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Research Article
The Extent of Acute Changes in Blood Glucose Levels (BGL) Followed by Consumption of Different Soft Drinks in Healthy Adult Females

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Abstract

Background and Objective: Now-a-days soft drinks are more favourite refreshment among people all over the world. These non-alcoholic drinks are usually carbonated, sweetened with sugars or artificial sweeteners, edible acids, natural or artificial flavours and colours. Present study was designed to measure and compare the immediate changes in blood glucose levels (BGL) after consuming different soft drinks based on their ingredients, in healthy adult females. **Materials and Methods:** For this purpose, after recording the postprandial blood glucose concentrations, all participants were randomly divided into 4 groups, were asked to consume 4 different brands of selected soft drinks. At 30, 60, 90 and 120 min of intervals BGL were measured. **Results:** After 30 min the groups who consumed brand I, III and IV showed a rise in the mean BGL due to the presence of simple sugars, whereas, consumption of brand II containing artificial sweetener did not show such trend, instead mean BGL decreased from baseline values. After 60 min, the groups who consumed brands I, II and IV showed a significant decline in mean BGL and indicated the release of insulin, while a slow reduction in mean BGL was observed in group consuming brand III which showed caffeine-induced decreased insulin sensitivity. In between 60-90 min the mean BGL again raised to maintain blood glucose concentration followed by glucagon release with brands I, II and IV. After 120 min, the mean BGL was lower in groups who consumed brands I, II and III than that of the initial (postprandial) blood glucose concentrations. **Conclusion:** As all brands of selected soft drinks not only contained different categories of sweeteners but some additives with their health-related harmful effects, so the best approach for patients of diabetes and metabolic disorders is to avoid or limit the intake of soft drinks. However, for normal healthy persons, it is better to consume a drink with minimum artificial additives.

Key words: Soft drinks, artificial sweeteners, blood glucose, insulin sensitivity, caffeine

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Soft drink is the common name given to non-alcoholic beverages[1]. Soft drinks quench our thirst in a pleasant way and have become necessary part of the daily diet of young children and adolescents[2].

Over the past century, soft drinks have changed extraordinarily from being a local pharmacy product to worldwide industry that earns $60 billion and produce 1 billion litres per year. Changes in production technology and marketing innovations are factors that increase the consumption of soft drinks[3]. This increased consumption of soft drinks was found especially among children and young adolescents aged 12-15 years of high income as well as low-income and middle-income countries[4,5]. Carbonated beverages are becoming an essential part of household food consumption in Pakistan[6].

Several categories of soft drinks are available based on their sugar contents, carbonation level, ingredients and functionality[7]. Soft drinks may also contain caffeine, colourings, preservatives and some other ingredients[8]. Generally, soft drinks can be classified into several types including: bottled waters, carbonated water, juice, nectar, squash/syrup, still drinks, iced/ready-to-drink caffeine containing beverages, sports and / or energy drinks[9,10].

The sweetened soft drink contains 150 calories per 355 mL. Most of the calories in soft drinks are in the form of refined cane sugar or corn syrup. Unless soft drinks are fortified, they contain little to no fibre, minerals, protein, vitamins, or other essential nutrients. A large number of soft drinks are acidic and some may have a pH of 3.0 or even lower[11].

Consumption of soft drinks is still a debatable issue for public health and public policy. Over the years, numerous studies have been conducted to find the possible links between soft drink consumption and health problems, the results of which, however, remain contested. Nevertheless, there are evidences to support the existence of health risks associated, especially, with over consumption and with certain artificial colourings and preservatives[10].

In middle-aged adults, frequent intake of sugar sweetened beverages (SSBs) are associated with higher prevalence and incidence of multiple metabolic risk factors[12] including, obesity, type 2 diabetes and cardiovascular diseases, kidney diseases, non-alcoholic liver disease and gout[13-15]. A recent study conducted in Pakistan reported that the prevalence of prediabetes (11%) and type 2 diabetes (17%) in the population aged 20 years and above is closely associated with over consumption of SSBs[16]. Whereas, among children and adolescents several studies suggested a strong association between frequent consumption of SSBs and increased risk of obesity[17], dental caries[18], early puberty[19] and aggressive behaviours[20].

Most of the reviews and investigations documented a direct association between soft drinks consumption and weight gain, obesity leading to general health problems among children and adolescents. Therefore, it is necessary to guide people about the harmful effects of different types of soft drinks. This study focused on to measure and compare immediate changes in blood glucose levels (BGL) after consuming different soft drinks based on their ingredients, in healthy adult females.

MATERIALS AND METHODS

A total of 40 healthy adult females 22-24 years of age were selected for this investigation. An informed consent form was filled and signed by each participant, females with the history of diabetes, hypertension or other metabolic disorders were excluded from the study.

