Acta Biomed 2011; 82: 181-186

Original article

Effect of camel milk on glucose metabolism in adults with normal glucose tolerance and type 2 diabetes in Raica community: a crossover study

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Abstract. *Background:* To investigate effects of camel milk consumption on insulin sensitivity and glycemic control in normal and type-2 diabetics of Raika and Non-Raika community. *Methods:* 28 raika and non-raika male were enrolled in study, categorized in 2 groups, non-diabetic and diabetic after one month stabilization. Non-diabetics were supplemented with cow milk and diabetics with camel milk; followed by one-month washout period. Afterwards regimen was interchanged for 3 months. Biochemical and anthropometric data was recorded at baseline, after stabilization, before and after washout and at end of study. *Results:* An improving trend was observed in both the groups for camel milk effect (FBS 203.86±24.09 to 161.43±11.39 mg/dl;$p<0.05$, OGTT 320.86±25.34 to 213.79±15.96 mg/dl;$p<0.05$ in diabetics and FBS 101.79±3.06 to 96.79±2.56 mg/dl, OGTT 114.36±7.99 to 100.36±6.74 mg/dl in control). HbA1c improved due to camel milk consumption (8.39±0.64 to 7.27±0.67%) whereas deteriorated in the case of cow milk (7.36±0.66 to 8.26±0.60%) in diabetic group. The HOMA-IR reduced from 13.21±4.88 to 4.38±0.75, AUC-glucose from 37253.57±2859.08 to 30724.29±3677.33 and AUC-insulin from 5871.86±1210.73 to 3301.86±629.98 in the camel milk group. *Conclusions:* In type-2 diabetics camel milk reduces FBS, post-prandial glucose and HbA_1c. AUC-insulin and AUC-glucose also decreased significantly along with HOMA-IR. It shows hypoglycemic effect of camel milk reducing insulin resistance. (www.actabiomedica.it)

Key words: camel milk, type-2 diabetes, Raica community, HOMA-IR

Introduction

Diabetes mellitus is a metabolic syndrome characterized by chronic hyperglycemia and disturbances of carbohydrate, protein and fat metabolism associated with absolute or relative deficiency in insulin secretion and action (1). Type 2 diabetes, formerly known as adult-onset diabetes, occurs when impaired insulin effectiveness (insulin resistance) is accompanied by the failure to produce sufficient β cell insulin (2). Diabetes mellitus is one of the fastest growing non-communicable diseases of the world. The global prevalence of diabetes mellitus was estimated to be 4% in 1995 and is projected to rise to 5.4% by the year 2025. Major part of this increase has been projected to occur in developing countries (3). According to WHO, it is likely to be one of the most substantial threats to human health in the 21st century (4). Insulin therapy is still the best treatment but type 2 diabetes patients can be placed on regimens to reduce weight or mange diet or treated with medication and, less often, insulin injections. The needle phobia and cost of treatment are the factors that force patient in our country to adopt alternative treatments. Camel milk has anti diabetic activity (5, 6). The health benefits of camel milk have been attributed to presence of high concentration

of immunoglobulin, lactoferrin, lactoperoxidase and peptidoglycan recognition protein in it (7). One of the camel milk proteins has many characteristics similar to insulin (8). Proteins are destroyed by acid in the stomach especially as milk forms a coagulum in the stomach, allowing acid and pepsin to break down proteins over a period of time. But camel milk lacks coagulum formation and passes rapidly through the stomach, together with the insulin like protein/ insulin. A large concentration of insulin i.e. 52 units/litre was detected in camel milk by using radioimmunoassay (9).

In this comparative crossover study, the effect of camel milk on glucose metabolism in adults with normal glucose tolerance was evaluated.

Subjects

Fourteen healthy male subjects and fourteen male type 2 diabetic patients were enrolled in the study from the outpatient diabetic clinic in P.B.M hospital, Bikaner, India. The subjects were selected form both Raica and Non-Raica population. The group I subjects were non-diabetic (glucose level<100 mg% and HbA1c level <6%). The group II diabetic subjects were selected according to WHO criteria (fasting plasma glucose > 126 mg% and 2 hour post glucose >200 mg %). Diabetic subjects taking insulin and with diabetic complications such as nephropathy, neuropathy or cardiovascular disease were excluded form the study. A written consent was taken from all the subjects before participation in the study and the protocol was approved by the medical ethical committee of the S.P.Medical College Hospital, Bikaner.

