ABSTRACT

The anti-obesity effect of milk intake has been suggested via a variety of designed studies, but findings of obesity interventions for Korean adults are scarcely reported. The study aimed to investigate the anti-obesity effect of cow milk in Korean adults with an 8-wk randomized intervention. A total of 121 adults overweight aged 19 to 60 yr old were randomly assigned to 1 of the 2 groups: milk or control. During the intervention, both groups were encouraged 500 kcal of restriction a day, and the milk group consumed 200 mL of milk twice a day; the same energy intake as the control group, including milk intake, was recommended for 8 wk. We detected no significant differences in body weight (BW) and body mass index (BMI) between the milk and control groups during the 8-wk intervention, although the changes in BW and BMI of those within the milk group were significant. High-density lipoprotein cholesterol levels and serum calcium levels increased significantly in the milk group compared with the control group. Calcium, phosphorus, vitamin A, and riboflavin intakes increased significantly, when compared with the control. In conclusion, 8-wk milk consumption had no effect on weight loss and BMI change but improved some blood biomarkers and nutrient intake in Korean adults who were overweight. To evaluate the effect of milk on obesity reduction, well-designed, long-term, and large-scale studies are needed.

Key words: milk, obesity, weight, body mass index, intervention study

INTRODUCTION

Obesity is becoming a more serious issue for individuals all around the world, including South Korea, and creates additional health and socioeconomic concerns, resulting in a reduced quality of life (Sarma et al., 2021). Reported risk factors for obesity are biological, behavioral, and environmental factors. The factors include age, sex, genetic factors, individual lifestyle, attitude, knowledge, transportation system, vehicle costs, and food costs, respectively (Baik, 2018; Chooi et al., 2019). According to statistics, around 1.1 billion people worldwide are overweight, and this figure is expected to quadruple by 2030 (NCD Risk Factor Collaboration, 2017). Unlike the cut-off point for obesity criteria worldwide (body mass index [BMI] ≥ 30 kg/m²), the diagnostic criteria for obesity in Korea were defined by the Korean Society for the Study of Obesity as follows: pre-obese BMI: 23 to 24.9 kg/m²; class I obesity: 25 to 29.9 kg/m²; class II obesity: 30 to 34.9 kg/m²; class III obesity: ≥ 35 kg/m² (Nam and Park, 2018). In Korea, the prevalence of obesity increased from 29.7% in 2010 to 35.7% in 2018 (Nam et al., 2020). According to the Korea National Health and Nutrition Examination Survey (KNHANES), one-third of Koreans are obese, with men accounting for 40% and women for 26% (Baik, 2018). The same study predicted that by 2030, women’s obesity rates would reach 37% and men’s obesity rates would reach 62%.

Milk has long been suggested as an aid for people to regulate their weight because it is high in calcium, minerals, and protein. Among those, calcium (Zemel et al., 2000; Dugan and Fernandez, 2014), short- and medium-chain fatty acids (Kasubuchi et al., 2015; Dougkas et al., 2019), whey protein (Jakubowicz and Froy, 2013), and CLA (Tsuboyama-Kasaoka et al., 2000) have been known as bioactive components that play a beneficial role against obesity. Accumulated observational evidence supports the inverse association between dairy consumption and obesity risk, suggesting plausible mechanisms for those bioactive components (Kratz et al., 2013). Meta-analyses of randomized-controlled clinical trials (RCT; Abargouei et al., 2012; Booth et al., 2015) showed that applying energy-restricted diets rich in dairy may result in decreased body fat mass. However, due to the inconsistent outcomes in a small number of prospective and Mendelian randomization
studies and the scarcity of well-designed RCT in adults, future research is necessary to elucidate the relationship in adults (Rajpathak et al., 2006; Snijder et al., 2008; te Velde et al., 2011).

