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A New Method for Calculating Calcium Content and Determining Appropriate Calcium Levels in Foods

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Abstract

The calcium content of some foods is inappropriately calculated per 100 kcal, 100 g or 100 mL, or the reference amount customarily consumed (RACC). So, making some food choices based on them to achieve adequate calcium may increase the risks of some chronic diseases. Calculating the calcium content and determining appropriate calcium levels based on the US Food and Drug Administration (FDA), the Codex Alimentarius Commission (CAC), and the proposed method were performed on 8260 food items. Making some food choices based on the FDA and CAC per serving (the serving is derived from the RACC) or CAC per 100 g or 100 mL to achieve adequate calcium exceeded energy needs, which could lead to overweight or obesity. Making some food choices based on the CAC per 100 kcal or CAC per 100 g or 100 mL to achieve adequate calcium did not meet calcium requirements, which could lead to calcium deficiency. Some foods that met calcium requirements were not appropriate food choices based on the CAC per 100 g or 100 mL or CAC per serving to achieve adequate calcium. On the basis of the proposed method, calculating the calcium content and determining appropriate calcium levels in foods are performed by considering RACCs and the energy content of foods. Thus, making food choices based on the proposed method met calcium requirements and did not exceed energy needs.

Keywords Dietary calcium · Adequate calcium · Calcium deficiency · Calcium-rich foods · Calcium-poor foods · Obesity

Introduction

Calcium is the most abundant mineral in the human body (Bass and Chan 2006; Jung et al. 2006). Over 99% of the total body calcium is found in the teeth and bones (Cashman 2002). Calcium as a nutrient is most commonly associated with the formation and metabolism of bone (IOM 2011). Calcium in the circulatory system, extracellular fluid, muscle, and other tissues is critical for mediating vascular contraction and vasodilatation, muscle function, nerve transmission, intracellular signaling, and hormonal secretion (IOM 2011). Despite the important roles of calcium in the human body, many people around the world do not meet the daily requirement for calcium (Balk et al. 2017; Fulgoni et al. 2011; Vatanparast et al. 2009; Wallace et al. 2014).

The calcium content of some foods is inappropriately calculated per 100 kcal, 100 g (for solids) or 100 mL (for liquids), or reference amount customarily consumed (RACC). So, making some food choices based on them to achieve adequate calcium may increase the risks of some chronic diseases. According to the regulatory requirements for nutrient content claims, appropriate calcium levels in foods should be determined based on the source (good source) and high (excellent source) claims for calcium. The source and high claims for calcium indicate the presence of calcium at mid and high levels, respectively. If one food meets the definition of high or source claim for calcium, that food is considered a high-calcium (excellent source of calcium) or calcium source (good source of calcium), respectively. Foods that meet the source or high claim for calcium are known as foods containing appropriate calcium levels. Nutrient content claims were established by several authorities, and the CAC and FDA are the most important among them. The source and high claims for calcium based on the CAC are expressed in reference amounts of 100 g or 100 mL, serving size (serving), and 100 kcal, and the source and high claims for calcium based

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on the FDA are expressed in a reference amount of serving. According to the source and high claims for calcium under the FDA and CAC per serving, the serving is derived from the RACC.

This study examined calculating the calcium content and determining appropriate calcium levels based on the FDA and CAC per serving, CAC per 100 g or 100 mL, and CAC per 100 kcal and introduced a new method for calculating the calcium content and determining appropriate calcium levels in foods. On the basis of the proposed method, calculating the calcium content and determining appropriate calcium levels in foods are performed by considering RACCs and the energy content of foods.

Methods

Food Items

Information on food and calcium profiles was provided from the USDA National Nutrient Database for Standard Reference, release 28 (SR28) (USDA ARS 2016). Of 8790 food items in the SR28, information on the calcium content of 348 food items was missing.

RACCs

RACC values represent the amount (edible portion) of food customarily consumed per eating occasion (FDA 2018). RACCs were not provided in the SR28 Excel data file. However, the preparation of results on the basis of the serving required the allocation of RACCs to food items. Thus, RACCs were allocated to SR28 food items using the guidance prepared by the Office of Nutrition and Food Labeling (FDA 2018). RACCs were allocated to 8596 food items, and 194 food items were excluded due to the lack of density or RACC.

Calculation of Calcium Content per 100 mL

The calcium content of food items in the SR28 was provided per 100 g. Since the calcium content of liquid food items based on the CAC per 100 mL should have been provided per 100 mL, the densities of liquid food items were calculated by formula 1. Then, the calcium content was converted from 100 g to 100 mL by formula 2. Solid and liquid foods refer to foods that are usually measured by weight and volume, respectively.

$$\text{Density}_{(\text{g/mL})} = \text{mass}_{(\text{g})} \div \text{volume}_{(\text{mL})} \quad (1)$$

$$\text{Calcium content}_{(\text{mg})} \text{ per 100 mL (for liquids)} = \text{density}_{(\text{g/mL})} \times \text{calcium content}_{(\text{mg})} \text{ per 100 g} \quad (2)$$

Calculation of Calcium Content per 100 kcal

Since the calcium content of food items based on the CAC per 100 kcal should have been provided per 100 kcal, the calcium content of food items was converted from 100 g to 100 kcal by formula 3.