Materials and Methods

A crossover design with two treatment periods and washout period in between the two treatments was used. Baseline blood samples were collected from all the subjects after overnight fasting. All the subjects underwent a 75 gm oral glucose tolerance test (OGTT). After one month stabilization period, group- I subjects (normal) were given 500 ml of boiled

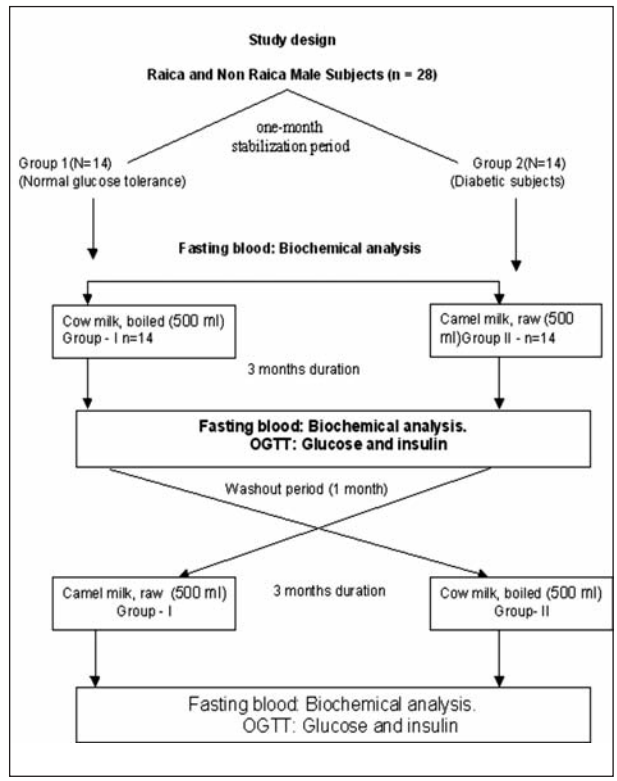

Figure 1.

cow milk and group- II subjects (diabetic) were given 500 ml raw camel milk. After three months of supplementation, fasting blood was collected followed by OGTT. This was followed by one-month washout period. After this period the regimen was interchanged and subjects of group I & II were switched over to camel milk (raw) and cow milk (boiled) respectively for three months (Fig. 1).

Biochemical Analysis

At the beginning (baseline) and end of each period, blood was collected after overnight fasting for analysis of biochemical parameters. Glucose, triglycerides and cholesterol were measured by enzymatic-calorimetric method. HbA1c was estimated by "ion exchange chromatography". Body mass index, waist hip ratio and diabetes quality of life score were also measured every week (10, 11). Radioimmunoassay method was used for insulin and C-peptide estimation. Glucose and insulin levels were estimated at 0

min, 60 min and 120 min after oral glucose load. Area under the curve (AUC) of glucose and insulin was calculated by trapezoidal rule. Insulin resistance was estimated by homeostasis model assessment (HOMA-IR) according to the formula:

$$\text{HOMA-IR} = \frac{\text{Fasting insulin } (\mu U/ml) \text{ x}}{\text{x Fasting glucose (m mol/l)}} \over 22.5$$

Statistical Analysis

In this randomized, crossover clinical trial, data were presented as means ± SEM. Comparison between baseline characteristics of each group and data at the end of each period was made by Wilcoxon matched pairs test. At p value <0.05, differences were considered significant.

Results

Characteristics in body mass index, waist hip ratio, systolic and diastolic blood pressure, fasting blood glucose, 2 hr post glucose along with HbA_1c, lipid profile, AUC glucose and insulin, HOMA-IR and c-peptide of control and type 2 diabetic subjects during study period are shown in table 1 and 2.

