Relationship between Dietary Calcium Intake, Body Mass Index, and Waist Circumference in MABAT – the Israeli National Health and Nutrition Study

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Abstract

Background: It has been suggested that increased calcium intake plays a role in preventing obesity and promoting weight loss.

Objectives: To assess the association between calcium intake, body mass index and waist circumference in Israel.

Methods: MABAT was a cross-sectional survey based on a random sample of 3246 Israelis aged 25 to 64. Of the 3246 survey participants, height and weight measurements were recorded for 2782 (1371 men and 1411 women). These were divided into three groups according to their BMI (group A ≤ 24.9, group B 25–29.9, and group C ≥ 30) and given a 24 hour dietary recall questionnaire. Waist circumference was measured in 2601 participants (1760 men and 841 women) and was considered to be excessive if ≥ 102 cm for men or ≥ 88 cm for women.

Results: The mean calcium intake was 511.5 ± 301.8 mg for group A, 499.4 ± 283.7 mg for group B, and 464.7 ± 280.1 mg for group C (group A significantly differed from group C, $P < 0.002$). The mean daily milk consumption in group A was higher than in groups B and C (103.4 ± 147.5, 85.7 ± 122.25, and 84.5 ± 135.1 g, respectively; $P < 0.01$). There was no correlation between daily dietary calcium intake and waist circumference for men, but women with a waist circumference below 88 cm consumed significantly more dietary calcium than those with a waist circumference ≥ 88 cm ($P < 0.03$).

Conclusions: The study confirms the inverse relationship between daily dietary calcium intake and obesity. This linkage relates to the intake of milk, but not to other dairy products.

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Recent publications have demonstrated the existence of a regulatory role of dietary calcium intake on adiposity and hypertension [1]. Zemel [2] reported that an increase in dietary daily calcium intake in obese individuals from about 400 to 1000 mg for one year caused a 4.9 kg reduction in body fat. An increase in adipocyte Ca^{2+} content results in stimulation of lipogenesis and inhibition of lipolysis. Therefore, it was assumed that increased dietary calcium suppresses adipocyte intracellular Ca^{2+}, stimulating lipolysis and weight loss. Subsequently, the risk of hypertension decreases and the prevention of cardiovascular diseases is enhanced [3]. The study of Jacqmain and co-authors [4] in 235 men and 235 women supported these observations, showing that low calcium intake was associated with greater adiposity, mainly in women. Papakonstantinou et al. [5] reported similar findings in rats that gained less weight and developed 29% less adipose tissue following consumption of a high calcium diet for 85 days. Furthermore, calcium in dairy products was more effective in attenuation of fat deposition than a comparable quantity of elemental calcium [2]. However, studies on agouti transgenic mice showed that high dietary calcium intake exerts its abolishing effect on fat accumulation mainly in conjunction with energy restriction [2,3]. Contrary to these observations, Macdonald et al. [6] failed to demonstrate any effect of dietary calcium intake on weight in postmenopausal women.

Most reports deal with the effect of dietary calcium on body weight. Since obesity may be more precisely defined by determining body mass index and fat distribution by assessing waist circumference, the goal of the present analysis was to elucidate the relationship of dietary calcium intake with BMI and waist circumference.

Subjects and Methods

The survey was based on the MABAT First National Health and Nutrition Survey ("MABAT" is an acronym in Hebrew) [7]. Participants in MABAT included a random sample from the Israeli population registry. Eligibility required that the participant be 25–64 years old, had lived in Israel for at least one year prior to the interview, and was not living in a long-term care environment or institute. The MABAT survey comprised 3246 participants. Measured height and weight data were complete for 1371 men and 1411 women, yielding a sample of 2782 participants for the current study. The participants were interviewed between 1999 and 2001, in their homes, using a structured questionnaire and the 24 hour dietary recall method. The participants were not hospitalized prior to the interview. The questionnaire included demographic details on the participant and family, and questions regarding health status, alcohol intake, exercise, smoking habits, eating and dieting habits, food allergies, use of food supplements, knowledge and attitude regarding nutrition, and 24 hour dietary recall. A second face-to-face interview on 24 hour dietary recall was conducted for 50% of the sample within 10 days of the first interview to assess intrapersonal variation. The Institutional Review Board of the Israel Ministry of Health approved the survey.

After the interview, the interviewer performed anthropometric measurements. Weight was measured using a portable analog

BMI = body mass index

scale with a dial showing a maximum of 130 kg and an accuracy of 0.5 kg. The scale was placed on a non-carpeted floor and calibrated to zero before weighing. The participant was asked to remove his or her shoes, heavy clothing, and heavy objects. If the two measurements differed by more than 1 kg a third measurement was carried out. Height was measured using a coil-spring tape measure and a fixed angle (wood, plastic or aluminum) to determine the intersection of the top of the head and the wall. Stickers were used to mark and record the height measurements. If the two measurements differed by more than 0.4 cm a third measurement was taken.

