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The effect of goat's milk consumption on the clinical health of middle-aged adults with lactose intolerance

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ABSTRACT

Introduction: People with lactose intolerance are suggested to consume dietary items containing less lactose, such as goat's milk. This study aimed to investigate the effects of goat's milk powder on the health of lactose intolerant middle-aged adults. **Methods:** A total of 60 subjects were recruited into this randomised controlled trial. They were divided into four groups and received different dietary interventions (goat's milk, goat's milk with curcumin, goat's milk with coffee, lactose-free milk) for five weeks. Health effects were compared between pre- and post-intervention. Anthropometric and biochemical parameters (blood glucose, insulin, lipid profile, C-reactive protein, and lactoferrin) were evaluated. Dietary intake was recorded using a food record. **Results:** Fifty-one lactose intolerant subjects completed the study. After ingestion of goat's milk, there were significant reductions in body fat (p=0.033) and a significant increase in the percentage of muscle (p=0.021). Waist circumference (WC) decreased in both the goat's milk with curcumin and goat's milk with coffee groups (p<0.05 for all). Unfortunately, high-density lipoprotein cholesterol (HDL-C) dropped after the five-week intervention in the goat's milk group (p=0.002). Lactoferrin level of the goat's milk group was higher than other groups at post-intervention (p<0.001). Besides, the goat's milk with coffee group seemed to consume more carbohydrates after completing the intervention (p=0.034). **Conclusion:** A five-week intake of goat's milk reduced the risk of abdominal obesity among middle-aged adults. In addition, it resulted in improved lactoferrin levels.

Keywords: goat's milk, lactoferrin, lactose-free, lactose intolerance, middle-aged adults

INTRODUCTION

Lactose is a disaccharide which consists of glucose and galactose, and appears in mammalian milk (Deng *et al.*, 2015). To absorb lactose, the body needs the digestive enzyme, lactase, to break down lactose's glycosidic bond. Generally, lactase can be found on the mucosal surface of the small intestine from eight week gestation onwards (Deng *et al.*, 2015). When lactase is deficient, digestion of lactose in the small intestine is disrupted, and lactose will be delivered to the large intestine. Colonic bacteria within the large intestine will then ferment this undigested lactose, eventually causing digestive symptoms

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such as nausea, bloating, flatulence, diarrhoea, and abdominal cramps. This disordered condition is called lactose intolerance (Law, Conklin & Pimentel, 2010).

Impaired lactose digestion is usually found in Asian adults due to age-related lactase reduction. Lactose intolerant people are recommended to avoid foods or beverages that contain lactose, such as cow's milk and dairy products. However, this probably leaves lactose intolerant people susceptible to nutrient deficiencies, especially nutrients found in milk and dairy products, such as highly-bioavailable calcium (National Institute of Diabetes and Digestive and Kidney Disease, 2020). To prevent nutrient deficiency, lactose-free milk or alternative milk products containing less lactose are suggested.

Goat's milk and its products are nutrient-rich alternatives, with a small lactose content. Additionally, with smaller fat globules and softer casein curd, goat's milk can be digested easier than cow's milk (Banjare *et al.*, 2017). Goat's milk has been studied for centuries. However, previous studies frequently focused on infants. A double-blind study among 72-hour-old infants was conducted to investigate the efficiency of goat's milk and cow's milk. Infants were randomly given 150-200 ml goat's milk or cow's milk per kilogram (kg) body weight per day until 168 days of age. At the end of the study, the frequency of intestinal movements in infants who received goat's milk infant formula was significantly better than those who received cow's milk infant formula (Grant *et al.*, 2005). This may have been a result of the differences in digestibility between goat's milk and cow's milk. In addition, goat's milk infant formula has been reported to contain a comparable level of prebiotics compared with human milk. The prebiotics found in goat's milk promote the growth of beneficial gut bacteria, as well as reduce the growth of pathogenic bacteria (Leong *et al.*, 2019).

Besides, to promote gut health, curcumin, a polyphenol contained in turmeric, has also been widely utilised. Curcumin considerably increases the beneficial bacteria and reduces the pathogenic bacteria in mice. It has also been found to induce weight loss in ovariectomised rats (Zam, 2018). Consistently, coffee has been reviewed for its effect on the gut. Due to its prebiotic constituents, consumption of coffee has been found to increase *Bifidobacterium* in both animals and humans (Cowan *et al.*, 2014).

