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Review Article

Evaluation of tools used to measure calcium and/or dairy consumption in adults

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Abstract

Objective: To identify and critique tools for the assessment of Ca and/or dairy intake in adults, in order to ascertain the most accurate and reliable tools available.
Design: A systematic review of the literature was conducted using defined inclusion and exclusion criteria. Articles reporting on originally developed tools or testing the reliability or validity of existing tools that measure Ca and/or dairy intake in adults were included. Author-defined criteria for reporting reliability and validity properties were applied.
Setting: Studies conducted in Western countries.
Subjects: Adults.
Results: Thirty papers, utilising thirty-six tools assessing intake of dairy, Ca or both, were identified. Reliability testing was conducted on only two dairy and five Ca tools, with results indicating that only one dairy and two Ca tools were reliable. Validity testing was conducted for all but four Ca-only tools. There was high reliance in validity testing on lower-order tests such as correlation and failure to differentiate between statistical and clinically meaningful differences. Results of the validity testing suggest one dairy and five Ca tools are valid. Thus one tool was considered both reliable and valid for the assessment of dairy intake and only two tools proved reliable and valid for the assessment of Ca intake.
Conclusions: While several tools are reliable and valid, their application across adult populations is limited by the populations in which they were tested. These results indicate a need for tools that assess Ca and/or dairy intake in adults to be rigorously tested for reliability and validity.

Keywords
Dairy
Calcium
Dietary assessment
Adults

The health benefits of consuming dairy foods, a major source of Ca[1], are well documented in the scientific literature[2,3]. Adequate intake across the life cycle is beneficial for the control of blood pressure[2], reduction in cardiovascular mortality[4] and reduced risk of osteoporosis[5]. Despite the importance of an adequate Ca intake, evidence consistently demonstrates that many individuals, and particularly women, have difficulty achieving dietary dairy/Ca recommendations[6–9]. National survey data from Australia, the UK and the USA report mean daily intakes for adult women of 663, 682 and 756 mg, respectively, and for men of 827, 860 and 962 mg, respectively, compared with an estimated average requirement of 840 to 1100 mg/d depending on age[10].

In order to identify those at risk of suboptimal Ca intake in Western populations it is necessary to accurately assess dairy/Ca intake. Traditional methods of dietary assessment (24 h recalls, food records) are burdensome and/or costly to administer as a screening tool for application at either the population or individual clinical level[11]. Thus an ideal method would be a short, easy-to-administer tool. A key criterion that supports the use of a tool in practice and research is relative validity, or its ability to accurately measure what it purports to measure, determined by how closely the results match those of a reference test[12,13]. Ideally, validity is tested using sensitivity (the ability of a test to correctly identify true positives) and specificity (the ability of a test to correctly identify true negatives); or when using continuous data a measure of agreement such as Bland–Altman analysis[13]. Tools should also have good reliability such that they produce consistent results when performed under similar circumstances, either over different time points or when conducted by different researchers[13].

The present paper is the second of two reviews with the overall aims to: (i) identify published tools that estimate dairy

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and/or Ca intake and allow classification of individuals according to whether intake requirements are met or not; and (ii) assess the testing of tool properties in order to recommend a tool(s) for use. The first paper focusing on tools for children and adolescents is published[14]. The current paper focuses on tools developed for use with adults.

Methods

A comprehensive search was completed to identify existing tools that measure dairy and/or Ca intake. The search was conducted using the databases MEDLINE, Scopus, Ovid, Informit and Web of Knowledge, with the keywords 'calcium', 'dairy', 'milk', 'diet', 'nutrition' and 'food', combined with 'tool', 'questionnaire', 'FFQ', 'survey', 'measurement', 'assessment', 'evaluation' and 'analysis'. The search was not limited by dates, but databases were searched from their year of inception, the earliest being 1948 in the case of MEDLINE, to February 2013. The search was limited to English-language papers only. In addition to this search strategy, an identical search was conducted in Google Scholar to identify any relevant tools or papers in the grey literature. Additional articles were identified by searching the reference lists of the articles found in the database searches.

The database searches identified 1113 articles which reduced to 1022 when duplicates were removed. These were screened for relevance, resulting in the identification of 121 potentially relevant articles. This was followed by a second screening phase which identified forty-eight articles that met the following inclusion and exclusion criteria. Articles that discussed (i) developing or testing the reliability or validity of a previously unpublished tool to measure dairy and/or Ca intake, (ii) testing the reliability or validity of an existing tool to measure dairy and/or Ca intake and (iii) tools intended for use in Western populations, were included for review. Articles that (i) referred to tools that did not assess dairy or Ca intake, (ii) utilised existing tools but did not test these for reliability or validity in the study sample, (iii) measured dairy and/or Ca intake in non-Western countries (due to differences in the major food sources of Ca), (iv) utilised traditional whole of diet methods such as 24 h recalls, food records or diet histories to measure dietary intake, (v) were not in English or (vi) were published abstracts only, were excluded from review. Two authors (K.M., L.B.) sorted the articles independently for relevance and where disagreement arose a third author (M.M.) provided input. Where controversy remained, the relevance of the article was discussed and a final decision made regarding inclusion. A third and final screening phase identified the articles as referring to tools developed for or tested with adults (n 30) or children/adolescents (n 18).