Waist and hip circumferences were measured in light clothing. Waist circumference was measured with a flexible nylon tailor's measuring tape with a maximum of 1.5 m. The tape was placed horizontally on the participant at waist level, the narrowest part of the body where the "fold" forms when bending over. If the two measurements differed by more than 0.5 cm a third measurement was taken. Hip circumference was measured with a flexible nylon tailor's measuring tape with a maximum of 1.5 m. The tape was placed horizontally on the participant at the widest part of the hips. If the two measurements differed by more than 0.5 cm a third measurement was taken. All measurement methods were validated before implementation.

Dietary intakes were entered into a specially adapted DOS-based program for dietary analysis that incorporates the revised and expanded Israel Food and Nutrient Database (BINAT). After completing 24 hour food recall data input, reports summarizing food intakes were produced in an Excel format. A full description of the methods and results appears in two volumes of the MABAT Survey – First Israeli National Health and Nutrition Survey [7,8].

The 2782 participants were divided into three groups according to their BMI: group A – individuals with a BMI ≤ 24.9 (470 men and 581 women), group B – a BMI of 25–29.9 (628 men and 466 women), and group C – a BMI of ≥ 30 (273 men and 364 women). Waist circumference was measured in 2601 participants (1760 men and 841 women) and considered pathological when ≥ 102 cm for men and ≥ 88 cm for women.

Statistical analysis

Data were analyzed using the statistical program SPSS (Statistical Package for Social Sciences, SPSS Inc.) version 10. Pearson correlation coefficients were used to assess the relationships of BMI and waist circumference to calcium intake and demographic characteristics. Student's *t*-test was carried out on intake of dairy products. Results are expressed as means ± SD (standard deviation) unless otherwise indicated.

Results

Table 1 shows the mean height, weight, BMI, dietary calcium intake, and waist circumference of the study participants. The mean BMI was 26.8 for men and 27.1 for women. Mean daily calcium intake was 524.2 mg for men and 468.4 mg for women. There was a statistically significant difference ($P < 0.001$) between the genders with 25.8% of the women and 19.9% of the men having a BMI of 30 or over. There was an inverse relationship between the mean daily calcium intake and BMI [Table 2]. Group A had a mean intake of 511.5 mg/day, compared to 464.71 mg/day for group C, the difference being statistically significant ($P < 0.002$). Group A consumed more milk on a daily basis than group C: 103.43 vs. 84.46 g/day respectively ($P < 0.01$). There was no statistically significant difference between the groups in amount of other dairy products consumed. A comparison between calcium and milk intake/kg of body weight is given in Table 2. This intake was statistically different in men and women from groups A and C ($P < 0.0001$). There was no difference in vegetable intake between participants in the three groups or for fruit intake between participants in groups A and C.

Calcium intake for women was significantly related to waist circumference [Table 3]. Those with a waist circumference of ≥ 88 cm had an intake of 449.9 mg/day, compared to 482.47 mg/day among those with a waist circumference of < 88 cm ($P < 0.03$). The results of an odds ratio examination showed that individuals in the upper quartile of calcium intake had a 34% less chance of being in group C than individuals in the lowest quartile ($P < 0.05$).

Discussion

The findings of the study show a tendency to overweight and even obesity among both genders in a relatively large population of healthy randomly chosen Israelis. When the participants were divided into three groups according to their BMI, group B had the largest number with 46% men and 33% women while group C comprised 20% men and 26% women.

The dietary intake of calcium was significantly higher in men than in women. There was an inverse relationship between daily dietary calcium intake and BMI among both men and women.

Table 1. Characteristics of the study population – First Israeli National Health and Nutrition Survey (MABAT), 1999–2001

	Total (n = 2782)		Men (n = 1371)		Women (n = 1411)		
A) Variable	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	**Mean ± SD**	**Range**	***P****
Age (yrs)	43.1 ± 11.0	25–64	43.2 ± 11.1	25–64	43.0 ± 10.9	25–64	0.652
Height (m)	166.8 ± 9.6	136.5–196	173.7 ± 7.2	146.6–196	160.2 ± 6.5	136.5–185	< 0.001
Weight (kg)	75.0 ± 14.9	37–126	80.8 ± 13.2	47.0–126.0	69.3 ± 14.2	37.0–124.0	< 0.001
BMI	26.9 ± 4.8	16.4–47.9	26.8 ± 3.9	17.0–43.1	27.1 ± 5.5	16.4–47.9	0.089
Dietary Ca^{2+} intake (mg)	495.9 ± 290	26.4–2456.3	524.2 ± 304.7	33.1–2456.3	468.4 ± 272.3	26.4–2158.4	< 0.0001
Waist circumference (cm)	90.9 ± 13.1	60–140	95.9 ± 11	60–140	86.1 ± 13	61–140	< 0.0001
	Total		**Men**		**Women**		
B) BMI by gender	**n**	**%**	**n**	**%**	**n**	**%**	***P****
Group A BMI ≤ 24.9	1051	37.8	470	34.3	581	41.2	< 0.001
Group B BMI 25–29.9	1094	39.3	628	45.8	466	33.0	< 0.001
Group C BMI ≥ 30	637	22.9	273	19.9	364	25.8	< 0.001
Total	2782	100	1371	100	1411	100	

* Significance between genders.

