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Association between Milk and Milk Product Consumption and Anthropometric Measures in Adult Men and Women in India: A Cross-Sectional Study

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Abstract

Background: The nutritional aetiology of obesity remains unclear, especially with regard to the role of dairy products in developing countries.

Objective: To examine whether milk/milk product consumption is associated with obesity and high waist circumference among adult Indians.

Methods: Information on plain milk, tea, curd and buttermilk/lassi consumption assessed using a Food Frequency Questionnaire was obtained from the cross-sectional sib-pair designed Indian Migration Study (3698 men and 2659 women), conducted at four factory locations across north, central and south India. The anthropometric measures included Body Mass Index (BMI) and Waist Circumference (WC). Mixed-effect logistic regression models were conducted to accommodate sib-pair design and adjust for potential confounders.

Results: After controlling for potential confounders, the risk of being obese (BMI ≥ 25 kg/m²) was lower among women (OR = 0.57; 95% CI: 0.43–0.76; p = 0.0001) and men (OR = 0.67; 95% CI: 0.51–0.87; p = 0.005), and the risk of a high WC (men: > 90 cm; women: > 80 cm) was lower among men (OR = 0.71; 95% CI: 0.54–0.93; p = 0.005) and women (OR = 0.79; 95% CI: 0.59–1.05; p = 0.05) who consume ≥1 portions of plain milk daily than those who do not consume any milk. The inverse association between daily plain milk consumption and obesity was also confirmed in sibling-pair analyses. Daily tea consumption of ≥1 portion was associated with obesity (OR = 1.51; 95% CI: 1.00–2.25; p > 0.050) and high WC (OR = 1.65; 95% CI: 1.08–2.51; p > 0.019) among men but not among women.

Conclusions: The independent, inverse association of daily plain milk consumption with the risk of being obese suggests that high plain milk intake may lower the risk of obesity in adult Indians. However, this is an observational finding and uncontrolled confounding cannot be excluded as an explanation for the association. Therefore, confirmatory studies are needed to clarify this relationship.

Introduction

India is in a state of transition with marked social, demographic and epidemiological changes underway [1]. This transition is characterised by increased longevity, an increasingly urbanised population, projected to rise from 28% in 2001 to 50% by 2025 [2] and a rising burden of chronic diseases [3]. In 2005 around 55% of India’s mortality was attributed to chronic diseases [4], a figure that is estimated to reach approximately 68% (8 million deaths) by 2020 [3,4]. This increase has been mirrored by a similar trend – that of escalating levels of obesity [5]. The prevalence of excess body weight has reached epidemic proportions, with more than 1·6 billion adults being overweight (BMI ≥ 25 kg/m²) worldwide of which 400 million are clinically obese (BMI ≥ 30 kg/m²) [6]. WHO projections suggest that by 2015, approximately 2·3 billion adults will be overweight and more than 700 million obese. Evidence shows that obesity is a risk factor for several chronic diseases and in itself is indicative of changes in activity and dietary patterns of population groups [7].
The change in food intake in Indian populations is characterized by an increase in the consumption of animal protein including dairy products [8,9]. Published global evidence mostly based on developed or high income countries' experience on dairy consumption and body weight is extensive but equivocal. Many studies have found a negative association between milk/dairy consumption and body mass index [10–16] and central adiposity [17]. However, some studies have found no association [18–20], while others have found a positive association [21,22]. Many studies have also distinguished between low and high fat dairy products, with only the former being associated with a more favourable risk profile [23].

Per capita consumption of dairy products is generally higher in high income countries (HICs) relative to low and middle income countries (LMICs) [24], with average dairy consumption levels of 245 kg/capita/year in HICs compared with only 66.2 kg/capita/year in LMICs [25].

Milk has a long history of usage in India [26]. Cows are worshipped by Hindus and milk from both cows and water buffaloes has long been valued as a food [26]. Promotions also emphasize milk’s links to growth, gaining in height and strength [27]. Dairy supply is increasing in India, with a report of annual per capita dairy supply increased from 39 kg to 70 kg during 1980–2003 [28], and according to Food and Agricultural Organisation [25], daily per capita supply of milk increased from 69 kcal in 1980 to 103 kcal in 2007. The National Sample Survey Organisation (NSSO) of India 2004–5 survey found that the proportion of energy from milk products and oils and fats were higher in urban than rural people [29]. The Indian Consumer Expenditure Survey of 2009–2010 found per capita monthly expenditure on milk and milk products was Rs. 81 (US$ 1.5) in rural India and Rs. 137 (US$ 2.55) in urban India [30]. However, despite increases, consumption levels remain low (and far below recommended as well as observed western levels), and some increase in animal products could be beneficial in increasing the amount of protein in the Indian diet [31].

In light of the increasing milk/milk product consumption in India and increasing levels of obesity [32], understanding the role that dairy consumption may be playing in fueling the risk in obesity is important. The objective of this analysis was therefore to assess whether the consumption of milk/milk products was associated with markers of obesity – body mass index (BMI), and waist circumference (WC) among men and women in India.

Methods

Study Design

Data from the Indian Migration Study (IMS) was used for this study. The design and sampling methodology of the IMS has been described previously [33–35]. Briefly, the IMS is a cross-sectional sub-pair study, part of a larger cardiovascular risk factor surveillance system [36] in industrial populations all over India. The IMS was carried out in factory settings in four cities from northern, central and southern India (Lucknow, Hindustan Aeronautics Ltd; Nagpur, Indorama Synthetics Ltd; Hyderabad, Bharat Heavy Electricals Ltd; and Bangalore, Hindustan Machine Tools Ltd). Information on rural-to-urban migration was solicited by an increase in the consumption of animal protein including dairy products [8,9]. Published global evidence mostly based on developed or high income countries’ experience on dairy consumption and body weight is extensive but equivocal. Many studies have found a negative association between milk/dairy consumption and body mass index [10–16] and central adiposity [17]. However, some studies have found no association [18–20], while others have found a positive association [21,22]. Many studies have also distinguished between low and high fat dairy products, with only the former being associated with a more favourable risk profile [23].

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Anthropometric Measurement

A digital weighing machine with ±100 gm accuracy (Model PS16, Beurer, Germany) was used to weigh the participants, while they were wearing light indoor clothing. For measuring height, the Frankfort plane was used with a portable plastic Stadiometer with a base plate, with 1 mm accuracy (Leicester height measure, Chasmors, London). Two measures of WC were taken at the narrowest part of the abdomen between the ribs and the iliac crest, as seen from the anterior aspect, on bare skin, with a non-stretch metallic tape with a blanket lead-in (Chasmors, London). Obesity was defined as BMI≥ 25 kg/m² following the recommendations of recent Indian consensus groups [37,38]. A high WC was defined as ≥90 cm in men and ≥80 cm in women following recommendations specific for Indian populations [38,39].

Dietary Assessment

Diet was assessed using an interviewer-administered semi-quantitative food frequency questionnaire (FFQ), details of which have been given in a previous publication [40,41]. Briefly, the questionnaire assessed portion size and frequency of intake of 184 commonly consumed food items, asking about consumption over the last year. A standard portion size was assigned to each food (e.g., teaspoon = 5 ml, tablespoon = 10 ml, ladel = 56 ml, standard glass = 125 ml, medium glass = 143 ml, and bowl = 220 ml), and participants were shown examples of these vessels and asked to report portions consumed as multiples of this. Frequency was recorded as daily, weekly, monthly, yearly/never. A single FFQ was used to cover the four regions of the study.

