Potent anti-obesity effect of enteric-coated lactoferrin: decrease in visceral fat accumulation in Japanese men and women with abdominal obesity after 8-week administration of enteric-coated lactoferrin tablets

Tomoji Ono1*, Michiaki Murakoshi1,2, Noriuki Suzuki1, Norio Iida1, Motoyasu Ohdera1, Masaaki Iigo3, Toshihide Yoshida2,4, Keikichi Sugiyama1,5 and Hoyoku Nishino2,5

1Research and Development Headquarters, Lion Corporation, Tajima 100, Odawara, Kanagawa 256-0811, Japan
2Kyoto Prefectural University of Medicine, Kawan-machi-Hirokoji, Kamigyō-ku, Kyoto 602-8566, Japan
3Graduate School of Medical Sciences and Medical School, Nagoya City University, Kawasumi 1, Mizuho-cho, Mizuho-ku, Nagoya 467-8601, Japan
4Kyoto City Hospital, Higashi-Takada-cho 1-2, Mibu, Nakagyō-ku, Kyoto 604-8845, Japan
5Ritsumeikan Global Innovation Research Organization, Ritsumeikan University, Nogihigashi 1-1-1, Kusatsu, Shiga 525-8577, Japan

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Lactoferrin (LF), a multifunctional glycoprotein in mammalian milk, is reported to exert a modulatory effect on lipid metabolism. The aim of the present study was to elucidate whether enteric-coated LF (eLF) might improve visceral fat-type obesity, an underlying cause of the metabolic syndrome. Using a double-blind, placebo-controlled design, Japanese men and women (n=26; aged 22–60 years) with abdominal obesity (BMI > 25 kg/m², and visceral fat area (VFA) > 100 cm²) consumed eLF (300 mg/d as bovine LF) or placebo tablets for 8 weeks. Measurement of the total fat area, VFA and subcutaneous fat area from computed tomography images revealed a significant reduction in VFA (−14.6 cm²) in the eLF group, as compared with the placebo controls (−1.8 cm²; P=0.009 by ANCOVA). Decreases in body weight, BMI and hip circumference in the eLF group (−1.5 kg, −0.6 kg/m², −2.6 cm) were also found to be significantly greater than with the placebo (+1.0 kg, +0.3 kg/m², +0.2 cm; P=0.032, 0.013, 0.041, respectively). There was also a tendency for a reduction in waist circumference in the eLF group (−4.4 cm) as compared with the placebo group (−0.9 cm; P=0.073). No adverse effects of the eLF treatment were found with regard to blood lipid or biochemical parameters. From these results, eLF appears to be a promising agent for the control of visceral fat accumulation.

Lactoferrin: Enteric-coated lactoferrin tablets: Visceral fat: Metabolic syndrome

The metabolic syndrome is a combination of medical disorders that increase the risk of developing CVD and other chronic ailments. Recently, the number of affected individuals has been rapidly increasing worldwide, because of a shift towards dietary excess, lack of exercise and increasing stress, causing social problems. Visceral fat-type obesity is one underlying reason for the metabolic syndrome. Excessive visceral fat accumulation disrupts the production of adiponec-tin, plasminogen activator inhibitor type 1, TNF and NEFA, which induces insulin resistance linked with high blood glucose, high blood pressure and dyslipidemia. To prevent the metabolic habits and maintain the balance of energy intake and consumption. One idea attracting increasing attention is the possibility of using specific food factors as supplements.

Lactoferrin (LF) is an Fe-binding glycoprotein which is found at highest concentrations in mammalian breast milk. It is multi-functional, with anti-bacterial, antiviral, immunostimulatory, antioxidant and cancer-preventive potential(1–3) and because LF is a natural component of breast milk which is ingested by infants, it is considered to be highly safe. Thus it has been approved as a food additive in Japan, and is included in the ‘generally recognized as safe’ (GRAS) category in the USA. Firstly, we focused on the anti-bacterial activity of LF, and found potent anti-pathogenesis activities against periodontal disease(4). In the course of conducting oral care research on LF, we also noted another highly interesting effect. Our results pointed to a new function – reducing the visceral fat that is the key cause of the metabolic syndrome – discovered through animal studies. There have been reports on the influence of LF on lipid metabolism. In the study of Takeuchi et al.(5), bovine LF reduced plasma TAG and NEFA accompanied by decreases in hepatic cholesterol and TAG contents in rodents. Tamano et al. reported a significant decrease of serum TAG to 72% of the control level(6). However, these reports were