Following four different brands of soft drink were selected for the study:

- **Brand I:** Lemon-lime-flavored non-caffeinated
- **Brand II:** Diet lemon-lime-flavored non-caffeinated
- **Brand III:** Caffeinated
- **Brand IV:** Fruits and Flower juices

Before the start of the experiment, all subjects were instructed about the procedure and randomly divided into 4 equal groups consisting of 10 participants in each. One brand of soft drink was assigned to each group. At zero - min, postprandial glucose concentrations of all subjects were recorded with the help of glucometer test strips (Accu-Check Active, Roche). Each member was asked to drink 200 mL of their assigned brand of soft drink. The measurement of BGL was repeated after time intervals of 30, 60, 90 and 120 min.

Statistical analyses: Data were analyzed using SPSS 21 program. Paired t-test, one-way ANOVA and post-hoc Tukey's test were used to test the significance of mean difference. Level of significance was set at $p<0.05$.

RESULTS

Brand I: Initial BGL ranged from 90-97 mg% with an average of 93.75±2.99 mg%. After 30 min the mean BGL significantly

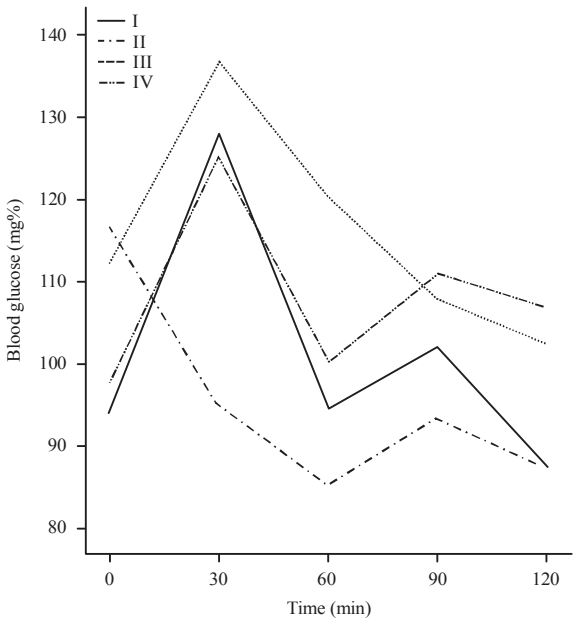

Fig. 1: Mean blood glucose concentrations (mg%) of subjects after consuming different brands of soft drinks at various time intervals

increased to 128±4.97 mg% followed by a significant decreased with mean 94.25±12.09 mg% at 60 min. The mean BGL after 90 min non-significantly increased to 101.75±7.27 mg%. However, after 120 min a significant decrease in mean BGL (87.25±2.22 mg%) was observed (Fig. 1).

Brand II: At zero - min, the BGL range was 108-126 mg% with mean 116.5±8.06 mg%. After 30 min BGL decreased significantly with an average of 94.5±2.08 mg%. A significant fall (85±4.24 mg%) and rise (93±4.97 mg%) in mean BGL were observed after 60 and 90 min respectively, after 120 min further non-significant decrease (87±2.16 mg%) in mean BGL were observed (Fig. 1).

Brand III: Initially BGL of this group ranged from 100-125 mg% with mean of 112±11.52 mg%. After 30 min BGL increased significantly with an average of 136.75±3.40 mg%. However, after 60 and 90 min the BGL continued to fall significantly with an average of 120.25±5.06 and 107.75±6.55 mg% respectively. The additional non-significant reduction of BGL with a mean of 102.25±3.5 mg% was observed after 120 min (Fig. 1).

Brand IV: At zero - min BGL ranged from 94-104 mg% with mean of 97.5±4.43 mg%. After 30 min BGL increased significantly with an average of 125±6.48 mg% followed by a significant decrease with the mean value of 100±4.32 mg% at 60 min. A significant increase (110.75±2.99 mg%) was observed in average BGL after 90 min, after120 min non-significant decrease with a mean value of 106.75±4.03 mg% was observed (Fig. 1).

DISCUSSION

Table 1 shows that all 4 brands of soft drinks used in the present experiment are a combination of additives with maximum 7 in brand II and III whereas, brand I and IV containing 5 and 6 additives respectively. These add-ons are used either as sweeteners, preservatives or flavour enhancers[21].

In the present study subjects were asked to drink different brands of soft drinks in postprandial state of glucose, where baseline BGL were less than 140 mg%[22] (Fig.1). The expected rise in mean BGL after 30 min[23] reached to peak values in groups of subjects who consumed brand I, III and IV. The BGL increased for a short period and ultimately fall in 60 min, can be justified by the fact that simple sugars present in these soft drinks are rapidly absorbed into the blood stream[24,25]. Consequently, the increased secretion of insulin lowers BGL by increasing glucose uptake into skeletal muscles and adipose tissues while decreasing glucose production by the liver[26].

After 30 min, the mean BGL was much higher in the group of subjects who consumed brand I and IV where sugar was added as sweetener. A moderate increase in BGL was observed in the group who consumed brand III which could be attributed primarily to High-fructose corn syrup (HFCS) (Fig.1) as the digestion, absorption and metabolism of fructose are different from those of glucose[27,28] and to caffeine also, since acute short term ingestion of caffeine in healthy subjects might shift glycaemic homeostasis toward hyperglycaemia[29]. On the other hand, consumption of brand II (containing artificial sweeteners aspartame and acesulfame), decreased the blood sugar[30], since the sweet taste of artificial sweeteners ultimately promoted pancratic dysfunction and insulin resistance[31-33].