In Korea, most previous studies regarding the relation between milk intake and obesity or metabolic syndrome were cross-sectional studies presenting strong inverse associations (Kwon et al., 2010; Lee et al., 2014; Lee and Cho, 2017; Shin et al., 2017). Only 1 prospective-cohort study has been performed to investigate whether dairy products were related to a lower risk of obesity (Shin et al., 2013), and there is no intervention study. Therefore, due to the paucity of data associating milk consumption to obesity risk in Koreans, we conducted a randomized intervention study in Korean adults to investigate the effect of milk intake on obesity. To the best of our knowledge, this is the first intervention study to examine the relationship between milk consumption and obesity-related variables in Korean adults.

MATERIALS AND METHODS

Eligibility Criteria

This study recruited 121 participants (male and female) aged 19 to 60 yr old with a BMI of ≥23 kg/m² from the local communities in Gyeonggi Province Republic of Korea. The number of cases was calculated using Kaats et al. (2006), which showed significant results in the same major endpoint in this study, with 80% statistical power. Considering the dropout rate of 30%, the number of cases to be enrolled was 54 per group, so 60 and 61 participants were assigned to each group, and the total number of participants was 121 (Kaats et al., 2006). Participants were recruited from July to December 2017. All the volunteer participants signed a written-informed consent before the commencement of the study. Exclusion criteria were as follows: people with chronic diseases, mental illness, allergies to milk or others, or those who have consumed milk every day for the past 3 mo. Individuals who planned for pregnancy within the last 3 mo or took part in other clinical trials were also excluded. After screening, the subjects were randomized into 2 groups: the milk group (61 participants) and the control group (60 participants). However, during the intervention period, some participants dropped out for the following reasons: inconsistent milk intake (9 from the milk group), not following the strict diet plan (9 from the control group), and poor compliance (4 from the milk group and 3 from the control group), as shown in Figure 1. Consequently, 96 participants (48 from the milk group and 48 from the control group) completed the study. The study was approved by the Institutional Review Board (IRB) at Gachon University [IRB No. 1044396–201705-HR-086–02].

Study Design and Intervention

The study design was an 8-wk intervention trial, and the subjects were randomized by using random sampling numbers into a milk group and a control group. Both groups were encouraged to continue their usual...
diet (dietary pattern) and lose 500 kcal/d for weight loss (Frestedt et al., 2008). The participants in the milk group were instructed to drink 200 mL of milk twice a day and the same energy intake as the control group, including milk intake (260 kcal/400 mL) was recommended for 8 wk. Whole fat–white cow milk (Namyang Dairy Products Co.; 130 kcal calories, 9 g of total carbohydrates, 6 g of protein, 8 g of total fat, 30 mg of cholesterol, 200 mg of calcium, 100 mg/200 mL sodium) was purchased from a local supermarket. During the intervention, the control group was instructed not to drink any milk, as well as yogurt. Nutritional education on calorie restriction and milk intake was conducted by professional dietitians before the commencement of the study and more than once during the intervention period. Everyday milk intake status and diet were checked via a social networking service (SNS) and over the phone individually during the trial to monitor compliance. To be specific, the milk group was asked to send a picture or text of themselves drinking milk via an SNS called Kakao Talk to researchers. Both groups were taught how to calculate calories and reduce 500 kcal/d using Korean food exchange lists (Ju et al., 2011) after an initiation meeting before intervention. In addition, participants were encouraged to record their diet diary to follow the diet plan, and participants reported whether they maintained calorie restriction or not to researchers more than once a week via text messaging. The participants were instructed to maintain their physical activity pattern during the study intervention.

**General Characteristics and Anthropometric Measures**

A self-administered questionnaire was used to collect information on sex, age, type of household, family income, sleeping hours, alcohol intake, and smoking history to examine the general characteristics of participants under the supervision of the researchers. Before and after the intervention, anthropometric measurements were taken twice. Body weight and height were measured without shoes on an electronic scale. Body mass index was calculated by dividing the weight (kg) by the square of height (m²) as a primary outcome for this study. The percentage of body fat was measured using the Bioelectric Impedance Analysis (In-Body 720, Biospace Co. Ltd.).

