker, skate ray, chili pepper, green pumpkin, chives, perilla leaf, and sea algae were included, but Korean pancake, nuts, bone soup, clam, various fruits, vegetables, and ramen were excluded in the Updated KCAT (Table 1). Regarding vitamin D sources, duck, cow liver, trout, flatfish, salmon, mackerel, herring, saury, and cutlassfish were included, but excluded in the Updated KCAT (Table 1).[7] Calcium and vitamin D contents for the selected foods were obtained from the National Standard Food Composition Tables DB 9.2 and KDRI.[7,21]

3. Statistical analysis

All analyses were performed using SPSS version 26.0 (SPSS Inc., Chicago, IL, USA), and *P*-values of less than 0.05 were

Table 1. List of food items newly included in the Updated KCAT

Nutrient	Food group	Food item	Serving size	KCAT	Updated KCAT ^{a)}
Calcium	Shellfish	Shrimp	1 cup ^{b)}	-	59.2 g
		Crab	1 crab	-	114.0 g
	Fish	Pollack	1 serving ^{c)}	18.0 g	28.8 g
		Croaker	1 serving	18.0 g	105.0 g
		Skate ray	1 serving	18.0 g	183.0 g
		Vegetable	Chili pepper	1 cup	-
		Green pumpkin	1 cup	-	22.2 g
		Chives	1 cup	-	22.2 g
		Perilla leaf	1 cup	-	147.7 g
		Sea algae	1 cup	-	81.4 g
Vitamin D	Meat	Duck	1 serving	-	36.9 µg
		Cow liver	1 piece	-	0.1 µg
	Fish	Trout	1 serving	5.0 µg	6.0 µg
		Flatfish	1 serving	5.0 µg	10.8 µg
		Salmon	1 serving	5.0 µg	19.2 µg
		Mackerel	1 serving	5.0 µg	6.6 µg
		Herring	1 serving	5.0 µg	13.2 µg
		Saury	1 serving	5.0 µg	11.4 µg
		Cutlass fish	1 serving	5.0 µg	8.4 µg
	Mushrooms	Juda's ear	1 cup	19.0 µg	27.3 µg
		Mushrooms	1 cup	2.0 µg	0.9 µg

^{a)}Based on National Standard Food Composition Tables DB 9.2.

^{b)}1 cup=180 mL.

^{c)}1 serving=60 g.

KCAT, Korean Calcium Assessment Tool.

regarded as statistically significant. The differences of calcium and vitamin D intake between the 2 questionnaires were analyzed by paired *t*-tests. Spearman correlation coefficients were obtained from both questionnaires to compare calcium and vitamin D intake. Cohen's κ coefficient was evaluated to verify the agreement between the 2 questionnaires.[22] The values were interpreted as follows: <0, no agreement with the methods; 0 to 0.20, slight agreement; 0.21 to 0.40, fair agreement; 0.41 to 0.60, moderate agreement; 0.61 to 0.80, substantial agreement; and 0.81 to 1.00, almost perfect agreement.[23] The Bland-Altman plots with 95% limits of agreement were calculated to visualize the mean differences of agreement between the KCAT and the Updated KCAT for calcium intake and vitamin D intake.[24]

The adequacy of the sample size was determined by the G*Power version 3.1 (Heinrich Heine University, Düsseldorf, Germany).[25] Based on the results of the previous study, [14] a sample size of 275 participants was calculated with a statistical power of 80% and a level of significance of 5%, and taking a 5% drop-out rate and incomplete survey, the study planned to enroll 289 participants.

RESULTS

Calcium intake calculated from the KCAT and the Updated KCAT were not significantly different, but vitamin D intake calculated from the Updated KCAT was significantly higher than that calculated from the KCAT (Table 2). Spearman correlation coefficient test showed that there was a

Table 2. Characteristics of participants and intake of calcium and vitamin D assessed by the KCAT and the Updated KCAT

	Total (N=285)	Range	P-value ^{a)}
Age (yr)	35.28 ± 12.71	19-84	
Weight (kg)	56.03 ± 7.89	42-85	
Height (cm)	161.26 ± 6.06	138-176	
Body mass index (kg/m ²)	21.56 ± 2.89	15.43-31.60	
Calcium (mg/day)			0.343
KCAT	566.58 ± 245.72	154.33-1572.10	
Updated KCAT	569.12 ± 248.85	160.94-1547.31	
Vitamin D (µg/day)			<0.001
KCAT	7.87 ± 5.40	0.93-31.50	
Updated KCAT	10.14 ± 8.46	0.55-67.28	

The data is presented as mean ± standard deviation.