Regarding the health benefits of goat's milk, current data is limited to younger age groups. Studies on the effect of goat's milk consumption among middle-age adults with lactose intolerance are insufficient. Therefore, this study was conducted to investigate whether consumption of goat's milk, goat's milk with curcumin, goat's milk with coffee or lactose-free milk promotes the health of lactose intolerant middle-aged adults.

MATERIALS AND METHODS

Study subjects

Subjects were recruited using a purposive sampling technique. Sixty lactose intolerant adults (40-60 years old) living in Bangkok, Thailand participated in this single-blind randomised controlled trial study, of which 51 completed the study. The subjects were asked to present their last 6-12 months medical check-up report. Those who were diagnosed with chronic diseases such as diabetes, chronic kidney disease and cancer, had any infection or inflammation six months prior to the study, were currently taking medication or nutritional supplements, smoking, or regularly drinking alcohol were excluded. Pregnant or lactating

women were also excluded. Subjects were individually informed of the risks, discomforts, and benefits associated with the study before providing their signed informed consent. The study procedure was approved by the Ethics Committee (Certificate of Approval No. MUPH 2019-129) and the trial was registered with the Thai Clinical Trials Registry (TCTR20210219001). Subjects were initially screened for the symptoms of lactose intolerance using an online questionnaire. Based on the questionnaire responses, those who had symptoms of lactose intolerance were asked to fast for eight hours, then blood samples were collected at baseline and 120 minutes after drinking 50 g of lactose. Subjects with a blood glucose increase of <1.1 mmol/L were defined as lactose intolerant.

Study intervention

All subjects were allocated to four study groups using stratified and blocked randomisation techniques. Each group was requested to consume isocaloric (approximately 211 kcal/day) milk (either goat's milk or lactose-free milk) contained in a sealed aluminium foil bag. The goat's milk provided to each group was similar and originated from the same source. The duration of the dietary intervention was five weeks. The experimental products which were given to each group were as follows: 1) goat's milk group: 40.0 g goat's milk powder (contains 31.9% fat, 28.0% protein, 32.3% lactose); 2) goat's milk + curcumin group: 40.0 g goat's milk powder and 0.025 g extracted curcumin powder (contains 31.9% fat, 28% protein, 32.3% lactose); 3) goat's milk + coffee group: 40.0 g goat's milk powder and 0.025 g coffee powder (contains 31.9% fat, 28.0% protein, 32.3% lactose); and 4) lactose-free group: 46.5 g lactose-free milk powder (contains 30.0% fat, 16.0% protein, lactose-free).

Dietary and anthropometry assessments

Subjects were requested to take photos of their dietary items prior to and after consuming them, and report their dietary intake three times a week (two weekdays and one weekend) using the food record provided. To estimate energy and macronutrient intakes, the NutriSurvey program (Copyright© 2007, SEAMEOTROPMED RCCN-University of Indonesia) was conducted.

At baseline and after the five-week intervention, anthropometric assessment and biochemical evaluation were performed. Regarding anthropometry, subjects' weight, percentage body fat, percentage visceral fat, and percentage muscle were assessed by using a body composition monitor (HBF-375, Omron Healthcare, Japan). To reduce errors, waist circumference (WC) and height were measured three times. WC at umbilical level was measured using a measuring tape to define abdominal obesity. After measuring height by a stadiometer, body mass index was calculated by dividing weight (kg) with height squared (m^2).

Biochemical parameters assessment

Blood pressure was taken using an automatic blood pressure monitor (HEM 7120, Omron) before blood sample withdrawal. Blood sampling was performed after an eight-hour fast. Fasting blood glucose (FBG) and lipid profile (total cholesterol: TC; high-density lipoprotein cholesterol: HDL-C; low-density lipoprotein cholesterol: LDL-C; triglyceride: TG) were evaluated using a Cobas® 6000 analyser (Roche Diagnostics Ltd., Switzerland). Fasting insulin was examined using a human insulin Elisa kit (ab200011, Abcam). FBG and fasting insulin were then used to assess insulin resistance by applying the homeostatic model assessment of insulin resistance (HOMA-IR) equation as follows: HOMA-IR = [Fasting insulin (μU/

ml) × FBG (mmol/L)] / 22.5 (Matthews *et al.*, 1985). High-sensitivity C-reactive protein (hs-CRP) was determined using the nephelometry method. Lactoferrin concentration was measured using the enzyme-linked immunosorbent assay technique.

