RESEARCH PAPER

The effect of low-fat versus whole-fat dairy product intake on blood pressure and weight in young normotensive adults

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Introduction

Hypertension is a leading public health problem, affecting more than one in four adults both in developing and developed countries (37% in the UK) (Primatesta et al., 2001; Kearney et al., 2005). It accounted for more than 7 million deaths worldwide in 2001 alone (Lopez et al., 2006). Dietary factors have been linked to the risk of developing hypertension (Appel et al., 2006). Current dietary recommendations for the prevention of hypertension suggest reducing intake of alcohol and sodium, increasing potassium intake, and following a dietary pattern rich in fruits, vegetables and low-fat dairy products, and reduced in total and saturated fats (Appel et al., 2006). This dietary pattern, named DASH after the Dietary Approaches to Stop Hypertension trial, has proven to be effective in

Keywords

blood pressure, dairy, randomised trial, weight change.

Abstract

Background: Epidemiologic and experimental studies suggest that higher intake of dairy products could be associated with lower risk of hypertension and obesity. Differences in nutrient composition of distinct dairy products suggest that their effect on these outcomes might be heterogeneous. However, little experimental research has examined the potentially different effects of low- and whole-fat dairy products on blood pressure (BP) and weight change. The present study aimed to assess whether supplementing diets with low- or whole-fat dairy products would differentially affect BP levels and weight.

Methods: A randomised crossover trial in 45 normotensive volunteers (18–24 years old, 49% female) was conducted. Participants alternatively received 3.5 servings/day of whole-fat or low-fat dairy products (milk and yogurt) in addition to their usual diet during two 8-week periods, with a 4-week washout period between both interventions. Weight and BP were measured at the beginning and end of each intervention.

Results: Whole-fat dairy supplementation significantly increased systolic BP [2.1 mmHg, 95% confidence interval (CI) = 0.1–4.0, \( P = 0.04 \)] and weight (1.0 kg, 95% CI = 0.5–1.5, \( P = 0.0002 \)), but not diastolic BP (\( P = 0.34 \)). Weight and BP did not change significantly after the low-fat dairy intervention (\( P > 0.10 \)). There were no significant differences in the effect of low-fat or whole-fat dairy products on BP (\( P > 0.60 \)), but whole-fat dairy increased weight significantly compared to low-fat dairy (1.2 kg, 95% CI = 0.5–1.8, \( P = 0.0007 \)).

Conclusions: In a young nonhypertensive population, dietary supplementation with whole-fat dairy products, compared to low-fat dairy, was associated with weight gain. No differential effects were observed for levels of BP.
reducing blood pressure (BP) levels in normotensive and hypertensive individuals (Appel et al., 1997). A few studies have assessed a potential independent effect of low-fat dairy products on blood pressure (Buonopane et al., 1992; Barr et al., 2000). However, there is no experimental evidence available indicating that low-fat dairy product intake reduces blood pressure in comparison with whole-fat dairy products and independently of other dietary components.

Several observational prospective studies have shown that individuals with a high intake of dairy products have a lower risk of developing hypertension (Pereira et al., 2002; Alonso et al., 2005; Moore et al., 2005). It has not been well established, however, whether any type of dairy or only low-fat dairy products would have a beneficial effect on BP. Indeed, high levels of saturated fat in whole-fat dairy foods could prevent the positive effects of other BP-lowering nutrients present in these products (Djoussé et al., 2006).

Dairy products are also of research interest for their potentially favourable effect on weight change, mainly through their calcium content (Zemel, 2005). Experimental studies of calcium supplementation indicate that lower weight gain is associated with a higher intake of calcium (Eagan et al., 2006), particularly among individuals with previous low calcium intake (Caan et al., 2007). However, the overall evidence regarding the role of dairy products is not clear (Barr, 2003), especially if we consider the important amount of saturated fats contained in whole-fat dairy products. For example, a recent study conducted in the USA showed that cheese consumption was associated with a higher body mass index (BMI) in men (but not in women) (Houston et al., 2008).

To determine whether low-fat dairy foods are more effective than whole-fat dairy foods in reducing BP levels, a cross-over trial was conducted in which young normotensive volunteers supplemented their diets with low-fat or whole-fat dairy products. As a secondary objective, the effect of both interventions on body weight was assessed.

