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Research Brief

Vitamin D Intake Among Young Canadian Adults: Validation of a Mobile Vitamin D Calculator App

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ABSTRACT

Objective: To establish the validity and reproducibility of the dietary component of a mobile vitamin D calculator app.

Methods: Participants entered their dietary intake into the Vitamin D Calculator app on 3 recording days over 1 month and underwent subsequent 24-hour dietary recalls.

Results: There were 50 adults (25 female), aged 18–25 years (mean, 22 ± 2 years). Paired-samples *t* tests tested for significant differences ($P < .05$) in mean vitamin D and calcium intake between the app and dietary recalls; Bland–Altman plots assessed agreement between the 2 measures. Intra-class correlations and Wilcoxon signed-rank tests assessed reproducibility of intakes estimated by the app. Mean vitamin D (n = 50) and calcium (n = 48) intakes and risk classifications did not differ significantly between the 2 measures ($P > .05$).

Conclusions and Implications: The Vitamin D Calculator app is a valid classification measure for dietary vitamin D and calcium intake. This tool could be used by the general public to increase awareness and intake of these nutrients.

Key Words: nutrition assessment, vitamin D, calcium, self-monitoring, mobile applications (*J Nutr Educ Behav*. 2015;47:242-247.)

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INTRODUCTION

Vitamin D is essential for the maintenance of bone health and to prevent rickets, osteomalacia, and bone fractures. It also may be implicated in other chronic diseases and bodily processes including cancer, cardiovascular disease, and diabetes, as well as immunity.[1] Vitamin D is available naturally in few dietary sources, the most significant of which is fatty fish. Fortified cow's milk and nondairy milk alternatives represent the main dietary contributors among Canadians[2]; however, research suggests that Canadian fortification levels are too low to prevent insufficiency.[3-5] Furthermore, vitamin D synthesis from the sun does not occur above 43° N latitude during the fall and winter months; hence, many Canadians have inadequate vitamin D intake and status, especially during the winter.[6-8]

Data from the 2004 Canadian Community Health Survey (CCHS)[9] indicated that mean dietary vitamin D in adults (aged 19–50 years) was 204 international units (IU) for women and 232 IU for men. This falls well below the Recommended Dietary Allowance (RDA) of 600 IU/d.[10] Furthermore, many researchers[11] and health associations recommend higher amounts; for instance, the Canadian Cancer Society recommends 1,000 IU/d for adults.[12] Therefore, tools to examine and promote dietary vitamin D are needed for both the general Canadian public and health professionals.

Mobile applications (apps) are promising tools for this purpose. Health apps are one of the most highly used types on the public market, with over 17,000 currently available[13] and projections of use by 500 million people worldwide by 2015.[14] Many researchers have successfully incorporated apps into research designs, including interventions to increase physical activity[15] or healthy eating.[16] Mobile apps also may be useful for dietary counseling or monitoring personal nutrition. A study examining 18 apps designed for dietary assessment and self-monitoring found that mobile apps frequently led to better adherence of self-monitoring behaviors and changes to dietary intake compared with traditional methods.[17]

Most diet-related apps on the public market have not been validated. Indeed, MyFitnessPal, one of the most popular and widely used dietary tracking apps, has not been assessed for accuracy, validity, or reliability.[18]

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The Vitamin D Calculator app (VDC-app) is a mobile application in which users enter their daily intake of vitamin D and calcium-containing foods and beverages. By providing immediate feedback on intake of these nutrients relative to current recommendations, the VDC-app represents a convenient means of monitoring personal intake. The purpose of this study was to establish the validity and reproducibility of the dietary component of the VDC-app.

METHODS

To validate the dietary component of the VDC-app, the researchers tested agreement between the app and 24-hour dietary recalls. The University of Guelph Research Ethics Board approved this study (Approval 13AP022). Participants consisted of 25 male and 25 female adults aged 18–25 years, living in Ontario, Canada. A sample size of at least 50 participants was recommended for the specific analyses being used[19]; a power calculation confirmed that a sample of 50 participants would provide 80% power to detect a significant difference in mean vitamin D intake between data from the VDC-app and dietary recalls. Participants were recruited in February to April, 2014 from the University of Guelph and the Guelph community using poster and online advertisements. Inclusion criteria included being age 18–25 years, being fluent in English, residing in Canada, and owning an iPhone, iPad, or iPod Touch.