Out of the 184 food items, the consumption of plain milk (refers to plain milk with or without sugar but not any other additions), consumption of tea, curd (refers to fermented milk) and buttermilk/lassi (refers to diluted beaten curds with or without seasonings) were used for the present study as the principal predictor variables. All these milk products exclude those added to beverages and preparations. Consumption of these four items was assessed in terms of numbers of portions consumed per day in grams (g). Amount in one portion: 120 g for plain milk measured in a glass; 124 g for tea measured in a glass; 143 g for buttermilk/lassi measured in a glass; 195 g for curd measured in a bowl.

In order to assess the reliability of the IMS-FFQ sub-samples were asked to complete the questionnaire 1–2 months (n = 185), as well as 12 months (n = 305) after completion of the questionnaire during the original period of data collection. These two subsamples were randomly selected and were independent of each other. Cohen’s k-statistic was used to compare participants’ tertile grouping across any two FFQ administrations in addition to intra class correlation coefficients calculation. Kappa coefficients for energy intake and dairy products were 0.45 and 0.46 respectively indicating moderate agreement and are similar to values obtained in other reliability studies [42–45]. Another 530 participants (53.9% male) were administered a reference method of three 24-hour recalls, which was used to validate the FFQ. Energy intake
was over-estimated by FFQ compared with 24 hour recalls by 409 kcals (19%) with a Spearman correlation coefficient of 0.61. Dairy products were also over-estimated by 36 g (18%) with a Spearman correlation coefficient of 0.65. These results are comparable with other Indian FFQ-24 h recall validations, most of which have shown an overestimation of consumption using FFQ relative to recalls and diaries [44,45].

Socio-economic, Demographic and Lifestyle Variables

Participants were asked to complete an interviewer-administered questionnaire to gather information on socio-demographic and demographic indicators, including age, socio-economic status, education, occupation, religion, caste/tribe and migration status. The Standard of Living Index (SLI) was calculated by applying standard weights to subsets of questions from a household level asset-based scale devised for Indian surveys, and rescaling them to the full score [34]. The score was then categorised into tertiles to produce low, medium and high socio-economic position (SEP) groups. Measurement at the household level is appropriate in the Indian context, in which the individual’s SEP has less impact on their material wealth. This asset-based score was considered a more appropriate indicator of SEP for these analyses than education, income, or occupation alone, because it is more likely to reflect the changes that migrants experience following their move to urban areas. In the context of developing countries, low SLI is associated with tobacco use [46] and with mortality [47], indicating its validity as a socioeconomic marker.

The questionnaire was also used to ask participants about lifestyle variables, such as current tobacco use in any form (smoked or chewed on a daily basis in the previous six months), and regular consumption of alcohol (on ≥10 days a month in the previous six months). Physical activity was assessed using a quantitative physical activity questionnaire (IMS-PAQ) developed for use in the IMS, adapted and validated for use in Indian populations [48,49]. This provided information on a participant’s habitual daily activity over the last one month in terms of MET (Metabolic Equivalent of Task) hours/day.

Quality Assurance of Measurements

All instruments and protocols were piloted before the start of the study. Fieldworkers at the four study sites were trained together and methods were standardised at the outset, and subsequently every six months. The anthropometric equipment was calibrated at the start of every clinic.

Statistical Analysis

Descriptive analysis was done using chi square tests. The association of milk and milk product consumption with anthropometric indicators was assessed using mixed-effect logistic regression models. Potential confounders controlled for included age, socio-economic status, education, migration, tobacco use, alcohol consumption, energy intake and physical activity.

Analyses were carried out separately in men and women, as we anticipated that there may be gender differences in the effect of milk and milk product intake, and also because of the statistical dependency between husbands and wives produced by the study design. Robust standard errors were used to account for clustering in sibling pairs.

In addition to these standard descriptive analyses we also carried out mixed effects logistic regression analyses proposed for twin studies [50], making use of the sibling-pair design of this study to investigate the extent to which associations may reflect factors shared by the siblings (early home environment and inheritance) as opposed to factors that were different (current environment) [46]. Mixed effects logistic regression models, using population-averaged approach, were fitted for the two primary binary outcomes of BMI and WC incrementally adjusting for confounders analogous to the standard analyses above. We also fitted mixed effects logistic regression models to estimate the association of plain milk, tea, curd, and buttermilk/lassi consumption with BMI, and WC separately for within-sibling-pairs and between-sibling-pairs. All analyses were conducted using STATA version 10 (StataCorp, College Station, TX, USA).

Ethics Approval

Information sheets (translated into local languages) were provided to the participants and informed consent was obtained through their signatures (or a thumb print if the individual was illiterate). Ethics committee approval was obtained from the All India Institute of Medical Sciences Ethics Committee, reference number A-60/4/8/2004, and the procedures followed were in accordance with the ethical standards of the Committee.

Results

The total IMS sample consisted of 2944 women and 4123 men. For the present study, individuals with known diabetes (n = 486), heart disease (n = 78), stroke (n = 25), and peptic ulcer (n = 121) were excluded as it is possible that diagnosis with these diseases may change the dietary habits of the participants. Thus, the final analysis is based on 3,698 men and 2,659 women aged 18 years and above.

The mean body mass index was 23.0 kg/m² and 24.4 kg/m² for men and women respectively; 30.4% men and 42.9% women were obese. The mean waist circumference was 84.1 (±11.6SD) and 78.1 (±10.8SD) for men and women respectively; 32.8% men and 42.5% women had WC above the threshold for obesity.

Sample Characteristics

Table 1 shows the distribution of the sample by selected characteristics. Almost half of the participants never consumed plain milk, whereas almost a third consumed <1 portion and almost a quarter consumed ≥1 portion daily. While a majority (>80%) of our sample population drinks ≥1 portion of tea daily, a quarter of the participants never consumed buttermilk/lassi, 61% consumed <1 portion and 14% consumed ≥1 portion daily. The distribution of curd consumption was similar to that of buttermilk consumption. More than three-fourth of the study participants belonged to the age group 25–54 years. While more than 80% of the participants lived in households with a high standard of living, less than one-tenth lived in households with a low standard of living. Participants were equally distributed across the rural, migrant and urban categories, as well as across the four cities. Between 74–80% of the participants had never consumed tobacco and/or alcohol. Men tended to consume more calories, and be more active than women.

Milk/milk Product Consumption in the Population according to Selected Characteristics

Table 2 shows the daily plain milk, tea, curd and buttermilk/lassi consumption pattern in the sample population according to selected characteristics. More than half the population with age >55 years, 54% of the women population, more than two third of the illiterate population, population belonging to low standard of living households never drink milk. Drinking ≥1 portion of milk daily was more common in the age group below 25 years, among men, among those with graduate and professional degrees and in the high standard of living households, among those who were
Table 1. Sample distribution according to milk/milk product consumption and other selected characteristics, Indian Migration Study, 2006.