Effect of camel milk on blood glucose levels

In group II (Diabetic) there was improvement in mean fasting blood glucose (184.43±19.28 to 161.43±11.39) after addition of camel milk in the treatment regimen. Improvement was also observed in 2hr post glucose (269.43±29.15 to 213.79±15.96; p<0.05) in the same group and this positive effect of camel milk consumption deteriorated after washout period when camel milk was substituted by cow milk. The mean values of both fasting blood sugar (197.2±23.93 to 215.93±27.67) and 2 hr post glucose (283.57±34.10 to 329.64±34.53) increased in group II after cow milk supplementation. When effect of camel milk in diabetic and control population was compared, an improving trend was observed in both the groups (FBS 203.86±24.09 to 161.43±11.39; p<0.05, OGTT 320.86±25.34 to 213.79±15.96; p<0.05 in diabetics and FBS 101.79±3.06 to 96.79±2.56, OGTT 114.36±7.99 to 100.36±6.74 in control) (table 4).

Table 1. Demographic Profile of the study population

Parameters	Non-Diabetic (n=14) Mean±SE	Diabetic (n=14) Mean±SE
Age (years)	44.14±3.56	54.64±2.34
Sex		
M	13	12
F	1	2
Community		
Raica	10	1
Non Raica	4	13
Type of Family		
Joint	9	4
Nuclear	5	10
Food Habits		
Veg	14	13
Non Veg	0	1
Physical Activity		
Sedentary	7	12
Moderate	7	2
Smoker/Non Smoker	5/9	1/13
Socioeconomic Status Lower/ Middle/Upper	3/9/2	0/7/7

Effect of camel milk on HbA1c

When effect of camel milk in diabetic and control population was compared an improving trend was observed in both the groups (8.34±0.54 to 7.27±0.67; p=0.001 in group II and 4.48±0.2 to 4.1±0.17; p=0.01 in group I) (table 4). When changes in HbA_{1C} levels in diabetic subjects due to camel milk and cow milk consumption were compared, the significant change due to camel milk consumption was positive (8.39±0.64 to 7.27±0.67), whereas it was negative in the case of cow milk (7.36±0.66 to 8.26±0.60).

Effect of camel milk on Insulin and HOMA-IR

Insulin levels on 0, 60 and 120 mins improved statistically (p<0.05) in diabetic subjects when the val-

Table 2. Biochemical and anthropometric parameters in diabetic subjects during study period

	Glucose Fasting (mg/dl)	HbA1c (%)	Insulin fasting (µU/ml)	Glucose 2 hrs (mg/dl)	AUC Glucose	AUC Insulin	HOMA-IR	C-peptide (ng/ml)	BMI (Kg/m²)	WHR	SBP (mm Hg)	DBP (mm Hg)	TG (mg/dl)	T.Chol. (mg/dl)	HDL (mg/dl)	LDL (mg/dl)
Baseline	204±24	8.3±0.5	22±5	321±25	37253±2858	5872±1210	14±5	3.1±0.4	27.1±0.9	0.97±0.01	139.0±4.7	82.1±2.6	135.6±16.0	181.6±11.3	42.1±2.6	112.2±9.4
Run in period (one month)	184±19	8.4±0.6	13±1	269±29	30672±2563	3714±928	6±1	3.1±0.3	27.1±0.9	0.95±0.02	138.8±3.7	83.1±2.4	151.6±14.3	180.0±8.7	39.5±1.9	110.0±6.7
Camel milk supp. (three months)	161±11	7.3±0.7	11±1	214±16	30724±3676	3301±629	5±1	3.0±0.3	26.8±0.8	0.96±0.02	135.7±4.6	79.6±2.5	137.5±20.8	179.0±8.9	39.2±2.1	112.2±6.8
Washout period (one month)	197±24	7.3±0.6	18±3	284±34	29275±2797	3953±563	8±2	2.7±0.2	27.0±0.7	0.96±0.02	132.6±3.7	81.1±2.2	174.6±23.2	175.6±9.0	38.6±1.5	102.1±6.9
Cross over (Cow milk, three months)	216±28	8.3±0.6	21±2	330±35	34120±3183	5396±725	10±1	3.2±0.2	26.5±0.8	0.96±0.02	133.0±3.1	83.7±1.9	165.5±34.5	185.0±9.0	39.1±2.3	112.8±7.1