Abbreviations: eLF, enteric-coated lactoferrin; JSCC, Japan Society of Clinical Chemistry; LF, lactoferrin.
* Corresponding author: Dr Tomoji Ono, fax +81 465 48 4079, email tomoono@lion.co.jp
the results of animal experiments, and, to our knowledge
there, has up till now been no human clinical trial aimed
at determining the influence of LF on lipid metabolism.
Furthermore, there has been no examination of the effects of
LF on visceral fat accumulation. Therefore, we conducted
the present investigation, focusing on lipid metabolism and
visceral fat in a human clinical study. Since orally adminis-
tered proteins are generally degraded by pepsin in the
stomach, we used enteric-coated LF (eLF) tablets as the test
food in the present evaluation of LF activity in a randomised
double-blind placebo-controlled trial.

Experimental methods
Design and subjects
This trial was performed during the period of January 2008
to May 2008 with volunteers at the Moriyama Hospital
in the Kanto District in Japan. The protocol was approved
by the institutional board and the trial was conducted in
accordance with the Helsinki Declaration under the supervi-
sion of clinical investigators. The subjects provided informed
consent, including their permission for the findings to be
published. Inclusion criteria were healthy Japanese men and
women more than 20 years of age, with a BMI > 25 kg/m²,
and a visceral fat area > 100 cm², who were considered to
be visceral fat-type obese, but had not been treated at an
out-patient department and had no serious disease.

This was a randomised double-blind placebo-controlled
trial, consisting of a 2-week run-in period and an 8-week
treatment period. After the run-in period, the subjects were
allocated to two groups designated as the eLF group (daily
ingestion of three eLF tablets: 300 mg/d as bovine LF) and
the control group (ingestion of three enteric-coated placebo
tablets). Randomisation was stratified by age, sex, and visceral
fat area measured at the time of the run-in period at hospital
(control group, six men and seven women; eLF group, five
men and eight women).

The test tablets that we used in the present study were eLF
tablets, containing LF 100 mg/tablet, and control enteric-
coated tablets, containing lactose instead of LF. Other
constituents of each tablet were crystalline cellulose, carboxy-
methylcellulose-Ca, sucrose ester, silicon dioxide, shellac,
sorbitol, arginine, dextrin and long pepper powder. In this
formulation, LF molecules are protected from proteolytic
digestion in the stomach, since the tablets are coated with
an acid-resistant material, shellac, which dissolves easily
under the neutral pH conditions in the intestine. The enteric-
coated properties of this formulation were checked by the
standard disintegration test to satisfy the criterion for the
Japanese Pharmacopoeia.

The subjects consumed three tablets of the test material
per d for 8 weeks. The time for ingestion of the test tablets
was not limited, but it was recommended that the subjects
take three test tablets after their evening meal/before sleep,
to maintain compliance.

Energy and fat intake was not limited throughout the trial
period, but supplemental food products or medications
known to influence lipid or carbohydrate metabolism were
prohibited. The subjects were instructed to maintain their
usual dietary intake and physical activity.

The subjects visited the medical institution at 4-week
intervals after the run-in period. Eating and drinking,
except for water, were prohibited from 21.00 hours on
the day before the visit until various measurements were
completed.

Anthropometry, measurements of circulatory parameters,
fasting blood sampling for biochemical and haematological
parameters, and interviews were performed at −2 (before
treatment), 0, 4 and 8 weeks. Computed tomography (CT)
was performed at 0 and 8 weeks to measure the abdominal
fat area.