| Characteristics                                      | Men     | Women    | Total   |
|-------------------------------------------------------|---------|----------|---------|
|                                                       | N (%)   | N (%)    | N (%)   |
| Daily plain milk consumption<sup>a</sup>              |         |          |         |
| Never                                                 | 1645 (44.5) | 1439 (54.1) | 3084 (48.5) |
| < 1 portion                                           | 1095 (29.6) | 688 (25.9) | 1783 (28.1) |
| ≥ 1 portion                                           | 958 (25.9) | 532 (20.0) | 1490 (23.4) |
| Daily tea consumption<sup>a</sup>                     |         |          |         |
| Never                                                 | 254 (6.9) | 313 (11.8) | 567 (8.9) |
| < 1 portion                                           | 310 (8.4) | 262 (9.9) | 572 (9.0) |
| ≥ 1 portion                                           | 3134 (84.8) | 2084 (78.4) | 5218 (82.1) |
| Daily curd consumption<sup>a</sup>                    |         |          |         |
| Never                                                 | 778 (21.0) | 641 (24.1) | 1419 (22.3) |
| < 1 portion                                           | 2259 (61.1) | 1642 (62.8) | 3901 (61.4) |
| ≥ 1 portion                                           | 661 (17.9) | 376 (14.1) | 1037 (16.3) |
| Daily buttermilk/lassi consumption<sup>a</sup>       |         |          |         |
| Never                                                 | 835 (22.6) | 747 (28.1) | 1582 (24.9) |
| < 1 portion                                           | 2356 (63.7) | 1501 (56.5) | 3857 (60.7) |
| ≥ 1 portion                                           | 507 (13.7) | 411 (15.5) | 918 (14.4) |
| Age (years)                                           |         |          |         |
| 18–25                                                 | 228 (6.2) | 220 (8.3) | 448 (7.1) |
| 25–34                                                 | 981 (26.5) | 622 (23.4) | 1603 (25.2) |
| 35–44                                                 | 1033 (27.9) | 957 (36.0) | 1990 (31.3) |
| 45–54                                                 | 1089 (29.5) | 705 (26.5) | 1794 (28.2) |
| ≥55                                                   | 367 (9.9) | 155 (5.8) | 522 (8.2) |
| Mean age (±SD)                                        | 40.6 (±10.6) | 39.1 (±9.9) | 40.1 (±10.3) |
| Education                                             |         |          |         |
| Illiterate                                            | 169 (4.6) | 394 (14.8) | 563 (8.9) |
| Literate, but no formal education                     | 57 (1.5) | 80 (3.0) | 137 (2.2) |
| Primary school complete                               | 352 (9.5) | 477 (17.9) | 829 (13.0) |
| Secondary and higher secondary complete               | 2017(54.5) | 1074 (40.4) | 3091 (48.6) |
| Graduate                                              | 788 (21.3) | 420 (15.8) | 1208 (19.0) |
| Professional degrees                                  | 315 (8.5) | 214 (8.1) | 529(8.3) |
| Standard of living index<sup>b</sup>                  |         |          |         |
| Low                                                   | 263 (7.1) | 162 (6.1) | 425 (6.7) |
| Medium                                                | 529 (14.3) | 273 (10.3) | 802 (12.6) |
| High                                                  | 2906 (78.6) | 2224 (83.6) | 5130 (80.7) |
| Migration status                                      |         |          |         |
| Rural                                                 | 1374 (40.5) | 596 (24.3) | 1970 (33.7) |
| Migrant                                               | 962 (28.3) | 867 (35.3) | 1829 (31.3) |
| Urban                                                 | 1059 (31.2) | 991 (40.4) | 2050 (35.1) |
| Tobacco consumption                                   |         |          |         |
| Never                                                 | 2177 (58.9) | 2563 (96.4) | 4740 (74.6) |
| Past                                                  | 156 (4.2) | 30 (1.1) | 186 (2.9) |
| Current                                               | 1365 (36.9) | 66 (2.5) | 1431 22.5) |
| Alcohol consumption                                   |         |          |         |
| Never                                                 | 2647 (71.6) | 2528 (95.1) | 5175(81.4) |
| Past                                                  | 149 (4.0) | 41 (1.5) | 190 (3.0) |
| Current                                               | 902 (24.4) | 90 (3.4) | 992 (15.6) |
more physically active and among those whose energy intake was high. One in eleven participants never drank tea while four out of five drink ≥1 portion tea daily. Drinking ≥1 portion of tea daily was more common in age 35–44 years, among men, among those with a secondary and higher secondary complete education, who belonged to high standard of living households, and those who never consumed tobacco or alcohol. More than one out of five sample population never consumed curd, while 16% consumed 1 portion daily. Drinking ≥1 portion of curd daily was more common in age 45–54 years, in men, among those with a secondary and higher secondary complete education, who belonged to high standard of living households, and among those who never consumed tobacco or alcohol. More than one out of five sample population never consumed curd, while 16% consumed ≥1 portion daily. Drinking ≥1 portion of curd daily was more common in age 45–54 years, in men, among those with a secondary and higher secondary complete education, who belonged to high standard of living households, and among those who never consumed tobacco or alcohol. One out of five participants never drink buttermilk/lassi while only 14% drink ≥1 portion daily. Other characteristics of the daily buttermilk/lassi drinkers were almost similar to the daily curd consumers.

Association of milk/milk Product Consumption and Socio-demographic and Lifestyle Variables with Anthropometric Indicators

Table 3 shows percentage prevalence of anthropometric indicators in the categories of milk and milk product consumption and as well as in the other socio-demographic and lifestyle variable categories. Daily consumption of plain milk was associated with lower prevalence of obesity among men (p<0.0001), as well as with lower WC among women (p = 0.005). The opposite trend was observed for tea, curd and buttermilk/lassi consumption, with increased consumption being associated with a higher prevalence of obesity and WC (p<0.0001) in both the sexes. Anthropometric measures also tend to increase with age, education and standard of living index (p<0.0001). Substantial differences across place of residence as well as between the rural, migrant and urban groups were also observed for both men and women (p<0.0001). Anthropometric indicators also tended to decrease with tobacco consumption, increase with alcohol consumption and was highest in the middle two quartiles of energy intake among men (p<0.0001), and decrease with increasing quartiles of physical activity among both men and women (p = <0.0001).

Association of Milk/milk Product Consumption and Anthropometric Indicators

Tables 4 show the effects of daily plain milk, tea, curd, and buttermilk/lassi consumption on BMI, and WC among men and women in four different models. The unadjusted odds (Model 1) of having a high BMI (≥25 kg/m²) were lower among men and women who consumed ≥1 portion of plain milk daily (men: OR = 0.66;95%CI,0.53–0.82;p<0.0001; women: OR = 0.63;95%CI,0.48–0.83; p = 0.001) than those who never consumed plain milk. Controlling for socioeconomic and demographic factors in Model 2, behavioural factors such as tobacco consumption, alcohol consumption, physical activity (MET hours/day) and energy intake (kcal) in Model 3 and all potential confounders together in Model 4 did not attenuate the strong inverse association between daily consumption of ≥1 portion of plain milk and the risk of having a high BMI.

A similar pattern of associations between WC and plain milk consumption was found for men and women although the relationship was less strong and the evidence of association was weak after adjustment for confounding factors, particularly among women.

Tea consumption of ≥1 portion/ day was associated with obesity (OR = 1.51;95%CI,1.00–2.25;p>0.050) and high WC (OR = 1.65;95%CI,1.08–2.51;p>0.019) among men but non-significant positive association (obesity OR = 1.25;95%CI,0.90–1.74; WC: OR = 1.22,95%CI,0.87–1.70) was observed in case of women in the fully adjusted model. A strong evidence of association was constantly observed between ≥1 portion/ daily tea consumption and high WC all through the unadjusted and the adjusted models in men (Table 4).

Daily curd consumption did not have an effect on the risk for an adverse anthropometric profile among men or women in either unadjusted or adjusted models. Buttermilk/lassi consumption did seem to have an effect in men though statistically not significant,
but the association is in the opposite direction to that of plain milk consumption in case of women. Unadjusted analysis in Model 1 shows daily consumption of ≥1 portion of buttermilk/lassi to increase the risk for an adverse anthropometric profile by almost two times among men (BMI [OR = 1.89; 95%CI, 1.40–2.55; p < 0.0001]; WC [OR = 1.90; 95%CI, 1.32–2.72; p = 0.001]) and these effects remain almost unchanged when behavioural factors are additionally controlled for in Model 3 (BMI [OR = 1.59; 95%CI, 1.15–2.19; p = 0.003]; WC [OR = 1.68; 95%CI, 1.21–2.33; p = 0.002]). However, these effects are markedly attenuated when socioeconomic and demographic factors are adjusted in Model 2 and when all the potential confounders were collectively controlled for in Model 4. In women an opposite trend to that of plain milk consumption in seen in between buttermilk/lassi, BMI as well as WC.