$$\text{Calcium content}_{(\text{mg})} \text{ per 100 kcal} = \left(100 \div \text{energy}_{(\text{kcal}/100\ \text{g})}\right) \times \text{calcium content}_{(\text{mg})} \text{ per 100 g} \quad (3)$$

Calculation of Calcium Content per RACC

Since the calcium content of food items based on the FDA and CAC per serving should have been provided per RACC, the calcium content was converted from 100 g to RACC by formula 4 for solids and formula 5 for liquids.

$$\text{Calcium content}_{(\text{mg})} \text{ per RACC (for solids)} = \left(\text{RACC}_{(\text{g})} \div 100\right) \times \text{calcium content}_{(\text{mg})} \text{ per 100 g} \quad (4)$$

$$\text{Calcium content}_{(\text{mg})} \text{ per RACC (for liquids)} = \left(\text{RACC}_{(\text{mL})} \div 100\right) \times \left(\text{density}_{(\text{g/mL})} \times \text{calcium content}_{(\text{mg})} \text{ per 100 g}\right) \quad (5)$$

Daily Values for Calcium

Daily values (DVs) for calcium were considered 1300 mg for all foods, excluding baby foods, and 700 mg for baby foods in the proposed method and FDA per serving (21 CFR101.9, revised as of April 1, 2018).

Nutrient Reference Values for Calcium

Nutrient reference values (NRVs) for calcium were considered 1000 mg (CAC 2017) for all foods, excluding baby foods, and 700 mg (21 CFR101.9, revised as of April 1, 2018) for baby foods in the CAC per serving, CAC per 100 g or 100 mL, and CAC per 100 kcal.

DVs or Daily Reference Values for Energy

DVs or daily reference values (DRVs) for energy were considered 2000 kcal (CAC 2017; 21 CFR101.9, revised as of April 1, 2018) for all foods, excluding baby foods, and 1000 kcal (21 CFR101.9, revised as of April 1, 2018) for baby foods in this study.

Source and High Claims for Calcium

Table S1 presents the source and high claims for calcium based on the proposed method, FDA and CAC per serving, CAC per 100 g or 100 mL, and CAC per 100 kcal (CAC 2007; CAC 2013; IOM 2010).

Calculation of Calcium Content of Foods Based on the Proposed Method in Conditions of Appropriate Energy Content

If the energy content per RACC is 200 kcal or less, the calcium content of all foods (based on the reference energy intake of 2000 kcal), excluding baby foods, is calculated per RACC, and if the energy content per RACC is 100 kcal or less, the calcium content of baby foods (based on the reference energy intake of 1000 kcal) is calculated per RACC. Also, if the energy content per RACC is 200 kcal or less, the source and high claims for calcium are defined respectively as 10–19% and 20% or more of the DV for calcium per RACC in all foods, excluding baby foods, and if the energy content per RACC is 100 kcal or less, the source and high claims for calcium are defined respectively as 10–19% and 20% or more of the DV for calcium per RACC in baby foods. The energy content per RACC for solid and liquid foods was calculated by formulas 6 and 7, respectively.

$$\text{Energy content}_{(\text{kcal})}\ \text{per RACC (for solids)} = \left(\text{RACC}_{(\text{g})} \div 100\right) \times \text{energy}_{(\text{kcal}/100\ \text{g})} \quad (6)$$

$$\text{Energy content}_{(\text{kcal})}\ \text{per RACC (for liquids)} = \left(\text{RACC}_{(\text{mL})} \div 100\right) \times \left(\text{density}_{(\text{g/mL})} \times \text{energy}_{(\text{kcal}/100\ \text{g})}\right) \quad (7)$$

Calculation of Calcium Content of Foods (Except Baby Foods) Based on the Proposed Method in Conditions of Inappropriate Energy Content

If the energy content per RACC is more than 200 kcal, the calcium content of all foods (based on the reference energy intake of 2000 kcal), excluding baby foods, is calculated per 200 kcal of RACC. Also, if the energy content per RACC is more than 200 kcal, the source and high claims for calcium are defined respectively as 10–19% and 20% or more of the DV for calcium per 200 kcal of RACC in all foods, excluding baby foods. If the energy content per RACC is more than 200 kcal, 200 kcal of RACC for solid and liquid foods is calculated by formulas 8 and 9, respectively.

$$200\ \text{kcal of RACC}_{(\text{g})}\ \text{(for solids)} = \left[200 \times \text{RACC}_{(\text{g})}\right] \div \left[\left(\text{RACC}_{(\text{g})} \div 100\right) \times \text{energy}_{(\text{kcal}/100\ \text{g})}\right] \quad (8)$$

$$200\ \text{kcal of RACC}_{(\text{mL})}\ \text{(for liquids)} = \left[200 \times \text{RACC}_{(\text{mL})}\right] \div \left[\left(\text{RACC}_{(\text{mL})} \div 100\right) \times \left(\text{density}_{(\text{g/mL})} \times \text{energy}_{(\text{kcal}/100\ \text{g})}\right)\right] \quad (9)$$

Calculation of Calcium Content of Baby Foods Based on the Proposed Method in Conditions of Inappropriate Energy Content