Statistical analysis

Sample size was computed using G*Power programme. The minimum sample in each group for detecting the difference of -3.7±2.7 cm in WC and -12.4±15.2 nmol/L in hs-CRP between pre- and post-intervention, with 80% power and α=0.05 was 11. Statistical analysis was performed using the Statistical Package for Social Science (SPSS) software for Windows version 18 (IBM Corp., United States). Differences between the four study groups before and after the intervention were determined by Kruskal-Wallis test and post-hoc Mann-Whitney U test. The Wilcoxon signed-rank test was utilised to evaluate differences between pre- and post-intervention within each study group. Data were expressed as median [interquartile range (IQR)]. A p<0.05 was considered to be statistically significant.

RESULTS

Baseline characteristics of study subjects

After screening, 60 subjects participated in this study. Nine subjects declined to participate in this study during the intervention period, thus there were 51 subjects (47 women and 4 men) at the end of the study (Figure 1). The median [IQR] age of subjects was 50 [45.0-54.0] years old. Both systolic and diastolic blood pressures of each study group were comparable (Table 1). There were no significant differences in anthropometric parameters when compared between study groups (Table 1). Regarding biochemical parameters, the goat's milk group had significantly higher median hs-CRP than the goat's milk with coffee group (p=0.031) and the lactose-free group (p=0.001) as shown in Table 2. Other biochemical parameters and dietary intake at baseline were similar among the four study groups (Tables 2 and 3).

Effects of goat's milk on blood pressure, anthropometric parameters, biochemical parameters, and dietary intake

The effect of experimental milks on study parameters after the five-week intervention are presented in Tables 1 to 3. Comparing between study groups, noteworthy differences were found in lactoferrin (p<0.001). The goat's milk group had significantly higher lactoferrin concentration relative to the other groups (goat's milk group vs. goat's milk with curcumin group: 1,029.1 [1,021.6-1,038.3] µg/L vs. 702.4 [381.3-945.3] µg/L, p=0.001; goat's milk group vs. goat's milk with coffee group: 1,029.1 [1,021.6-1,038.3] µg/L vs. 908.4 [832.4-986.1] µg/L, p=0.001; goat's milk group vs. lactose-free group: 1,029.1 [1,021.6-1,038.3] µg/L vs. 926.2 [682.5-996.1] µg/L, p<0.001). Additionally, the lactoferrin level of the goat's milk with coffee group was remarkably higher than that of the goat's milk with curcumin group (908.4 [832.4-986.1] µg/L vs. 702.4 [381.3-945.3] µg/L, p=0.041).

Comparing within each study group, notable changes appeared in blood pressure, anthropometric parameters, and biochemical indices as shown in Tables 1 and 2, respectively. The lactose-free group experienced a significant decrease in systolic blood pressure after the five-week intervention (week 0: 122.5 [110.0-140.5] mmHg vs. week 5: 112.5 [105.3-143.8] mmHg, p=0.037). Regarding anthropometry, the 5th-week body mass index of the lactose-free group was significantly increased compared to

baseline (week 0: 24.4 [20.0-27.9] kg/m^2 vs. week 5: 24.6 [20.2-28.4] kg/m^2, p=0.040). The subjects who consumed goat's milk with curcumin or with coffee had significantly reduced WC at post-intervention (week 0: 82.5 [76.6-85.8] cm vs. week 5: 78.5 [73.9-85.0] cm, p=0.038 and week 0: 83.0 [75.5-92.5] cm vs. week 5: 80.0 [76.0-88.0] cm, p=0.008, respectively). Body fat percentage of the goat's milk group also significantly dropped upon completion of the study (week 0: 34.9 [33.4-37.6] vs. week 5: 33.5 [32.2-37.7], p=0.033). Simultaneously, muscle mass percentage of the goat's milk group substantially increased after the five-week intervention (week 0: 22.6 [22.1-23.4] vs. week 5: 22.9 [22.3-24.1], p=0.021).

No significant differences were observed in FBG, fasting insulin, and HOMA-IR between pre- and post-intervention for all study groups (Table 2). Regarding lipid profile, subjects who consumed lactose-free milk experienced a remarkable decline in TC after the intervention (week 0: 5.5 [4.8-6.5] mmol/L vs. week 5: 5.3 [4.5-5.7] mmol/L, p=0.006). HDL-C of the goat's milk group and the lactose-free group had notably decreased after the five-week intervention (week 0: 1.6 [1.4-2.0] mmol/L vs. week 5: 1.5 [1.4-1.8] mmol/L, p=0.002 and week 0: 2.2 [1.5-