Measures

A sociodemographic survey designed by the researchers gathered general demographic information, including age, sex, ethnicity, education, and student status. The VDC-app was originally developed by an independent party (Agarwal, Jacksonville, FL, 2014); the researchers collaborated in updating the app to include Canadian nutrient and ultraviolet (UV) index data. The app allows users to enter daily intake of vitamin D and calcium-containing foods and beverages, supplements, and time spent in sunlight. Immediate feedback is provided by the app regarding participants' estimated daily vitamin D (IU) and calcium (milligrams) intake, both in numeric form and in a pie chart displaying percent intake from dietary sources, supplements, and sun exposure (vitamin D only). A bar graph provides visual representation of vitamin D intake; cutoffs are < 400 IU, 400–600 IU, and > 600 IU, reflecting the current estimated average requirement (EAR) and RDA of 400 and 600 IU, respectively.[10] Vitamin D from solar UVB is estimated by linking the user's postal code to the daily UV forecast from Environment Canada[20] (data not shown). Average vitamin D and calcium content for each item in the app were identified a priori based on the 2010 Canadian Nutrient File (CNF).[21] The user manually enters multivitamin/supplement amounts.

Procedure

Participants were interviewed on an individual basis by either the primary student investigator or a single trained research assistant. During an initial visit, participants provided informed written consent and completed the paper demographic survey. Each participant received an instruction package and was shown how to use the VDC-app. Participants downloaded the app on their personal device in the presence of the researcher, entering a unique subject identification number for confidentiality. Three recording days were scheduled over the subsequent month; 1 weekend and 2 weekdays were assigned. On each of the 3 recording days, participants entered their intake of vitamin D and calcium-containing foods, beverages, and supplements. The day after each recording, participants returned for a study visit in which the research assistant conducted an oral multiple-pass, 24-hour dietary recall.[22] Measuring cups and food models (Nasco, Salida, CA, 2014) helped participants gauge portion sizes. After the final recall, participants received a debriefing letter and $40 in gift cards ($10/visit) as remuneration.

Data Analysis

Data from the dietary recalls were analyzed using ESHA Food Processor, version 10.13.1 (ESHA Research, Salem, OR, 2013). Two research assistants entered dietary recall data, maintaining a database of items entered to ensure consistency. Whenever possible, Canadian data (ie, CNF or Canadian brands) were selected. Data entered into the VDC-app were electronically transmitted to a secure database server at the University of Guelph and downloaded by the researcher. Three-day mean vitamin D and calcium intakes were computed for each participant, and statistical analyses were conducted using SPSS, version 21.0 (SPSS Statistics, IBM Corp, Armonk, NY, 2012).

To assess validity, the researchers used Wilcoxon signed-rank test (WSRT) and intraclass correlations (ICCs) to assess the classification of mean intakes by the app vs dietary recall, respectively. Specifically, WSRTs were analyzed using intake quartiles, which were defined a priori (vitamin D: ≤ 200, 201–400, 401–600, and ≥ 601 IU/d; calcium: ≤ 800, 801–1,000, 1,001–2,500, and ≥ 2,501 mg/d). Vitamin D quartiles were based on the 1997 adequate intake of 200 IU/d[23] and the current EAR (400 IU/d) and RDA (600 IU/d)[10]; calcium quartiles were based on the current EAR, RDA, and tolerable upper intake level of 800, 1,000 and 2,500 mg/d, respectively (for adults aged 19–30 years).[10] Quartiles were collapsed to create binary intake categories for ICCs (vitamin D: ≤ 400 and ≥ 401 IU/d; calcium: ≤ 1,000 and ≥ 1,001 mg/d). This determined whether the app and dietary recall were similarly classifying intake into risk vs no/low-risk categories (ie, failing to meet vs meeting the EAR of 400 IU/d for vitamin D or the RDA of 1,000 mg/d for calcium).