^{a)}Paired *t*-test used for statistical difference on intake of calcium and vitamin D between the KCAT and the Updated KCAT. KCAT, Korean Calcium Assessment Tool.

significant positive correlation between the intake of calcium and vitamin D calculated from the KCAT and the Updated KCAT (Fig. 1). The extent of misclassification by the 2 questionnaires was assessed, and Cohen's κ coefficient of 0.95 indicated that the Updated KCAT was able to correctly classify participants into the same quartile of calcium intake, with no participants being grossly misclassified (Table 3). Gross classification according to the quartiles of vitamin D intake also showed moderate agreement between the 2 questionnaires (Table 4). The Bland-Altman plot showed that the mean differences between the KCAT and the Updated KCAT were 2.54 with 95% limits of agreement between -51.99 to 57.07 mg/day for calcium and 14.28 with

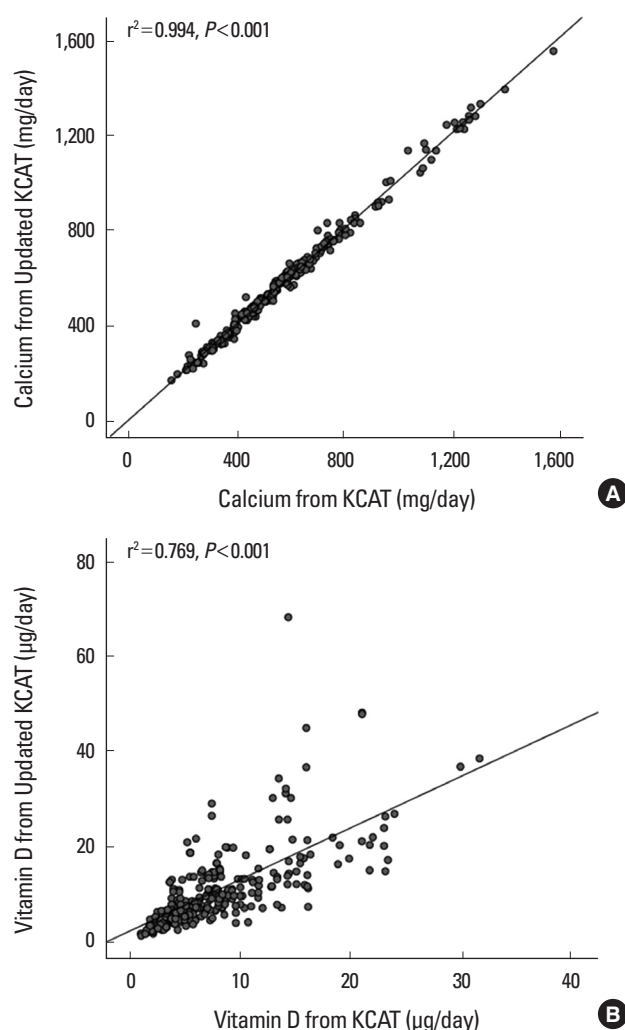


Fig. 1. Correlation of calcium intake (A) and vitamin D intake (B) assessed by the Korean Calcium Assessment Tool (KCAT) and the Updated KCAT.

Table 3. Joint classification of calcium intake assessed of participants according to quartile by the KCAT and the Updated KCAT

Calcium intake by KCAT (mg/day)	Calcium intake by Updated KCAT (mg/day)				Cohen's κ coefficient ^{a)}
	1 (≤ 398.84)	2 (>398.84 to ≤ 529.71)	3 (>529.71 to ≤ 657.17)	4 (>657.17 to ≤ 1547.31)	
1 (≤ 390.46)	0.97	0.03	0.00	0.00	0.949
2 (>390.46 to ≤ 532.25)	0.03	0.96	0.00	0.00	
3 (>532.25 to ≤ 658.55)	0.00	0.02	0.96	0.04	
4 (>658.55 to ≤ 1572.10)	0.00	0.00	0.04	0.96	

^{a)}Cohen's κ coefficient of 0.81-1 indicates almost perfect agreement. KCAT, Korean Calcium Assessment Tool.