Anthropometric and vital sign measurements
Height (only at −2 weeks), body weight, waist circumference
and hip circumference were measured at each visit. BMI was
calculated from the height and body weight. Waist and hip
circumference, at the umbilical level and at the level of the
greatest posterior protuberance (maximal gluteal circum-
ference), respectively, were measured using a non-elastic
anthropometric tape measure. Systolic blood pressure, dia-
tolic blood pressure and pulse rate were assessed using an
Hg manometer with subjects in a seated position after resting
quietly for 10 min.

Evaluation of the abdominal fat level
The abdominal fat level, including total fat area, visceral fat
area and subcutaneous fat area, were measured from CT
images by Pronto-Xi/Si (Hitachi, Tokyo, Japan), using Fat
Pointer software (version 2; Hitachi Medico Co., Tokyo,
Japan), under X-ray conditions of a tube voltage of 120 kVp
(peak voltage) and 100 mA. Several CT images around the
umbilicus were obtained and single scan images at the precise
point of the umbilicus were used for analysis.

Blood biochemical examination
The serum total cholesterol (cholesterol oxidase method(10)),
HDL-cholesterol (selective inhibition method(11)), LDL-
cholesterol (enzymic method(12)), TAG (enzymic method
after eliminating endogenous free glycerol(13)), total lipid
(sulfo-phospho-vanillin method(14)), NEFA (enzymic
method(15)), total protein (biuret method(16)), albumin (brom-
cresol green (BCG) method(17)), glutamic oxaloacetic trans-
aminase (standard methods established by the Japan Society
of Clinical Chemistry (JSCC)(18)), glutamic pyruvate transam-
inase (standard methods established by the JSCC(18)), lactate
dehydrogenase (standard methods established by the
JSCC(18)), alkaline phosphatase (standard methods established
by the JSCC(18)), γ-glutamyl transferase (standard methods
established by the JSCC(18)), total bilirubin (enzymic
method(19)), direct bilirubin (enzymic method(19)), creatinine
(enzymic method(20)), blood urea N (enzymic method(21)),
uric acid (uricase–peroxidase method(22)), creatine kinase
(standard methods established by the JSCC(18)), C-reactive
protein (immunonephelometry(23)), blood glucose (glucose
oxidase–peroxidase method(24)), glycyslated HbA1c (latex
particle agglutination method(25)) and insulin (enzyme immu-
noassay (EIA) method(26)) were measured in fasting blood
samples. Non-HDL-cholesterol was calculated from the
value of total cholesterol and HDL-cholesterol. The albumin:globulin ratio was calculated from the value of total protein and albumin.

Dietary diary and daily living records

The subjects recorded the content of their meals in a dietary diary for 3 d before the visits at 0, 4 and 8 weeks. Based on the information in the diaries, dietitians analysed the daily energy intake, fat intake and fat:energy ratio, using Standard Tables of Food Composition in Japan, the 5th revised and enlarged edition, and mean values for the 3 d were calculated. In addition, the subjects recorded their compliance of the test tablet intake, and daily activities, including eating habits and exercise, measured by a passometer (Spalding cumulative passometer PS453; Tokyo Compass Mfg. Co. Ltd, Tokyo, Japan) every day from 0 to 8 weeks, in a daily living record using a simple checklist. The clinical investigators provided feedback of the daily living record to the subjects to encourage a constant level of daily activity. Physical conditions and adverse effects were examined by a physician in the interview at each visit.

Statistical analysis

Data presented for all test parameters are mean values and standard deviations. Results are expressed either in actual values or changes from 0 to 4 weeks (Δvalue at week 4) or 0 to 8 weeks (Δvalue at week 8). To compare the week 0 values for the two groups, an unpaired t test (two-sided) was employed. An intergroup comparison by repeated-measures ANOVA was performed using actual values from week 0 to week 8. Post hoc analysis was conducted by ANCOVA, the Dunnett test, or the paired t test. The statistically significant level was set at P<0.05. The data were analysed using JMP (version 5.0.1a; SAS Institute Inc., Cary, NC, USA).