**Biochemical Examination**

For biochemical analysis, blood samples were collected, and serum was separated using a centrifuge (Combi-514R, Hanil Co. Ltd.) at 2,000 × g for 15 min at 4°C. The standard Biuret method was used to determine total protein, whereas the dye binding-bromocresol green method was used to determine albumin. The International Federation of Clinical Chemistry method was used to assess serum glutamic-oxaloacetic transaminase (SGOT) and serum glutamate-pyruvate transaminase (SGPT) using assay kits (JW Bio Science, Korea) per the instructions of the manufacturer. Total cholesterol, high-density lipoprotein cholesterol (HDL-C), and triglycerides (TG) were analyzed by an enzymatic (JW Bio Science, Korea) as secondary outcomes for this study. Calcium was measured using the arsenazo III dye method, whereas high-sensitivity C-reactive protein (hs-CRP) was measured using the immunoturbidimetric assay (ITA, JW Bio Science, Korea).

**Assessment of Dietary Intake**

The daily energy and nutritional intake were assessed using the semiquantitative food frequency questionnaire (FFQ). The KNHANES validated the FFQ, which consists of 112 food items (Kim et al., 2015; Park et al., 2020). As for the assessment of the usual diet for participants, the semiquantitative FFQ was measured twice, before and after the intervention. The intake categories of food items were followed as never, once a month, 2 to 3 times a month, once a week, 2 to 4 times a week, 5 to 6 times a week, once a day, twice a day, and thrice a day. To compute daily nutritional intake, the frequency of intake was converted to several intakes per day.

**Statistical Analysis**

For this study, data processing and analysis were performed by SPSS 20.0 Statistics (SPSS Inc., Chicago, IL) and SAS statistical software (version 9.4; SAS Institute Inc., Cary, NC). The baseline characteristics of the participants were presented as percentages or the mean ± standard deviation to check for differences between 2 groups. A chi-squared test and Student’s t-test were applied for categorical and continuous variables, respectively. Fisher’s exact test was performed instead of the chi-squared test if more than 20% of cells had expected frequencies of <5. Paired t-test or Wilcoxon signed rank test (when cases did not have normal distribution after Shapiro-Wilk test) were applied to detect changes in pre- and post-anthropometrics, blood components, and nutritional intake within each group, whereas a Student’s t-test was applied to analyze the differences in delta values between the groups. In addition, Linear mixed models were applied to determine the effects attributed to differences by group, time (before and after intervention), and group-by-time interaction.
RESULTS

General Characteristics

A total of 121 participants were randomly assigned into 2 groups after screening, and the final 8-wk sample included 96 participants who were overweight (Figure 1). Table 1 shows the baseline characteristics of the participants who were analyzed. The milk group had 28 males (58.3%), whereas the control group had 29 males (60.4%). The average age of the subjects in both groups was 27.3. In terms of residential characteristics, the number of participants who were unmarried, living with family, was the highest in both groups, at 27 (56.2%) in the milk group and 28 (58.3%) in the control group. With regard to the income level, the prevalence of subjects with >5 million KRW income (>US$3,750) was the highest in both groups; 18 for the milk group (37.5%) and 20 for the control group (41.7%), followed by 3 million KRW to <5 million KRW (US$2,250 to <3,750), 1 million KRW to <3 million KRW (US$750 to <2,250), and <1 million KRW (<US$750). As for smoking status, the number of nonsmokers was the highest in both groups, with 45 in the milk group (93.8%) and 38 in the control group (79.2%), whereas the number of current smokers was 2 in the milk group (4.2%) and 9 (18.8%) in the control group. Both groups had the highest current number of drinkers in terms of alcohol consumption, with 39 (81.2%) in the milk group and 38 (79.2%) in the control group. In both groups, sleeping time was broken into 4 categories, with the highest number sleeping 5 to 7 h, followed by 7 to 9 h, <5 h, and >9 h. We observed 30 participants in the milk group (62.5%) and 29 in the control group (60.4%) for the first category. As for regular exercise, the number of participants who exercised regularly was 41.7% in the milk group and 50.0% in the control group. No significant baseline differences were reported between the groups for general characteristics. We detected no significant variation in physical activity between the milk and control groups before and after the intervention.