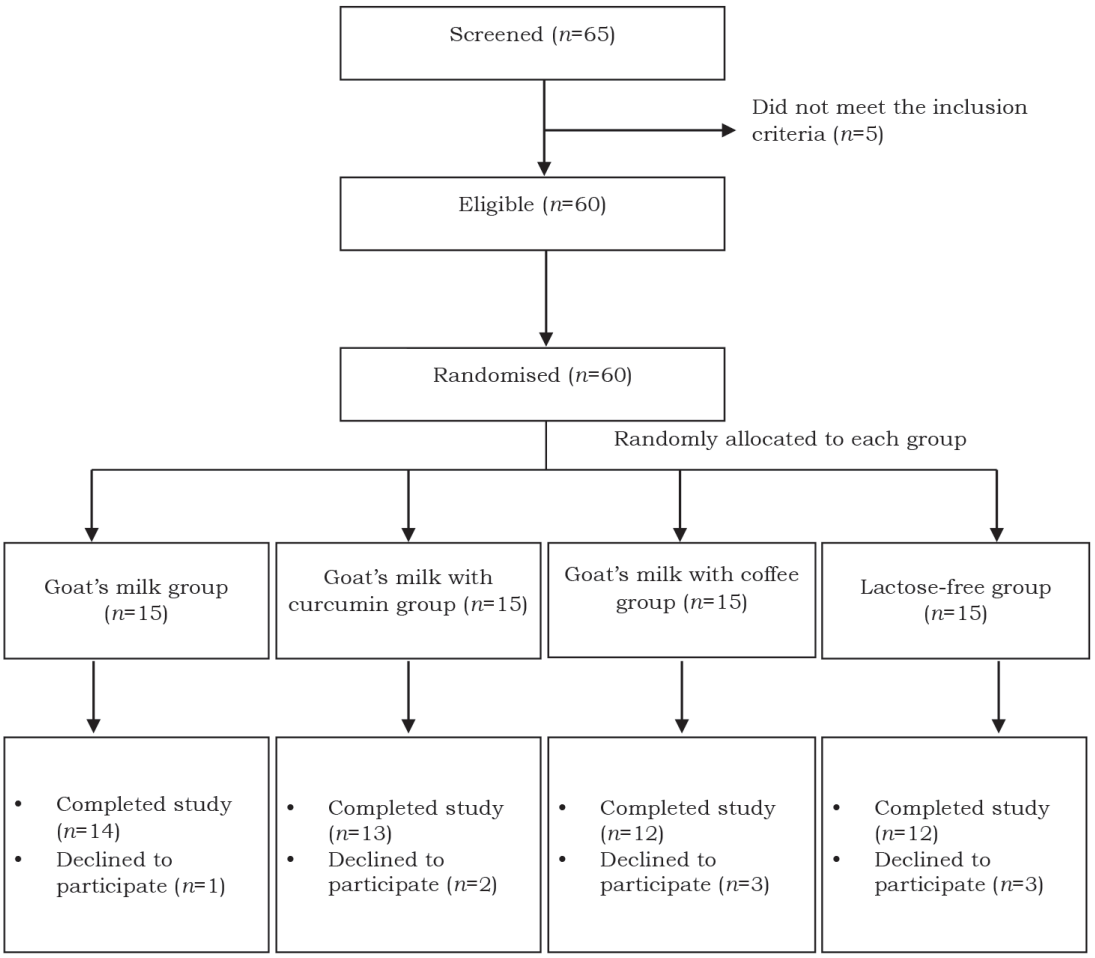

Figure 1. Flow diagram of the study

Table 1. Comparison of subject's blood pressure and anthropometric parameters between pre- and post-intervention