Values Mean ± SEM, No of Subjects - 14

Table 3. Biochemical and anthropometric parameters in control subjects during study period

	Glucose Fasting (mg/dl)	HbA1c (%)	Insulin fasting (µU/ml)	Glucose 2 hrs (mg/dl)	AUC Glucose	AUC Insulin	HOMA-IR	C-peptide (ng/ml)	BMI (Kg/m²)	WHR	SBP (mm Hg)	DBP (mm Hg)	TG (mg/dl)	T.Chol. (mg/dl)	HDL (mg/dl)	LDL (mg/dl)
Baseline	88±2	5.0±0.2	12±2	116±5	13922±860	4003±603	3.0±0.5	2.1±0.3	24.1±0.8	0.9±0.02	129.2±3.1	77.8±2.6	124.3±19.2	190.3±9.5	46.9±3.4	118.6±7.9
Run in period (one month)	86±2	4.9±0.2	7±2	106±8	13398±1102	3914±871	1.7±0.5	1.8±0.2	23.1±1.2	0.9±0.02	123.2±5.2	78.6±2.8	137.8±12.6	188.2±9.4	40.8±2.2	119.7±7.6
Cow milk supp. (three months)	100±3	4.6±0.2	10±4	97±4	13390±760	2858±727	2.5±1.1	2.5±0.3	23.1±1.1	0.9±0.02	119.0±4.2	78.2±2.9	103.7±12.1	180.1±9.1	41.5±2.0	117.8±8.6
Washout period (one month)	102±3	4.5±0.2	9±1	114±8	13118±997	3230±560	2.0±0.3	1.8±0.2	23.4±1.2	0.9±0.02	120.0±3.4	80.8±2.4	154.7±25.4	176.3±8.5	38.6±1.7	106.8±7.5
Cross over (Camel milk, three month)	98±3	4.1±0.2	14±3	100±7	14220±599	4519±569	3.1±0.6	2.1±0.3	23.2±1.2	0.9±0.02	121.8±4.3	84.7±7.0	104.2±16.0	168.6±9.2	38.8±2.3	108.5±6.8

Values Mean ± SEM, No of Subjects - 14

ues after camel milk supplementation were compared to baseline values (insulin for 0 min 22.57±5.10 to 10.96±1.55, for 60 mins 58.79±13.23 to 35.98±7.44, for 120 mins 53.86±13.64 to 27.15±5.83). The consistent results were found for HOMA-IR when baseline values were compared with values after camel milk supplementation values (13.67±5.01 to 5.32±1.09; $p<0.05$) in the same group.

Table 4. Effect of Camel Milk in Diabetic and Control population on different parameters

Parameters	Diabetic						Control					
	After Baseline (I)		After Camel Milk Suppl. (III)		Wilcoxon Matched Pairs Test		After Washout (IV)		After Camel Milk Suppl. (V)		Wilcoxon Matched Pairs Test	
	Mean	SE	Mean	SE	z	p level	Mean	SE	Mean	SE	z	p level
BMI	27.18	0.87	26.83	0.84	1.2	0.214	23.41	1.21	23.24	1.17	0.76	0.445
WHR	0.97	0.02	0.96	0.02	1.1	0.272	0.88	0.02	0.87	0.02	0.94	0.345
SBP	139	4.67	135.79	4.65	1	0.311	120	3.45	121.79	4.31	0.21	0.834
DBP	82.14	2.61	79.57	2.54	1.1	0.26	80.86	2.4	84.71	7.05	0.17	0.866
FBS	203.86	24.09	161.43	11.39	2.2	0.026	101.79	3.06	96.79	2.56	1.73	0.084
OGTT	320.86	25.34	213.79	15.96	3.3	0.001	114.36	7.99	100.36	6.74	1.63	0.103
HbA1c	8.34	0.54	7.27	0.67	2.8	0.006	4.48	0.2	4.1	0.17	3.3	0.001
TG	135.57	16.07	137.5	20.8	0.2	0.826	154.71	25.45	104.21	16.03	2.92	0.004
TCH	181.57	11.32	178.93	8.87	0	0.975	176.36	8.59	168.57	9.26	1.19	0.235
HDLC	42.16	2.6	39.21	2.07	1.5	0.133	38.57	1.69	38.86	2.34	0.17	0.861
LDLC	112.21	9.44	112.29	6.8	0.2	0.875	106.86	7.49	108.5	6.8	0.5	0.616
VLDLC	27.11	3.21	27.5	4.16	0.2	0.826	30.94	5.09	20.84	3.21	2.92	0.004
Insulin												
0	22.57	5.1	10.96	1.55	3.1	0.002	8.64	1.41	13.71	2.71	1.73	0.084
60	58.79	13.23	35.98	7.44	2.6	0.009	40.57	7.77	50.29	6.89	1.38	0.167
120	53.86	13.64	27.15	5.83	2.4	0.017	17.71	4.36	36.29	6.05	2.51	0.012
Homa IR	13.67	5.01	5.32	1.19	3.2	0.002	1.98	0.33	3.08	0.66	1.6	0.109
AUC Glucose	37253.57	2859.08	30724.29	3677.33	2.4	0.019	13118.57	997.62	14220	599.33	1.91	0.056
AUC Insulin	5871.86	1210.73	3301.86	629.98	2.9	0.004	3230.14	559.89	4519	569.26	1.85	0.064
C-peptide	3.19	0.43	2.96	0.32	0.4	0.695	1.83	0.16	1.14	0.3	1.92	0.055