If the energy content per RACC is more than 100 kcal, the calcium content of baby foods (based on the reference energy intake of 1000 kcal) is calculated per 100 kcal of RACC. Also, if the energy content per RACC is more than 100 kcal, the source and high claims for calcium are defined respectively as 10–19% and 20% or more of the DV for calcium per 100 kcal of RACC in baby foods. If the energy content per RACC is more than 100 kcal, 100 kcal of RACC for solid and liquid baby foods is calculated by formulas 10 and 11, respectively.

$$100\ \text{kcal of RACC}_{(\text{g})}\ \text{(for solids)} = \left[100 \times \text{RACC}_{(\text{g})}\right] \div \left[\left(\text{RACC}_{(\text{g})} \div 100\right) \times \text{energy}_{(\text{kcal}/100\ \text{g})}\right] \quad (10)$$

$$100\ \text{kcal of RACC}_{(\text{mL})}\ \text{(for liquids)} = \left[100 \times \text{RACC}_{(\text{mL})}\right] \div \left[\left(\text{RACC}_{(\text{mL})} \div 100\right) \times \left(\text{density}_{(\text{g/mL})} \times \text{energy}_{(\text{kcal}/100\ \text{g})}\right)\right] \quad (11)$$

Results

Foods Containing Appropriate Calcium Levels Based on the Proposed Method

About 96.5% of foods contained calcium. On the basis of the proposed method, the average (%) of foods containing appropriate calcium levels in food groups was 11.38%, of which 8.39% was the average of calcium source (good source of calcium) foods, and 2.99% was the average of high-calcium (excellent source of calcium) foods. Dairy and egg products with 58.91%, baby foods with 40.27%, and breakfast cereals

with 28.29% had the highest averages of foods containing appropriate calcium levels. Dairy and egg products with 22.55%, legumes and legume products with 10.93%, baby foods with 10.14%, and beverages with 6.93% had the highest averages of high-calcium foods (Fig. 1). All foods containing appropriate calcium levels in the group of dairy and egg products were allocated to dairy products. Foods containing appropriate calcium levels in dairy products mainly included cheese, milk, and yogurt.

Most foods containing appropriate calcium levels in 12 food groups (baby foods; baked products; beverages; breakfast cereals; fast foods; fruits and fruit juices; legumes and legume products; meals, entrees, and side dishes; restaurant foods; snacks; soups, sauces, and gravies; sweets) were allocated to dairy-containing foods (except dairy products) or calcium-fortified foods.

The highest amounts of calcium were found in breakfast cereal (calcium-fortified), calcium-set tofu, malted milk drink (calcium-fortified), nutrition shake (calcium-fortified), almond milk drink (calcium-fortified), coconut milk drink (calcium-fortified), formulated bar (calcium-fortified), granola bar (calcium-fortified), waffle (calcium-fortified), cheese product (calcium-fortified), soy milk (calcium-fortified), milk beverage (calcium-fortified), whey protein powder isolate, orange juice (calcium-fortified), rennet tablets (unsweetened), sheep milk, cow milk, grapefruit juice (calcium-fortified), buttermilk, chocolate bar (calcium-fortified), Indian buffalo milk, yogurt, goat milk, canned Atlantic sardine with bone, kefir, drink mix (calcium-fortified), American cheese (calcium-fortified), Gruyère cheese, vegetable juice (calcium-fortified), pasta in tomato and cheese sauce (calcium-fortified), orange drink (calcium-fortified), soy yogurt (calcium-fortified), Swiss cheese, fat-free mozzarella cheese, rice milk drink (calcium-fortified), collards, hard goat cheese, fat-free cheddar cheese, and acid whey.

Foods containing appropriate calcium levels were not found in four food groups (cereal grains and pasta; fats and oils; lamb, veal, and game products; spices and herbs) and were very few in four food groups (beef products, pork products, poultry products, sausages and luncheon meats). Appropriate calcium levels in five foods (mechanically separated beef, mechanically separated pork, mechanically deboned hen, mechanically deboned turkey, frankfurter made from mechanically separated pork) of these four food groups were due to the presence of bone in them. The absence of foods containing appropriate calcium levels in spices and herbs is due to the fact that spices and herbs are customarily consumed in small amounts. Spices and herbs provide sensory attributes such as flavor, aroma, and color to food (Kubra et al. 2016).

Animal products, excluding dairy products and bone-containing foods, had almost no foods containing appropriate