Tools described in the articles were classified as (i) dairy assessment tools that assess the quantity or frequency of intake of dairy foods or (ii) Ca assessment tools that assess quantity or are able to classify respondents into specific categories of Ca intake. Some tools collected information on intake of dairy foods and other Ca-containing foods and were considered to be both Ca and dairy assessment tools.

When assessing reliability and validity of tools, a sample size of at least 100 subjects was considered acceptable[11], tests of association (correlation coefficients) were considered weak statistical analysis, whereas tests that measured agreement (Bland–Altman or κ) and/or sensitivity and specificity were considered to provide strong systematic analysis[15]. A mean difference between two administrations or between test and reference method of 100 mg (representing about 10 % of the recommended daily intake, or one-third of a serving of dairy products) was considered clinically significant. Further a κ value $> 0{\cdot}5$ was considered moderate agreement, a value $> 0{\cdot}7$ as good agreement and a value $> 0{\cdot}8$ as very good agreement[15].

Results

The thirty articles report on thirty-six tools that had been used in those aged 18 years or over. Four articles report on two tools[16–19], one article reports on three tools[20], and another reports on what is assumed an online and paper version of the same tool but this is not clearly stated[21]. Two tools[17,22] are each reported in second articles[23,24]. Four tools assess both dairy and Ca intake[16,25–27] and thirty-two assess Ca intake alone. Details of each of the tools are provided in Table 1. The tools were used in a range of population groups of differing age, gender, race, menopausal status, living situation, educational status and disease state.

Tool characteristics

All tools used an FFQ, with varying response options covering a variable period. Nineteen tools were quantitative[16–18,20,22,23,26–35] allowing an estimate of milligrams of Ca, fifteen semi-quantitative[19–21,36–44] and two qualitative (i.e. frequency of intake of specified items)[25,45]. Quantitative tools allowed varying serving sizes, the semi-quantitative tools provided a standard serving size and the qualitative tools included dairy products and other foods that make important contributions to Ca intake. In terms of food coverage, all tools included dairy products and nineteen included other foods that make an important contribution to Ca intake. One tool was designed to assess several nutrients and the foods included reflected this[45]. The remaining tools were general FFQ that were tested for their ability to assess Ca intake.

Two tools were completed via computer[21,30] and most could be self-administered (31/36). Visual aids were provided with five tools to assist respondents to identify portion size and quantify foods. Six tools were reported to take less than 15 min to complete, demonstrating an adequate user-friendliness and efficiency. Time to complete was not provided for most tools, but where sufficient

Table 1 Summary and key features of studies describing dairy and/or calcium assessment tools utilised in adult populations

Author (year), country	Tool purpose: number of items; tool type; population, age	Food coverage	Time required to complete	Application
Angbratt and Möller (1999)[16], Sweden	D+Ca:8, Ca:52; Q-FFQ; 20–30 years, 50–60 years	D+Ca: milk, cheese, Ca tablets, vit/min tablets Ca: milk, cheese, Ca tablets, vit/min tablets, bread, fruit, vegetables, egg, sandwich spread, dishes containing milk, ice cream, chocolate	D: NR, est. <5 min Ca: NR, est. ≥15 min	Self-administered. Includes portion size illustrations
Gans *et al.* (2006)[25], USA	D+Ca:27; QL-FFQ; university medical students, mean age 43·2 years	Whole grains, dairy, Ca-rich foods, fruit, vegetables, fat, saturated fat and cholesterol, sugary beverages and foods, Na, alcoholic beverages	10 min	Self-administered. Not D/Ca-specific. Includes questions on physical activity. Identifies 'at risk' answers
Goldbohm *et al.* (2011)[26], Netherlands	D+Ca:150; Q-FFQ; 55–69 years	27 food groups spanning whole diet: potatoes, rice, vegetables, citrus fruits, other fruits, bread, milk and milk products, cheese, eggs, meat, meat products, fish, other sandwich fillings, added fats, added sugar, cakes/cookies, soup, non-alcoholic beverages, alcoholic beverages, pulses, cereals, mixed dishes, nuts, snacks, candy, soya products	NR, est. ≥15 min	Self-administered. Not D/Ca-specific. Lengthy. Computer calculated
Welten *et al.* (1995)[27], Netherlands	D+Ca:61; Q-FFQ; 27–29 years	Dairy products only – milk, cheese and milk products, mixed dished based on dairy products	NR, est. ≥15min	Interviewer-administered. Computer calculated. Ca-specific
Beck and Ovesen (1999)[45], Denmark	Ca:12, version 1 and 2; QL-FFQ; >65 years	Ca:12: bread, potatoes, rice, pasta, milk, fermented milk products, cheese, fruit or juice, vegetables, fish on bread, fatty fish at a meal, supplements	NR, est. <5 min	Interviewer- or self-administered. Short and fast to complete. Not D/Ca-specific; immediate identification 'at risk' of inadequate energy, Ca, Vit C, Vit D. Items interpreted differently in version 2
Blalock *et al.* (1998)[28], USA	Ca:15; Q-FFQ; women, 35–43 years	Milk, cheese, yoghurt, dishes incl. cheese, ice cream, spaghetti, biscuits, collards, broccoli, bread	NR, est. <15 min	Self-administered. Portion sizes: small, medium, large. Ca-specific
Block *et al.* (1990)[22], USA	Ca:60; Q-FFQ; healthy males (mean age 66 years), females (45–70 years)	Total diet	17 min	Self- or interviewer-administered. Portion sizes: small, medium, large. Computer calculated. Not D/Ca-specific
Clover *et al.* (2007)[17], Australia	Ca:35, Ca:15; Q-FFQ; >65 years	Ca:35: milk-based beverages, dairy foods including cheese, yoghurt, dairy-based desserts, bread, breakfast cereals, porridge Ca:15: as Ca:35, excluding bread, breakfast cereals and porridge	Ca:35: NR, est. 5–10 min Ca:15: NR, est. ~5 min	Self-administered, standard verbal and written instructions. FFQ reviewed by investigator for clarity and completeness. Computer calculated
Cummings *et al.* (1987)[18], USA	Ca:34, Ca:18; Q-FFQ; >65 years	Ca:34: foods representing 85 % Ca intake of adults in NHANES II – dairy, dairy-based desserts, eggs, dried beans, bread and cereal products, baked goods, mixed dishes with cheese, salad, orange juice, cereal-based dishes e.g. spaghetti, potatoes, soup (excl. vegetable soup), chocolate candy, greens, beef steaks/roasts, oranges/tangerines, tomatoes/tomato juice, coffee, beer, wine Ca:18: Ca-rich foods or commonly eaten sources of Ca – dairy, dairy-based desserts, eggs, beans/peas, bread and cereal products, canned fish/crustaceans, baked goods, nuts	Ca:34: NR, est. ≥15 min Ca:18: NR, est. <15 min	Dietitian-administered. Ca-specific. Ca:34: 3 portion size options. Ca:18: portion size at discretion of respondent. Computer calculated. Short and fast to complete. Shortened Block *et al.* (1990) questionnaire

