Table 3. Changes in fasting plasma biomarkers of chronic inflammation and endotoxin exposure (Mean values with their standard errors; *n* 30/group)

		Time (weeks)						
		0		9		Significance (*P*)*		
Biomarkers	Group	Mean	SE	Mean	SE	Treatment	Obesity	Treatment × obesity
IL-6 (pg/l)	CN	0·74	0·08	0·89	0·11	0·4408	0·3934	0·6610
	YN	0·88	0·13	0·87	0·10			
	CO	1·56	0·13	1·47	0·11			
	YO	1·86	0·22	1·59	0·19			
hsCRP (mg/l)	CN	1·24	0·26	1·33	0·23	0·2670	0·5546	0·3711
	YN	1·15	0·21	1·22	0·22			
	CO	2·97	0·31	2·98	0·32			
	YO	2·63	0·37	2·42	0·32			
TNF-*α*/sTNF-RII (‰)	CN	0·52	0·03	0·53	0·03	0·0013	0·9574	0·8901
	YN	0·57	0·05	0·53	0·04			
	CO	0·51	0·04	0·53	0·04			
	YO	0·59	0·04	0·55	0·04			
TNF-*α* (pg/ml)	CN	1·10	0·07	1·21	0·09	0·0219	0·8384	0·0827
	YN	1·14	0·09	1·05	0·09			
	CO	1·25	0·10	1·23	0·08			
	YO	1·52	0·12	1·42	0·10			
sTNF-RII (pg/ml)	CN	2130	70	2210	90	0·5178	0·5843	0·0108
	YN	2030	70	2020	70			
	CO	2450	90	2390	100			
	YO	2550	100	2640	100			
LBP/sCD14 ratio	CN	7·14	0·69	8·32	0·85	0·0477	0·0995	0·2227
	YN	6·89	0·44	7·72	0·64			
	CO	8·62	0·58	9·60	0·68			
	YO	9·13	0·73	8·71	0·68			
LBP (μg/ml)	CN	9·9	0·9	10·5	1·0	0·1098	0·4572	0·6965
	YN	9·3	0·6	9·4	0·6			
	CO	12·4	0·7	12·9	0·9			
	YO	12·3	0·9	11·7	0·8			
sCD14 (ng/ml)	CN	1421	50	1323	48	0·9977	0·2134	0·0755
	YN	1402	59	1287	55			
	CO	1481	45	1365	44			
	YO	1388	45	1388	49			
LPS (EU/ml)	CN	14·2	0·9	16·6	0·7	0·0548	0·0190	0·1962
	YN	11·9	1·0	16·2	1·0			
	CO	16·2	1·2	13·4	0·9			
	YO	13·8	0·8	16·7	1·1			
EndoCab IgM (MMU/ml)	CN	99·6	10·6	97·9	9·6	0·0052	0·4230	0·3939
	YN	101	10	107	11			
	CO	70·7	4·2	70·0	4·0			
	YO	68·7	7·1	72·2	8·0			
AEA (nM)	CN	0·75	0·04	0·78	0·05	0·5334	0·1620	0·1565
	YN	0·85	0·04	0·80	0·05			
	CO	1·15	0·06	1·03	0·06			
	YO	1·10	0·06	1·11	0·08			
2-AG (nM)	CN	3·46	0·29	3·43	0·31	0·1188	0·7493	0·0372
	YN	3·45	0·30	3·30	0·35			
	CO	4·60	0·33	3·74[a]	0·32			
	YO	4·10	0·27	4·11[b]	0·30			

CN, control non-obese; CO, control obese; YN, yogurt non-obese; YO, yogurt obese; hsCRP, high-sensitivity C-reactive protein; sTNF-RII, soluble TNF II; LPS, lipopolysaccharide; EU, endotoxin units; LBP, lipopolysaccharide-binding protein; sCD14, soluble CD14; IgM EndoCAb, IgM endotoxin-core antibody; MU, median units; AEA, anandamide; 2-AG, 2-arachidonoylglycerol.