Table 2. Daily calcium intake, consumption of milk, and consumption of other dairy products, fruit and vegetable , according to BMI group

	Group A			Group B			Group C		
	Total	Men	Women	Total	Men	Women	Total	Men	Women
Mean calcium intake (mg ± SD)	511.5 ± 301.8*	549.78 ± 318.3†	479.9 ± 282.8*	499.35 ± 283.73	517.34 ± 293.3	475.1 ± 268.6	464.71 ± 280.13*	495.76 ± 304.22†	441.42 ± 258.6*
Calcium intake (range, mg)	38.05–2358	49.9–2358	38–2158	33.1–2279	33.1–2250	54.6–1722.1	26.4–2456	75.6–2456.3	26.4–2034
Calcium intake (mg/kg body weight)	8.2 ± 4.8#	8.0 ± 4.6#	8.4 ± 5.0#	6.6 ± 3.7	6.3 ± 3.6	6.9 ± 3.9	5.1 ± 3.1#	5.1 ± 3.1#	5.1 ± 3.1#
Mean milk intake (g ± SD)	103.43 ± 147.47‡§	96.05 ± 153.64**	109.41 ± 142.15**	85.7 ± 122.25§	80.92 ± 128.2	92.13 ± 113.53**	84.46 ± 135.14‡	74.31 ± 134.27**	92.07 ± 135.47**
Mean milk intake/kg body weight (g ± SD)	1.7 ± 2.4	1.4 ± 2.3	1.9 ± 2.5	1.1 ± 1.6	1.0 ± 1.6	1.3 ± 1.6	0.9 ± 1.5	0.8 ± 1.4	1.1 ± 1.6
Milk intake (range, g)	0–1260	0–1260	0–1000	0–750	0–750	0–700	0–1000	0–1000	0-900
Mean intake of other dairy products (g ± SD)	86.07 ± 114.09	85.31 ± 115.34	86.69 ± 113.17	94.7 ± 182.64	91.55 ± 127.92	98.94 ± 123.13	92.1 ± 125.24	89.82 ± 132.68	93.82 ± 119.51
Other dairy intake (range, g)	0–1041	0–750	0–1041	0–1340	0–1340	0–800	0–795	0–795	0–529
Mean total dairy intake (g ± SD)	189.51 ± 186.49	181.36 ± 194.99	196.1 ± 179.22	180.4 ± 182.64	172.48 ± 188.44	191.07 ± 174.15	176.57 ± 192.12	164.13 ± 207.9	185.89 ± 179.1
Mean total dairy intake//kg body weight (g ± SD)	3.1 ± 3.0	2.6 ± 2.9	3.4 ± 3.1	2.4 ± 2.4	2.1 ± 2.3	2.8 ± 2.5	2.0 ± 2.1	1.7 ± 2.1	2.2 ± 2.1
Total dairy intake (range, g)	0–1320.0	0–1320	0–1041	0–1940	0–1940	0–980	0–1530	0–1530	0–1050
	Group A			**Group B**			**Group C**		
	Total	**Men**	**Women**	**Total**	**Men**	**Women**	**Total**	**Men**	**Women**
Mean fruit intake (g ± SD)	209.7 ± 254.4@	209.8 ± 272.9	479.9 ± 282.8	234.7 ± 274.0@	233.0 ± 299.3	475.1 ± 268.6	216.0 ± 268.8	232.2. ± 298.9	441.42 ± 258.6
Mean vegetable intake (g ± SD)	241.1 ± 225.6	259.7 ± 254.2	226.1 ± 198.5	255.4 ± 274.0	264.0 ± 224.2	243.7 ± 216.5	243.1 ± 190.5	264.3 ± 195.7	227.1 ± 185.3

Statistical significance:
* $P < 0.002$ for calcium intake between groups A and C
† $P < 0.02$ for calcium intake between men of groups A and C
‡ $P < 0.01$ for milk intake between groups A and C
§ $P < 0.003$ for milk intake between groups A and B
# $P < 0.0001$ for calcium intake/kg body weight intake between groups A and C
** $P < 0.05$ for milk intake between men of groups A and C and women of groups A, B, and C
@ $P < 0.003$ for mean fruit intake between groups A and B