Table 1 *Continued*

Author (year), country	Tool purpose: number of items; tool type; population, age	Food coverage	Time required to complete	Application
Hacker-Thompson *et al.* (2009)[21], USA	Ca:34 online, SQ-FFQ; Ca: unknown printed; >18 years	Ca:34: Ca-containing foods Printed: Ca-containing foods	NR, est. <15 min	Online: self-administered, computer calculated. Printed: self-administered, total Ca servings calculated. Ca-specific
Hertzler and Frary (1994)[36], USA	Ca:27; SQ-FFQ; adults	Dairy products, soya milk, mixed dishes containing dairy, fruit, vegetables, breads/cereals, meat/fish/poultry/dry beans/nuts, fat/sugar/alcohol	NR, est. ~10 min	Self-administered. Short and fast to complete. Requires calculations to complete. Ca-specific. Food checklist and portion size drawings
Hung *et al.* (2011)[37], Canada	Ca:26; SQ-FFQ; postmenopausal women	Foods abundant in Ca and commonly eaten in British Columbia	NR, est. <15 min	Interviewer-administered. Ca-specific
Johansson (2008)[38], UK	Ca:unknown; SQ-FFQ; men, 55–88 years	Total diet. Foods that are important sources of nutrients in average British diets	NR, est. ≥15 min	Self-administered. Not Ca-specific, lengthy. Computer calculated. Modified from US questionnaire (Willett 1985)
Krall *et al.* (1989)[29], USA	Ca:unknown; Q-FFQ; postmenopausal women	Ca- and Vit D-rich foods not further specified	Unknown	Dietitian-administered. Food models and household measures provided. Not D/Ca-specific
Magkos *et al.* (2006)[44], Greece	Ca:30; SQ-FFQ; children, 10–15 years; adults, 26–33 years; elderly, 60–75 years	Ten dairy products (milk, yoghurt, 8 types soft and hard cheeses), 4 types pie, 2 cereal products, 2 types of nuts, 4 vegetable products, legumes, 4 fish products, eggs, ice cream, chocolate	~5 min	Self-administered. Short and fast to complete. Computer/professional calculation
Matthys *et al.* (2004)[30], Belgium	Ca:286; Q-FFQ; women, 18–39 years	All food items were identified as contributing substantially to the overall Fe intake or containing a dietary component that affects Fe absorption (Ca), in the Flemish meal pattern	60 min	Self-administered via computer. Standardised audiovisual explanation on use. 3 sections: meal frequency, meal-based diet history, checklist specific food items. Not Ca-specific, key purpose Fe intake
Montomoli *et al.* (2002)[31], Italy	Ca:15; Q-FFQ; women, 25–75 years	Dairy products, pasta/rice, bread, potatoes, meat/fish, eggs, legumes, vegetables, fruit, chocolate, water, Ca-rich mineral water	10 min	Dietitian-administered. Ca-specific. Quick calculation
Musgrave *et al.* (1989)[32], USA	Ca:53; Q-FFQ; postmenopausal women, 48–56 years	Not specified	NR, est. ≥15 min	Self-administered, dietitians available for assistance with portion sizes, etc. Ca-specific
Osowski *et al.* (2007)[39], USA	Ca:138; SQ-FFQ; adults	Total diet	~30 min	Self-administered, computer calculated. Version of Willett FFQ. Not D/Ca-specific
Pasco *et al.* (2000)[40], Australia	Ca:31; SQ-FFQ; women, 20–90 years	Dairy products, pasta/rice, bread, potatoes, meat/fish, eggs, legumes, vegetables, fruit, chocolate, water, Ca-rich mineral water	NR, est. 5–10 min	Self-administered, computer calculated. Short and fast to complete. Ca-specific