[a,b] Mean values within a column with unlike superscript letters were significantly different ($P < 0·05$) by two-tailed *t* test.

* The group difference at week 9 was compared by ANCOVA with baseline (week 0) as covariate (PROC GLM).

On the other hand, neither plasma IL-6 nor hsCRP was affected by dietary treatment or obesity status.

Fasting biomarkers of endotoxin exposure and intestinal barrier function

After 9 weeks intervention, IgM EndoCAb increased in both YN and YO ($P_{treatment} = 0·0052$) (Table 3). The primary study outcome, fasting plasma sCD14 was unchanged (Table 3). Similarly, LBP was not affected by the dietary treatment over 9 weeks. The ratio of LBP:sCD14 was determined as an exploratory outcome, as recent data have indicated this may be a better marker of endotoxin exposure than either marker alone[18,19]. The LBP/sCD14 ratio was lower in the yogurt consumption groups than in the control groups ($P_{treatment} = 0·0477$) (Table 3). However, plasma LPS was not affected

by the dietary treatment. A significant dietary treatment × obesity interaction effect on plasma 2-AG was detected ($P_{\text{treatment} \times \text{obesity}} = 0{\cdot}0372$). Subgroup analysis indicated yogurt consumption led to higher 2-AG in YO than in CO ($P = 0{\cdot}0114$) (Table 3). On the other hand, plasma AEA was not changed.

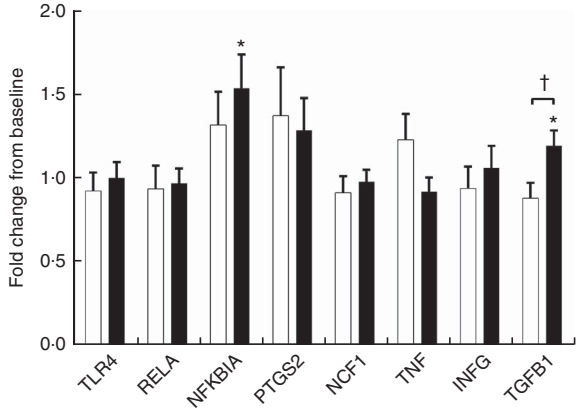

Fig. 2. Fold-change of fasting peripheral blood mononuclear cells (PBMC) gene expression between weeks 0 and 9, during which obese participants consumed 339 g of yogurt or 324 g of a non-dairy product control snack daily (*n* 30/group). Values are means with their standard errors. The relative expression of target genes between groups was compared by independent *t* test. No significant differences between yogurt obese (YO, ■) or control obese (CO, □) gene expression was detected. The fold-change from baseline of target genes between groups was compared by independent *t* test. The difference between weeks 0 and 9 in each group was compared by paired *t* test. * $P < 0{\cdot}05$, *v.* baseline in YO. † $P < 0{\cdot}05$, YO *v.* CO. *TLR4*, encoding Toll-like receptor 4; *RELA*, encoding p65 subunit of NF-κB; *NFKBIA*, encoding NF-κB inhibitor alpha; *PTGS2*, encoding cyclo-oxygenase-2, or COX-2; *NCF1*, encoding the p47 subunit of NADPH oxidase; IFNG, encoding interferon-γ; *TGFB1*, encoding transforming growth factor β1, or TGFβ.

Peripheral blood mononuclear cells mRNA expression

Endotoxin induces the production of inflammatory cytokines via TLR4/NF-κB pathway. We evaluated PBMC mRNA expression of key components of the NF-κB pathway in the obese group. At baseline, YO and CO gene expression did not differ (online Supplementary Fig. S1). After 9 weeks, YO *NFKBIA* (encoding NF-κB inhibitor α (IκBα)) and encoding transforming growth factor β1 (*TGFB1*) increased by 54 and 20 % from baseline, respectively (Fig. 2). In contrast, the mRNA expression of these genes did not change in CO.