Bland–Altman (BA) plots[24] were conducted as a secondary test of validity. Three-day mean and difference scores between the app and recall were plotted for calcium and vitamin D separately and limits of agreement were calculated (mean ± 2 SD). Differences in mean estimated vitamin D and calcium intake between the app and dietary recalls were analyzed further using paired-samples t tests and Pearson correlations. To assess the reproducibility of daily intake estimates over the 3 time points, quartile mean intakes from the first vs last recording day were compared using

WSRT, and binary mean intakes were compared using ICC.

A square-root transformation was applied to correct abnormally distributed and positively skewed raw data.[25] for ease of interpretation, raw data are used to report means and SDs. Results of statistical tests are reported using square root transformed data, with the exception of the BA plots. The log transformation was used for BA plots because it is considered the most appropriate for interpreting abnormally distributed BA plots.[26]

RESULTS

The mean ± SD age of participants (n = 50) was 22 ± 2 years; participants were 50% female (n = 25) (Table 1). Two outliers with unattainably high calcium intake values in the app data were removed for statistical tests relating to calcium intake; therefore, final sample sizes were n = 50 for vitamin D and n = 48 for calcium. Table 2 displays 3-day mean intakes of vitamin D and calcium for the app and dietary recalls.

Results of the validity assessment indicated that ICCs comparing binary classification of 3-day mean intakes for the dietary recall vs the app were fairly strong. Similarly, WSRT indicated validity in that quartiles did not differ significantly between the recall and VDC-app (Table 3). The percentage of points within the limits of agreement on BA plots was 44% for vitamin D and 60% for calcium (data not shown). Three-day mean vitamin D and calcium intakes estimated by the app were significantly positively correlated and not significantly different from the recalls (Table 2). Table 3 displays mean intakes of vitamin D and calcium for the 3 recording days separately. Results of the reproducibility assessment using WSRT indicated that mean vitamin D and calcium intakes for app recording day 1 did not differ significantly from recording day 3 ($Z = -1.19$, $P = .24$; $Z = -1.76$, $P = .08$, respectively). For both nutrients, recording days 1 vs 2 and 2 vs 3 also were not statistically significantly different ($P > .05$ for all) (Table 3). Intraclass correlation analyses comparing app recording day 1 vs 3 for mean vitamin D and calcium intakes resulted in ICC = 0.40 (95% confidence interval, 0.14–0.61; $P = .002$) and ICC = 0.22 (95% confidence interval, –0.06 to 0.47; $P = .06$), respectively.

Table 1. Sociodemographic Data for 18- to 25-Year-Old Adults Enrolled in Vitamin D Calculator App Validation Study (n = 50)

Variable	% (n)
Sex	
Female	50 (25)
Male	50 (25)
Age, y	
18–19	12 (6)
20–21	30 (15)
22–23	38 (19)
24–25	20 (10)
Ethnicity	
White/Caucasian	60 (30)
Asian, South Asian, Southeast Asian	24 (12)
Other ethnicity	16 (8)
Highest level of education	
Some university, or undergraduate degree	56 (28)
Some graduate school, or graduate degree	44 (22)
Student status	
Currently a student	96 (48)
Nutrition background	
Taken a nutrition course in past	72 (36)

DISCUSSION

This study validated a mobile app for the purpose of classifying vitamin D and calcium intake. Previous studies assessed energy intake and used photograph analyses[27] but this study validated the nutrient-centered app, VDC-app. Results from several different analyses suggested that the VDC-app is a valid and strong classification measure of dietary vitamin D and calcium intakes. Reproducibility analyses were less consistent, with WSRT suggesting good reproducibility of mean intake estimates, whereas although ICCs were statistically significant, they were fair for vitamin D and poor for calcium (Table 3). These inconsistent results for validity and reproducibility are not surprising given the high inter- and intra-individual variation in dietary intake,[28] especially of vitamin D and calcium. Indeed, although 3 days of intake data have been commonly collected by researchers examining nutrient intake,[29,30] it has been suggested that a mean of 7–10 days is required to estimate true average calcium intake for groups.[31] Furthermore, vitamin D is available in few natural food sources and thus dietary intake tends to vary greatly[3,4] unless supplements are taken regularly. Some researchers have suggested that when conducting dietary assessments for vitamin D, a longer period of time (eg, 3 months) might be needed to adequately capture less commonly consumed foods such as fatty fish.[32] Therefore, it is unsurprising that the BA plots and the reproducibility of intake estimates, especially in the case of vitamin D, were not optimal.