Anthropometric Measures and Biochemical Profile

The results for anthropometric measurement and blood analysis for both groups are presented in Table 2. In the milk group, BW (75.21 ± 8.79 to 74.41 ± 9.29 kg, \( P = 0.029 \)) and BMI (26.52 ± 2.11 to 26.24...
± 2.33 kg/m², \( P = 0.027 \) before and after intervention decreased significantly. However, compared with the control group, 8-wk milk intervention had no effect on reducing BW and BMI in Korean adults who were overweight (\( P = 0.243 \) for the difference of weight change and \( P = 0.258 \) for the difference of BMI change between the 2 groups, respectively). In the milk group, a nonsignificant difference was detected in the percentage of body fat from baseline to 8 wk, but the control group reported a significant increase from 20.39\% to 21.44\% (\( P = 0.002 \)) with no significant difference between the groups in delta values. With regard to total protein, albumin, SGOT, and SGPT levels, we detected no significant differences after 8 wk in both groups. In the milk group, we observed no significant change in total cholesterol level, but in the control group, total cholesterol significantly (\( P = 0.008 \)) decreased (190.98 ± 32.76 to 183.81 ± 37.91 mg/dl) showing no significant difference between the groups in delta values. High-density lipoprotein cholesterol significantly increased by 3.48 mg/dl from 55.10 to 58.58 mg/dl in the milk group (\( P = 0.004 \)), whereas a nonsignificant reduction was reported in the control group, resulting in a significant delta value difference between the 2 groups (\( P = 0.021 \)). The milk group showed nonsignificant reductions in TG and hs-CRP, while calcium levels were significantly increased (\( P = 0.43 \)) across both groups. The difference between both groups in delta values of calcium concentrate was statistically significant (\( P = 0.41 \)). In addition, using linear mixed models (Supplemental Table S1, https://figshare.com/s/fd66c97edd1c80228f1a), the results of group × time interaction analysis showed that body fat was decreased (\( P = 0.019 \)), but HDL-C (\( P = 0.022 \)) and serum calcium (\( P = 0.041 \)) in the milk group compared with the control group.

**Nutritional Intake**

Table 3 shows the nutritional intake in milk and the control groups. In the control group, total calorie intake decreased significantly (\( P = 0.004 \)) from 2,597.90 to 2,162.03 kcal, whereas the difference between groups in delta values was not significant. The amount of carbohydrate intake in both groups was reduced significantly (milk, \( P = 0.011 \)) and (control, \( P = 0.003 \)) with no significant difference between treatments in delta values. In the milk and the control groups, we observed nonsignificant (92.18 to 85.12 g) and significant (17.16 g from 109.30 to 92.14 g, \( P = 0.022 \)) reductions in the protein levels, respectively, with no significant delta value difference between treatments. Calcium intake was significantly increased by