Anthropometric changes

After 9 weeks intervention, BMI was affected by obesity status, but not dietary treatment ($P_{\text{obesity}} = 0{\cdot}0084$) (Table 4). BMI increased continuously in both YO and CO. However, dietary records did not indicate increased energy intake (online Supplementary Table S3). Despite this weight gain, YO and CO waist circumferences were unchanged. Yogurt consumption significantly reduced diastolic blood pressure ($P_{\text{treatment}} = 0{\cdot}0188$), but not systolic blood pressure (Table 4). Within YO, diastolic blood pressure decreased by 2·82 (SEM 0·90) mmHg at week 3, with less decreases at weeks 6 and 9.

Discussion

The present study demonstrated that consuming two servings of low-fat yogurt daily for 9 weeks reduced fasting biomarkers of chronic inflammation and endotoxin exposure in apparently healthy premenopausal women. These findings are of significance because of the known role of compromised intestinal barrier function and subsequent endotoxin exposure as a mechanism of chronic inflammation, particularly in obesity[3,4].

Table 4. Changes from baseline in BMI, waist circumference (WC), and blood pressure (BP) of participants during the 9-week intervention (Mean values with their standard errors; *n* 30/group)

		Time (weeks)											
		0		3		6		9		Significance (*P*)*			
Measurements	Group	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Treatment	Obesity	Time	Treatment × obesity
ΔBMI (kg/m^2)	CN	0	0	0·00	0·08	0·10	0·09	0·02	0·10	0·7942	0·0084	0·0130	0·9939
	YN	0	0	−0·07	0·06	−0·04	0·09	0·08	0·11				
	CO	0	0	0·14	0·08	0·30	0·13	0·37	0·16				
	YO	0	0	0·15	0·08	0·19	0·09	0·33	0·11				
ΔWC (cm)	CN	0	0	0·08	0·31	−0·06	0·30	−0·22	0·33	0·8274	0·9351	0·0956	0·1443
	YN	0	0	−0·12	0·13	−0·77	0·33	−0·70	0·32				
	CO	0	0	−0·32	0·20	−0·22	0·17	−0·55	0·27				
	YO	0	0	0·03	0·16	−0·03	0·36	−0·27	0·43				
ΔSysBP (mmHg)	CN	0	0	0·23	1·48	−1·73	1·04	0·33	1·57	0·1233	0·3109	0·4783	0·5015
	YN	0	0	0·13	1·29	−0·72	1·46	−2·45	1·64				
	CO	0	0	2·57	1·22	1·71	1·39	1·12	1·70				
	YO	0	0	−1·13	1·48	−0·68	1·29	−0·25	1·17				
ΔDiaBP (mmHg)	CN	0	0	1·57	1·22	−1·48	1·05	0·15	1·14	0·0188	0·2859	0·7587	0·0902
	YN	0	0	0·02	0·77	0·50	1·09	−0·75	1·11				
	CO	0	0	0·78	0·91	1·02	0·91	0·77	1·22				
	YO	0	0	−2·82	0·90	−2·10	0·83	−1·90	0·95				

CN, control non-obese; CO, control obese; YN, yogurt non-obese; YO, yogurt obese; SysBP, systolic blood pressure; DiaBP, diastolic blood pressure.
* The effects of treatment, obesity, and treatment × obesity were determined by two-factor repeated-measures ANOVA with time as a covariate (PROC MIXED).

Increased proinflammatory biomarkers such as IL-6, hsCRP and TNF-α have been associated with obesity in both adults and children[20,21]. Consuming low-fat yogurt for 9 weeks resulted in a modest, but significant reduction of the levels of TNF-α, which may be partly explained by reduced activation of the TLR4-mediated inflammatory pathway. Upon TLR4 activation by endotoxin, a downstream signaling cascade is triggered that leads to activation of the NF-κB pathway[22]. IκBα (encoded by *NFKBIA*) inhibits the NF-κB pathway by trapping the heterodimeric complex in the cytosol[23]. Since YO *NFKBIA* was increased at the end of the intervention, yogurt consumption may suppress TLR4 activation of NF-κB. TGF-β1 is an anti-inflammatory and reparative cytokine that suppresses proinflammatory signaling from Toll-like receptors[24]. YO *TGFB1* (encoding TGF-β1) expression was increased by the intervention but other downstream genes of NF-κB including *PTGS2*, *NCF1*, *TNF* and *IFNG* were not affected by the intervention. Given the reduction in YO plasma TNF-α, non-PBMC sources of TNF such as the immunocytes resident in the intestine, adipose tissue, or skeletal muscle may have contributed to this change.