After 60 min, consumption of brands I, II and IV showed a significant decrease (8-10 %) in mean BGL. This result agrees with the findings of Bloomer[31], who demonstrated that the ingestion of a sugar-rich beverages increased the insulin that persisted for approximately 60-90 min after consumption as well as artificially sweetened beverages did not increase the blood sugar or insulin for two-hour as compared to postprandial period.

Table 1: Ingredients of selected brands of soft drinks

	Brands			
Ingredients	I	II	III	IV
Caffeine	x	x	√	x
Carbonated water	√	x	√	Rose water
Citric acid	√	√	x	√
Colour	x	x	Caramel	Food and Natural
Emulsifier	x	x	√	x
Malic acid	x	√	x	x
Natural flavour	√	√	√	Fruit juices
Phosphoric acid	x	x	√	x
Sodium benzoate	x	√	x	√
Sodium citrate	√	√	x	x
Sugar	√	AceK*+Aspartame	HFCS**	√

*Acesulfame potassium, **High-fructose corn syrup

However, with the course of time, the group of subjects who consumed brand III exhibited less reduction in BGL because the HFCS causes slight impairment of hepatic insulin's action[28]. Further the presence of caffeine induces a reduction in insulin sensitivity either by releasing epinephrine and/or by blocking peripheral glucose uptake[29,34].

In between 60-90 min, brands I, II and IV showed increased mean BGL. This trend may be due to the fact that the secretion of glucagon is regulated by plasma glucose concentration. Normally around 90 mg% of BGL, glucagon is secreted in basal levels to counterbalance the effect of basal insulin secretion thus maintaining blood glucose concentrations[35].

Group of the subjects who consumed brands I, II and III, after 120 min their mean BGL was lower than that of the initial (postprandial) blood glucose concentrations, however, mean BGL remained higher till the end of experiment in subjects who consumed brand IV because of added fruit juices containing high concentration of fructose. The experimental studies have suggested that in normal non-exercising subjects, approximately half of the fructose is converted into glucose within 2-6 h which is further lower in women compared to men[36].

Over consumption of artificial sweeteners (e.g. added in brand II and III) increases the risk of nutrients deficiencies and weight gain[37]. There is also a relationship between sweeteners and certain cancers, chronic fatigue syndrome, Parkinson's disease, Alzheimer's disease, multiple sclerosis, autism and systemic lupus[38].

All soft drinks under study have acidic pH due to the presence of citric acid (e.g. brands I, II and IV), sodium citrate (e.g. brand I, II), phosphoric acid and malic acid (e.g. brand III). Although, within the oral cavity, acid neutralization mechanisms are present but still the pH is low enough to cause erosion of the enamel surface and cementum of both deciduous and permanent teeth. Thus, continuous consumption of soft drinks not only lead to irreversible damage to the tooth structure[39-41] and risk of fractures[42] but also developing hypocalcaemia in both children and postmenopausal women[43,44].

A previous study was conducted including the secondary school female students and found an association between the consumption of caffeinated soft drinks (e.g., brand III) and stress, anxiety and depression[45]. Moreover, the increased risk of spontaneous abortions[46] and metabolic impairments due to synergistic effect of sugar and caffeine on insulin-mediated perturbations were documented[47]. Additionally, in vitro and animal evidences suggested that additives such as emulsifiers (brand III) may contribute to gut and metabolic disease development[48].

Even though sodium benzoate (brand II, IV) is accepted as a safe substance and did not show significant acute adverse effect on glucose homeostasis[49] but some review articles documented the adverse effects of short-term exposure to sodium benzoate including irritation of eyes, skin and respiratory tract, damage to the hepatocyte cell membrane and mitochondria, liver and kidney dysfunction[50] and consumption of sodium benzoate above 5 mg kg^{-1} (acceptable daily intake) for a limited time was considered genotoxic, clastogenic, neurotoxic, besides being responsible for altering the cell cycle and intercalation in the DNA structure[51]. Similarly, colour (brands III, IV) and flavours (brands I, II, III, IV) are the additives which may have immediate effects (headaches, nausea, allergies, hyperactivity, change in energy level and alterations in mental concentration, behaviour, or immune response) moreover, long term and frequent consumption of soft drinks increase the risk of cancer, cardiovascular disease, brain damage and other degenerative conditions[52,53].

CONCLUSION

Based on the above discussion it can be concluded that patients of diabetes and other metabolic complications should strictly avoid any kind of soft drink. Further, the normal healthy individuals who could not control the urge to drink soft drink beside all health hazards, it is better to use a soft drink with minimum additives like brand I. For healthy individuals whose energy requirements are higher e.g. growing children or fasting persons, brand IV with natural ingredients could be a better choice as it provides a sustained BGL for longer duration.

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