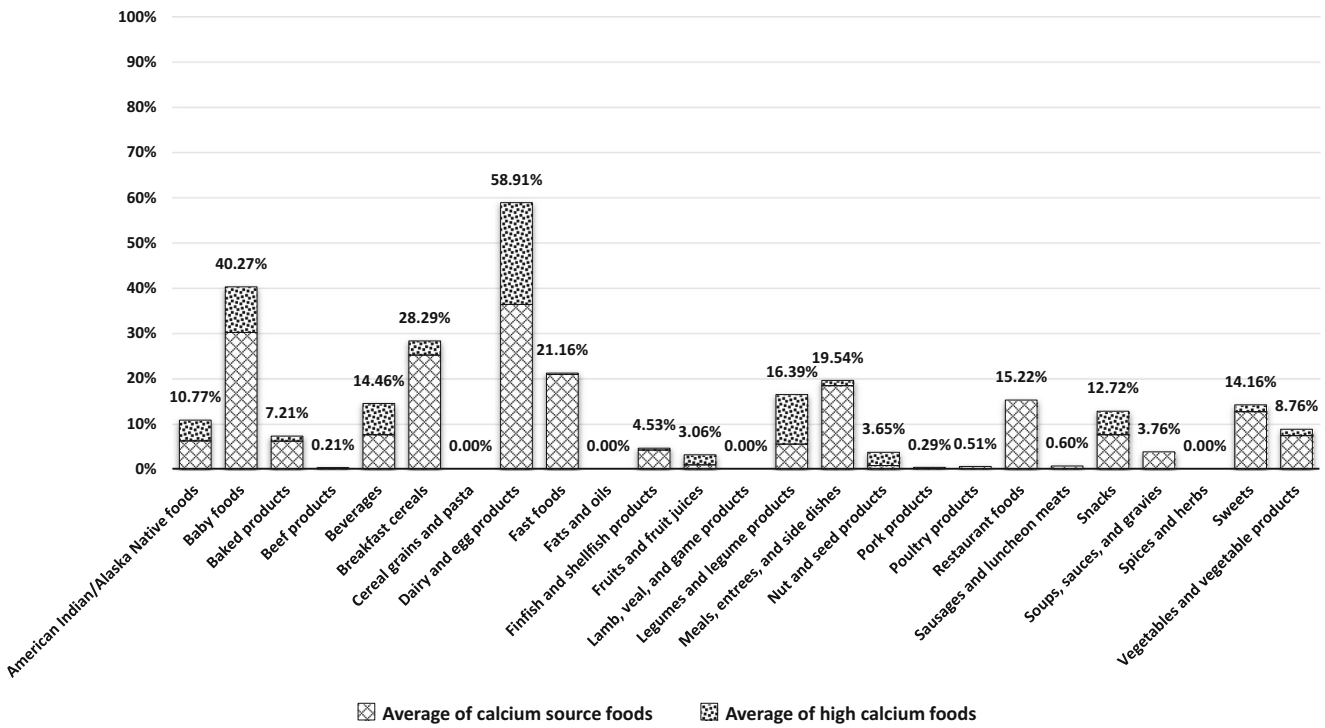

Fig. 1 Averages (%) of foods containing appropriate calcium levels (to achieve adequate calcium) based on the proposed method in food groups. All high-calcium (excellent source of calcium) and calcium source (good source of calcium) foods, excluding high-calcium and calcium source baby foods, are based on the reference energy intake of 2000 kcal for adults and children aged 4 years and older. High-calcium and calcium source baby foods are based on the reference energy intake of 1000 kcal for children 1 through 3 years of age

calcium levels. Plant products, excluding calcium-fortified foods and dairy-containing foods, had few foods containing appropriate calcium levels. In addition, some foods containing appropriate calcium levels in plant products contain oxalic acid (oxalate) or phytic acid (phytate), which decreases calcium absorption. Major foods containing appropriate calcium levels were allocated to dairy products, dairy-containing foods (except dairy products), and calcium-fortified foods.

Achieving the DVs for calcium by consuming high-calcium foods required an average of consuming 3.9 servings. So, the DVs for calcium are easily achieved by consuming high-calcium foods. Achieving the DVs for calcium by consuming calcium source foods required an average of consuming 7.6 servings. So, the DVs for calcium are moderately achieved by consuming calcium source foods. Since achieving the DVs for calcium without consuming high-calcium and calcium source foods required consuming more than 10 servings (or more than 20 servings in 81.3% of foods), it is difficult to achieve the DVs for calcium without consuming high-calcium and calcium source foods. According to the proposed method, the serving is derived from the RACC or 200 kcal of RACC for all foods, excluding baby foods, and RACC or 100 kcal of RACC for baby foods.

The averages (%) of foods containing appropriate calcium levels based on the proposed method in food groups are shown in Figure 1. High-calcium and calcium source foods based on the proposed method are given in Tables S2 and S3, respectively.

Foods Containing Appropriate Calcium Levels Based on the FDA per Serving

Since calculating the calcium content and determining appropriate calcium levels based on the FDA per serving are performed without considering the energy content of foods, making some food choices based on the FDA per serving to achieve adequate calcium met calcium requirements but exceeded energy needs. For example, if one cheeseburger (NDB number 21399) contains 253 kcal of energy per 100 g, RACC of 195 g, and 132.6 mg of calcium per RACC, is it defined as high-calcium or calcium source food based on the proposed method and FDA per serving? Since this cheeseburger contains 132.6 mg of calcium per RACC, it is defined as calcium source food based on the FDA per serving. Consuming 9.804 RACCs of the cheeseburger meets the DV for calcium but results in receiving 4837 kcal of energy, which is 2837 kcal more than the DV or DRV for energy. Since the serving of this cheeseburger based on the proposed method is 79.05 g, and this amount of cheeseburger contains 53.75 mg of calcium, this cheeseburger is not defined as high-calcium or calcium source food based on the proposed method.