Obesity is associated with subclinical endotoxaemia which increases chronic inflammation[5]. Contrary to others[25], the obese group did not have increased LPS relative to the non-obese group in the present study. We expected plasma LPS to be reduced by yogurt consumption, however non-significant increases in plasma LPS were observed after the dietary intervention. Direct quantitation of LPS by the LAL method is challenging, due to its short half-life, low blood concentrations and the difficulty of removing interference from the blood matrix[26]. The LAL assay also does not account for lipoprotein-bound LPS[27]. In addition, other bacterial compounds such as glycolipids and lipoproteins derived from pathogenic Gram-positive bacteria are pro-inflammatory[28]. Therefore, it is likely that quantitation of LPS by the LAL method does not account for total bioactive endotoxin, and could be masked by lipoprotein differences between experimental groups. Thus, the extent fasting LPS values in the present study reflect intestinal barrier function and true endotoxin load is unclear.

LBP and sCD14 have been proposed as surrogate biomarkers of endotoxaemia because of their roles in sequestering and translocating LPS and other bacterial compounds to inflammatory signaling pathways[28]. Similar to the present study, LBP was higher in overweight/obese individuals than in normal-weight individuals, indicating low-grade chronic endotoxaemia[3]. Serum LBP was also associated with increased abdominal obesity and proinflammatory cytokines IL-6 and IL-8[29]. However, the originally proposed primary outcome, fasting plasma sCD14, was not different between the obese and non-obese groups in the present study. Similarly, sCD14 was not associated with obesity in another study population (n 420, 55 % females, age 18–92 years)[29]. Therefore, sCD14 alone may not be an appropriate biomarker for low-grade endotoxaemia. LBP and sCD14 act together to detoxify endotoxin. Healthy men have postprandial plasma LBP/sCD14 ratios that are correlated with plasma endotoxin[18,19]. We observed that obese participants had 27 % higher plasma LBP:sCD14 ratio than the non-obese participants at baseline, which suggested increased endotoxin exposure. Moderate increases in LBP/sCD14 ratio were found in control but not the yogurt-consuming groups, suggesting protective effects of yogurt against chronic endotoxaemia.

Another surrogate biomarker of endotoxaemia is IgM EndoCAb, which can bind to the inner core of endotoxin and protect against endotoxin[30]. In a cross-sectional study involving ninety-three age-matched middle-aged women, IgM EndoCAb in obese and obese diabetic women was 55 and 30 % of non-obese participants[31]. Similarly, IgM EndoCAb level in obese participants was 69 % of that in the non-obese in the present study. Yogurt consumption increased the IgM EndoCAb level in both obese and non-obese participants, suggesting decreased level of endotoxin exposure resulting from the yogurt intervention.

Intestinal barrier function is regulated in-part by eCB. 2-AG improves the intestinal barrier, whereas AEA is associated with decreased intestinal barrier function[4]. After the 9-week intervention, a modest decrease in 2-AG was observed in CO, but not in YO. This may suggest protective effects of yogurt on intestinal barrier function relative to the control snack.

Yogurt directly increased tight junction proteins and improved barrier function in Caco-2 cells[32]. A few dietary interventions have improved intestinal barrier function in various populations. For example, consumption of 300 g/d yogurt containing *Lactobacillus johnsonii* for 4 weeks decreased plasma LBP and intestinal permeability in elderly adults with intestinal bacterial overgrowth[7]. Intervention studies on the anti-inflammatory effects of yogurt consumption are also limited. In elderly individuals, consumption of 100 g/d yogurt containing *Lactobacillus acidophilus* and *Bifidobacterium lactis* for 2 weeks decreased faecal haptoglobin, but plasma inflammatory biomarkers were not determined[9]. In children with *Helicobacter pylori*, 400 ml/d yogurt containing *L. acidophilus* and *B. lactis* for 4 weeks decreased serum IL-6[10]. The yogurt in the present study is a commercially available product that is more representative of typical yogurt products in the USA. Thus, probiotic fortification may not be necessary in yogurt to modulate chronic inflammation in apparently healthy women. Nevertheless, dietary intervention alone might not be sufficient to manage obesity-associated inflammation. Other strategies such as weight management and pharmaceutical approaches should be incorporated.