In analyses taking account of the sibling-pair data structure (Table 5), the inverse association between milk consumption and BMI for men and women were similar in between-sibling-pairs and within-sibling-pairs, with no statistical evidence of differences between the effects (Table 5). The findings were also similar for WC.

Discussion

The present study demonstrates evidence of a substantial inverse association of daily plain milk consumption with the risk of being obese in a large sample of adult men and women in India. This association, found for BMI and WC in men and women, is independent of age, education, standard of living, migration status, alcohol intake, tobacco consumption, energy intake and physical activity levels in both sexes. High tea consumption daily was associated with increased risk of obesity and high WC in men but not among women. There was no strong evidence of associations between daily curd or buttermilk/lassi consumption with BMI or WC in either men or women.

Mechanisms

It is possible that higher dairy product consumption is associated with an overall healthy diet and lifestyle, which may track through the life course and ultimately lead to lower weight gain in adults [51]. Our analyses, adjusting for physical activity and several lifestyle characteristics, provide limited evidence against this mechanism. Milk is a source of high-quality protein and other nutrients, including lactose, proteins, fats, calcium, biotin, iodine, magnesium, pantothenic acid, potassium, riboflavin, selenium, thiamine, vitamin A, vitamin B12 and vitamin D [52] which may be implicated in metabolic pathways relevant to obesity. Two major biological mechanisms – body weight regulation and appetite regulation - for explaining the effects of dairy products have been proposed with some evidence to support roles for calcium, linoleic acid, medium chain fatty acids, milk proteins, carbohydrates and fats [53]. The precise biological and molecular mechanisms of action of dairy products remain to be fully elucidated.

Results in Context of Other Studies

The results of this study are in line with other observational epidemiologic studies where an inverse association has been found between dairy consumption and risk of being overweight or obese. A recent study in India [54] showed that consumption of plain milk was higher among normal-weight than among obese individuals (p<0.05). Normal-weight individuals consumed 1.7-times more whole milk than did obese individuals, while the latter consumed 1.5-times more skimmed milk and 2.6-times more toned milk [54]. An inverse association between milk drinking and body weight or BMI is shown in the cross-sectional baseline data of a number of large cohort studies, [55–58] all from developed countries. For example, an association between dairy food consumption and body fat was found in the NHANES III survey data, in which the odds ratio of a subject whose milk intake was in the highest quartile, compared to the lowest quartile, was 0.16 (0.09–0.28) [59]. In a limited overview of six observational studies and three controlled trials [60] a consistent negative effect of calcium intake on body fat and body weight was reported and the authors estimated that each 300 mg increment in habitual dietary calcium intake (equivalent to an average portion of dairy food) is associated with ~1 kg less body fat in children and ~2.5–3.0 lower body weight in adults [61]. Unsurprisingly, there have been few relevant randomized trials assessing this question owing to difficulties in conducting long-term dietary intervention trials. Those that have been conducted were typically of less than 1 year duration and found no effects on changes in weight [53]. In one trial weight loss was greater in participants randomized to dairy, compared with those receiving equivalent amounts of calcium as a supplement or those on a low calcium diet [62].

We found daily consumption of more than one portion of tea is associated with increased risk of obesity and high WC among men but not among women in our study. However, this association attenuates when we do a gender adjusted analysis. The tea – obesity association is almost certainly due to the sugar content of the tea and drinking tea with sugar and milk is almost universal practice among Indians. Our plain milk variable does not include milk taken as tea, but when we added this consumption to give a ‘total milk’ consumption variable (combining plain milk, curd, buttermilk and tea), we still got an inverse association with obesity in the total population but the association was not significant. However, studies on tea consumption and obesity risk mostly focused on green and other tea (black, herbal etc.) consumption generally without milk [63–65] which have been linked to lower weight gain and thus studies to confirm our finding are lacking.

Contrary to popular belief, in this study we did not find low-fat dairy products such as curd and buttermilk/lassi to be more beneficial to weight status than regular-fat dairy products such as plain milk. Our study findings are in line similar to other studies which suggest the reverse may be true. The weight of evidence from a recent review [66] suggested that milk intake was more likely to be associated with beneficial weight outcomes in a number of studies [67–71], while a very small number of studies [72] showed beneficial effects of other dairy products such as yoghurt/cheese among subjects with specific baseline characteristics. In our study, milk and curd consumption were associated (chi², 4 dof, 177.9, p<0.0005) but the pattern of association did not suggest that curd or buttermilk/lassi was substituted for milk in those taking no milk or vice versa. Though buttermilk and curds are similar in their origin, they do differ in composition and benefits. There is a regional variation in the consumption patterns of these two popular milk products in India. Buttermilk/lassi is mostly consumed in north India while curd in south India. Buttermilk is for drinking only and can be consumed as a whole, but curd is normally consumed additionally along with other food items in India, less frequently alone and thus required us to study these (plain milk, curd and buttermilk) separately because of their geographical variability in consumption and the method of preparation and consumption pattern in India.

Strengths and Limitations

One of the strengths of the study is that analysis was confined to the healthy population of the sample, therefore minimizing errors associated with underlying disease conditions that may influence...
Table 2. Daily plain milk, tea, curd, and buttermilk/lassi consumption pattern in the sample population according to selected background characteristics, lifestyle indicators, energy intake and physical activity, Indian Migration Study, 2006.