Results

A total of thirty subjects volunteered to participate in the study. Of the subjects, two withdrew agreement and were excluded from the original thirty subjects enrolled before the release of the double-blinding. In addition, two subjects (one in the control group and one in the eLF group) were discontinued because of job relocation or pressure of work. Data were analysed using the per-protocol samples of twenty-six subjects (control group, six men and seven women; eLF group, five men and eight women). The flow of participants in the trial is shown in Fig. 1. The baseline characteristics of the study subjects did not differ significantly between the groups (Table 1). Compliance of test tablet intake in the eLF group and the control group was 98.0 and 96.7 %, respectively.

Table 2 shows the daily energy, protein, carbohydrate and fat intakes. No significant differences were found between the two groups. Daily living records indicated that exercise levels were maintained at a constant level during the study.

Table 3 shows changes in anthropometric parameters and circulatory parameters. Body weight (P<0.05 at week 4, P<0.01 at week 8), BMI (P<0.05 at week 4, P<0.01 at week 8), waist circumference (P<0.01 at week 8) and hip circumference (P<0.05 at week 8) decreased significantly in the eLF group by the Dunnett test as compared with week 0. Body weight (P=0.037 at week 4, P=0.013 at week 8), BMI (P=0.041 at week 8) and hip circumference (P=0.032 at week 8) were statistically different between the eLF and control groups as analysed by ANCOVA. There was also a tendency for a greater reduction in waist circumference (P=0.073 at week 8) in the eLF group than with the placebo. No significant differences in circulatory parameters were found between the groups.

Table 4 shows changes in abdominal fat areas. Visceral fat area and total fat area decreased significantly over time (P<0.01 at week 8; paired t test) in the eLF group. The decreases in visceral fat area, subcutaneous fat area and total fat area at week 8 from baseline were −14.6, −13.4 and −28.0 cm in the eLF group, and −18, −9.9 and −11.7 cm.
in the control group, respectively. A significant difference between the eLF and the control visceral fat area was found at week 8 ($P = 0.0089$), as analysed by ANCOVA.

Tables 5 and 6 show changes in blood lipid parameters and biochemical parameters. No significant differences were found between the two groups. No adverse effects of eLF were apparent.

**Discussion**

The present investigation of effects of eLF tablets (as 300 mg LF/d for 8 weeks) on visceral fat accumulation in Japanese men and women with abdominal obesity demonstrated a significant benefit as compared with the placebo regarding the visceral fat area and a tendency for greater improvement in anthropometric data.

Major sources of exogenous LF in our daily diet are dairy products from bovine milk. LF contents in bovine colostrum and normal milk are 1000 and 20–350 mg/ml, respectively. During the milk pasteurisation process, LF is inactivated by heating, but unpasteurised dairy products, such as natural cheese, contain approximately 300 mg LF per 100 g. Therefore, during the treatment period, the daily intake of LF for the eLF group was almost the same as approximately 100 g of natural cheese per d (28), although LF in natural cheese naturally will be degraded in the stomach. Under our conditions, 8 weeks of oral administration of eLF tablets significantly reduced the accumulation of visceral fat, compared