### Table 2. Comparison of anthropometric measures and biochemical analysis before and after the intervention

<table>
<thead>
<tr>
<th>Item</th>
<th>Milk (n = 48)</th>
<th>Control (n = 48)</th>
<th>Δ Group comparison</th>
<th>Before</th>
<th>After</th>
<th>Before</th>
<th>After</th>
<th>Δ Group comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>75.21 ± 8.79</td>
<td>74.41 ± 9.29</td>
<td>0.029</td>
<td>73.38 ± 10.59</td>
<td>73.01 ± 10.69</td>
<td>0.243</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>26.52 ± 2.11</td>
<td>26.32 ± 2.43</td>
<td>0.373</td>
<td>25.77 ± 2.13</td>
<td>25.63 ± 2.53</td>
<td>0.059</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>22.74 ± 5.56</td>
<td>22.64 ± 5.86</td>
<td>0.573</td>
<td>20.39 ± 6.82</td>
<td>20.14 ± 7.33</td>
<td>0.059</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total protein (g/dL)</td>
<td>7.56 ± 0.37</td>
<td>7.54 ± 0.38</td>
<td>0.384</td>
<td>7.54 ± 0.39</td>
<td>7.55 ± 0.37</td>
<td>0.059</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Albumin (g/dL)</td>
<td>4.94 ± 0.26</td>
<td>4.94 ± 0.26</td>
<td>0.573</td>
<td>4.96 ± 0.27</td>
<td>4.97 ± 0.27</td>
<td>0.059</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGOT (IU/L)</td>
<td>20.73 ± 11.64</td>
<td>20.85 ± 13.36</td>
<td>0.573</td>
<td>20.81 ± 12.76</td>
<td>20.82 ± 14.57</td>
<td>0.059</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGPT (IU/L)</td>
<td>24.58 ± 20.28</td>
<td>24.69 ± 20.38</td>
<td>0.573</td>
<td>24.68 ± 20.49</td>
<td>24.70 ± 22.64</td>
<td>0.059</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total C (mg/dL)</td>
<td>191.67 ± 32.34</td>
<td>192.58 ± 34.38</td>
<td>0.573</td>
<td>190.98 ± 32.76</td>
<td>191.37 ± 34.64</td>
<td>0.059</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HDL-C (mg/dL)</td>
<td>55.10 ± 11.30</td>
<td>55.20 ± 11.41</td>
<td>0.573</td>
<td>54.81 ± 12.31</td>
<td>54.90 ± 12.41</td>
<td>0.059</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TG (mg/dL)</td>
<td>110.77 ± 70.40</td>
<td>107.96 ± 91.10</td>
<td>0.573</td>
<td>95.08 ± 44.75</td>
<td>125.84 ± 194.04</td>
<td>0.059</td>
<td></td>
<td></td>
</tr>
<tr>
<td>hs-CRP (mg/L)</td>
<td>1.78 ± 4.83</td>
<td>1.78 ± 4.83</td>
<td>0.573</td>
<td>1.80 ± 4.90</td>
<td>1.80 ± 4.90</td>
<td>0.059</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calcium (mg/dL)</td>
<td>9.66 ± 0.38</td>
<td>9.72 ± 0.43</td>
<td>0.573</td>
<td>9.74 ± 0.34</td>
<td>9.74 ± 0.34</td>
<td>0.059</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Values are presented as mean ± SD. BMI = body mass index; SGOT = serum glutamic-oxaloacetic transaminase; SGPT = serum glutamate-pyruvate transaminase; Total C = total cholesterol; HDL-C = high-density lipoprotein cholesterol; TG = triglyceride; hs-CRP = high-sensitivity C-reactive protein. Differences of before and after intervention within each group were evaluated by paired t test or Wilcoxon signed rank test (when cases did not have normal distribution/Shapiro-Wilk). Differences of delta values between groups were evaluated by Student’s t test.
256.44 mg (501.45 to 757.89 mg) in the milk group ($P = 0.000$), and a nonsignificant decrease (523.14 to 474.86 mg) was observed in the control group, resulting in a significant delta value difference between treatments ($P = 0.000$). For phosphorus, a nonsignificant increase from 1,160.66 to 1,222.13 mg in the milk group and a significant decrease from 1,326.25 to 1,127.44 mg in the control group were reported, respectively, with a significant delta difference between groups ($P = 0.015$). The amount of iron was significantly decreased in the milk ($P = 0.017$) and control ($P = 0.025$) groups, with a nonsignificant delta difference between groups. As far as thiamine intake is concerned, a significant reduction in the control group was detected (2.70 ± 1.57 to 2.24 ± 1.03 mg/d; $P = 0.008$) with no significant delta value difference between treatments ($P = 0.000$). For riboflavin, a significant ($P = 0.013$) increase in the milk group (1.64 ± 0.88 to 1.87 ± 0.61 mg/d) was reported with a significant delta value difference between the 2 groups, but calcium, phosphorus, vitamin A, and riboflavin showed a significant delta value difference between the 2 groups.

**DISCUSSION**

In this study, we found that there were no significant differences in changes of weight and BMI between the milk and control groups in Korean adults who were overweight after 8-wk intervention, although reductions in weight and BMI were observed in the milk group. As for the biomarkers and nutrient intakes, the milk group exhibited a significant increment in HDL-C and serum calcium levels and nutrient intakes, including calcium, phosphorus, vitamin A, and riboflavin, compared with the control group. In contrast, the control group showed a significant increase in body fat and a decrease in serum total cholesterol following the intervention. Only serum HDL cholesterol, serum calcium, and body fat displayed a significant group (milk vs. control) × time (before-after) interaction.