| Characteristics         | Daily plain milk consumption | Daily tea consumption | Daily curd consumption | Daily buttermilk/lassi consumption |
|-------------------------|------------------------------|-----------------------|------------------------|-----------------------------------|
|                         | Never | <1 portion | ≥ 1 portion | Never | <1 portion | ≥ 1 portion | Never | <1 portion | ≥ 1 portion | Never | <1 portion | ≥ 1 portion | Never | <1 portion | ≥ 1 portion |
| N(%)                    |       |            |            | N(%)                   |            |            | N(%)                    |       |            |            | N(%)                   |            |            |
| Age (years)             |       |            |            | p = 0.0001             |            | p = 0.0001 | p = 0.0001             | p = 0.0001 |
| 18–25                   | 137    | 30.6       | 181        | 40.4                  | 130        | 29.0       | 329        | 6.3       | 67          | 4.7       | 350         | 9.0       | 31          | 3.0       | 350         | 11.6       |
| 25–34                   | 1026   | 51.6       | 504        | 25.3                  | 460        | 23.1       | 1663       | 31.9      | 479         | 33.8      | 1172        | 30.0      | 339         | 32.7      | 526         | 35.7       |
| 35–44                   | 944    | 52.6       | 411        | 22.9                  | 439        | 24.5       | 145        | 25.4      | 147         | 28.2      | 466         | 32.8      | 975         | 25.0      | 333         | 34.0       |
| ≥ 55                    | 288    | 55.2       | 122        | 23.4                  | 112        | 21.5       | 44         | 8.0       | 41          | 8.0       | 280         | 10.4      | 95          | 9.2       | 171         | 10.8       |
| Gender                  |       |            |            | p = 0.0001             |            | p = 0.0001 | p = 0.0001             | p = 0.0001 |
| Men                     | 1645   | 44.5       | 1095       | 29.6                  | 958        | 25.9       | 329        | 6.3       | 67          | 4.7       | 350         | 9.0       | 31          | 3.0       | 350         | 11.6       |
| Women                   | 1439   | 54.1       | 688        | 25.9                  | 532        | 20.0       | 208        | 39.9      | 64          | 45.2      | 1642        | 42.1      | 376         | 36.3      | 747         | 47.2       |
| Education               |       |            |            | p = 0.0001             |            | p = 0.0001 | p = 0.0001             | p = 0.0001 |
| Illiterate              | 380    | 67.5       | 110        | 19.5                  | 73         | 13.0       | 54         | 9.4       | 45          | 8.6       | 186         | 13.1      | 30          | 7.7       | 293         | 18.5       |
| Literate, but no formal education | 84 | 61.3 | 31 | 22.6 | 22 | 16.0 | 13 | 2.3 | 8 | 1.4 | 11 | 2.2 | 43 | 3.0 | 80 | 2.1 | 14 | 1.4 | 52 | 3.3 | 70 | 1.8 | 15 | 1.6 |
| Primary school complete | 471    | 56.8       | 21         | 25.5                  | 147        | 17.7       | 87         | 15.3      | 69          | 12.1      | 245         | 17.3      | 446         | 11.4      | 138         | 13.3      | 260         | 16.4       |
| Secondary and higher secondary complete | 144 | 46.8 | 93 | 30.3 | 70 | 22.9 | 246 | 43.4 | 306 | 33.5 | 259 | 48.7 | 652 | 46.0 | 1939 | 49.7 | 500 | 48.2 | 650 | 41.1 | 2007 | 52.0 | 434 | 47.3 |
| Graduate                | 485    | 50.2       | 366        | 30.3                  | 35         | 9.7       | 123        | 21.7      | 104         | 18.2      | 981         | 18.8      | 211         | 14.9      | 790         | 20.3      | 207         | 20.0       |
| Professional degrees    | 217    | 41.0       | 130        | 24.6                  | 182        | 34.4       | 39         | 6.9       | 31          | 5.4       | 45          | 8.8       | 82          | 5.8       | 346         | 8.9       | 101         | 9.7       |
| Standard of living index|       |            |            | p = 0.0001             |            | p = 0.0001 | p = 0.0001             | p = 0.0001 |
| Low                     | 283    | 66.4       | 89         | 20.9                  | 54         | 12.7       | 41         | 7.2       | 60          | 10.5      | 32          | 46.2      | 167         | 11.8      | 226         | 58.8      |
| Medium                  | 381    | 47.5       | 235        | 29.3                  | 186        | 23.2       | 73         | 12.9      | 93          | 16.3      | 63          | 12.2      | 229         | 16.1      | 480         | 12.3      |
| High                    | 424    | 47.2       | 145         | 28.4                 | 125         | 24.4       | 45         | 7.9       | 41          | 7.3       | 425         | 8.1       | 1023        | 27.2      | 3195        | 81.9      |
| Migration status        | p = 0.017 | p = 0.001 | p = 0.0001 | p = 0.0001             |            | p = 0.0001 | p = 0.0001             | p = 0.0001 |
| Rural                   | 892    | 45.3       | 566        | 28.7                  | 51          | 26.0       | 190        | 36.0      | 202         | 38.9      | 1578        | 32.9      | 511         | 39.2      | 1175        | 32.8      |
| Migrant                 | 915    | 50.0       | 516        | 28.2                  | 398        | 21.8       | 148        | 28.0      | 173         | 33.7      | 1506        | 31.4      | 387         | 29.7      | 1072        | 29.9      |
| Urban                   | 993    | 48.4       | 572        | 27.9                  | 485        | 23.7       | 190        | 36.0      | 142         | 27.4      | 1718        | 35.8      | 406         | 31.1      | 1338        | 37.3      |
| Tobacco consumption     | p = 0.014 | p = 0.001 | p = 0.057 | p = 0.0001             |            | p = 0.0001 | p = 0.0001             | p = 0.0001 |
### Table 2. Cont.

| Characteristics | Daily plain milk consumption | Daily tea consumption | Daily curd consumption | Daily buttermilk/lassi consumption |
|-----------------|-----------------------------|-----------------------|------------------------|------------------------------------|
|                 | N[%] | N[%] | N[%] | N[%] | N[%] | N[%] | N[%] | N[%] | N[%] | N[%] | N[%] | N[%] |
| Never           | 2256[47.6] | 1348[28.4] | 1136[24.0] | 504[88.9] | 457[79.9] | 377[72.4] | 1095[77.2] | 2874[73.7] | 771[74.4] | 1172[74.1] | 2805[72.7] | 763[83.1] |
| Past            | 111[59.7] | 41[22.0] | 34[18.3] | 15[2.7] | 20[3.5] | 151[2.9] | 33[2.5] | 113[2.9] | 38[3.7] | 48[3.0] | 105[2.7] | 33[3.6] |
| Current         | 717[50.1] | 394[27.5] | 320[22.4] | 48[8.5] | 95[16.6] | 128[24.7] | 289[30.4] | 914[23.4] | 228[22.0] | 362[22.9] | 947[24.6] | 122[13.3] |

| Alcohol consumption | p<0.0001 | p<0.0001 | p<0.0001 | p<0.0001 | p<0.0001 | p<0.0001 | p<0.0001 | p<0.0001 | p<0.0001 | p<0.0001 | p<0.0001 | p<0.0001 |
|---------------------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| Never               | 2368[45.8] | 1508[29.1] | 1299[25.1] | 505[89.1] | 477[83.4] | 419[80.4] | 112[79.6] | 325[83.4] | 792[76.4] | 1207[76.3] | 3197[82.9] | 771[84.0] |
| Past                | 103[54.2] | 48[25.3] | 39[20.5] | 15[2.7] | 15[2.7] | 160[3.1] | 48[3.4] | 102[2.6] | 40[3.9] | 54[3.4] | 105[2.8] | 30[3.3] |
| Current             | 613[61.8] | 227[22.9] | 152[15.3] | 47[8.3] | 80[14.0] | 865[16.6] | 242[17.1] | 545[14.0] | 205[19.8] | 321[20.3] | 554[14.4] | 117[12.8] |

| Energy expenditure (MET hours/day) | p<0.0001 | p<0.0001 | p<0.0001 | p<0.0001 |
|-----------------------------------|-----------|-----------|-----------|-----------|
| Never                             | 845[53.6] | 408[25.9] | 323[20.5] | 146[25.8] |
| Quartile I                        | 747[47.5] | 446[28.4] | 380[24.2] | 133[22.7] |
| Quartile II                       | 754[47.9] | 434[27.6] | 387[24.6] | 147[25.9] |
| Quartile III                      | 738[45.2] | 495[30.3] | 400[24.5] | 141[24.9] |
| Quartile IV                       | 577[36.3] | 550[34.6] | 462[29.1] | 91[16.1] |

Note: p values are from chi square test of significance.
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Table 3. Percentage distribution of anthropometric indicators among Men (n=3,698) and Women (n=2,659) according to milk/milk product consumption and other selected characteristics, Indian Migration Study, 2006.