Table 1 *Continued*

Author (year), country	Tool purpose: number of items; tool type; population, age	Food coverage	Time required to complete	Application
Plawecki *et al.* (2009)[41], USA	Ca:46; SQ-FFQ; postmenopausal women, 60–60 years	Dairy (6 foods), foods with dairy (5 foods), fruits (6), vegetables (3), grains (10), meats (8), other foods (8, e.g. chocolate)	NR, est. 5–10 min	Self-administered. Computer calculated. Ca-specific
Pritchard *et al.* (2010)[33], Canada	Ca:160; Q-FFQ; overweight/obese postmenopausal women, ≥65 years	Food items contributing ≥30 mg Ca, ≥0·25 μg (≥10 IU) Vit D and ≥1 μg Vit K per average serving size. 9 food groups spanning diet. Includes dairy/egg products, fruit, Ca-fortified juice, soya beverage, supplements	~25 min	Self-administered. Photo album to aid identification of foods and serving sizes. Lengthy. Not D/Ca-specific
Schrager *et al.* (2005)[42], USA	Ca: >50; SQ-FFQ; women	High-Ca foods including milk, cheese, Ca-fortified juices, other dairy products, pizza, bread, almonds, bok choy, other greens, winter squash	NR, est. ≥15 min	Self-administered, computer calculated
Sebring *et al.* (2007)[20], USA	Ca:124, Ca:87, Q-FFQ; Ca:25, SQ-FFQ; adults	Ca:124: total diet, incl. supplements Ca:87: foods identified as major Ca sources as per NHANES II and 1994–1996 CSFII and supplements Ca:25: major dietary sources Ca including supplements	Ca:124: 1 h Ca:87: 15–30 min Ca:25: <10 min	All self-administered. Ca:124: not D/Ca-specific. Ca:87 & Ca:25: Ca-specific
Severo *et al.* (2009)[43], Portugal	Ca:7; SQ-FFQ; adults	Milk, yoghurt, cheese, canned, white and oily fish, eggs, red meat	NR, est. <5 min	Administration not specified, 2 modes; computerized or circular ruler. Not D/Ca-specific
Smith *et al.* (1999)[19], USA	Ca:70, Ca:25; SQ-FFQ; postmenopausal women	Ca:70: good food sources of Ca, Vit D, caffeine Ca:25: Ca-containing foods	Ca:70: NR, est. ≥15 min Ca:25: NR, est. ~5 min	Both self-administered. Ca:70 computer required. Ca:25 hand calculated
Szymelfejnik *et al.* (2006)[34], Poland	Ca:11; Q-FFQ; adults	Milk; hard, processed, fresh, homogenized cheeses; cheese for spreading like 'Fromage' or 'Surage'; natural yoghurt; fruit yoghurt; kefir or buttermilk or flavoured milk; ice cream; cream	NR, est. <15 min	Self-administered. Ca-specific. Short and fast to complete
Varenna *et al.* (2001)[35], Italy	Ca:5; SQ-FFQ; postmenopausal women	Milk, aged cheese, soft cheese, cottage cheese and yoghurt	3–5 min	Self-administered. Ca-specific. Short and fast to complete
Wirfält *et al.* (1998)[23], USA	Ca:153, Ca:60 (Block); SQ-FFQ; women, 25–49 years	Total diet	NR, est. ≥15 min	Self-administered, computer calculated. Not D/Ca-specific

D, dairy; Q-FFQ, quantitative FFQ; QL-FFQ, qualitative FFQ; SQ-FFQ, semi-quantitative FFQ; vit/min, vitamin and mineral; NHANES II, National Health and Nutrition Examination Survey II; Vit D, vitamin D; Vit K, vitamin K; CSFII, Continuing Survey of Food Intake by Individuals; NR, not reported; est, estimated; Vit C, vitamin C.

information was obtainable an estimate was made based on the number of items by comparing with a comparable tool for which time to complete had been reported. Most tools required computer analysis or professional assistance to determine total daily Ca intake and/or adequacy; however, a few tools were able to provide an immediate indication of daily Ca intake.

Tool reliability

Test–retest reliability was reported for only six tools, two were dairy/Ca tools and four were Ca tools (Table 2). Inter-rater reliability was tested for one Ca tool(45). The statistical analyses varied, with correlation (Pearson, Spearman or intra-class) the most frequently used test. One study reported a κ value within a range for all nutrients tested(45) and another used cross-classification(27). The tools were mostly tested in samples of less than 100 with only two tools tested in a sample of 100 or greater(24,36). The period between the two administrations of the tool varied from a minimum of 4 d(45) up to 1 year(27), with most being 2–3 weeks.