Materials and methods

Study participants and design
During September and October 2006, 55 college students (28 male and 27 female) at the University of Navarra (Pamplona, Spain), aged 18–24 years, residing in two student residences, were invited to participate in a trial to assess the effect of the intake of whole-fat versus low-fat dairy products on BP. Individuals with a BMI higher than 30 kg m$^{-2}$, or reporting a diagnosis of hypertension, previous history of cardiovascular disease, severe gastrointestinal disease, diabetes, or lactose intolerance, were excluded. After applying exclusion criteria and refusals to participate, 48 volunteers were included in the study; however, one developed gastrointestinal symptoms and two withdrew voluntarily from the study, leaving 45 who completed the entire protocol.

The trial had a block-randomised crossover design. After recruitment, participants were randomly assigned to supplement their diets with whole-fat or low-fat dairy products for 8 weeks. Following a washout period of 4 weeks, during which they were advised not to consume dairy products, they received the alternative intervention for another 8 weeks (Fig. 1).

Study participants received a small monetary compensation at the end of the study for their collaboration. The Institutional Review Board at the University of Navarra approved the study protocol (protocol number 116/2006). Participants provided their individual written informed consent before they were enrolled.

Intervention
After randomisation, the dining services in the participant’s residence supplied them with 3.5 servings (serving size: 250 g) of whole-fat or low-fat dairy products each day (three servings of milk, half a serving of yogurt). Participants were advised to consume the supplied food during the day and to avoid intake of dairy products from other sources, but not to change their usual diet or lifestyle in other ways (Sánchez-Villegas et al., 2003). Additional efforts to maintain total energy intake constant were not made. Nutrient composition of the two dairy product supplements is provided in Table 1. To assess intervention compliance, the participants recorded their intake of dairy products on a daily basis in a dietary record. In addition, they completed a self-administered food frequency questionnaire (136 items) before and after each intervention period (see below).

![Figure 1: Crossover trial design and profile. BP, blood pressure measurement; FFQ, dietary assessment (self-administered food frequency questionnaire).](image-url)
Table 1 Average nutrient composition of dairy product supplements (per day)

<table>
<thead>
<tr>
<th></th>
<th>Whole-fat dairy products</th>
<th>Low-fat dairy products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Servings</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Energy (kJ)</td>
<td>2177</td>
<td>1357</td>
</tr>
<tr>
<td>Protein (g)</td>
<td>28</td>
<td>31</td>
</tr>
<tr>
<td>Carbohydrates (g)</td>
<td>40</td>
<td>46</td>
</tr>
<tr>
<td>Total fat (g)</td>
<td>31</td>
<td>3</td>
</tr>
<tr>
<td>Saturated fats (g)</td>
<td>19</td>
<td>2</td>
</tr>
<tr>
<td>Polyunsaturated fats (g)</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Monounsaturated fats (g)</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>Vitamin D (µg)</td>
<td>0.3</td>
<td>0.01</td>
</tr>
<tr>
<td>Calcium (mg)</td>
<td>976</td>
<td>1136</td>
</tr>
<tr>
<td>Potassium (mg)</td>
<td>1304</td>
<td>1598</td>
</tr>
<tr>
<td>Sodium (mg)</td>
<td>395</td>
<td>245</td>
</tr>
<tr>
<td>Magnesium (mg)</td>
<td>109</td>
<td>236</td>
</tr>
</tbody>
</table>

Outcome and other covariates assessment

A member of the study group, who was blinded to the intervention assignment, measured BP and weight at the beginning and end of each intervention period. BP was measured using an Omron 705-IT automatic oscillometer (Coleman et al., 2006). After resting for 5 min, six BP measurements were taken (three in the left arm and three in the right), with the participant in seated position. The participant’s BP for that visit was an average of the last five measurements. Weight was measured using a validated scale with a precision equal to 0.1 kg.

The study visits also included dietary and physical activity evaluations. Diet was assessed using a semi-quantitative food frequency questionnaire, previously validated in a Spanish population (Martínez-González et al., 1993). The questionnaire included 136 items, of which 15 related to dairy products (whole-fat milk, partially skim milk, skim milk, sweetened condensed milk, whipped cream, yogurt, fat-free yogurt, milkshake, cottage cheese or junket, petit Suisse cheese, spreadable cheese wedges, soft fresh cheese, other cheese, custard, and ice cream). The questionnaire allowed for nine different frequencies of intake (from never or almost never to more than six times a day). For the physical activity assessment, information on involvement in and time spent on 17 different leisure-time activities was collected using a validated questionnaire (Ainsworth et al., 2000; Martinez-González et al., 2005).