**Table 1.** The baseline (week 0) characteristics of the study subjects (Mean values and standard deviations)

| Parameter               | Group       | Mean | SD  | Mean | SD  | P*
|-------------------------|-------------|------|-----|------|-----|-----
| Sex (n)                 | eLF (n 13)  |      |     | Control (n 13) |      |     |
| Men                     | 5           | 8    |     |       |     |     |
| Women                   | 8           | 7    |     |       |     |     |
| Age (years)             | 42.8        | 10.1 | 46.8 | 9.2  | 0.30
| Height (cm)             | 161.1       | 8.4  | 161.0 | 11.3 | 0.99
| Weight (kg)             | 77.7        | 12.3 | 72.9  | 17.0 | 0.41
| BMI (kg/m$^2$)          | 30.0        | 4.8  | 27.7  | 2.9  | 0.15
| Waist circumference (cm) | 96.6        | 10.1 | 93.2  | 12.8 | 0.17
| Hip circumference (cm)  | 105.7       | 7.4  | 101.9 | 10.1 | 0.28
| Visceral fat area (cm$^2$) | 118.1      | 32.2 | 116.6 | 49.1 | 0.93
| Subcutaneous fat area (cm$^2$) | 284.6    | 126.4 | 241.7 | 107.7 | 0.96
| Total fat area (cm$^2$)  | 402.7       | 128.5 | 358.3 | 133.7 | 0.40
| Systolic blood pressure (mmHg) | 128.2      | 11.3 | 132.0 | 8.7  | 0.35
| Diastolic blood pressure (mmHg) | 79.5       | 11.9 | 78.6  | 14.1 | 0.87
| Pulse rate (beats/min)   | 77.6        | 11.8 | 80.3  | 11.6 | 0.56
| Total cholesterol (mmol/l) | 5.73       | 0.87 | 5.63  | 0.55 | 0.72
| HDL-cholesterol (mmol/l) | 1.54        | 0.37 | 1.51  | 0.44 | 0.87
| LDL-cholesterol (mmol/l) | 3.69        | 0.64 | 3.42  | 0.51 | 0.26
| TAG (mmol/l)             | 1.47        | 0.87 | 1.95  | 1.50 | 0.33
| Total lipid (g/l)        | 6.97        | 1.30 | 7.34  | 1.62 | 0.52
| NEFA (mmol/l)            | 0.76        | 0.36 | 0.61  | 0.21 | 0.21
| Non-HDL-cholesterol (mmol/l) | 4.20      | 0.69 | 4.12  | 0.58 | 0.76

eLF, enteric-coated lactoferrin.  
* Except for sex, t test between groups.  
† Square test between groups.

**Table 2.** Daily energy, protein, carbohydrate and fat intakes (Mean values and standard deviations)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Group</th>
<th>Week 0 Mean</th>
<th>Week 0 SD</th>
<th>Week 4 Mean</th>
<th>Week 4 SD</th>
<th>Week 8 Mean</th>
<th>Week 8 SD</th>
<th>P*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy intake (kJ/d)</td>
<td>eLF</td>
<td>8552</td>
<td>1703</td>
<td>7719</td>
<td>2531</td>
<td>7778</td>
<td>1523</td>
<td>0.84</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>8004</td>
<td>2038</td>
<td>8577</td>
<td>2381</td>
<td>8326</td>
<td>2494</td>
<td>0.07</td>
</tr>
<tr>
<td>Protein intake (g/d)</td>
<td>eLF</td>
<td>82.8</td>
<td>17.6</td>
<td>71.1</td>
<td>15.5</td>
<td>75.3</td>
<td>13.6</td>
<td>0.66</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>70.5</td>
<td>24.6</td>
<td>78.3</td>
<td>19.9</td>
<td>76.6</td>
<td>25.7</td>
<td>0.46</td>
</tr>
<tr>
<td>Fat intake (g/d)</td>
<td>eLF</td>
<td>72.6</td>
<td>11.7</td>
<td>60.8</td>
<td>19.2</td>
<td>60.2</td>
<td>16.1</td>
<td>0.61</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>62.2</td>
<td>16.4</td>
<td>70.2</td>
<td>14.1</td>
<td>68.3</td>
<td>25.0</td>
<td>0.13</td>
</tr>
<tr>
<td>Carbohydrate intake (g/d)</td>
<td>eLF</td>
<td>255.0</td>
<td>63.2</td>
<td>240.7</td>
<td>59.8</td>
<td>243.6</td>
<td>55.2</td>
<td>0.57</td>
</tr>
<tr>
<td></td>
<td>Control</td>
<td>251.1</td>
<td>77.0</td>
<td>252.6</td>
<td>86.3</td>
<td>257.4</td>
<td>81.1</td>
<td>0.21</td>
</tr>
</tbody>
</table>