Variables	*Goat's milk*	*Goat's milk with curcumin*	*Goat's milk with coffee*	*Lactose-free*	*p*†
	Median [IQR]	*Median [IQR]*	*Median [IQR]*	*Median [IQR]*	
n (female/male)	14 (12/2)	13 (12/1)	12 (12/0)	12 (11/1)	0.609‡
Age (years)	50.0 [43.5-53.0]	52.0 [45.5-55.0]	48 [41.3-54.5]	48.0 [41.3-54.5]	0.619
Systolic blood pressure (mmHg)					
Week 0	121.5 [113.5-128.0]	128.0 [110.5-135.5]	122.0 [108.0-125.0]	122.5 [110.0-140.5]	0.569
Week 5	116.5 [110.0-123.0]	117.0 [110.5-128.0]	118.0 [107.0-120.0]	112.5 [105.3-143.8]	0.924
p§	0.157	0.074	0.286	0.037*	
Diastolic blood pressure (mmHg)					
Week 0	80.0 [71.8-86.3]	76.0 [69.0-85.5]	74.0 [70.0-78.0]	74.0 [67.0-93.3]	0.662
Week 5	77.0 [70.5-81.5]	75.0 [66.8-83.3]	71.0 [67.5-77.3]	75.0 [61.5-92.8]	0.585
p§	0.068	0.540	0.371	0.134	
Weight (kg)					
Week 0	58.9 [55.2-62.7]	51.6 [50.5-52.4]	55.6 [51.3-65.9]	56.0 [48.9-68.8]	0.177
Week 5	58.6 [54.4-62.7]	51.6 [50.0-52.0]	54.8 [51.0-66.0]	55.8 [49.3-70.0]	0.186
p§	0.056	0.944	0.212	0.247	
Body mass index (kg/m^2)					
Week 0	23.4 [22.4-26.8]	21.6 [19.6-22.8]	23.9 [19.9-25.6]	24.4 [20.0-27.9]	0.213
Week 5	23.3 [22.4-26.9]	21.6 [19.3-23.1]	23.6 [20.3-25.8]	24.6 [20.2-28.4]	0.268
p§	0.194	0.786	0.478	0.040*	
Waist circumference (cm)					
Week 0	84.7 [79.5-95.1]	82.5 [76.6-85.8]	83.0 [75.5-92.5]	87.3 [77.9-102.5]	0.381
Week 5	86.8 [78.6-91.4]	78.5 [73.9-85.0]	80.0 [76.0-88.0]	87.9 [80.5-99.4]	0.137
p§	0.055	0.038*	0.008**	0.286	
Body fat (%)					
Week 0	34.9 [33.4-37.6]	31.9 [27.8-33.2]	32.9 [29.8-37.9]	32.1 [29.0-37.8]	0.071
Week 5	33.5 [32.2-37.7]	31.3 [27.7-32.9]	32.2 [29.9-37.7]	30.8 [28.8-36.9]	0.120
p§	0.033*	0.230	0.307	0.084	
Visceral fat (%)					
Week 0	6.5 [5.0-9.6]	5.0 [3.0-6.8]	5.8 [2.9-6.9]	4.0 [3.3-8.5]	0.139
Week 5	6.3 [5.0-9.5]	4.8 [3.1-7.3]	5.8 [3.0-6.9]	4.0 [3.3-8.5]	0.200
p§	0.083	0.257	0.655	0.157	
Muscle (%)					
Week 0	22.6 [22.1-23.4]	23.9 [22.7-25.4]	24.9 [23.2-25.5]	23.7 [21.5-24.5]	0.092
Week 5	22.9 [22.3-24.1]	24.0 [22.9-25.5]	24.6 [23.6-25.1]	23.8 [20.7-24.5]	0.081
p§	0.021*	0.210	0.766	0.953	

Data are presented as median [interquartile range (IQR)].

†Significant difference between study groups before and after intervention based on Kruskal-Wallis test'

‡Significant difference between study groups based on Chi-square test

§Significant difference between pre- and post-intervention based on Wilcoxon signed-rank test, *p<0.05, **p<0.01