Statistical analysis

Study sample size was estimated assuming a two-tailed alpha error probability of 5%, a within-individual standard deviation of 9 mmHg for the difference in systolic BP change after the two interventions and a statistical power of 80% to detect differences of 4 mmHg or higher between the interventions. Using these assumptions, the estimated sample size was 42.

The main outcome variables were changes in systolic and diastolic BP, and changes in weight after each intervention. Comparisons between the two interventions were performed using a paired Student’s t-test. To adjust for potential confounders and to evaluate the presence of interactions and period or sequence effects, a general mixed linear model applying proc mixed in SAS was used. The model included interaction terms or indicator variables for period and sequence, and the variables: BMI, physical activity, sodium intake, and fruits and vegetables intake. Statements about statistical significance refer to the conventional 0.05 cut-off point.

Results

Compliance with the intervention, as assessed by the self-reported dietary record, was excellent. Study participants, on average, consumed their corresponding dairy product supplement on more than 95% of the intervention days. The characteristics of the participants who finished the study are shown in Table 2.

Table 2 Characteristics of study participants at baseline

<table>
<thead>
<tr>
<th></th>
<th>Total sample (n = 45)</th>
<th>Group receiving first WFD (n = 23)</th>
<th>Group receiving first LFD (n = 22)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>19.9 (1.5)</td>
<td>19.9 (1.4)</td>
<td>19.9 (1.6)</td>
</tr>
<tr>
<td>Sex (% female)</td>
<td>48.9</td>
<td>52.2</td>
<td>45.5</td>
</tr>
<tr>
<td>BMI (kg m⁻²)</td>
<td>23.5 (3.6)</td>
<td>23.4 (3.5)</td>
<td>23.7 (3.7)</td>
</tr>
<tr>
<td>Physical activity (METs – h week⁻¹)</td>
<td>38.4 (32.7)</td>
<td>39.1 (36.1)</td>
<td>37.7 (29.6)</td>
</tr>
<tr>
<td>Total energy intake (kJ day⁻¹)</td>
<td>9094 (3555)</td>
<td>8826 (3739)</td>
<td>9374 (3412)</td>
</tr>
<tr>
<td>Systolic BP (mmHg)</td>
<td>117.7 (10.8)</td>
<td>118.5 (11.3)</td>
<td>116.9 (10.5)</td>
</tr>
<tr>
<td>Diastolic BP (mmHg)</td>
<td>68.7 (6.7)</td>
<td>68.6 (6.2)</td>
<td>68.7 (7.3)</td>
</tr>
<tr>
<td>Intake of</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcohol (g day⁻¹)</td>
<td>1.9 (3.2)</td>
<td>1.9 (2.5)</td>
<td>1.9 (3.9)</td>
</tr>
<tr>
<td>Sodium (g day⁻¹)</td>
<td>4.1 (2.3)</td>
<td>3.7 (2.2)</td>
<td>4.5 (2.4)</td>
</tr>
<tr>
<td>Calcium (g day⁻¹)</td>
<td>1.1 (0.4)</td>
<td>1.1 (0.4)</td>
<td>1.1 (0.4)</td>
</tr>
<tr>
<td>Fruits and vegetables (servings day⁻¹)</td>
<td>2.9 (2.3)</td>
<td>2.8 (1.8)</td>
<td>3.2 (2.7)</td>
</tr>
<tr>
<td>Total dairy products (g day⁻¹)</td>
<td>491.6 (198.0)</td>
<td>519.5 (212.7)</td>
<td>462.4 (181.5)</td>
</tr>
<tr>
<td>Low-fat dairy products (g day⁻¹)</td>
<td>117.1 (156.2)</td>
<td>100.0 (122.6)</td>
<td>135.0 (186.3)</td>
</tr>
</tbody>
</table>

Values correspond to the mean (SD) unless otherwise stated. BP, blood pressure; BMI, body mass index; WFD, whole-fat dairy product intervention; LFD, low-fat dairy product intervention.
whole-fat dairy product intake increased significantly during the whole-fat dairy product period supplementation and decreased when participants received low-fat dairy products. The opposite pattern was observed for the intake of low-fat dairy products. Increasing intake of low-fat dairy products did not significantly affect systolic or diastolic BP. During the low-fat dairy product intervention, there was a significant gain in body weight (Table 3). In a paired analysis, this gain was still apparent; weight increased 1.2 kg (95% CI = 0.5–1.8, P = 0.0007) during the whole-fat dairy product intervention compared to low-fat dairy product intervention. In addition, a significant increase in sodium intake after the whole-fat dairy product intervention (+1.2 g day⁻¹, 95% CI = 0.4–2.1, P = 0.005) was observed. Calcium intake increased similarly after both interventions (Table 3).