The average (%) of similarities between the proposed method and the FDA per serving was 97.33% for high-calcium and calcium source foods in food groups. Both the proposed method and FDA per serving had the same high-calcium and calcium source foods in 14 food groups and 12 food groups, respectively. However, calculating the calcium content of some foods in large amounts (due to not considering the energy content of foods) based on the FDA per serving increased the averages (%) of foods containing appropriate calcium levels in 12 food groups (fast foods; meals, entrees, and side dishes; restaurant foods; baked products; sweets; baby foods; legumes and legume products; breakfast cereals; poultry products; dairy and egg products; beverages; lamb, veal, and game products) as compared with the proposed method. For example, the averages (%) of foods containing appropriate calcium levels in fast foods and meals, entrees, and side dishes were respectively 55.94% and 35.63% based on the FDA per serving and 21.16% and 19.54% based on the proposed method.

The averages (%) of foods containing appropriate calcium levels based on the FDA per serving in food groups are shown in Figure S1. High-calcium and calcium source foods based on the FDA per serving are given in Tables S4 and S5, respectively.

Foods Containing Appropriate Calcium Levels Based on the CAC per Serving

Since calculating the calcium content and determining appropriate calcium levels based on the CAC per serving are performed without considering the energy content of foods, making some food choices based on the CAC per serving to achieve adequate calcium met calcium requirements but exceeded energy needs. For example, if one sandwich with cheese (NDB number 21255) contains 266 kcal of energy per 100 g, RACC of 195 g, and 152.1 mg of calcium per RACC, is it defined as high-calcium or calcium source food based on the proposed method and CAC per serving? Since this sandwich contains 152.1 mg of calcium per RACC, it is defined as calcium source food based on the CAC per serving. Consuming 6.574 RACCs of the sandwich meets the NRV for calcium but results in receiving 3410 kcal of energy, which is 1410 kcal more than the DV or DRV for energy. Since the serving of this sandwich based on the proposed method is 75.19 g, and this amount of sandwich contains 58.65 mg of calcium, this sandwich is not defined as high-calcium or calcium source food based on the proposed method.

According to the CAC per serving, since the calcium source foods are determined by employing the high calcium amounts of the source claim for calcium, some foods that met calcium requirements were not appropriate food choices based on the CAC per serving to achieve adequate calcium. For example, if Limburger cheese (NDB number 1024) contains RACC of 30 g, 149.1 mg of calcium per RACC, and 327 kcal of energy per 100 g, is it defined as high-calcium or calcium

source food based on the proposed method and CAC per serving? Since this Limburger cheese contains less than 150 mg of calcium per RACC, it is not defined as high-calcium or calcium source food based on the CAC per serving. Consuming 201.2 g of the Limburger cheese meets the NRV for calcium, and this Limburger cheese is customarily consumed 300 g in 10 eating occasions. Since the serving of this Limburger cheese based on the proposed method is 30 g, and this amount of Limburger cheese contains 149.1 mg of calcium, this Limburger cheese is defined as calcium source food based on the proposed method.

The average (%) of similarities between the proposed method and the CAC per serving was 95.81% for high-calcium and calcium source foods in food groups. Employing strict criteria of the high and source claims for calcium based on the CAC per serving decreased the averages (%) of foods containing appropriate calcium levels in 12 food groups (baby foods; breakfast cereals; sweets; dairy and egg products; American Indian/Alaska Native foods; snacks; vegetables and vegetable products; beverages; sausages and luncheon meats; legumes and legume products; soups, sauces, and gravies; beef products) as compared with the proposed method. Also, calculating the calcium content of some foods in large amounts (due to not considering the energy content of foods) based on the CAC per serving increased the averages (%) of foods containing appropriate calcium levels in six food groups (fast foods; meals, entrees, and side dishes; restaurant foods; baked products; poultry products; lamb, veal, and game products) as compared with the proposed method. For example, the averages (%) of foods containing appropriate calcium levels in fast foods, baby foods, and meals, entrees, and side dishes were respectively 48.99%, 18.9%, and 34.48% based on the CAC per serving and 21.16%, 40.27%, and 19.54% based on the proposed method.

The averages (%) of foods containing appropriate calcium levels based on the CAC per serving in food groups are shown in Figure S2. High-calcium and calcium source foods based on the CAC per serving are given in Tables S6 and S7, respectively.

Foods Containing Appropriate Calcium Levels Based on the CAC per 100 g or 100 mL

Since calculating the calcium content and determining appropriate calcium levels based on the CAC per 100 g or 100 mL are performed without considering RACCs, making some food choices based on the CAC per 100 g or 100 mL to achieve adequate calcium did not meet calcium requirements. Employing a fixed food amount of 100 g for one solid food or 100 mL for one liquid food may be high for some foods. Thus, calculating the calcium content per 100 g of one solid food or 100 mL of one liquid food based on the CAC may show the calcium content of some foods inappropriately high. For example, if chili powder (NDB number 2009) contains RACC of 0.7 g and 330 mg of calcium per 100 g, is it defined as high-calcium or calcium source food based on the proposed method and CAC per 100 g? Since this chili powder contains 330 mg of calcium per 100 g, it is defined as high-calcium food based on the CAC per 100 g. Consuming 303.03 g of the chili powder meets the NRV for calcium, but this chili powder is customarily consumed 7 g in 10 eating occasions. Since the serving of this chili powder based on the proposed method is 0.7 g, and this amount of chili powder contains 2.31 mg of calcium, this chili powder is not defined as high-calcium or calcium source food based on the proposed method.