Table 2. The effect of goat's milk consumption on blood parameters

Variables	*Goat's milk*	*Goat's milk with curcumin*	*Goat's milk with coffee*	*Lactose-free*	$p^{\dagger}$
	Median [IQR]	*Median [IQR]*	*Median [IQR]*	*Median [IQR]*	
Fasting blood glucose (mmol/L)					
Week 0	4.9 [4.6-5.1]	4.8 [4.5-5.0]	5.1 [4.7-5.3]	4.8 [4.6-5.2]	0.666
Week 5	4.9 [4.8-5.0]	4.7 [4.6-4.9]	5.2 [4.7-5.3]	4.8 [4.7-5.2]	0.078
$p^{\ddagger}$	0.284	0. 580	0.091	1.000	
Fasting insulin (pmol/L)					
Week 0	20.8 [15.5-26-9]	17.6 [15.1-33.1]	14.3 [13.1-15.5]	20.6 [15.4-37.1]	0.099
Week 5	18.7 [14.7-18.7]	15.9 [11.1-32.6]	24.7 [13.0-30.7]	17.2 [14.0-31.1]	0.839
$p^{\ddagger}$	0.139	0.515	0.116	0.953	
HOMA-IR					
Week 0	0.5 [0.4-0.7]	0.7 [0.5-1.3]	0.5 [0.4-0.6]	0.6 [0.4-1.2]	0.352
Week 5	0.7 [0.5-1.1]	0.7 [0.4-1.5]	0.7 [0.4-0.9]	0.7 [0.5-1.6]	0.991
$p^{\ddagger}$	0.594	0.844	0.575	0.432	
Total cholesterol (mmol/L)					
Week 0	5.2 [4.7-5.7]	5.3 [5.1-6.0]	5.3 [4.9-5.9]	5.5 [4.8-6.5]	0.494
Week 5	4.9 [4.4-5.6]	5.5 [5.2-6.5]	5.6 [4.9-6.3]	5.3 [4.5-5.7]	0.226
$p^{\ddagger}$	0.084	0.695	0.272	0.006**	
Triglyceride (mmol/L)					
Week 0	1.0 [0.7-1.2]	0.9 [0.6-1.0]	1.0 [0.9-1.2]	0.8 [0.8-1.2]	0.648
Week 5	1.0 [0.9-1.2][a,b]	0.9 [0.6-1.1][a]	1.1 [1.0-1.4][b]	0.9 [0.8-1.1][a]	0.034*
$p^{\ddagger}$	0.925	0.953	0.066	0.824	
HDL-C (mmol/L)					
Week 0	1.6 [1.4-2.0]	1.9 [1.6-2.0]	1.7 [1.6-2.1]	2.2 [1.5-2.7]	0.203
Week 5	1.5 [1.4-1.8]	1.7 [1.4-2.0]	1.8 [1.5-1.9]	1.9 [1.5-2.4]	0.199
$p^{\ddagger}$	0.002**	0.152	0.075	0.006**	
LDL-C (mmol/L)					
Week 0	3.4 [2.4-3.9]	3.1 [2.7-3.5]	3.5 [3.0-3.7]	3.0 [2.7-4.1]	0.840
Week 5	3.2 [2.5-3.6]	3.1 [2.5-4.0]	3.7 [3.3-4.2]	2.9 [2.5-3.7]	0.200
$p^{\ddagger}$	0.600	0.789	0.114	0.091	
hs-CRP (nmol/L)					
Week 0	9.5 [6.4-22.8][a]	11.2 [3.8-30.2][a,b]	5.2 [3.0-7.9][b]	4.6 [3.9-5.5][b]	0.036*
Week 5	9.1 [5.4-14.0]	6.3 [4.0-32.0]	5.7 [3.8-6.3]	4.7 [3.3-6.2]	0.093
$p^{\ddagger}$	0.136	0.937	0.446	0.624	
Lactoferrin (µg/L)					
Week 0	966.7 [841.1-1033.7]	924.6 [873.1-1039.1]	1001.6 [954.9 -1039.5]	967.4 [848.1-1018.0]	0.541
Week 5	1,029.1 [1,021.6-1,038.3][a]	702.4 [381.3-945.3][b]	908.4 [832.4-986.1][c]	926.2 [682.5-996.1][b,c]	<0.001**
$p^{\ddagger}$	0.066	0.004**	0.013*	0.110	

Abbreviations: HOMA-IR, the homeostatic model assessment of insulin resistance; HDL-C, high-density lipoprotein cholesterol; LDL-C, low-density lipoprotein cholesterol; hs-CRP, high-sensitivity C-reactive protein

Data are presented as median [interquartile range (IQR)]

[†]Significant difference between study groups before and after intervention based on Kruskal-Wallis test'

[‡]Significant difference between pre- and post-intervention based on Wilcoxon signed-rank test, *p<0.05, **p<0.01

[a,b,c]Different alphabets denote significant differences between the study groups using Kruskal-Wallis test and post-hoc Mann-Whitney U test

Table 3. Comparison of the subject's dietary intake at baseline and week 5

Variables	*Goat's milk*	*Goat's milk with curcumin*	*Goat's milk with coffee*	*Lactose-free*	$p^{\dagger}$
	Median [IQR]	*Median [IQR]*	*Median [IQR]*	*Median [IQR]*	
Energy intake (kcal/d)					
Week 0	1419 [1103-1769]	1375 [1045-1774]	1525 [1301-1819]	1242 [1079-1862]	0.801
Week 5	1566 [1281-2134]	1333 [1134-1755]	1949 [1331-2096]	1170 [935-1801]	0.264
$p^{\ddagger}$	0.069	0.477	0.139	0.374	
Carbohydrate (g/d)					
Week 0	180 [140-212]	161 [121-211]	180 [155-241]	229 [139-245]	0.527
Week 5	199 [175-308]	194 [146-238]	244 [194-299]	205 [125-249]	0.427
$p^{\ddagger}$	0.086	0.139	0.034*	0.374	
Protein (g/d)					
Week 0	55 [50-64]	59 [41-73]	66 [55-77]	57 [45-81]	0.622
Week 5	59 [46-69]	56 [46-62]	68 [60-78]	53 [47-63]	0.061
$p^{\ddagger}$	0.445	0.767	0.260	0.612	
Fat (g/d)					
Week 0	48 [43-80]	58 [52-72]	65 [51-78]	61 [49-75]	0.845
Week 5	68 [47-89]	61 [33-73]	70 [50-85]	42 [35-74]	0.246
$p^{\ddagger}$	0.260	0.508	0.646	0.013*	