The results did not change after adjusting for BMI, physical activity, sodium intake and fruit and vegetables consumption at baseline. The effect of the intervention on BP or weight did not differ significantly by BMI, mean BP or saturated fat intake at the beginning of the trial. Finally, the analysis did not reveal statistically significant period or sequence effects for any of the observed outcomes.

### Discussion

The present study did not reveal any beneficial effect of dietary supplementation with low-fat dairy versus whole-fat dairy products on BP levels in a small group of young normotensive individuals. However, whole-fat dairy product supplementation was associated with a significant increase in weight compared to low-fat dairy supplementation.

The lack of an effect of low-fat dairy products on BP is at odds with previous research suggesting that intake of dairy products could decrease levels of BP. Dairy products are rich in calcium, potassium and magnesium, nutrients that have been connected to lower risk of hypertension or lower levels of BP in different studies (Appel et al., 1997; Sacks et al., 2001). In that study, a diet rich in fruits, vegetables and low-fat dairy products (i.e. the so-called DASH diet) was more effective in reducing BP than a diet only rich in fruits and vegetables. However, other characteristics of the DASH diet (i.e. reduction in total and saturated fat, lower intake of meat and fish) have been proven to be effective in inhibiting the angiotensin-converting enzyme, a protein implicated in BP control, and thus reducing BP (Jauhiainen & Korpela, 2007). One relevant piece of evidence supporting the potential beneficial effect of dairy products on BP comes from the DASH trial (Appel et al., 1997; Sacks et al., 2001). In that study, a diet rich in fruits, vegetables and low-fat dairy products (i.e. the so-called DASH diet) was more effective in reducing BP than a diet only rich in fruits and vegetables. However, other characteristics of the DASH diet (i.e. reduction in total and saturated fat, lower intake of meat...
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and sweets) could have been responsible for the observed effect on BP levels. Additionally, participants’ weight was kept constant by design, via changes in total energy intake, further impeding a comparison of the DASH trials with the present study.

Several prospective observational studies have shown a lower risk of developing hypertension among individuals with a higher intake of dairy products, especially low-fat products. In the Coronary Artery Risk Development In Young Adults (CARDIA) study, in which 3157 young adults were followed up for 10 years, the intake of dairy products was associated with a lower risk of developing elevated BP, particularly among overweight individuals (Pereira et al., 2002). After 15 years of follow up, milk intake was still associated with lower risk of developing elevated BP in the same cohort (Steffen et al., 2005). Similarly, among 5880 participants in the Seguimiento Universidad de Navarra (SUN) study, those with a higher intake of low-fat dairy products had a lower risk of reporting a medical diagnosis of hypertension. No association was observed for whole-fat dairy products (Alonso et al., 2005). Lastly, researchers from the Framingham Children’s Study reported a lower rise in BP after 8 years of follow up among children aged 3–6 at baseline who had two or more daily servings of dairy products (Moore et al., 2005).

Although the results reported in the present study are in disagreement with those obtained in previous observational studies, there are several reasons that might explain the apparently contradictory results. First, the study population had very low baseline BP values, making it difficult for a brief nonpharmacological intervention to produce a noticeable effect on BP in this population. Studying a population with prehypertension (systolic BP between 120–139 mmHg, diastolic BP between 80–89 mmHg) would have increased the chances of finding an effect on BP. Second, a short-term dietary intervention might not last long enough to have a significant effect on BP, although this has not been the case in other dietary trials, such as the DASH study, in which an 8-week intervention produced a noticeable and significant effect on BP (Appel et al., 1997). Third, the study sample had a high intake of dairy products at baseline, which could limit the study’s power to detect an effect of additional dairy products intake. Fourth, special efforts to maintain constant total energy intake and intake of other dietary components different from dairy products were not made. Particularly, significant increases in total energy intake and estimated sodium intake were observed after whole-fat dairy product supplementation. Nonetheless, given the limitations of food frequency questionnaires to determine dietary sodium (McKeown et al., 2001), it is not possible to determine the impact of these changes on the results of the study. It could also be hypothesised that dairy products could substitute other dietary components, such as fruits for dessert. But there were no significant changes in the intake of fruits and vegetables, a major determinant of BP (John et al., 2002; Appel et al., 2006). Finally, it is conceivable that dairy products did not have a beneficial effect on BP and the results from observational studies were confounded by other lifestyle factors: individuals with a higher intake of low-fat dairy products adhere, in general, to healthier lifestyles and, therefore, have a lower risk of developing hypertension (National High Blood Pressure Education Program Working Group, 1993). Although published observational studies used multivariate regression procedures to adjust their estimates for potential confounding variables, residual confounding could still explain the reported protective association between dairy products and hypertension.