Welten *et al.* provided the most comprehensive range of tests and these suggested moderate to good reliability (mean difference of 80 mg Ca, Pearson's correlation of 0·78, exact agreement of 62·1 % and gross misclassification of 3·4 %)(27). Miller *et al.* had comparable moderate intra-class correlation values across the two versions of their FFQ (thirty-five-item and fifteen-item; $r=0{\cdot}5$ and $r=0{\cdot}6$, respectively)(24) but did not report any findings from additional tests. The other three studies testing reliability reported only correlations and these were moderate to high. Inter-rater reliability tested by Beck *et al.* using the κ statistic showed a good level of agreement ($\kappa=0{\cdot}81$ to $0{\cdot}88$)(45).

Tool validity

Twenty-six articles reported tests of relative validity, on four dairy/Ca tools(16,25–27) and thirty-four Ca tools (Table 3), using an array of common reference methods. Sixteen studies used an estimated food record ranging in length from 3 to 14 d, three studies used multiple 24 h recalls, two used a general FFQ, two used diet histories and two used a single 24 h recall. The sample sizes of the studies varied greatly, ranging from fifteen subjects(33) to 2414 subjects(43) with 12/26 having a sample size less than 100. A range of statistical tests were performed, including correlation, comparison of mean values, Bland–Altman analysis, agreement using κ, cross-classification and assessment of sensitivity and specificity (Table 3). While correlation values may be moderate to high, this analysis tests only association. Ideally tool validity should be assessed by tests of agreement such as sensitivity and specificity, the κ statistic or Bland–Altman analysis(15).

The four dairy/Ca tools identified in the present review were tested for relative validity. Two reported non-significant mean differences between the tool and reference method of less than 100 mg Ca(16,26) but reported no other tests. Only Welten *et al.* conducted higher-level tests

Table 2 Details of reliability testing of tools that assess dairy and/or calcium intake in adults

Author (year), country	Tool	Population	Period	Statistical tests		
				Paired *t* test	Correlation: Pearson, transformed Pearson, Spearman, intra-class correlation	Cross-classification; κ
Gans *et al.* (2006)(25), USA	D + Ca:27	*n* 94, mean age 43·2 years	2–3 weeks		Total score, correlation analysis (not defined): $r=0{\cdot}86$, $P<0{\cdot}001$ Dairy servings, correlation analysis (not defined): NR	
Welten *et al.* (1995)(27), Netherlands	D + Ca:61	*n* 29, 27–29 years	1 year	1190 (SD 517) mg *v.* 1110 (SD 509) mg	P: $r=0{\cdot}78$ (*P* value NR), 95 % CI (0·57, 0·89)	CC: 62·1 % exact agreement; 3·4 % gross misclassification
Beck and Oveson (1999)*(45), Denmark	Ca:12	*n* 55, nursing home residents or at home, > 65 years	4–45 d (median 15·5 d)			κ: 0·81–0·88 for all nutrients, no specific Ca value
Hertzler *et al.* (1994)(36), USA	Ca:27	*n* 119, adults and college students	3 weeks		P: $r=0{\cdot}80$	
Matthys *et al.* (2004)(30), Belgium	Ca:286	*n* 51, women 18–39 years	2 months	Unadjusted: $P=0{\cdot}924$ Adjusted tool: $P=0{\cdot}884$	S: Unadjusted: $r=0{\cdot}64$ Adjusted: $r=0{\cdot}73$	
Miller *et al.* (2010)(24) [Clover *et al.* tool], Australia	Ca:35, Ca:15	*n* 100, >65 years	2 weeks		Ca:35: ICC = 0·5 (95 % CI 0·27, 0·59) Ca:15: ICC = 0·6 (95 % CI 0·48, 0·73)	

D, dairy; *n*, sample size; P, Pearson's correlation; NR, not reported; S, Spearman's correlation; ICC, intra-class correlation; CC, cross-classification; κ, kappa coefficient.
*Inter-rater reliability.

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Table 3 Details of validity testing of tools that assess dairy and/or calcium intake in adults