In this study, obese participants gained approximately 1 kg body weight, even though dietary records did not reveal increased energy intake. Most obese participants reported an energy intake below the calculated estimated energy requirements, indicating underreporting. The interventions supplied 54 g of sugar, which contributed to the increased sugar consumption by YO and CO. It is estimated that individuals having higher sugar intake have 0·75 kg (95 % CI 0·30, 1·19; $P=0·001$) more body weight than those consuming less sugar during short-term interventions[33]. Diastolic blood pressure was lower in YO at week 3, but rebounded at later weeks, possibly because of weight gain at later weeks. Thus, it is possible that sustained increased sugar intake diminished the beneficial effect of yogurt consumption. This study adds to the existing evidence that increased dairy product consumption might

reduce blood pressure in obese individuals. A meta-analysis of prospective cohort studies associated an increased daily intake of 200 g of low-fat dairy products with decreased risk of hypertension (RR 0·96; 95 % CI 0·93, 0·99)[34].

Several limitations should be considered when interpreting the results of this study. Since only women were included as participants, the results cannot be directly extended to men. Furthermore, we did not recruit obese participants on the basis of metabolic syndrome status, which could affect response to dairy product interventions[35]. In addition, participants self-selected days to complete food records, which helps to improve participant compliance to study procedures but may introduce bias in selecting convenient days to record food intake (e.g. low diversity of foods or skipped meals). Further studies are needed to establish the extent regular yogurt consumption contributes to nutrient intake and diet quality. A strength of this study was that yogurt intervention consisted of commercially available products within the recommended dietary guidance for dairy product consumption. Notably, the yogurt was not fortified with probiotics, but this study was not designed to test the effects of fermentation. Other studies have demonstrated specific anti-inflammatory and intestinal barrier-promoting activity of probiotics[7,9].

A number of factors could have contributed to the benefits of yogurt consumption in the present study. Preclinical studies suggest milk oligosaccharides and lactoferrin promote intestinal barrier function and have anti-inflammatory properties[36,37]. Dairy product fermentation also liberates peptides with hypotensive activity, as reviewed elsewhere[6]. Other simultaneous dietary changes occurring with the intervention cannot be ruled out for their effect on biomarkers of chronic inflammation and intestinal barrier function.

In summary, this study demonstrated that consuming 339 g of low-fat yogurt daily for 9 weeks modestly reduced chronic inflammation and inhibited markers of endotoxaemia in apparently healthy premenopausal women. The anti-inflammatory effect of yogurt consumption was partially attributable to improved intestinal barrier function indicated by EndoCAb and LBP:sCD14 in comparison to the non-dairy product control.

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B. W. B. and R. S. B. designed the research. R. P., D. M. D., K. K. P. and D. A. M. recruited and screened participants. R. P., D. M. D., Q. G., C. C. and C. O. S. performed research and data analysis. B. W. B., R. P., R. S. B., H. M. W. and C. O. S. supervised data analysis. R. P., B. W. B. and R. S. B. were responsible for data interpretation and had primary responsibility for final content. R. P. and B. W. B. wrote the paper. All authors have approved the final manuscript.

The authors declare that there are no conflicts of interest.