| Characteristics                  | Body Mass Index ≥25 kg/m² | Waist Circumference |       |       |       |       |       |       |
|----------------------------------|---------------------------|---------------------|-------|-------|-------|-------|-------|-------|
|                                  | N (%)                     | N (%)               | ²p value | N (%) | N (%) | ²p value | N (%) | N (%) | ²p value |
| Daily plain milk consumption     |                           |                     |       |       |       |       |       |       |
| Never                            | 572 (34.8)                | 678 (47.1)          | <0.0001 | 612 (37.2) | 652 (45.3) | 0.005 |
| < 1 portion                      | 287 (6.2)                 | 258 (37.5)          | <0.0001 | 281 (25.7) | 266 (38.7) |       |
| ≥ 1 portion                      | 265 (27.7)                | 205 (38.5)          | <0.0001 | 318 (33.2) | 211 (40.0) |       |
| Daily tea consumption            |                           |                     | <0.0001 | 0.005  | 0.001  | 0.014 |
| Never                            | 70 (27.6)                 | 146 (46.7)          | <0.0001 | 74 (29.1)  | 137 (43.8) |       |
| < 1 portion                      | 61 (19.7)                 | 89 (34.0)           | <0.0001 | 75 (24.2)  | 89 (34.0)  |       |
| ≥ 1 portion                      | 992 (31.7)                | 903 (43.4)          | <0.0001 | 1062 (33.9) | 903 (43.3) |       |
| Daily curd consumption           |                           |                     | <0.0001 |       |       | <0.0001 | <0.0001|
| Never                            | 263 (33.8)                | 307 (47.9)          | <0.0001 | 284 (36.5) | 303 (47.3) |       |
| < 1 portion                      | 616 (27.3)                | 631 (38.4)          | <0.0001 | 679 (30.1) | 631 (38.4) |       |
| ≥ 1 portion                      | 245 (37.1)                | 203 (54.0)          | <0.0001 | 248 (37.5) | 195 (51.9) |       |
| Daily buttermilk/lassi consumption |                       |                     | <0.0001 |       |       | <0.0001 | <0.0001|
| Never                            | 226 (27.1)                | 324 (43.4)          | <0.0001 | 255 (30.5) | 317 (42.4) |       |
| < 1 portion                      | 705 (29.9)                | 586 (39.0)          | <0.0001 | 743 (31.5) | 592 (39.4) |       |
| ≥ 1 portion                      | 193 (38.1)                | 231 (56.2)          | <0.0001 | 213 (42.0) | 220 (53.5) |       |
| Age (years)                      |                           |                     | <0.0001 |       |       | <0.0001 | <0.0001|
| 18–25                            | 12 (5.3)                  | 8 (3.6)             | <0.0001 | 8 (3.3)   | 21 (9.6)   |       |
| 25–34                            | 167 (17.0)                | 149 (24.0)          | <0.0001 | 117 (11.9) | 155 (24.9) |       |
| 35–44                            | 348 (33.7)                | 497 (51.9)          | <0.0001 | 350 (33.9) | 456 (47.7) |       |
| 45–54                            | 479 (44.0)                | 416 (59.0)          | <0.0001 | 566 (52.0) | 416 (59.0) |       |
| > 55                             | 118 (32.2)                | 71 (45.8)           | <0.0001 | 170 (46.3) | 81 (52.3)  |       |
| Education                        |                           |                     | <0.0001 |       |       | <0.0001 | <0.0001|
| Illiterate                       | 27 (16.0)                 | 132 (33.5)          | <0.0001 | 28 (16.6)  | 147 (37.3) | 0.002 |
| Literate, but no formal education | 32 (40.0)                 | 16 (28.1)           | <0.0001 | 38 (47.5)  |       |       |
| Primary school complete          | 70 (19.9)                 | 238 (49.9)          | <0.0001 | 83 (23.6)  | 234 (49.1) |       |
| Secondary and higher 600 (29.8) secondary complete | 436 (40.6) | 618 (30.6) | <0.0001 | 435 (40.5) |       |       |
Table 3. Cont.

| Characteristics        | Body Mass Index ≥25 kg/m² | Waist Circumference Men (≥90 cm) | Waist Circumference Women (≥80 cm) | p value | p value | p value | p value |
|-------------------------|---------------------------|----------------------------------|------------------------------------|---------|---------|---------|---------|
| N (%)                   | N (%)                     | N (%)                            | N (%)                              |         |         |         |         |
| Graduate                | 284 (36.0)                | 189 (45.0)                       | 318 (40.4)                         | 172 (41.0) |         |         |         |
| Professional degrees    | 130 (41.3)                | 114 (33.3)                       | 148 (47.0)                         | 103 (48.1) |         |         |         |
| Standard of living index| <0.0001                   | <0.0001                          | <0.0001                            | <0.0001 |         |         |         |
| Low                     | 17 (6.5)                  | 26 (16.1)                        | 24 (9.1)                           | 35 (21.8) |         |         |         |
| Medium                  | 64 (12.1)                 | 53 (20.2)                        | 62 (11.7)                          | 64 (23.4) |         |         |         |
| High                    | 1043 (35.9)               | 1060 (47.7)                      | 1125 (38.7)                        | 1030 (46.3) |         |         |         |
| Migration status        | <0.0001                   | <0.0001                          | <0.0001                            | <0.0001 |         |         |         |
| Rural                   | 236 (17.2)                | 158 (26.5)                       | 270 (19.7)                         | 181 (30.4) |         |         |         |
| Migrant                 | 389 (40.4)                | 417 (48.1)                       | 429 (44.6)                         | 435 (50.2) |         |         |         |
| Urban                   | 429 (40.5)                | 509 (51.4)                       | 437 (41.3)                         | 455 (45.9) |         |         |         |
| Tobacco consumption     | <0.0001                   | 0.155                            | <0.0001                            | 0.581   |         |         |         |
| Never                   | 718 (33.0)                | 1109 (43.3)                      | 781 (36.9)                         | 1090 (42.5) |         |         |         |
| Past                    | 57 (36.5)                 | 10 (33.3)                        | 60 (38.5)                          | 10 (33.3) |         |         |         |
| Current                 | 349 (25.6)                | 22 (33.3)                        | 370 (27.1)                         | 29 (43.9) |         |         |         |
| Alcohol consumption     | 0.015                     | 0.086                            | 0.001                              | 0.788   |         |         |         |
| Never                   | 769 (29.1)                | 1086 (43.0)                      | 818 (30.9)                         | 1074 (42.5) |         |         |         |
| Past                    | 54 (36.2)                 | 23 (56.1)                        | 52 (34.9)                          | 19 (46.3) |         |         |         |
| Current                 | 301 (33.4)                | 32 (35.6)                        | 341 (37.8)                         | 36 (40.0) |         |         |         |
| Energy expenditure      | <0.0001                   | <0.0001                          | <0.0001                            | <0.0001 |         |         |         |
| (MET hours/day)         |                           |                                  |                                    |         |         |         |         |
| Quartile I              | 163 (24.3)                | 370 (40.2)                       | 189 (28.2)                         | 377 (41.0) |         |         |         |
| Quartile II             | 246 (30.9)                | 377 (47.5)                       | 279 (35.1)                         | 371 (46.7) |         |         |         |
| Quartile III            | 332 (33.5)                | 248 (41.4)                       | 378 (38.2)                         | 243 (40.6) |         |         |         |
| Quartile IV             | 383 (30.8)                | 146 (42.2)                       | 365 (29.4)                         | 138 (40.0) |         |         |         |
| Energy intake (kcal)    | 0.001                     | 0.018                            | <0.0001                            | 0.036   |         |         |         |
| Quartile I              | 296 (39.0)                | 381 (46.7)                       | 314 (41.3)                         | 390 (47.8) |         |         |         |
| Quartile II             | 294 (31.6)                | 321 (44.0)                       | 334 (39.6)                         | 313 (42.9) |         |         |         |
| Quartile III            | 230 (19.8)                | 285 (44.3)                       | 325 (34.9)                         | 273 (42.4) |         |         |         |
| Quartile IV             | 245 (23.0)                | 154 (32.8)                       | 238 (20.5)                         | 153 (32.6) |         |         |         |

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Table 4. Unadjusted and adjusted association (ORs with 95%CI) of milk/milk product consumption on anthropometric indicators for men (n = 3,698) and women (n = 2,659), Indian Migration Study, 2006.