eLF, enteric-coated lactoferrin.  
* Repeated-measures ANOVA.
### Table 3. Changes in anthropometric and circulatory parameters after taking enteric-coated lactoferrin (eLF) or control tablets for 8 weeks (Mean values and standard deviations for thirteen subjects per group)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Group</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
<th>Mean</th>
<th>SD</th>
<th>Time Group</th>
<th>Time × group</th>
<th>Week 4</th>
<th>Week 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (kg)</td>
<td>Control</td>
<td>72.9</td>
<td>17.0</td>
<td>72.5</td>
<td>17.5</td>
<td>-0.3</td>
<td>1.1</td>
<td>0.0047</td>
<td>0.045</td>
<td>0.037</td>
<td>0.013</td>
</tr>
<tr>
<td></td>
<td>eLF</td>
<td>77.7</td>
<td>12.3</td>
<td>76.4*</td>
<td>12.0</td>
<td>-1.3</td>
<td>1.2</td>
<td>-1.5</td>
<td>1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>Control</td>
<td>27.7</td>
<td>2.8</td>
<td>27.6</td>
<td>3.0</td>
<td>-0.2</td>
<td>0.4</td>
<td>0.0040</td>
<td>0.053</td>
<td>0.12</td>
<td>0.041</td>
</tr>
<tr>
<td></td>
<td>eLF</td>
<td>30.0</td>
<td>4.8</td>
<td>29.5*</td>
<td>4.6</td>
<td>-0.5</td>
<td>0.5</td>
<td>29.4</td>
<td>4.37</td>
<td>-0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Waist circumference (cm)</td>
<td>Control</td>
<td>93.2</td>
<td>12.9</td>
<td>93.2</td>
<td>13.4</td>
<td>0.0</td>
<td>6.8</td>
<td>0.0049</td>
<td>0.083</td>
<td>0.45</td>
<td>0.073</td>
</tr>
<tr>
<td></td>
<td>eLF</td>
<td>99.6</td>
<td>10.1</td>
<td>97.4</td>
<td>9.1</td>
<td>-2.2</td>
<td>2.1</td>
<td>95.2**</td>
<td>8.9</td>
<td>-4.4</td>
<td>4.0</td>
</tr>
<tr>
<td>Hip circumference (cm)</td>
<td>Control</td>
<td>101.9</td>
<td>10.1</td>
<td>100.0</td>
<td>8.9</td>
<td>-1.9</td>
<td>4.5</td>
<td>101.7</td>
<td>10.0</td>
<td>-0.2</td>
<td>1.8</td>
</tr>
<tr>
<td></td>
<td>eLF</td>
<td>105.7</td>
<td>7.4</td>
<td>104.1</td>
<td>7.7</td>
<td>-1.6</td>
<td>2.1</td>
<td>103.4*</td>
<td>6.5</td>
<td>-2.6</td>
<td>2.9</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>Control</td>
<td>132.0</td>
<td>8.7</td>
<td>132.7</td>
<td>9.6</td>
<td>+0.7</td>
<td>10.4</td>
<td>126.8</td>
<td>11.9</td>
<td>-5.2</td>
<td>9.4</td>
</tr>
<tr>
<td></td>
<td>eLF</td>
<td>128.2</td>
<td>11.3</td>
<td>125.8</td>
<td>9.8</td>
<td>-2.5</td>
<td>8.1</td>
<td>124.9</td>
<td>6.8</td>
<td>-3.3</td>
<td>8.5</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>Control</td>
<td>78.6</td>
<td>14.1</td>
<td>83.6</td>
<td>9.7</td>
<td>+5.0</td>
<td>15.3</td>
<td>78.8</td>
<td>11.0</td>
<td>+0.2</td>
<td>12.6</td>
</tr>
<tr>
<td></td>
<td>eLF</td>
<td>79.5</td>
<td>11.9</td>
<td>80.8</td>
<td>9.6</td>
<td>+1.3</td>
<td>7.8</td>
<td>79.7</td>
<td>9.4</td>
<td>+0.2</td>
<td>10.0</td>
</tr>
<tr>
<td>Pulse rate (beats/min)</td>
<td>Control</td>
<td>80.3</td>
<td>11.6</td>
<td>81.8</td>
<td>9.6</td>
<td>+1.5</td>
<td>10.1</td>
<td>79.1</td>
<td>10.2</td>
<td>-1.2</td>
<td>12.9</td>
</tr>
<tr>
<td></td>
<td>eLF</td>
<td>77.6</td>
<td>11.8</td>
<td>79.8</td>
<td>8.4</td>
<td>+2.2</td>
<td>8.9</td>
<td>72.8</td>
<td>10.0</td>
<td>-4.8</td>
<td>9.1</td>
</tr>
</tbody>
</table>