Supplementary material

For supplementary material/s referred to in this article, please visit https://doi.org/10.1017/S0007114517003038

References

1. Lumeng CN & Saltiel AR (2011) Inflammatory links between obesity and metabolic disease. *J Clin Invest* **121**, 2111–2117.
2. Gregor MF & Hotamisligil GS (2011) Inflammatory mechanisms in obesity. *Annu Rev Immunol* **29**, 415–445.
3. Sun L, Yu Z, Ye X, *et al.* (2010) A marker of endotoxemia is associated with obesity and related metabolic disorders in apparently healthy Chinese. *Diabetes Care* **33**, 1925–1932.
4. Cani PD, Plovier H, Van Hul M, *et al.* (2016) Endocannabinoids - at the crossroads between the gut microbiota and host metabolism. *Nat Rev Endocrinol* **12**, 133–143.
5. Andreasen AS, Larsen N, Pedersen-Skovsgaard T, *et al.* (2010) Effects of *Lactobacillus acidophilus* NCFM on insulin sensitivity and the systemic inflammatory response in human subjects. *Br J Nutr* **104**, 1831–1838.
6. Pei R, Martin DA, DiMarco DM, *et al.* (2017) Evidence for the effects of yogurt on gut health and obesity. *Crit Rev Food Sci Nutr* **57**, 1569–1583.
7. Schiffrin EJ, Parlesak A, Bode C, *et al.* (2009) Probiotic yogurt in the elderly with intestinal bacterial overgrowth: endotoxaemia and innate immune functions. *Br J Nutr* **101**, 961–966.
8. Zeng J, Li YQ, Zuo XL, *et al.* (2008) Clinical trial: effect of active lactic acid bacteria on mucosal barrier function in patients with diarrhoea-predominant irritable bowel syndrome. *Aliment Pharmacol Ther* **28**, 994–1002.
9. Matsumoto M, Ohishi H & Benno Y (2001) Impact of LKM512 yogurt on improvement of intestinal environment of the elderly. *FEMS Immunol Med Microbiol* **31**, 181–186.
10. Yang YJ & Sheu BS (2012) Probiotics-containing yogurts suppress Helicobacter pylori load and modify immune response and intestinal microbiota in the Helicobacter pylori-infected children. *Helicobacter* **17**, 297–304.
11. Warensjö E, Jansson JH, Cederholm T, *et al.* (2010) Biomarkers of milk fat and the risk of myocardial infarction in men and women: a prospective, matched case–control study. *Am J Clin Nutr* **92**, 194–202.
12. Tong X, Dong JY, Wu ZW, *et al.* (2011) Dairy consumption and risk of type 2 diabetes mellitus: a meta-analysis of cohort studies. *Eur J Clin Nutr* **65**, 1027–1031.
13. Ralston RA, Lee JH, Truby H, *et al.* (2012) A systematic review and meta-analysis of elevated blood pressure and consumption of dairy foods. *J Hum Hypertens* **26**, 3–13.
14. Laugerette F, Vors C, Géloën A, *et al.* (2011) Emulsified lipids increase endotoxemia: Possible role in early postprandial low-grade inflammation. *J Nutr Biochem* **22**, 53–59.
15. Campbell MJ & Swinscow TDV (2009) *Statistics at Square One*, 11th ed. West Sussex: Wiley-Blackwell, Inc.
16. Pickering TG, Hall JE, Appel LJ, *et al.* (2005) Recommendations for blood pressure measurement in humans and experimental animals. Part 1: blood pressure measurement in humans: a statement for professionals from the subcommittee of professional and public education of the American Heart