Although day-to-day intakes of study participants varied considerably, mean estimates seemed reasonable because they were comparable to intakes from food sources from the 2004 CCHS for vitamin D (mean, 236 IU) and calcium (mean, 1,107 mg) (adults aged 19–30 years).[9] In addition, whereas BA plots yielded a wide spread of data points using individual intake values, comparison of 3-day means from the app against the recalls suggests that the app is correctly classifying intake into risk categories. Because the app aims to assist users with self-monitoring of vitamin D and calcium intake, this classification has practical significance.

Although the app tracks daily rather than weekly or monthly dietary intake, similar to a food frequency questionnaire (FFQ), the app allows users to enter their daily intake by selecting specific vitamin D and calcium-containing foods from a prescribed list. The FFQ was originally designed to provide descriptive qualitative information about usual food-consumption patterns.[33] Similarly, the VDC-app does not aim to measure exact intake or to appraise vitamin D or calcium status; it can be considered a qualitative tool that provides feedback regarding one's intake compared with dietary standards. A previous Canadian study assessed the validity of FFQs vs a 7-day food diary to estimate dietary vitamin

Table 2. Three-Day Mean Intake of Vitamin D and Calcium for Participants Using Vitamin D Calculator App and Completing Subsequent 24-Hour Dietary Recall

3-Day Mean Source	Vitamin D, IU/d (n = 50)								Calcium, mg/d (n = 48)							
	App		Recall		Agreement Between App and Recall		Difference Between App and Recall		App		Recall		Agreement Between App and Recall		Difference Between App and Recall	
	Mean	SD	Mean	SD	r(DF)	P	t(DF)	P	Mean	SD	Mean	SD	r(DF)	P	t(DF)	P
Food	279	263	246	187	$r(50) = 0.84$	< .001	$t(49) = -1.31$	.20	1,068	436	1,113	475	$r(48) = 0.63$	< .001	$t(47) = 0.70$	.49
Supplements	229	404	217	398	$r(50) = 0.98$	< .001	$t(49) = -1.22$	.23	16	62	15	62	$r(48) = 0.98$	< .001	$t(47) = -1.00$	.32
All sources	508	483	452	424	$r(50) = 0.92$	< .001	$t(49) = -1.81$	.08	1,084	457	1,128	482	$r(48) = 0.65$	< .001	$t(47) = 0.70$	.49

DF indicates degrees of freedom; IU, International Units.

Note: Threshold for significance was set at $P < .05$. Agreement between app and 24-hour dietary recall on mean intakes of vitamin D and calcium were assessed using Pearson correlation (*r*). Differences between means produced by app vs 24-hour dietary recall were tested using Student *t* test. One-way analysis of variance tests indicated that neither 3-day mean vitamin D nor calcium intake from the app nor 24-hour recall differed significantly by age, gender, ethnicity, education level, student status, or whether participants had taken a nutrition course in the past ($P > .05$ for all). Likewise, the difference scores between the app and 24-hour recall for mean intakes of vitamin D and calcium did not significantly differ by these same sociodemographic variables ($P > .05$ for all).

D intake and found that mean vitamin D estimates from the FFQ were significantly higher than from the food diary. The authors speculated that participants might have overestimated intake when given a prescribed list of serving sizes in the FFQ.[34] In the case of the VDC-app, there was no difference between the vitamin D intakes from the app vs the recall. The VDC-app therefore has an advantage over the traditional FFQ in that participants manually enter the amount of each item consumed (eg, 1.5 cups) rather than choosing from preset serving sizes (eg, small, medium, or large). This is similar to a 7-day food diary or 24-hour recall in which participants are asked to estimate amounts of each item consumed; the VDC-app might therefore be considered a hybrid of the FFQ and 24-hour recall.