According to the CAC per 100 g or 100 mL, since the calcium content of some foods is calculated in small amounts, and the high-calcium and calcium source foods (except liquid foods) are determined by employing the high calcium amounts of the high and source claims for calcium, some foods that met calcium requirements were not appropriate food choices based on the CAC per 100 g or 100 mL to achieve adequate calcium. Employing a fixed food amount of 100 g for one solid food or 100 mL for one liquid food may be low for some foods. Thus, calculating the calcium content per 100 g of one solid food or 100 mL of one liquid food based on the CAC may show the calcium content of some foods inappropriately low. For example, if vanilla or lemon yogurt (NDB number 1184; made from fat-free milk with low-calorie sweetener) contains RACC of 170 g and 143 mg of calcium per 100 g, is it defined as high-calcium or calcium source food based on the proposed method and CAC per 100 g? Since this yogurt contains 143 mg of calcium per 100 g, it is not defined as high-calcium or calcium source food based on the CAC per 100 g. Consuming 699.3 g of the yogurt meets the NRV for calcium, and this yogurt is customarily consumed 1700 g in 10 eating occasions. Since the serving of this yogurt based on the proposed method is 170 g, and this amount of yogurt contains 243.1 mg of calcium, this yogurt is defined as calcium source food based on the proposed method.

Since calculating the calcium content and determining appropriate calcium levels based on the CAC per 100 g or 100 mL are performed without considering the energy content of foods, making some food choices based on the CAC per 100 g or 100 mL to achieve adequate calcium exceeded energy needs. For example, if dried Brazil nuts (NDB number 12078) contain 659 kcal of energy per 100 g, RACC of 30 g, and 160 mg of calcium per 100 g, are they defined as high-calcium or calcium source foods based on the proposed method and CAC per 100 g? Since these Brazil nuts contain 160 mg of calcium per 100 g, they are defined as calcium source foods based on the CAC per 100 g. Consuming 625 g of the Brazil nuts meets the NRV for calcium but results in receiving 4119 kcal of energy, which is 2119 kcal more than the DV or DRV for energy. Since the serving of these

Brazil nuts based on the proposed method is 30 g, and this amount of Brazil nuts contains 48 mg of calcium, these Brazil nuts are not defined as high-calcium or calcium source foods based on the proposed method.

The average (%) of similarities between the proposed method and the CAC per 100 g or 100 mL was 90.88% for high-calcium and calcium source foods in food groups. Calculating the calcium content of some foods in large amounts and some other foods in small amounts and employing strict criteria of the high and source claims for calcium based on the CAC per 100 g or 100 mL increased the averages (%) of foods containing appropriate calcium levels in 15 food groups (spices and herbs; nut and seed products; baked products; snacks; fast foods; cereal grains and pasta; dairy and egg products; breakfast cereals; legumes and legume products; beverages; sausages and luncheon meats; American Indian/Alaska Native foods; finfish and shellfish products; fruits and fruit juices; lamb, veal, and game products) and decreased the averages (%) of foods containing appropriate calcium levels in seven food groups (meals, entrees, and side dishes; restaurant foods; baby foods; vegetables and vegetable products; sweets; poultry products; soups, sauces, and gravies) as compared with the proposed method. For example, the averages (%) of foods containing appropriate calcium levels in spices and herbs, nut and seed products, baked products, and snacks were respectively 71.88%, 20.44%, 21.15%, and 21.97% based on the CAC per 100 g or 100 mL and 0%, 3.65%, 7.21%, and 12.72% based on the proposed method.

The averages (%) of foods containing appropriate calcium levels based on the CAC per 100 g or 100 mL in food groups are shown in Figure S3. High-calcium and calcium source foods based on the CAC per 100 g or 100 mL are given in Tables S8 and S9, respectively.

Foods Containing Appropriate Calcium Levels Based on the CAC per 100 kcal

Since calculating the calcium content and determining appropriate calcium levels based on the CAC per 100 kcal are performed without considering RACCs, making some food choices based on the CAC per 100 kcal to achieve adequate calcium did not meet calcium requirements. Employing a fixed energy amount of 100 kcal may be high for some foods. Thus, calculating the calcium content per 100 kcal of food based on the CAC may show the calcium content of some foods inappropriately high. For example, if pepper sauce (NDB number 6168) contains 11 kcal of energy per 100 g, RACC of 4.7 g, and 8 mg of calcium per 100 g, is it defined as high-calcium or calcium source food based on the proposed method and CAC per 100 kcal? Since this pepper sauce contains 72.7 mg of calcium per 100 kcal, it is defined as calcium source food based on the CAC per 100 kcal. Consuming 12,500 g of the pepper sauce meets the NRV for calcium, but this pepper sauce is customarily consumed 47 g in 10 eating occasions. Since the serving of this pepper sauce based on the proposed method is 4.7 g, and this amount of pepper sauce contains 0.376 mg of calcium, this pepper sauce is not defined as high-calcium or calcium source food based on the proposed method.