Effect of camel milk on AUC glucose and AUC insulin

Statistically significant ($p<0.05$) decreasing trend was observed in both AUC glucose and AUC insulin when the values obtained after camel milk supplementation were compared with values at baseline (37253.57±2859.08 to 30724.29±3677.33 for AUC glucose and 5871.86±1210.73 to 3301.86±629.98 for AUC insulin) in group II.

Discussion

The present study was designed to observe the role of camel milk on insulin sensitivity and glycemic control in normal individuals and type 2 diabetic subjects of Raica and Non-Raica community.

Improvements in fasting blood sugar and 2 hr post glucose levels in diabetic patients (group II) were observed. This glycemic control may be because of hypoglycemic effect of camel milk. Since blood glucose level is controlled by endocrine, panacrine and autocrine interactions there might be some other active principal in milk and that too, more, in camel milk compared to cow milk. Sahani et al revealed after a 3 week trial study that rats getting raw camel milk showed a significant decrease in mean blood sugar level compare to rats getting raw cattle milk (12). Breitling also observed hypoglycemic activity of camel milk (13).

Findings related to BMI, systolic and diastolic blood pressure, blood sugar level were not significant in this study. This may be due to use of insufficient dose of camel milk as well as insufficient follow up period i.e. 3 months only. Agrawal et al observed a significant improvement in mean BMI after one year of camel milk treatment in type 1 diabetic patients (6).

The important observation of the study was significant improvement in HbA_1C level in patients of group II. HbA_1C is used as a marker of glycemic con-

trol which reduced in diabetic patients in this study suggesting efficacious role of camel milk in improving glycemic control. These findings are consistent with our earlier study which showed a significant hypoglycemic effect of camel milk when given as an adjunctive therapy (14).

In diabetic group, the values of 0, 60 and 120 minutes insulin decreased significantly after camel milk supplementation which suggest that camel milk may play an important role in control of insulin resistance.

A novel approach, HOMA, was employed to assess insulin resistance in this study. Researchers utilized HOMA in a study and concluded that assessing insulin sensitivity and pancreatic beta cell function with this model is likely to result in a more rational approach for achieving better glycemic control in type 2 diabetic patients (15). Another study related to insulin resistance proved utility of HOMA to underline role of a new insulin secretagogue (16). In another study, researchers employed homeostasis model assessment and found it important to take into account the degree of IR in assessing insulin secretion (17). HOMA-IR, an important parameter used in this study to measure insulin resistance, also favoured the same as its values decreased significantly after camel milk supplementation. The improving trend in AUC glucose and AUC insulin persists through stabilization period to camel milk supplementation period, again emphasizes on importance of camel milk conferring glycemic control to diabetic patients.

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Accepted: September 21th 2011
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