Association council on high blood pressure research. *Hypertension* **45**, 142–161.
17. Thompson FE & Subar AF (2017) Dietary Assessment Methodology. In *Nutrition in the Prevention and Treatment of Disease*, 4th ed., pp. 5–48 [AM Coulston, CJ Boushey, MG Ferruzzi and LM Delahanty, editors]. London: Academic Press.
18. Laugerette F, Furet JP, Debard C, *et al.* (2012) Oil composition of high-fat diet affects metabolic inflammation differently in connection with endotoxin receptors in mice. *Am J Physiol Endocrinol Metab* **302**, 374–386.
19. Laugerette F, Alligier M, Bastard JP, *et al.* (2014) Overfeeding increases postprandial endotoxemia in men: inflammatory outcome may depend on LPS transporters LBP and sCD14. *Mol Nutr Food Res* **58**, 1513–1518.
20. Panagiotakos DB, Pitsavos C, Yannakoulia M, *et al.* (2005) The implication of obesity and central fat on markers of chronic inflammation: the ATTICA study. *Atherosclerosis* **183**, 308–315.
21. Mauras N, DelGiorno C, Kollman C, *et al.* (2010) Obesity without established comorbidities of the metabolic syndrome is associated with a proinflammatory and prothrombotic state, even before the onset of puberty in children. *J Clin Endocrinol Metab* **95**, 1060–1068.
22. Manco M, Putignani L & Bottazzo GF (2010) Gut microbiota, lipopolysaccharides, and innate immunity in the pathogenesis of obesity and cardiovascular risk. *Endocr Rev* **31**, 817–844.
23. Scherer DC, Brockman JA, Chen ZJ, *et al.* (1995) Signal-induced degradation of I-kappa-B-alpha requires site-specific ubiquitination. *Proc Natl Acad Sci U S A* **92**, 11259–11263.
24. Serhan CN & Savill J (2005) Resolution of inflammation: the beginning programs the end. *Nat Immunol* **6**, 1191–1197.
25. Kallio KAE, Hatonen KA, Lehto M, *et al.* (2015) Endotoxemia, nutrition, and cardiometabolic disorders. *Acta Diabetol* **52**, 395–404.
26. Gnauck A, Lentle RG & Kruger MC (2015) The Limulus Amebocyte Lysate assay may be unsuitable for detecting endotoxin in blood of healthy female subjects. *J Immunol Methods* **416**, 146–156.
27. Pais de Barros J-P, Gautier T, Sali W, *et al.* (2015) Quantitative lipopolysaccharide analysis using HPLC/MS/MS and its combination with the limulus amebocyte lysate assay. *J Lipid Res* **56**, 1363–1369.
28. Schroder NWJ & Schumann RR (2005) Non-LPS targets and actions of LPS binding protein (LBP). *J Endotoxin Res* **11**, 237–242.
29. Gonzalez-Quintela A, Alonso M, Campos J, *et al.* (2013) Determinants of serum concentrations of lipopolysaccharide-binding protein (LBP) in the adult population: the role of obesity. *PLOS ONE* **8**, e54600.
30. Poxton IR (1995) Antibodies to lipopolysaccharide. *J Immunol Methods* **186**, 1–15.
31. Hawkesworth S, Moore SE, Fulford AJ, *et al.* (2013) Evidence for metabolic endotoxemia in obese and diabetic Gambian women. *Nutr Diabetes* **3**, e83.
32. Putt K, Pei R, White W, *et al.* (2017) Yogurt inhibits intestinal barrier dysfunction in Caco-2 cells by increasing tight junctions. *Food Funct* **8**, 406–414.
33. Morenga LT, Mallard S & Mann J (2012) Dietary sugars and body weight: Systematic review and meta-analyses of randomised controlled trials and cohort studies. *BMJ* **345**, e7492.
34. Soedamah-Muthu SS, Verberne LDM, Ding EL, *et al.* (2012) Dairy consumption and incidence of hypertension: a dose-response meta-analysis of prospective cohort studies. *Hypertension* **60**, 1131–1137.
35. Bordoni A, Danesi F, Dardevet D, *et al.* (2017) Dairy products and inflammation: a review of the clinical evidence. *Crit Rev Food Sci Nutr* **57**, 2497–2525.
36. Boudry G, Hamilton MK, Chichlowski M, *et al.* (2017) Bovine milk oligosaccharides decrease gut permeability and improve inflammation and microbial dysbiosis in diet-induced obese mice. *J Dairy Sci* **100**, 2471–248.
37. Anderson RC, Bassett SA, Haggarty NW, *et al.* (2017) Short communication: early-lactation, but not mid-lactation, bovine lactoferrin preparation increases epithelial barrier integrity of Caco-2 cell layers. *J Dairy Sci* **100**, 886–891.

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