Data are presented as median [interquartile range (IQR)]
†Significant difference between study groups before and after intervention based on Kruskal-Wallis test'
‡Significant difference between pre- and post-intervention based on Wilcoxon signed-rank test, *p<0.05, **p<0.01

2.7] mmol/L vs. week 5: 1.9 [1.5-2.4] mmol/L, p=0.006, respectively). Significant changes were also found in lactoferrin concentrations of the goat's milk with curcumin group and goat's milk with coffee group. At the end of the study, lactoferrin concentration was likely to be higher than its level at baseline in the goat's milk group, but not significant; while the goat's milk with curcumin group and goat's milk with coffee group expressed significantly lower levels (week 0: 924.6 [873.1-1,039.1] µg/L vs. week 5: 702.4 [381.3-945.3] µg/L, p=0.004 and week 0: 1001.6 [954.9-1,039.5] µg/L vs. week 5: 908.4 [832.4-986.1] µg/L, p=0.013, respectively).

Regarding dietary intake as presented in Table 3, no significant differences were observed in energy and protein intakes between pre- and post-intervention for all study groups. However, the goat's milk with coffee group consumed more carbohydrates at the end of the study (week 0: 180 [155-241] g/d vs. week 5: 244 [194-299] g/d, p=0.034). On contrary, compared to baseline, the median fat intake in the lactose-free group decreased at the end of the study (week 0: 61 [49-75] g/d vs. week 5: 42 [35-74] g/d, p=0.013).

DISCUSSION

Lactose malabsorption is a condition in which people

typically secrete low concentrations of β-galactosidase from the small bowel mucosa, thus the body cannot properly digest and absorb lactose in the small intestine. Most adults worldwide (approximately 70%), particularly in Asian countries, have been reported to have hypolactasia (Di Costanzo & Berni Canani, 2018). Restriction of lactose consumption is recommended for lactose intolerant people. Goat's milk is an alternative food, which comprises of approximately 4.2 g lactose/100 g, and is commonly used to replace higher lactose dairy products due to its digestibility, nutritional components, and hypoallergenic property (Szilagyi & Ishayek, 2018; Stergiadis *et al.*, 2019). Globally, especially in Asia, consumption of goat's milk has risen year by year, with increased goat's milk production (Skapetas & Bampidis, 2016). However, evidence in support of the effects of goat's milk consumption in lactose intolerant adults is not well understood, therefore this study aimed to clarify its effects.

The study results revealed significant alterations in body composition, lipid profile, and lactoferrin level after intake of goat's milk for five weeks. At baseline, the subjects were above the abdominal obesity cut-off point (WC >80 cm for women and >90 cm for men) (WHO, 2008). However, after the five-week goat's milk intervention, body fat remarkably decreased. Likewise, after intake of either goat's milk with curcumin or goat's milk with coffee, waist circumference significantly dropped. Reasonably, the muscle percentage among subjects who consumed goat's milk significantly elevated. The subjects reported no changes in their daily physical activities. When dietary intake was observed to define whether changes in body composition was a result from dietary pattern modification, the results showed a similar dietary pattern between baseline and at the end of the study. Actually, the lactose-free group tended to reduce food intake as there were negative changes in energy, carbohydrate, protein, and fat intakes; whereas the macronutrients intake of subjects who consumed goat's milk, goat's milk with curcumin, and goat's milk with coffee increased. These changes were probably a result of the higher protein content in goat's milk relative to that of lactose-free milk.