We observed evidence showing that milk or dairy product consumption has a favorable effect on obesity. However, a few studies have indicated the opposite (Du et al., 2004; Berkey et al., 2005; DeBoer et al., 2015; Dubois et al., 2016). Geng et al. (2018) suggested that these disparities are most likely attributable to sample size differences, diverse population categories, and different experimental study designs and durations. A

<table>
<thead>
<tr>
<th>Item</th>
<th>Before</th>
<th>After</th>
<th>Δ Group comparison</th>
<th>P-value² Before</th>
<th>P-value² After</th>
<th>Δ Group comparison P-value²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total calories (kcal/d)</td>
<td>2,200.00 ± 1,124.49</td>
<td>1,820.68 ± 608.78</td>
<td>0.203</td>
<td>2,597.90 ± 1,270.59</td>
<td>2,162.03 ± 875.59</td>
<td>0.004</td>
</tr>
<tr>
<td>Carbohydrate (g/d)</td>
<td>307.75 ± 156.32</td>
<td>256.28 ± 111.98</td>
<td>0.011</td>
<td>357.47 ± 159.08</td>
<td>292.14 ± 127.76</td>
<td>0.003</td>
</tr>
<tr>
<td>Protein (g/d)</td>
<td>92.18 ± 59.76</td>
<td>85.12 ± 37.37</td>
<td>0.545</td>
<td>109.30 ± 65.96</td>
<td>92.14 ± 41.55</td>
<td>0.022</td>
</tr>
<tr>
<td>Fat (g/d)</td>
<td>61.99 ± 39.43</td>
<td>63.36 ± 26.57</td>
<td>0.222</td>
<td>74.70 ± 46.96</td>
<td>64.64 ± 32.51</td>
<td>0.000</td>
</tr>
<tr>
<td>Calcium (mg/d)</td>
<td>501.45 ± 299.07</td>
<td>757.89 ± 150.82</td>
<td>0.000</td>
<td>523.14 ± 300.33</td>
<td>474.86 ± 229.36</td>
<td>0.000</td>
</tr>
<tr>
<td>Phosphorus (mg/d)</td>
<td>1,160.66 ± 668.47</td>
<td>1,222.13 ± 397.62</td>
<td>0.121</td>
<td>1,326.25 ± 723.16</td>
<td>1,127.44 ± 482.85</td>
<td>0.025</td>
</tr>
<tr>
<td>Iron (mg/d)</td>
<td>14.80 ± 8.75</td>
<td>12.49 ± 5.54</td>
<td>0.017</td>
<td>16.54 ± 9.69</td>
<td>14.19 ± 6.51</td>
<td>0.025</td>
</tr>
<tr>
<td>Sodium (mg/d)</td>
<td>4,225.61 ± 2,937.28</td>
<td>3,641.98 ± 1,895.05</td>
<td>0.117</td>
<td>4,839.37 ± 3,694.95</td>
<td>4,169.86 ± 2,267.02</td>
<td>0.068</td>
</tr>
<tr>
<td>Potassium (mg/d)</td>
<td>2,599.54 ± 1,533.45</td>
<td>2,659.96 ± 971.17</td>
<td>0.383</td>
<td>3,003.70 ± 1,470.72</td>
<td>2,680.65 ± 1,411.13</td>
<td>0.068</td>
</tr>
<tr>
<td>Vitamin A (μg RE/d)</td>
<td>587.37 ± 361.92</td>
<td>643.85 ± 254.04</td>
<td>0.193</td>
<td>689.73 ± 469.72</td>
<td>589.05 ± 321.63</td>
<td>0.024</td>
</tr>
<tr>
<td>Thiamine (mg/d)</td>
<td>2.21 ± 1.40</td>
<td>1.92 ± 0.82</td>
<td>0.000</td>
<td>2.70 ± 1.03</td>
<td>2.24 ± 0.61</td>
<td>0.008</td>
</tr>
<tr>
<td>Riboflavin (mg/d)</td>
<td>1.64 ± 0.88</td>
<td>1.87 ± 0.61</td>
<td>0.013</td>
<td>1.88 ± 1.12</td>
<td>1.62 ± 0.73</td>
<td>0.001</td>
</tr>
<tr>
<td>Niacin (mg/d)</td>
<td>17.23 ± 11.56</td>
<td>14.98 ± 7.24</td>
<td>0.166</td>
<td>20.48 ± 12.63</td>
<td>17.63 ± 8.56</td>
<td>0.063</td>
</tr>
<tr>
<td>Vitamin C (mg/d)</td>
<td>46.49 ± 30.27</td>
<td>44.31 ± 20.81</td>
<td>0.541</td>
<td>48.80 ± 32.82</td>
<td>46.08 ± 25.19</td>
<td>0.078</td>
</tr>
</tbody>
</table>