Mean value was significantly different from that at baseline (week 0): * P<0.05, ** P<0.01 (Dunnett’s test).
† The value is the change from week 0 to week 4.
‡ The value is the change from week 0 to week 8.
§ Repeated-measures ANOVA.
|| ANCOVA.
with control, and total fat area, hip circumference, body weight and BMI were also significantly decreased by eLF. No adverse events were observed with regard to safety parameters. In addition to its known anti-bacterial, anti-virus, immunostimulatory, antioxidant and cancer-preventive properties\(^{1-5}\), the present results thus point to a novel function of eLF in reducing visceral fat.

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<tr>
<th>Parameter</th>
<th>Group</th>
<th>Mean</th>
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<th>Mean</th>
<th>SD</th>
<th>Time</th>
<th>Group</th>
<th>Time x group</th>
<th>P $^\ddagger$</th>
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<tr>
<td>Visceral fat area (cm$^2$)</td>
<td>Control</td>
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<td>49·1</td>
<td>114·8</td>
<td>46·7</td>
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<td>Subcutaneous fat area (cm$^2$)</td>
<td>Control</td>
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<td>107·7</td>
<td>231·7</td>
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<td>−9·9</td>
<td>33·6</td>
<td>0·064</td>
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<td>0·96</td>
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<td>Total fat area (cm$^2$)</td>
<td>Control</td>
<td>358·3</td>
<td>133·7</td>
<td>346·6</td>
<td>132·1</td>
<td>−11·7</td>
<td>36·6</td>
<td>0·0051</td>
<td>0·47</td>
<td>0·22</td>
<td>0·34</td>
</tr>
</tbody>
</table>

Table 4. Abdominal fat area after taking enteric-coated lactoferrin (eLF) or control tablets for 8 weeks

(Mean values and standard deviations for thirteen subjects per group)

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<th>Time x group</th>
<th>P $^\ddagger$</th>
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</thead>
<tbody>
<tr>
<td>Total cholesterol (mmol/l)</td>
<td>Control</td>
<td>5·63</td>
<td>0·55</td>
<td>5·68</td>
<td>0·52</td>
<td>5·93</td>
<td>0·66</td>
<td>0·59</td>
<td>0·79</td>
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<tr>
<td>HDL-cholesterol (mmol/l)</td>
<td>Control</td>
<td>1·51</td>
<td>0·44</td>
<td>1·52</td>
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<td>1·56</td>
<td>0·48</td>
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<td>TAG (mmol/l)</td>
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<td>Total lipid (g/l)</td>
<td>Control</td>
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<td>1·62</td>
<td>7·50</td>
<td>1·36</td>
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<td>NEFA (mmol/l)</td>
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<td>Non-HDL-cholesterol (mmol/l)</td>
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<td>0·59</td>
<td>4·16</td>
<td>0·55</td>
<td>4·37</td>
<td>0·43</td>
<td>0·61</td>
<td>0·55</td>
<td>0·32</td>
<td></td>
</tr>
</tbody>
</table>

* Repeated-measures ANOVA.

Table 5. Changes in serum lipid parameters after taking enteric-coated lactoferrin (eLF) or control tablets for 8 weeks

(Mean values and standard deviations for thirteen subjects per group)
inhibits the plasma clearance of chylomicrons in the mouse\(^{(37)}\). Moreover, Hofmann et al. reported that LRP1 is expressed in visceral fat and modulates postprandial lipid transport and glucose homeostasis in mice \(^{(38)}\). These findings suggest that LF may bind LRP1 to block incorporation of lipid in the visceral fat. Further experimentation should be conducted to validate these hypotheses, as well as to determine the LF distribution after administration of eLF.

In summary, this trial clarified that the ingestion of eLF for an 8-week period can reduce visceral fat in men and women without the need for any lifestyle change. Additional analysis, with larger sample sizes, of this potential to prevent obesity and decrease risk of the metabolic syndrome is clearly warranted.

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The authors have no conflict of interest associated with the present study.

References