		Tests			
Author (year), country	Tool; reference tool; population	Correlation: Pearson's, Spearman's	Paired *t* test/Mann–Whitney *U*/Wilcoxon signed rank test	Cross-classification/Intra-class correlation	Sensitivity/specificity; Bland–Altman; κ
Angbratt and Möller (1999)[16], Sweden	D:8 *v.* diet history, *n* 22 Ca:52 *v.* diet history, *n* 12 women aged 20–30, 50–60 years		T: D:8: 596 (SD 233) *v.* 574 (SD 252) mg Ca, NS Ca:52: 463 (SD 197) *v.* 471 (SD 259) mg Ca, NS		
Gans *et al.* (2006)[25], USA	D+Ca:27 *v.* 3 d food diary, *n* 94, adults	(not specified) Dairy servings: $r=0{\cdot}21$, $P=0{\cdot}04$			
Goldbohm *et al.* (2011)[26], Netherlands	D+Ca:150 *v.* 3 × 3 d food diary, *n* 109, 55–69 years	S: Milk, milk products: $r=0{\cdot}60$ Cheese: $r=0{\cdot}61$ P: Ca, unadjusted: $r=0{\cdot}60$ Ca, adjusted (energy, sex): $r=0{\cdot}62$	T: Milk & products: 311 (SD 192) *v.* 363 (SD 230) g Cheese: 21 (SD 15) *v.* 33 (SD 20) g Ca: 908 (SD 268) *v.* 1012 (SD 332) mg		
Welten *et al.* (1995)[27], Netherlands	D+Ca:61 *v.* diet history, *n* 160, 27–29 years	P: Ca: $r=0{\cdot}64$ Cheese: $r=0{\cdot}58$ Milk & milk products: $r=0{\cdot}65$		CC: Ca: Exact agreement: 51·9 % Gross misclassification: 13·1 % Cheese: Exact agreement: 55·6 % Gross misclassification: 12·3 % Milk & milk products: Exact agreement: 51·9 %; Gross misclassification: 13·7 %	Ca: BA: Mean bias: 72·6 mg LOA: ± 1000 mg Ca: $\kappa=0{\cdot}60$ Cheese: $\kappa=0{\cdot}67$ Milk & milk products: $\kappa=0{\cdot}60$
Beck and Ovesen (1999)[45], Denmark	Ca:12 (version 1), *n* 70 Ca:12 (version 2), *n* 17 *v.* 4 d food record, >65 years				SE: Version 1, 6 %: version 2, 40 % SP: Version 1, 97 %; version 2, 86 %
Blalock *et al.* (1998)[28], USA	Ca:15 *v.* diet history questionnaire, *n* 536, women, 35–43 years	(not specified) $r=0{\cdot}99$			
Block *et al.* (1990)[22], USA	Ca:60 *v.* 3 × 4 d food records, *n* 260, women 45–70 years; or *v.* 2 × 7 d food records, *n* 83, men mean age 66 years		Group means: Ca: Women *n* 102, 705 *v.* 702 mg; *n* 58, 756 *v.* 743 mg Men *n* 83, 836 *v.* 985 mg $P<0{\cdot}05$		
Clover *et al.* (2007)[17], Australia	Ca:15, Ca:35 *v.* 4 d food record, *n* 102, >65 years				SE: Ca:35, 86 %; Ca:15, 82 % SP: Ca:35, 57 %; Ca:15, 46 % BA: Mean bias: Ca:35, + 5 mg; Ca:15, – 28 mg LOA: Ca:35, – 739, + 729 mg; Ca:15, – 936, + 879 mg

Table 3 *Continued*

		Tests			
Author (year), country	Tool; reference tool; population	Correlation: Pearson's, Spearman's	Paired *t* test/Mann–Whitney *U*/Wilcoxon signed rank test	Cross-classification/Intra-class correlation	Sensitivity/specificity; Bland–Altman; κ
Cummings *et al.* (1987)[18], USA	Ca:34, Ca:18, *v.* 7 d food record, *n* 37, women >65 years	Ca:34: $r=0{\cdot}64$ Ca:18: $r=0{\cdot}49$			
Hacker-Thompson *et al.* (2009)[21], USA	Ca:34 online, Ca:unknown printed *v.* 3 d food record, *n* 140, women >18 years	P: Online: $r=0{\cdot}37$, $P<0{\cdot}001$ Printed: $r=0{\cdot}37$, $P<0{\cdot}001$			BA: Mean bias: online, – 67 mg; printed, – 182 mg LOA: ± 1000 mg
Hertzler *et al.* (1994)[36], USA	Ca:27 *v.* 3 d food record, *n* 390, adults & college students	P: $r=0{\cdot}28$ Removed outliers: $r=0{\cdot}68$			
Hung *et al.* (2011)[37], Canada	Ca:26 *v.* 3 d food record, *n* 348, postmenopausal women	P: $r=0{\cdot}57$			SE: 500 mg, 73 %; 1000 mg, 71 % SP: 500 mg, 79 %; 1000 mg, 72 % BA: Mean bias: 121 mg LOA: – 600, + 841 mg
Johanssson (2008)[38], UK	Ca:unknown, *v.* 4 × 4 d weighed record *n* 75, men 55–88 years			CC quartiles: Correct classification: 43 % Gross misclassification: 4·7 % for all nutrients (no specific data for Ca)	
Magkos *et al.* (2006)[44], Greece	Ca:30 *v.* 24 h recall, *n* 1001, children 10–15 years, adults 26–33 years, elderly 60–75 years,	$r=0{\cdot}64$, $P<0{\cdot}001$			SE: 82·8 %; SP: 54·9 % BA: Mean bias: –133 mg LOA: – 799, + 533 mg
Matthys *et al.* (2004)[30], Belgium	Ca:286 *v.* 11 d food record, *n* 50, women 18–39 years	S: Unadjusted: 0·48 Adjusted: 0·52	T: Unadjusted: $P=0{\cdot}296$ Adjusted: $P=0{\cdot}003$	CC: Unadjusted: Same tertile: 42 % Opposite tertile: 8 % Adjusted: Same tertile: 38 % Opposite tertile: 8 %	κ: Unadjusted: 0·25 Adjusted: 0·20
Montomoli *et al.* (2002)[31], Italy	Ca:15, *v.* 14 d food record, *n* 206, women 25–75 years	P: $r=0{\cdot}90$			SE: 89·4 %; SP: 86·6 % BA: Mean bias: 11·3 mg LOA: – 244, + 222 mg
Musgrave *et al.* (1989)[32], USA	Ca:53 *v.* 4 d food record, *n* 26, women 48–56 years	P: Winter: $r=0{\cdot}73$, $P<0{\cdot}001$ Summer: $r=0{\cdot}84$ $P<0{\cdot}001$			
Osowski *et al.* (2007)[39], USA	Ca:138 *v.* 4 × 24 h recalls, *n* 81, adults	S: Unadjusted: $r=0{\cdot}49$ Adjusted for energy: $r=0{\cdot}59$		CC: Unadjusted: Same quartile: 33 % Same quartile ± 1: 78 % Grossly misclassified: 2 % Adjusted for energy: Same quartile: 44 % Same quartile ± 1: 83 % Grossly misclassified: 1 %	