Limitations

The VDC-app is limited in that it contains only foods and beverages that are significant sources of vitamin D and/or calcium; certain foods with insignificant amounts of these nutrients (eg, mayonnaise) were not included. This could have led to an underestimation of vitamin D or calcium intake compared with the dietary recall, which captured all items consumed by the participant; however, significant differences were not found. Similarly, the values for vitamin D and calcium used in the app were based on averages for selected representative foods and may have differed somewhat from dietary recall items entered into ESHA.[21] However, because both were based on the CNF and/or Canadian brand data, it is not expected that altering the values used in the app would change study results. Indeed, mean intakes derived by the app and dietary recalls were similar. Although SDs were large, this could have resulted from large inter-individual variations in calcium and vitamin D intakes.

Although criterion validity of the dietary component of the app has been suggested, estimates were not analyzed in relation to blood concentrations of 25(OH)D (vitamin D_3) or to vitamin D from solar UVB. Thus, although it provides a valid classification of dietary vitamin D intake, the

Table 3. Group Means for 3 Days of Vitamin D and Calcium Intake Data for Participants Using Vitamin D Calculator App and Completing Subsequent 24-Hour Dietary Recall

Recording Day	Vitamin D, IU/d (n = 50)				Calcium, mg/d (n = 48)			
	App		Recall		App		Recall	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
1	624	785	508	574	1,289	804	1,187	623
2	485	530	483	482	1,066	506	1,186	618
3	414	551	397	541	898	646	1,011	591

IU indicates International Units.

Notes: No statistically significant values are displayed; all differences are $P > .05$. Quartile mean intakes comparing days 1 vs 2, 2 vs 3, and 1 vs 3 were not significantly different for vitamin D or calcium based on Wilcoxon signed-rank test ($P > .05$ for all). Intraclass correlation (ICC) tests (single measures, 2-way mixed, and absolute agreement definition) based on binary categorization of intakes were ICC = 0.40–0.54 for vitamin D and ICC = 0.13–0.25 for calcium. Intraclass correlation comparisons between days 1 and 3 were significant ($P < .05$), except for calcium on day 1 compared with day 3 (ICC = 0.22; 95% confidence interval [CI], –0.06 to 0.47; $P = .06$) and day 2 (ICC = 0.13; 95% CI, –0.17 to 0.40; $P = .20$). Intraclass correlations comparing binary classification of 3-day mean intakes for the dietary recall vs the app were ICC = 0.88 (95% CI, 0.80–0.93; $P < .001$) for vitamin D and ICC = 0.50 (95% CI, 0.25–0.68; $P < .001$) for calcium. Wilcoxon signed-rank test assessing quartile classification of 3-day mean vitamin D and calcium intakes did not differ significantly between the recall and app ($Z = -0.50$, $P = .62$; and $Z = -0.46$, $P = .65$, respectively).

app is not a measure of overall vitamin D status. Blood tests of 25(OH)D would capture not only changes in vitamin D from dietary intake and the sun, but also inter-individual metabolic differences that lead to changes in vitamin D status. Finally, the VDC app is currently available for select Apple devices only and was validated in a self-selected convenience sample of 18- to 25-year-old adults in Ontario. Therefore, results may not necessarily be generalizable to other populations, including those from other cultures whose dietary habits may differ.

IMPLICATIONS FOR RESEARCH AND PRACTICE

Because estimated mean vitamin D intake has not increased meaningfully in the decade since the 2004 CCHS,[9] there is a clear need for initiatives to increase vitamin D intake in Canadians. The VDC-app is a valid measure of intake classification and could be used in future studies that aim to compare intake of vitamin D and/or calcium with current recommendations. The app provides immediate dietary intake feedback and is available for handheld devices, which makes it convenient for daily use. Members of the general public may find this app to be a valuable self-monitoring tool for tracking personal intake. Future updates of the app might include expanding its compatibility to other platforms (eg, Android) to increase public access. Finally, the app represents a useful tool physicians or dietitians could use in clinical counseling to aid patients in increasing their intake of vitamin D and/or calcium.

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