| Characteristics | Model 1 Unadjusted | Model 2 Adjusteda | Model 3 Adjustedb | Model 4 Adjustedd |
|-----------------|--------------------|-------------------|-------------------|-------------------|
|                 | BMI OR[95%CI]      | WC OR[95%CI]      | BMI OR[95%CI]     | WC OR[95%CI]      |
| MEN             |                    |                   |                   |                   |
| Daily plain milk consumption | | | | |
| Never           | 1.00[ref]          | 1.00[ref]         | 1.00[ref]         | 1.00[ref]         |
| < 1 portion     | 0.61[0.50–0.76]    | 0.72[0.56–0.92]   | 0.69[0.53–0.89]   | 0.71[0.55–0.91]   |
| ≥ 1 portion     | 0.66[0.53–0.82]    | 0.72[0.55–0.93]   | 0.65[0.50–0.83]   | 0.67[0.51–0.87]   |
| Daily tea consumption | | | | |
| Never           | 1.00[ref]          | 1.00[ref]         | 1.00[ref]         | 1.00[ref]         |
| < 1 portion     | 0.63[0.39–1.00]    | 0.78[0.59–1.00]   | 0.71[0.54–0.92]   | 0.73[0.55–0.96]   |
| ≥ 1 portion     | 1.39[0.97–1.97]    | 1.49[0.99–2.22]   | 1.46[1.00–2.12]   | 1.51[1.00–2.28]   |
| Daily curd consumption | | | | |
| Never           | 1.00[ref]          | 1.00[ref]         | 1.00[ref]         | 1.00[ref]         |
| < 1 portion     | 0.72[0.58–0.90]    | 0.78[0.60–1.01]   | 0.70[0.54–0.92]   | 0.73[0.55–0.96]   |
| ≥ 1 portion     | 1.25[0.95–1.63]    | 1.03[0.74–1.42]   | 1.09[0.82–1.47]   | 0.93[0.66–1.30]   |
| Daily buttermilk/lassi consumption | | | | |
| Never           | 1.00[ref]          | 1.00[ref]         | 1.00[ref]         | 1.00[ref]         |
| < 1 portion     | 1.23[0.99–1.54]    | 1.15[0.88–1.49]   | 1.15[0.91–1.46]   | 1.11[0.85–1.46]   |
| ≥ 1 portion     | 1.89[1.40–2.55]    | 1.68[1.21–2.33]   | 1.68[1.21–2.33]   | 0.95[0.65–1.38]   |
| WOMEN           |                    |                   |                   |                   |
| Daily plain milk consumption | | | | |
| Never           | 1.00[ref]          | 1.00[ref]         | 1.00[ref]         | 1.00[ref]         |
| < 1 portion     | 0.61[0.47–0.78]    | 0.61[0.50–0.83]   | 0.70[0.59–0.97]   | 0.70[0.53–0.97]   |
| ≥ 1 portion     | 0.63[0.48–0.83]    | 0.70[0.50–0.98]   | 0.78[0.59–1.04]   | 0.78[0.58–0.97]   |
| Daily tea consumption | | | | |
| Never           | 1.00[ref]          | 1.00[ref]         | 1.00[ref]         | 1.00[ref]         |
| < 1 portion     | 0.54[0.35–0.84]    | 0.54[0.35–0.83]   | 0.64[0.42–0.97]   | 0.64[0.42–0.97]   |
| ≥ 1 portion     | 0.89[0.65–1.22]    | 1.26[0.91–1.74]   | 0.86[0.62–1.18]   | 0.99[0.73–1.34]   |
| Daily curd consumption | | | | |
| Never           | 1.00[ref]          | 1.00[ref]         | 1.00[ref]         | 1.00[ref]         |
| < 1 portion     | 0.64[0.48–0.85]    | 0.83[0.64–1.09]   | 0.70[0.56–1.02]   | 0.68[0.54–0.86]   |

a. Model 2 adjusts for age and study site.
b. Model 3 adjusts for age, study site, and education level.
c. Model 4 adjusts for age, study site, education level, and household wealth.
d. Model 4 adjusts for age, study site, education level, household wealth, and body fat percentage.
## Table 4.

| Characteristics | Model 1 Unadjusted | Model 2 Adjusted | Model 3 Adjusted | Model 4 Adjusted |
|-----------------|-------------------|-----------------|-----------------|-----------------|
|                 | BMI               | WC              | BMI             | WC              | BMI             | WC              | BMI             | WC              |
| BMI             | OR[95%CI]         | OR[95%CI]       | OR[95%CI]       | OR[95%CI]       | OR[95%CI]       | OR[95%CI]       | OR[95%CI]       | OR[95%CI]       |
| ≥1 portion      | 1.34[0.96–1.88]   | 1.03[0.70–1.51] | 0.82[0.59–1.19] | 0.73[0.51–1.04] | 1.25[0.89–1.77] | 1.21[0.88–1.69] | 0.81[0.56–1.17] | 0.72[0.43–1.05] |
| Daily buttermilk/lassi consumption | 1.00[ref] | 1.00[ref] | 1.00[ref] | 1.00[ref] | 1.00[ref] | 1.00[ref] | 1.00[ref] | 1.00[ref] |
| 1 portion       | 0.83[0.66–1.05]   | 0.79[0.60–1.05] | 1.02[0.79–1.32] | 1.03[0.75–1.43] | 0.78[0.61–0.99] | 0.87[0.69–1.10] | 1.08[0.83–1.41] | 1.04[0.75–1.44] |
| 1 portion       | 1.84[1.34–2.54]   | 1.13[0.78–1.66] | 1.03[0.73–1.45] | 1.23[0.80–1.90] | 1.76[1.27–2.44] | 1.69[1.24–2.26] | 1.10[0.78–1.57] | 1.25[0.82–1.73] |

- Model 1 is unadjusted using mixed-effect logistic regression analysis.
- Model 2 is adjusted for socioeconomic and demographic characteristics: age, education, standard of living, migration status with an individual-specific random effect of sib-pair.
- Model 3 is adjusted for behavioral factors: tobacco consumption, alcohol consumption, energy expenditure and energy intake with an individual-specific random effect of sib-pair.
- Model 4 is adjusted for behavioral factors: tobacco consumption, alcohol consumption, energy expenditure and energy intake with an individual-specific random effect of sib-pair.

Dependent variable BMI: 0–25 kg/m^2 and 1 obese.

Dependent variable Men WC: 0–90 cm & 1 obese. Women WC: 0–80 cm & 1 obese.
Table 5. Within and between sib-pair effects of milk/milk product consumption on obesity and waist circumference among men (n = 3698) and women (n = 2659) (Estimates from a population-average approach).