Table 4. Joint classification of vitamin D intake assessed of participants according to quartile by the KCAT and the Updated KCAT

Vitamin D intake by KCAT ($\mu\text{g/day}$)	Vitamin D intake by Updated KCAT ($\mu\text{g/day}$)				Cohen's κ coefficient ^{a)}
	1 (≤ 4.86)	2 (>4.86 to ≤ 7.59)	3 (>7.59 to ≤ 12.90)	4 (>12.90 to ≤ 67.28)	
1 (≤ 3.95)	0.62	0.29	0.09	0.00	0.410
2 (>3.95 to ≤ 6.36)	0.31	0.40	0.17	0.13	
3 (>6.36 to ≤ 9.99)	0.06	0.23	0.46	0.25	
4 (>9.99 to ≤ 31.5)	0.01	0.08	0.29	0.62	

^{a)}Cohen's κ coefficient of 0.41-0.60 indicates moderate agreement. KCAT, Korean Calcium Assessment Tool.

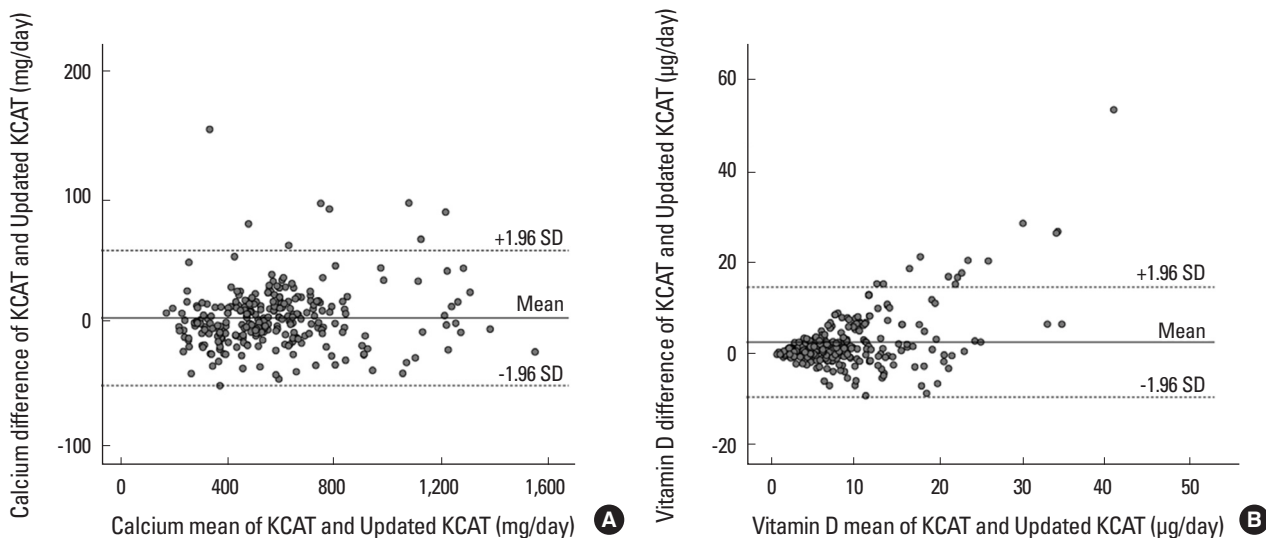


Fig. 2. Differences against mean of calcium intake (A) and vitamin D intake (B) between the Korean Calcium Assessment Tool (KCAT) and the Updated KCAT.

limits of agreement between -9.73 to $14.28 \mu\text{g/day}$ for vitamin D (Fig. 2).

DISCUSSION

The present study showed that intakes of calcium and vitamin D assessed by the KCAT and the Updated KCAT were positively correlated and correctly classified participants

into the same quartile of intake, suggesting that the Updated KCAT was a valid tool to assess the calcium intake of Korean women. In the present study, the correlation coefficient for which using continuous variables of calcium intake estimated by the KCAT and the Updated KCAT was 0.99, and κ coefficient for which using categorical variables was 0.95, almost perfect agreement. In the previous studies, the correlation coefficients obtained from calcium in-