Table 3. Comparison of nutritional intake before and after the intervention

1Values are presented as mean ± SD.

2Differences of before and after intervention within each group were evaluated by paired t-test or Wilcoxon signed rank test (when cases did not have a normal distribution/Shapiro-Wilk).

3Differences of delta values between groups were evaluated by Student’s t-test.
Despite the discrepancies among previous studies, this finding did not show a clear relationship between reduced BW and BMI with milk consumption. However, it did demonstrate a trend that is consistent with the majority of previous evidence. It has been known that calcium, whey protein, short- and medium-chain fatty acids, and conjugated linoleic acid are bioactive components in milk that are beneficial for obesity (Tsuboyama-Kasaoka et al., 2000; Zemel et al., 2000; Jakubowicz and Froy, 2013; Dugan and Fernandez, 2014; Kasubuchi et al., 2015; Dougkas et al., 2019). Among these components in milk, considerable evidence indicated that dietary calcium can reduce BW and BMI (Dugan and Fernandez, 2014; Dougkas et al., 2019). A previous observational study based on KNHANES (2007–2009) showed that a high intake of dairy products is associated with a lower prevalence of obesity in Korean adults aged 19 to 64 yr old, with calcium in dairy products being one of the contributing factors (Lee et al., 2014).

Two previous studies (Lukaszuk et al., 2007; Faghih et al., 2011) with the same duration of intervention and the same calorie restriction reported higher weight loss compared with our study. In Lukaszuk’s study, the weight loss was −4.27 kg for the soy milk group and −3.76 kg for the skim milk group. In Faghih’s study, the weight loss was −4.43 kg for the low-fat milk group and −2.87 kg for the control group. However, the weight loss in this study was pretty low (−0.79 kg for milk and −0.37 kg for control), which was not significantly different between the milk and the control groups. The possible reasons for these results could be due to demographic differences, such as the method of intervention, higher mean ages, higher baseline BMI, and a much smaller sample size than this study (Lukaszuk et al., 2007; Faghih et al., 2011). In addition, the intervention types and volumes were soy milk at 720 mL/d for Lukaszuk’s study and low-fat milk at 220 mL/d for Faghih's study (Lukaszuk et al., 2007; Faghih et al., 2011). Another study examined the effects of a high-calcium diet combined with resistance exercise and a moderate energy restriction on the body composition of overweight-postmenopausal women with higher BMI compared with this study. The combined treatment had no significant effect on body fat reduction (Thomas et al., 2010). Despite the significantly higher intakes of calcium after milk intervention, no significant effect on weight reduction was observed in our study, which corroborates the finding of Thomas et al. (2010). Another intervention study of 1-yr duration corroborated our study results. The study on young and healthy women showed that increased intake of dairy products and calcium has no effect on fat mass or BW (Gunther et al., 2005). Similar to our study, an intervention study by Wennersberg et al. (2009) on middle aged–overweight subjects found no significant changes in BW or body composition in the milk and control groups. Additionally, past systematic research has only weakly supported the effect of dairy consumption on BW and fat loss (Barr, 2003; Lanou and Barnard, 2008).