| Outcome measures                  | Model 1 Unadjusted | Model 2 Adjusted | Model 3 Adjusted | Model 4 Adjusted |
|-----------------------------------|---------------------|------------------|------------------|------------------|
|                                   | OR [95%CI]          | OR [95%CI]       | OR [95%CI]       | OR [95%CI]       |
| **MEN**                           |                     |                  |                  |                  |
| Obesity (BMI≥25 kg/m²)            |                     |                  |                  |                  |
| Plain milk within                 | 0.84 [0.71–1.00]    | 0.90 [0.74–1.09] | 0.82 [0.70–0.99] | 0.89 [0.73–1.08] |
| Plain milk between                | 0.82 [0.74–0.91]    | 0.85 [0.75–0.95] | 0.81 [0.73–0.90] | 0.83 [0.73–0.93] |
| Test within = between             | 0.7864              | 0.6017           | 0.7970           | 0.5498           |
| Tea within                        | 1.53 [1.21–1.93]    | 1.43 [1.10–1.87] | 1.51 [1.19–1.90] | 1.40 [1.08–1.83] |
| Tea between                       | 1.17 [1.00–1.37]    | 1.18 [0.99–1.41] | 1.16 [0.99–1.36] | 1.18 [0.98–1.41] |
| Test within = between             | 0.0530              | 0.2188           | 0.0619           | 0.2690           |
| Curd within                       | 1.29 [1.05–1.59]    | 1.14 [0.90–1.44] | 1.11 [0.97–1.47] | 1.11 [0.88–1.41] |
| Curd between                      | 1.00 [0.88–1.15]    | 0.94 [0.81–1.09] | 0.95 [0.84–1.11] | 0.91 [0.78–1.06] |
| Test within = between             | 0.0441              | 0.1776           | 0.0823           | 0.1606           |
| Buttermilk/lassi within           | 1.32 [1.03–1.68]    | 1.04 [0.79–1.36] |(387,755)(387,755) 1.19 [0.92–1.51] | 1.02 [0.78–1.34] |
| Buttermilk/lassi between          | 1.27 [1.11–1.45]    | 1.01 [0.86–1.19] | 1.17 [1.03–1.37] | 1.02 [0.86–1.21] |
| Test within = between             | 0.7925              | 0.8438           | 0.9516           | 0.9986           |
| Waist circumference (>90cm)       |                     |                  |                  |                  |
| Plain milk within                 | 0.87 [0.75–1.02]    | 0.90 [0.73–1.09] | 0.87 [0.74–1.02] | 0.89 [0.73–1.09] |
| Plain milk between                | 0.91 [0.83–1.00]    | 0.90 [0.80–1.02] | 0.94 [0.85–1.04] | 0.89 [0.78–1.01] |
| Test within = between             | 0.6281              | 0.9587           | 0.9260           | 0.9820           |
| Tea within                        | 1.63 [1.31–2.04]    | 1.58 [1.20–2.07] | 1.63 [1.30–2.04] | 1.54 [1.18–2.02] |
| Tea between                       | 1.11 [0.95–1.30]    | 1.12 [0.93–1.33] | 1.11 [0.95–1.30] | 1.11 [0.93–1.33] |
| Test within = between             | 0.0039              | 0.0324           | 0.0049           | 0.0447           |
| Curd within                       | 1.32 [1.09–1.60]    | 1.19 [0.93–1.51] | 1.27 [1.04–1.54] | 1.16 [0.90–1.48] |
| Curd between                      | 0.98 [0.86–1.12]    | 0.95 [0.81–1.11] | 0.97 [0.85–1.11] | 0.92 [0.78–1.08] |
| Test within = between             | 0.0110              | 0.1304           | 0.0264           | 0.1263           |
| Buttermilk/lassi within           | 1.50 [1.20–1.88]    | 1.14 [0.86–1.50] | 1.35 [1.07–1.70] | 1.10 [0.83–1.46] |
| Buttermilk/lassi between          | 1.26 [1.11–1.44]    | 1.05 [0.89–1.24] | 1.21 [1.06–1.39] | 1.06 [0.90–1.26] |
| Test within = between             | 0.1950              | 0.6362           | 0.4247           | 0.8248           |
| **WOMEN**                         |                     |                  |                  |                  |
| Obesity (BMI≥25 kg/m²)            |                     |                  |                  |                  |
| Daily plain milk within           | 0.78 [0.64–0.96]    | 0.74 [0.57–0.96] | 0.76 [0.62–0.94] | 0.73 [0.56–0.95] |
| Daily plain milk between          | 0.83 [0.74–0.92]    | 0.81 [0.70–0.92] | 0.82 [0.72–0.90] | 0.81 [0.70–0.92] |
| Test within = between             | 0.6443              | 0.5412           | 0.6856           | 0.5295           |
| Tea within                        | 1.16 [0.93–1.46]    | 1.15 [0.86–1.55] | 1.15 [0.91–1.44] | 1.14 [0.85–1.54] |
| Tea between                       | 0.97 [0.85–1.10]    | 1.09 [0.94–1.27] | 0.95 [0.83–1.09] | 1.08 [0.92–1.27] |
were either rural-urban migrant or urban dwellers and studies showed that migration was associated with both an increased fat intake and reduced physical activity in both men and women, as compared with rural dwellers, and this likely contributes to the higher levels of obesity observed in migrants [33]. Also, in comparisons with the 3rd National Family Health Survey [80] and the 2001 Census of India [81], our study population had lower proportions of illiterate individuals and higher proportions of individuals with access to household facilities and assets, indicating a generally wealthier and more educated population than the national average in both rural and urban areas. It is a still paradox in India that overweight and obesity is positively associated with higher education (23.8% and 18.8% overweight/obesity in women and men respectively with 12 or more years of education in comparison to the illiterates-7.3% in women and 3.6% in men) and higher wealth status (30.5% and 23.6% overweight/obesity in women and men respectively in highest wealth category in comparison to lowest wealth category — 1.8% in women and 1.4% in men) in the population [80].

Like all cross sectional studies, the data from this study was also prone to recall bias and despite use of a sib-pair design it is possible that residual confounding occurred and results should be interpreted with caution. Although physical activity and alcohol/tobacco consumption were controlled for, which further strengthens the negative association observed between milk intake and obesity, it does not exclude the possibility that milk intake may have been a proxy indicator of a generally healthier dietary pattern or lifestyle in this population.

The validity of the adjustment of association models for total energy intake needs to be carefully considered when interpreting study results and conducting cross-study comparisons. Given the high degree of correlation between total energy intake and adiposity, adjustment for total energy intake appears appropriate [82].

| Table 5. Cont. |
|---------------|
| Outcome measures | Model 1 Unadjusted* | Model 2 Adjusteda | Model 3 Adjustedb | Model 4 Adjustedc |
| Test | within = between | OR [95%CI] | OR [95%CI] | OR [95%CI] | OR [95%CI] |
| Curd within | 1.02 [0.79–1.33] | 0.7495 [0.59–1.00] | 0.7621 [0.59–1.00] |
| Curd between | 1.04 [0.90–1.20] | 0.93 [0.79–1.09] | 0.93 [0.78–1.11] |
| Test | within = between | 0.9027 | 0.5666 | 0.9698 | 0.5792 |
| Buttermilk/lassi within | 1.07 [0.81–1.40] | 0.96 [0.69–1.33] | 0.96 [0.69–1.34] |
| Buttermilk/lassi between | 1.22 [0.07–1.40] | 1.03 [0.88–1.21] | 1.07 [0.91–1.26] |
| Test | within = between | 0.3778 | 0.7027 | 0.3299 | 0.5758 |
| Waist circumference (>80cm) | | | | |
| Plain milk within | 1.21 [0.92–1.59] | 1.25 [0.92–1.69] | 1.24 [0.91–1.69] |
| Plain milk between | 0.78 [0.68–0.91] | 0.85 [0.72–1.00] | 0.85 [0.72–1.00] |
| Test | within = between | 0.0075 | 0.0281 | 0.0162 | 0.0365 |
| Tea within | 1.21 [0.96–1.53] | 1.20 [0.90–1.59] | 1.19 [0.89–1.58] |
| Tea between | 1.02 [0.89–1.16] | 1.06 [0.91–1.23] | 1.05 [0.90–1.23] |
| Test | within = between | 0.2047 | 0.4461 | 0.2230 | 0.4712 |
| Curd within | 1.10 [0.78–1.57] | 0.95 [0.66–1.37] | 0.95 [0.65–1.39] |
| Curd between | 0.91 [0.76–1.10] | 0.82 [0.68–0.99] | 0.81 [0.66–0.99] |
| Test | within = between | 0.3520 | 0.4952 | 0.2804 | 0.4377 |
| Buttermilk/lassi within | 1.13 [0.79–1.62] | 1.04 [0.72–1.52] | 1.08 [0.74–1.58] |
| Buttermilk/lassi between | 0.99 [0.84–1.17] | 1.04 [0.82–1.26] | 1.10 [0.90–1.33] |
| Test | within = between | 0.5065 | 0.9928 | 0.6797 | 0.9524 |

*Model 1 is unadjusted.

bModel 2 is adjusted for behavioral factors: tobacco consumption, alcohol consumption, MET hours/day and energy intake.

cModel 3 is adjusted for socioeconomic and demographic characteristics: age, education, standard of living, and migration status.

dModel 4 is adjusted for all the above factors.

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