Table 3 *Continued*

		Tests			
Author (year), country	Tool; reference tool; population	Correlation: Pearson's, Spearman's	Paired *t* test/Mann–Whitney *U*/Wilcoxon signed rank test	Cross-classification/Intra-class correlation	Sensitivity/specificity; Bland–Altman; κ
Pasco *et al.* (2000)[40], Australia	Ca:37 *v.* 4 d weighed food record, *n* 32, women 20–90 years			CC: High tertile: 50 % Mid tertile: 50 % Low tertile: 60 % Misclassification: 1 subject	BA: Mean bias: 121 mg LOA: – 593, 835 mg κ: 0·4
Plawecki *et al.* (2009)[41], USA	Ca:46 *v.* 24 h recall, *n* 185, postmenopausal women	P: $r = 0·53$, $P < 0·001$			SE: 63 %; SP: 64 % BA: Mean bias: + 221 mg LOA estimated: – 750, + 1250 mg
Pritchard *et al.* (2010)[33], Canada	Ca:161 *v.* 5 d food record, *n* 15, postmenopausal women	P: $r = 0·63$, $P < 0·05$		CC: Same quartile: 47 % ± 1 quartile: 87 % Misclassified: 0 %	BA: Mean bias: + 576 mg LOA: – 688, + 1821 mg
Sebring *et al.* (2007)[20], USA	Ca:124, Ca:87, Ca:25 *v.* 7 d food record, *n* 341, >18 years				BA: Ca:124 ($P < 0·001$): Mean bias: – 94 mg LOA: unknown Ca:87 ($P < 0·001$): Mean bias: + 177 mg LOA: unknown Ca:25 ($P = 0·09$): Mean bias: + 34 mg LOA: unknown
Severo *et al.* (2009)[43], Portugal	Ca:3 *v.* full *n* 2414, >18 years			CC: Correct classification: 89 % Misclassified: 10 %	BA: Mean bias: 0·0 mg LOA: – 220, + 220 mg $κ = 0·75$
Smith *et al.* (1999)[19], USA	Ca:70, Ca:25 *v.* 97-item FFQ *n* 91, postmenopausal women	P: Ca:25: $r = 0·33$ Ca:70: $r = 0·53$			
Szymelfejnik *et al.* (2006)[34], Poland	Ca:11, Q-FFQ, 7 × 24 h recalls, *n* 90, university students (mean age 22·6 years)				SE: 88 %; SP: 69 %
Wirfält *et al.* (1998)[23], USA	Ca:60 *v.* Ca:153 *v.* 3 × 24 h recalls, *n* 101, healthy women, 25–49 years	P: Unadjusted: Ca:153 *v.* Ca:60: $r = 0·55$ Ca:153 *v.* 24 h recalls: $r = 0·43$ Ca:60 *v.* 24 h recalls: $r = 0·29$ Adjusted for energy: Ca:153 *v.* Ca:60: $r = 0·56$ Ca:153 *v.* 24 h recalls: $r = 0·56$ Ca:60 *v.* 24 h recalls: $r = 0·41$		CC: Exact agreement: Ca:153 *v.* Ca:60: 34 % Ca:153 *v.* 24 h recalls: 35 % Ca:60 *v.* 24 h recalls: 26 %	

D, dairy; *n*, number; S, Spearman's correlation; P, Pearson's correlation; T, paired *t* test; CC, cross-classification; BA, Bland–Altman; LOA, limits of agreement; κ, kappa coefficient; SE, sensitivity; SP, specificity.

Table 4 Final recommendations for dairy and/or calcium tools that are well validated for implementation in the practice and research setting in adults

	Author	Recommended population	Tool	Potential limiting factors
Dairy				
1	Welten *et al.*[27]*	Young adults (13–27 years) Group settings only	Dairy questionnaire	Recall bias Small sample size in reliability study Results indicate only moderate reliability and validity
Calcium				
1	Montomoli *et al.*[31]	Across all adults	Ca FFQ	Not tested for reliability Sampling bias
2	Hacker-Thompson *et al.*[21]	Group settings only	Online questionnaire	Not tested for reliability No limits of agreement reported
3	Clover *et al.*[17]	Only validated in the elderly, >65 years Group settings only	35- or 15-item FFQ	Recall bias
4	Sebring *et al.*[20]	Group settings only	Short Ca questionnaire (Ca:124 and Ca:25 only)	Not tested for reliability No limits of agreement reported Recall bias
5	Severo *et al.*[43]	Across all adults	3-item Ca FFQ	Recall bias Not tested for reliability

*Also tested for reliability.
†Tested for reliability in the study by Miller *et al.* (2010)[24].

and reported moderate κ values for both dairy foods and Ca (0·60–0·76)[27]. However, results of the Bland–Altman analysis conducted in the same study indicated only 52 % exact agreement and very wide limits of agreement (±1000 mg) indicating that this tool would not perform well at the individual level[27].