The average (%) of similarities between the proposed method and the CAC per 100 kcal was 87.44% for high-calcium and calcium source foods in food groups. Calculating the calcium content of some foods in large amounts based on the CAC per 100 kcal increased the averages (%) of foods containing appropriate calcium levels in all 25 food groups as compared with the proposed method. For example, the averages (%) of foods containing appropriate calcium levels in spices and herbs and vegetables and vegetable products were respectively 76.56% and 60.46% based on the CAC per 100 kcal and 0% and 8.76% based on the proposed method.

The averages (%) of foods containing appropriate calcium levels based on the CAC per 100 kcal in food groups are shown in Figure S4. High-calcium and calcium source foods based on the CAC per 100 kcal are given in Tables S10 and S11, respectively.

Discussion

Some scientific literature, similar to the proposed method, FDA and CAC per serving, CAC per 100 g or 100 mL, and CAC per 100 kcal, defined milk (Pennington et al. 1987; Toba et al. 1999), most yogurts (Fisberg and Machado 2015; Gahruie et al. 2015; Smith et al. 1985), buttermilk (Mudgil et al. 2016), whey (González-Martínez et al. 2002; Zawadzki et al. 2020), calcium-set tofu (Cai et al. 1997; He and Chen 2013; Riciputi et al. 2016; Tseng et al. 1977), and collards (Fischer et al. 2008; Fung et al. 1978; Tordoff and Sandell 2009) as foods containing appropriate calcium levels (to achieve adequate calcium).

Some scientific literature, in contrast to the proposed method, FDA and CAC per serving, CAC per 100 g, and CAC per 100 kcal, defined sweet corn (Oktem et al. 2010), sweet peppers (Faustino et al. 2007; Jadon et al. 2016; Mamedov et al. 2015), and sapodilla (Akesowan et al. 2020; Alrashood et al. 2020) as foods containing appropriate calcium levels. Consuming 65,000 g of raw sweet corn (NDB number 11167; 2 mg of calcium per 100 g; 86 kcal of energy per 100 g), 18,571.4 g of raw sweet peppers (NDB number 11821; 7 mg of calcium per 100 g; 31 kcal of energy per 100 g), or 6190.5 g of raw sapodilla (NDB number 9313; 21 mg of calcium per 100 g; 83 kcal of energy per 100 g) meets the DV for calcium. Also, consuming 50,000 g of the sweet corn, 14,285.7 g of the sweet peppers, or 4761.9 g of the sapodilla meets the NRV for calcium. However, these sweet

peppers, sweet corn, and sapodilla are customarily consumed 850 g, 850 g, and 1400 g in 10 eating occasions, respectively. In addition, consuming 65,000 g of the sweet corn, 18,571.4 g of the sweet peppers, and 6190.5 g of the sapodilla results in receiving 55,900 kcal, 5757.1 kcal, and 5138.1 kcal of energy, respectively. Also, consuming 50,000 g of the sweet corn, 14,285.7 g of the sweet peppers, and 4761.9 g of the sapodilla results in receiving 43,000 kcal, 4428.6 kcal, and 3952.4 kcal of energy, respectively. However, the DV or DRV for energy in adults and children aged 4 years and older is 2000 kcal.

The CAC per serving, in contrast to the proposed method, FDA per serving, CAC per 100 g, CAC per 100 kcal, and some scientific literature (Jalili 2016; Motawee and McMahon 2009), did not define Feta cheese as food containing an appropriate calcium level. Consuming 263.7 g of Feta cheese (NDB number 1019; 493 mg of calcium per 100 g; 264 kcal of energy per 100 g) meets the DV for calcium. Also, consuming 202.8 g of the Feta cheese meets the NRV for calcium, and this Feta cheese is customarily consumed 300 g in 10 eating occasions.

The CAC per 100 kcal, in contrast to the proposed method, FDA and CAC per serving, and CAC per 100 g, defined table salt as food containing an appropriate calcium level. Consuming 5416.7 g of table salt (NDB number 2047; 24 mg of calcium per 100 g; 0 kcal of energy per 100 g) meets the DV for calcium. Also, consuming 4166.7 g of the table salt meets the NRV for calcium. However, this table salt is customarily consumed 15 g in 10 eating occasions.

The CAC per 100 mL, in contrast to the proposed method, FDA and CAC per serving, and CAC per 100 kcal, defined malt syrup as food containing an appropriate calcium level. Consuming 1518.7 mL of malt syrup (NDB number 19352; 85.6 mg of calcium per 100 mL; 446.2 kcal of energy per 100 mL) meets the DV for calcium. Also, consuming 1168.2 mL of the malt syrup meets the NRV for calcium. However, this malt syrup is customarily consumed 300 mL in 10 eating occasions. In addition, consuming 1518.7 mL of the malt syrup results in receiving 6777.1 kcal of energy, which is 4777.1 kcal more than the DV or DRV for energy. Also, consuming 1168.2 mL of the malt syrup results in receiving 5213.1 kcal of energy, which is 3213.1 kcal more than the DV or DRV for energy.

The FDA and CAC per serving, in contrast to the proposed method, CAC per 100 g, and CAC per 100 kcal, defined pineapple upside-down cake as food containing an appropriate calcium level. Consuming 1083.3 g of pineapple upside-down cake (NDB number 18119; 120 mg of calcium per 100 g; 150 mg of calcium per RACC; 319 kcal of energy per 100 g; RACC of 125 g) meets the DV for calcium but results in receiving 3455.8 kcal of energy, which is 1455.8 kcal more than the DV or DRV for energy. Also, consuming 833.3 g of the cake meets the NRV for calcium but results in receiving 2658.3 kcal of energy, which is 658.3 kcal more than the DV or DRV for energy.