Consumption of goat's milk and lactose-free milk did not affect insulin resistance parameters including FBG, fasting insulin, and HOMA-IR, except those who consumed goat's milk fortified with coffee powder that were likely to exhibit improved fasting plasma insulin concentration. This might have been a result of the fortified coffee contained in the experimental milk. A study conducted in China revealed that subjects had greater insulin levels after consumption of coffee (Gao *et al.*, 2018). Similarly, Alperet *et al.* (2016) conducted a study and found an improvement in insulin sensitivity after daily consumption of coffee for 24 weeks. Likewise, when diabetic subjects received 5 mg caffeine/kg body weight, insulin concentrations significantly increased (Robinson *et al.*, 2004).

Regarding lipid profile, subjects who ingested lactose-free milk showed a reduction in TC. Surprisingly, an undesirable change was observed in anti-atherogenic blood cholesterol; HDL-C concentrations of the subjects who consumed goat's milk and lactose-free milk dropped following the intervention. Shin *et al.* (2017) also reported a reduction in HDL-C concentrations, whereby consuming >1 serving of milk per day (for men) and >2 servings daily (for women) was associated with lower HDL-C. Unfortunately, the authors did not collect data regarding the sub-types of milk. Likewise, Villalpando *et al.* (2015) conducted a study to determine the effects of consuming cow's milk on

blood cardiovascular indicators and found that consumers of defatted milk had significantly reduced TC, LDL-C, and HDL-C after a four-month intervention. In contrast, a three-week randomised cross-over study among healthy adults revealed a noteworthy increase in HDL-C after the ingestion of whole milk (Engel *et al.*, 2018). Differences in the response of HDL-C might be explained by differences in the proportion of fatty acids contained in the experimental milks. As a previous study reported, increments in LDL-C and HDL-C were observed after increasing intakes of saturated fatty acids (Lichtenstein, 2006).

Lactoferrin is an iron-binding glycoprotein which is found in mammalian milk, such as human milk, goat's milk, and sheep's milk. This protein plays an antimicrobial role, regulating the inflammatory responses and enhancing gastrointestinal tract health (Park & Nam, 2015). When lactoferrin is ingested, a derivative of lactoferrin named lactoferricin is created. This derivative peptide can potentially act against both gram-positive and gram-negative pathogenic bacteria (Newburg & Walker, 2007). Lactoferrin exerts anti-inflammatory action by promoting the activity of natural killer cells, phagocytic cells, and macrophages. Modulation of macrophages in response to inflammation results in the secretion of cytokines such as tumour necrosis factor-alpha (TNF-α), interleukin-6 (IL-6), and nitric oxide (NO) (Hanson, 2007; Actor, Hwang & Kruzel, 2009). A previous study (Sorimachi *et al.*, 1997) reported that cytokines, such as TNF-α and NO, are secreted when macrophages are cultured with lactoferrin. Moreover, lactoferrin is capable of promoting gut health by stimulating the proliferation and differentiation of the intestinal cells (Playford, MacDonald & Johnson, 2000). In this study, an increased trend of lactoferrin level was observed after goat's milk ingestion. Consistently, Ochoa *et al.* (2013) conducted a randomised double-blind placebo-controlled trial to investigate the effect of lactoferrin on diarrhoea prevention among children. They reported a decrease in longitudinal prevalence and severity of diarrhoea after receiving 0.5 g of lactoferrin diluted in 25 ml of water twice daily.

CONCLUSION

In conclusion, this trial revealed positive health effects related to goat's milk consumption among middle-aged adults. Ingestion of goat's milk for five weeks could significantly reduce the risk of non-communicable diseases as found in the reductions of WC and body fat. Furthermore, the intake of goat's milk promotes gastrointestinal health by increasing blood lactoferrin concentration.

The current study still contains limitations. Firstly, the intervention period was short because it was interrupted by the pandemic of COVID-19. Secondly, the data observed in this study were mostly obtained from female subjects. Thus, further studies should investigate the long-term effect of goat's milk consumption and include men in order to define the different effects between men and women.

List of abbreviations

WC: Waist circumference; TC: total cholesterol; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; TG: triglyceride; HOMA-IR: the homeostatic model assessment of insulin resistance; hs-CRP: high-sensitivity C-reactive protein.

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Authors' contributions

CP, principal investigator, conceptualised and designed the study, supervised data collection, advised on data analysis and interpretation, prepared the draft of the manuscript, and reviewed the manuscript; CP, led the data collection, data analysis and interpretation, assisted in drafting of the manuscript, and reviewed the manuscript; CH, conceptualised and designed the study, advised on data analysis and interpretation, and reviewed the manuscript; PPP, led the data collection and reviewed the manuscript; KK, advised on data analysis and interpretation, and reviewed the manuscript.

Conflict of interest

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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