A majority of the Ca tools (22/26) were tested for relative validity. Virtually all studies reported correlation between the tool and reference method, with five studies reporting no additional tests[18,19,28,32,36]. Due to the limited value of correlation tests no further discussion of these results is provided although values are reported in Table 3.

Sensitivity and specificity were calculated by seven studies[17,31,34,37,41,44,45] (Table 3). While sensitivity values ranged from 71 %[37] to 95 %[45], specificity ranged from 46 %[17] to 97 %[45]. Ideally both the sensitivity and specificity for a screening tool would be high; however, only two studies reported both sensitivity and specificity to be greater than 80 %[31,45].

Cross-classification statistics, which identified the percentage of subjects correctly classified by the tool into quartiles or tertiles of Ca intake, were reported by eight studies[23,27,30,33,38,39,40,43] (Table 3). Osowski *et al.* reported the lowest correct classification of only 33%[39] while Severo *et al.* reported the highest agreement between methods of 89%[43]. Gross misclassification, defined as classification of Ca intake by the tool in the opposite quartile or tertile of intake, ranged from 0 % as reported by Pritchard *et al.*[33] to 8 % reported by Matthys *et al.*[30].

Three studies calculated the κ statistic for the level of agreement between the two methods, Matthys *et al.* reported $\kappa = 0{\cdot}20$[30], Pasco *et al.* reported $\kappa = 0{\cdot}40$[40] and Severo *et al.* reported $\kappa = 0{\cdot}75$[43].

A greater number of studies used Bland–Altman plots to illustrate the level of agreement[17,20,21,31,33,37,40,41,43,44]. The mean bias between the tool and reference method ranged from + 5 mg/d[17] to + 576 mg/d[33]. Limits of agreement varied widely between studies extending from ± 233 mg[31] to ± 1254 mg[33].

Discussion

The present review identified thirty papers using thirty-six tools that met the criteria for inclusion; four tools that assessed both dairy and Ca intake and thirty-two that assessed Ca intake only. Based on the review of methods used and results of the reliability and validity testing, one tool for assessing dairy and Ca intake[27] and five tools for assessing Ca intake are recommended[17,20,21,31,43] (Table 4). While appropriate testing methods for relative validity and adequate levels of sensitivity, specificity and/or agreement were reported for these tools, only two[17,27] were tested for test–retest reliability which was shown to be moderate[24,27].

The common limitations of the testing of tool properties were the lack of testing for reliability, the high reliance on correlation which assesses association only, and the lack of tests that provide a measure of agreement. In addition when assessing validity it is important to determine a clinically meaningful level of significance as opposed to relying on statistical significance alone. None of the papers defined a level of clinical significance at which the results were meaningful in terms of dietary adequacy. This lack of recognition between statistically and clinically significant results limits conclusions relevant to clinical practice. In order to define clinically meaningful results we applied a 100 mg Ca cut-off for bias when assessing studies, or approximately the amount of Ca that might be delivered by one-third of a standard serving of dairy foods.

The lack of testing for reliability limits the ability to be confident in recommending a tool for use. In addition, relative validity results for those tools that assessed Ca vary such that some should be considered with caution while others appear to have acceptable levels of agreement and/or sensitivity and specificity. With respect to Ca tools, those that appear to be best in levels of relative validity are those developed by Clover *et al.*[17], Montomoli *et al.*[31], Hacker-Thompson *et al.*[21], Sebring *et al.*[20] and Severo *et al.*[43]. Each of these studies included a minimum of 100 participants, considered to be the smallest acceptable sample size for a validation study[11], had a sensitivity and specificity of > 80 %, or a Bland–Altman mean bias of < 100 mg, or a κ statistic > 0·80, or a correct classification of > 80 %. One exception is that Clover *et al.* reported a specificity of <80 %, but importantly this was the only one of these five tools that was tested for reliability[24].

There are some additional limitations to the findings presented here, in particular the quality of the study design. The key study design criteria include level of evidence, potential sources of error and bias, and sample size. These have been discussed in the companion paper and the issues identified there equally apply to the adult studies in the current paper[14]. In brief, all eligible papers were identified as having III-2 level of evidence, as defined by the National Health and Medical Research Council evidence hierarchy for diagnostic accuracy[46], and there was potential for recall bias, positive respondent bias and recruitment bias. Many of the studies reported here targeted specific populations and thus when selecting a tool for use it is important to consider the population in which the tool properties were tested. Validity in one population does not guarantee validity in another population of different age, gender or physiological state.

Conclusion

In conclusion, based on the present review we recommend one tool for assessing dairy and Ca intake and five tools for assessing Ca intake. However, these should be considered cautiously as there are inherent limitations to all the reported studies suggesting they may not perform as well if tested using a study design of a higher level and this should be considered in future application of the tool. Further, when selecting a tool for use the relevance of the tool items to the food culture of the target population should be considered. The present literature review has identified gaps in the literature which may inform future research. Overall few tools were tested for reliability; therefore further research should be conducted to ensure that other Ca or dairy tools are adequately reliable for use.

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