The FDA and CAC per serving, in contrast to the proposed method, CAC per 100 g, and CAC per 100 kcal, defined hotcakes and sausage as a food item containing an appropriate calcium level. Consuming 1666.7 g of hotcakes and sausage (NDB number 21364; 78 mg of calcium per 100 g; 152.1 mg of calcium per RACC; 294 kcal of energy per 100 g; RACC of 195 g) meets the DV for calcium but results in receiving 4900 kcal of energy, which is 2900 kcal more than the DV or DRV for energy. Also, consuming 1282.1 g of the hotcakes and sausage meets the NRV for calcium but results in receiving 3769.2 kcal of energy, which is 1769.2 kcal more than the DV or DRV for energy.

Conclusion

It is well-known that excessive energy intake can lead to overweight or obesity. However, calculating the calcium content and determining appropriate calcium levels based on the FDA and CAC per serving and CAC per 100 g or 100 mL are

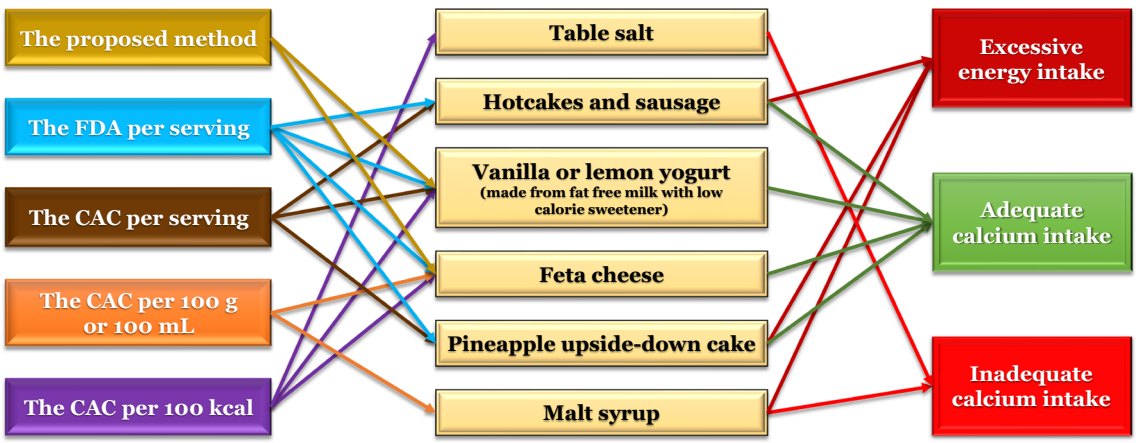

Fig. 2 Results of food choices based on different methods for achieving adequate calcium

performed without considering the energy content of foods. Thus, making some food choices based on the FDA and CAC per serving or CAC per 100 g or 100 mL to achieve adequate calcium exceeded energy needs, which could lead to overweight or obesity.

RACC values represent the amount (edible portion) of food customarily consumed per eating occasion (FDA 2018). However, calculating the calcium content and determining appropriate calcium levels based on the CAC per 100 g or 100 mL and CAC per 100 kcal are performed without considering RACCs. Thus, making some food choices based on the CAC per 100 kcal or CAC per 100 g or 100 mL to achieve adequate calcium did not meet calcium requirements, which could lead to calcium deficiency. Also, according to the CAC per 100 g or 100 mL, since the calcium content of some foods is calculated in small amounts, and the high-calcium and calcium source foods (except liquid foods) are determined by employing the high calcium amounts of the high and source claims for calcium, some foods that met calcium requirements were not appropriate food choices based on the CAC per 100 g or 100 mL to achieve adequate calcium.

According to the CAC per serving, since the calcium source foods are determined by employing the high calcium amounts of the source claim for calcium, some foods that met calcium requirements were not appropriate food choices based on the CAC per serving to achieve adequate calcium.

On the basis of the proposed method, calculating the calcium content and determining appropriate calcium levels in foods are performed by considering RACCs and the energy content of foods. Thus, making food choices based on the proposed method met calcium requirements and did not exceed energy needs. According to the proposed method, RACCs and DVs for calcium and energy are used as a reference for calculating calcium content and determining appropriate calcium levels in foods. Thus, making a food choice based on the proposed method without employing the statistical significance is considered a reliable choice (Fig. 2).

Abbreviations *CAC,* Codex Alimentarius Commission; *FDA,* US Food and Drug Administration; *RACC,* Reference amount customarily consumed; *DV,* Daily value; *NRV,* Nutrient reference value; *DRV,* Daily reference value

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Declarations

Ethical Approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed Consent Not applicable.

Conflict of Interest Abed Forouzesh declares that he has no conflict of interest. Fatemeh Forouzesh declares that she has no conflict of interest. Sadegh Samadi Foroushani declares that he has no conflict of interest. Abolfazl Forouzesh declares that he has no conflict of interest. Eskandar Zand declares that he has no conflict of interest.

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