take to validate questionnaires were in the range of 0.41 to 0.98.[14,26-34] Correlation coefficients were 0.51 to 0.98 in Asian populations,[14,28-33] and 0.64 to 0.90 in the western population.[26,27,33,34] Generally, the correlation coefficients for calcium questionnaires were higher with narrow ranges in studies done in Americans and Europeans than in studies done in Asian. These differences could be partly due to the difference of calcium sources. In western population, their calcium sources were simple. Their calcium sources are mostly dependence on milk and milk products, while Asians including Koreans were more varied than the Westerners. Their calcium sources include dark green vegetables, seaweed, beans, and seafood.[35,36] Calcium in dairy products has high bioavailability and is more easily absorbed in the intestine than calcium from nondairy products.[37,38] However, large servings of nondairy products such as dark green vegetables, seaweed, beans, and seafood could also be an important sources of calcium, especially for Koreans.[11] In the present study, Bland-Altman plot also showed good agreement between the KCAT and the Updated KCAT, and calcium estimated by the Updated KCAT was 2.54 mg/day higher than those estimated by the KCAT. This difference could be due to the newly added foods containing high amount of calcium such as crab, croaker, perilla leaf, and sea algae. Calcium intake estimated by the Updated KCAT was 569 mg/day, which was in the range of 513 to 586 mg/day in the urban areas reported by the KNHANES.[39-42] Since KDRI recommends a daily calcium intake of 700 to 800 mg for Korean women,[7] calcium intake is only 71% to 81% of recommended level.

In the present study, correlation coefficients of vitamin D intake between the KCAT and the Updated KCAT were 0.77. This value is higher than the desirable value which is 0.5 and it suggests that the Updated KCAT could be a good tool to assess the intake of vitamin D.[36] Previous studies reported that the correlation coefficients assessed vitamin D intake were in the range of 0.56 to 0.75.[14,26] However, vitamin D intake assessed by the Updated KCAT was higher than that assessed by the KCAT (10.14 µg/day vs. 7.87 µg/day) in the present study. This difference could be explained by the newly added food sources high in vitamin D, such as duck, cow liver, and fishes, which were included in newly reported the National Standard Food Composition Tables DB 9.2. The average intake fish of the participants was 4.5 µg/day. Fish and mushrooms are an important food source

of vitamin D. The intake of fish and shellfish has been increasing 100% from 2012 to 2017-2019 according to the Korea Rural Economic Institute [43] and the intake of mushrooms has been increasing 32% from 2012 to 2017-2019 according to the Korea Health Industry Development Institute.[44] The reason for the increased vitamin D intake between 2 questionnaires could be due to the updated food containing vitamin D (Table 1). Therefore, it is possible that the KCAT underestimated the vitamin D intake, also our results suggested using the Updated KCAT. However, intake of vitamin D in Korean women was still lower than the recommended intake of vitamin D, 10 to 15 µg/day according to KDRI.[7]

There were a few potential weaknesses in this study. First, FFQ used in these questionnaires was not a quantitative tool to analysis food consumption. To overcome this limitation, FFQ needs to include detailed questions including visual aids for estimating portion sizes. Second, the Updated KCAT might have some reporting bias since self-reported dietary intake data was used. Third, the intake of calcium and vitamin D could be affected by seasonal variation, but the Updated KCAT was not assessed during all 4 seasons. Forth, since participants of the study were only recruited from Seoul, selection bias might be existed. Fifth, the exclusion criteria of participants were different to the previous study that validated original version of KCAT.

The Updated KCAT has a few strengths. First, the Updated KCAT is the only available survey tool to assess dietary intake of calcium and vitamin D for Korean population. Second, the Updated KCAT is simple, convenient, and easy to estimate intake of calcium and vitamin D since it can be completed within 10 to 15 min. Third, the dietary intake of calcium and vitamin D can be assessed with good validity and reproducibility. In conclusion, this study suggests that the Updated KCAT can be a useful clinical tool for the rapid evaluation of calcium and vitamin D intake for Korean women. The further study is needed to validate the Updated KCAT for other population.

DECLARATIONS

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Authors' contributions

JW conducted the study, performed the statistical analysis, and wrote the first draft. YJ revised the manuscript. YP designed the study, finalized the manuscript, and was responsible for the work. All authors have read and agreed to the published version of the manuscript.

Ethics approval and consent to participate

The study protocol conformed to the ethical guidelines of the World Medical Association Declaration of Helsinki and was approved by the Institutional Review Board (IRB) of Hanyang University (HYUIRB-202103-021). Informed consent were obtained from all participants.

Conflict of interest

No potential conflict of interest relevant to this article was reported.

ORCID

Joowon Jin <https://orcid.org/0000-0002-7448-8649>

Yunjung Lee <https://orcid.org/0000-0001-9878-3872>

Yongsoon Park <https://orcid.org/0000-0001-5110-5716>

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