Recent studies show that intracellular Ca^{2+} plays an important role in the modulation of fat accumulation and obesity by stimulating fatty acid synthetase, which plays a major role in regulating lipid storage in the adipocyte. This process is linked to the function of the agouti protein in agouti yellow obese mice [9]. Dietary calcium, through its negative role on intracellular Ca^{2+}, affects fat accumulation and weight gain. According to Zemel [10], the lipolytic effect of dietary calcium, with a subsequent loss in body weight, may be explained by the ability of dietary calcium to attenuate intracellular Ca^{2+}. Consequently, since intracellular Ca^{2+} stimulates lipogenic gene expression, suppression of intracellular Ca^{2+} results in increased lipolysis and a decrease in adipocyte filling and body fat. Although this mechanism is active even in cases of no caloric restriction, it is conceivable that a combination of increased dietary calcium intake and caloric restriction will result in the acceleration of body weight loss. On the other hand, it has been reported that increased calcitrol production due to a low calcium diet stimulates Ca^{2+} influx, followed by adipocyte lipogenesis and weight gain [10-12]. Recently Jacobsen and team [13] observed that a short-term increase in dietary calcium intake increases fecal fat and energy excretion. This observation may further explain the beneficial effect of dietary calcium on adiposity. Supplemental calcium is less active in attenuating adiposity than calcium in dairy products [2,3,6,14]. Moreover, there was no evidence of weight differences in people with hypercalcemia due to primary hyperparathyroidism before and after surgery [15].

A substantial number of studies have demonstrated the beneficial effect of dairy products on weight regulation [14]. Indeed, in our study, individuals from group A (with the lowest BMI) consumed the largest amount of milk and had the highest daily calcium intake. Papakonstantinou et al. [5] reported that rats fed a high calcium diet with half the protein provided by non-fat dry milk gained less weight than rats fed a standard diet. Zemel et al. [16] obtained a double rate of fat loss in mice by adding small amounts of milk, which induced a minimal increase of dietary calcium from 1.2% to 1.3%. Interestingly, individuals from group A

Table 3. Mean calcium intake by waist circumference

	Total		Men		Women	
	Below pathological waist measurement	Above pathological waist measurement	< 102 cm	≥ 102 cm	< 88 cm	≥ 88 cm
Number	1760	841	949	327	811	514
Mean calcium intake (mg ± SD)	508.5 ± 294.11	473.8 ± 282.83	530.7 ± 297.46	511.32 ± 327.6	482.47 ± 288.15*	449.95 ± 247.63*

* Statistically significant at $P < 0.03$

in the present study consumed the highest percentage of milk from their daily quantity of dairy products (54%), suggesting that milk consumption is more effective for maintaining a low BMI. This observation is in accordance with the results of the CARDIA study [17] and those of Barba at al. [18] demonstrating a negative association between milk consumption with both insulin resistance and obesity. If, indeed, consumption of milk modulates the BMI and tendency towards obesity, the question arises whether it is the calcium or other substances in milk that is involved in weight loss.

According to Zemel and collaborators [16], although dietary calcium plays an important role in regulation of obesity, additional milk compounds accelerate lipolysis. In this sense, one factor present in milk is an angiotensin-converting enzyme inhibitor that possesses a mild attenuating effect on obesity in rodents [19]. These and other possible factors in milk, such as branched-chain amino acids reviewed by Zemel and Miller [11], suggest that the lower BMI of group A cannot be attributed solely to the relatively small amounts of calcium in Israeli milk.

Since abdominal obesity is a better predictor of coronary heart disease, hypertension and stroke than the level of obesity itself [20,21], we examined whether there was a correlation between daily dietary calcium intake and waist circumference. Among our subjects 26% of the men and 40% of the women had a waist circumference larger than that commonly accepted as a cutoff point, i.e., 102 cm for men and 88 cm for women, similar to the percentage observed in western countries [21]. As for the men, there was no correlation between daily dietary calcium intake and waist circumference. On the other hand, women who consumed more calcium-containing products had a smaller waist circumference, significantly different from those with a larger waist circumference and lower calcium intake. This observation is in accordance with findings in other studies reported in the literature. Lin et al. [22] have shown that calcium intake in young women participating in an exercise intervention program was inversely related to changes in weight and body fat regardless of the body workout.

In short, our study participants had a marked tendency towards obesity as defined by BMI or waist circumference. There was a significant inverse correlation between daily dietary calcium intake and BMI for both men and women, but a significant correlation between dietary calcium and waist circumference was found only in women. Milk consumption correlated with BMI better than other dairy products, supporting the assumption that a combination of calcium content and other factors present in milk increases its anti-obesity effect. The results indicate that there is a correlation between increased milk consumption and lower BMI, and this is not correlated with adoption of a healthier diet.

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