Recent research has reported that dairy matrix components, including calcium, peptides, phosphorus, and the milk fat globule membrane, can improve blood lipid profiles (Thorning et al., 2017; Feeney et al., 2018; Weaver, 2021). It is widely accepted that obesity is associated with lower HDL-C levels, which is a known risk factor for cardiovascular disease (Bora et al., 2017; Stadler and Marsche, 2020). In our study, a significant increase in HDL-C levels was observed with a significant difference between the 2 groups. The results are in contrast to an earlier intervention study where no significant differences were observed for HDL-C between milk and control groups (Wennersberg et al., 2009). Therefore, HDL-C increase from milk supplementation in our study may have health benefits.

Furthermore, both the milk and control groups showed increases in body fat, but no significant difference (P = 0.059) was observed between the 2 groups. Our subjects were requested to reduce 500 kcal/d during the intervention. The control group, however, witnessed a significant (P = 0.002) increase in body fat before and after intervention (Table 2). It could be due to a metabolic switch to compensate for the reduced energy availability (Bruss et al., 2010). However, a substantial difference between the milk and control groups was revealed using a linear mixed model analysis, possibly as a result of the employment of different analytical methods (Supplemental Table S1, https://figshare.com/s/ff66c97edd1c8028f1a).

Concerning nutritional intakes, the changes for calcium, phosphorus, vitamin A, and riboflavin were found to be significantly higher in the milk group compared with the control. In our study, despite a significant increase in calcium intake after milk intervention, no significant changes have been observed for BW and BMI. Many previous studies have supported no association between the nutrient calcium and BW and fat mass reductions (VENTI et al., 2005; MURAKAMI et al., 2006; RAJPATHAK et al., 2006). However, our findings are consistent with a recent cross-sectional study on Japanese
female junior high school students that looked at the association between milk consumption and vitamin and mineral adequacy. They discovered that participants who consumed more milk had more vitamin B2, calcium, potassium, and magnesium (Matsumoto et al., 2021). Interestingly, a recent cross-sectional study discovered that low riboflavin intake was associated with central obesity in postmenopausal Korean women (Shin and Kim, 2019). A previous in vitro study indicated that riboflavins reduce the proinflammatory-inflammatory activity of adipocyte and macrophage cocultures, suggesting the potential role of riboflavin against obesity (Mazur-Bialy and Poché, 2016). However, the beneficial role of riboflavin on obesity is required to be verified via future well-designed clinical trials.

The strengths of the present study are the randomization of participants into groups, everyday monitoring of milk intake, and calorie restriction, and keeping track of physical activity patterns through text messages more than once a week. However, we still detected several limitations to the present study, such as its short duration and potential performance bias. Although we provided education on the assessment of food intake amounts, the dietary assessment used in this study may not accurately reflect the actual amount of food consumed. Future studies should include a diverse Korean population, including older subjects. The assessment of physical activity in this study was conducted qualitatively, but it will be necessary to measure it accurately and quantitatively. In this study, the possibility of the effect of cow milk on obesity was demonstrated in Korean adults via the first randomized intervention design; however, 8-wk milk consumption was not associated with obesity reduction but improved some biomarkers and nutrient levels in the Korean population. More research is needed to further understand the effect of milk consumption on obesity in the Korean population.

**CONCLUSIONS**

This is the first intervention study to evaluate the effect of commercial cow milk intake on obesity in Korean adults. The main finding of the study is that milk intake twice a day was not significantly associated with reductions in weight and BMI during 8-wk intervention. The milk group's HDL-C level and serum calcium were higher, with a significant delta value difference between the milk and control groups. Body fat, serum HDL-C, and serum calcium showed significant group × time (before-after) interactions. Furthermore, calcium, phosphorus, vitamin A, and riboflavin intakes were significantly different between the 2 groups after the intervention. Conclusively, the 8-wk milk intervention was not associated with obesity reduction but showed health benefits by improving some biomarkers and nutrient levels in the Korean population. More research on long intervention durations, and a large sample pool is needed to further understand the effect of milk consumption on obesity in the Korean population.

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