Dairy product intake, too, has been linked to lower weight or reduced weight gain in some, but not all, prospective studies. Several biological mechanisms have been advanced to explain how nutrients present in dairy products, including calcium and whey proteins, could favour weight loss (Zemel, 2005). Intracellular calcium stimulates lipogenesis and inhibits lipolysis, resulting in increased adiposity in animal models and humans (Zemel, 2003). A major determinant of intracellular calcium levels is circulating vitamin D, which enhances the inflow of calcium to the intracellular space. Low intake of calcium increases circulating vitamin D levels, resulting in higher intracellular calcium and pro-lipogenic state. The opposite pattern would be seen with high calcium intake (Zemel et al., 2000). The angiotensin-converting enzyme inhibitory activity of some peptides and the high concentration of branched amino acids present in dairy products could also contribute to reduced adiposity (Zemel, 2005). Additionally, there is experimental evidence supporting a role for calcium in weight control. In the Women’s Health Initiative trial, supplementation with calcium and vitamin D was associated with lower weight gain, particularly among women with low calcium intake at baseline (Caan et al., 2007). Similarly, in a randomised trial conducted in 32 obese adults, higher calcium intake boosted weight loss associated with caloric restriction (Zemel et al., 2004). Results from other trials, as well as observational studies, have not been consistent, however, and fail to provide clear proof of the possible weight reducing effect of dairy products (Barr, 2003; Macdonald et al., 2003; Shapses et al., 2004; Rajpathak et al., 2006; Rosell et al., 2006).

By contrast to some previous experimental studies in obese individuals (Zemel et al., 2004; Caan et al., 2007), whole-fat dairy product supplementation was associated with weight gain in the present study. Higher intake of saturated fats, abundant in whole-fat dairy products, in addition to higher energy intake not compensated by an
increase in physical activity or a reduced intake of other foods, could explain the observed weight gain and the elevation in systolic BP. Indeed, saturated fat intake has been associated with a higher likelihood of weight gain in some populations (Field et al., 2007), although the evidence supporting this association is scarce.

The present study has several limitations. The sample size was relatively small and, thus, insufficient to detect an effect similar to that found in the DASH trial (2.7 mmHg comparing the DASH diet and the diet rich in fruits and vegetables) (Appel et al., 1997). Additionally, as mentioned previously, the study participants had low baseline BP, making it extremely difficult to produce a significant reduction on BP through nonpharmacological means. Furthermore, the trial did not include a run-in period at the beginning of the study in which participants reduced their dairy product intake. Attempts to maintain total energy intake constant during the trial were not made. This fact could explain the higher caloric intake and the consequent weight increase during the phase of whole-fat dairy product supplementation. Finally, the study was not designed to test whether dairy (whole or low-fat) products would have a beneficial effect on BP or weight compared to other foods and beverages, such as sweetened beverages or meat. However, the study design offers some advantages. First, the lower within-subject variability in a cross-over trial increases the statistical power and the probability of detecting any effect, if it exists. Second, the intervention was conducted in free living subjects, providing better generalisability of the present results.

In conclusion, this small cross-over trial did not reveal any comparative benefit of low-fat dairy compared with whole-fat dairy products on BP levels. However, the present results indicate a possible undesirable effect of whole-fat dairy product intake in some individuals, probably linked to elevated levels of saturated fats and high caloric content. To further clarify this topic, future research should be conducted on mild hypertensives who are not receiving medication or on populations with a higher risk of developing hypertension.

Acknowledgments

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Conflict of interests, source of funding and authorship

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References


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