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ORIGINAL ARTICLE

The Effects of Ingestion of Sugarcane Juice and Commercial Sports Drinks on Cycling Performance of Athletes in Comparison to Plain Water

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A Concept / Design
B Acquisition of Data
C Data Analysis / Interpretation
D Manuscript Preparation
E Critical Revision of the Manuscript
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Abstract

Purpose: **Sugarcane juice (ScJ) is a natural drink popular in most tropical Asian regions. However, research on its effect in enhancing sports performance is limited. The present investigation was to study the effect of sugarcane juice on exercise metabolism and sport performance of athletes in comparison to a commercially available sports drinks.**

Methods: **Fifteen male athletes (18-25 yrs) were asked to cycle until volitional exhaustion at 70% VO_2 max on three different trials viz. plain water (PW), sports drink (SpD) and ScJ. In each trial 3ml/kg/BW of 6 % of carbohydrate (CHO) fluid was given at every 20 min interval of exercise and a blood sample was taken to measure the hematological parameters. During recovery 200 ml of 9% CHO fluid was given and blood sample was drawn at 5, 10, 15 min of recovery.**

Results: **Ingestion of sugarcane juice showed significant increase ($P<0.05$) in blood glucose levels during and after exercise compared to SpD and PW. However, no significant difference was found between PW, SpD and ScJ for total exercise time, heart rate, blood lactate and plasma volume.**

Conclusion: **ScJ may be equally effective as SpD and PW during exercise in a comfortable environment (<30^{0}C) and a more effective rehydration drink than SpD and PW in post exercise as it enhances muscle glycogen resynthesis.**

Key Words: Sugarcane Juice; Exercise Performance; Fluids; Natural Drink

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INTRODUCTION

Fluid intake during prolonged exercise is effective in improving exercise performance and delaying the onset of fatigue [1]. To sustain high rate of work output or exercise performance in heat requires availability of carbohydrate (CHO) as fuel for the working muscle. Ingestion of CHO from 20 to 15 min prior to the exercise results in an increase in plasma glucose [2-4], time of performance [5], CHO oxidation during exercise [6] and reduces endogenous glucose production [1,7]. CHO solutions containing 6-8% will increase exercise performance [4,8-10] more than 8-10% solutions [11,12] in hot and humid conditions.

Ingestion of plain water post exercise results in rapid fall in plasma sodium and plasma osmolality and with subsequent diuresis [13,14]. CHO ingestion during short term recovery from prolonged exercise has been shown to increase the capacity for subsequent exercise in a warm environment [15]. The rate of glycogen resynthesis is dependent on the amount of CHO ingested [16,17]. In recovery, a beverage containing 5-10% CHO with 30-40 mEq sodium should be ingested to achieve euhydration. A minimum of 50g/ hour of CHO should be ingested in the first 2 hours to maximize glycogen depletion? [18].

Sports beverages containing CHOs and electrolytes may be consumed before, during, and after exercise to help maintain blood glucose concentration, provide fuel for muscles, and decrease risk of dehydration and hyponatremia. Natural fruit drinks such as young coconut water [19,20], honey [21] and milk [22,23] have been shown to be effective hydration drinks.

Sugarcane juice (ScJ) is a common indigenous drink, economical and widely consumed by Indian athletes. It is rich in CHOs and a few electrolytes, comparable with planned sports drinks. Though it is consumed regularly, the efficacy of ScJ in sports performance hasn't been reported. Hence, the present investigation was envisaged to study the effect of sugarcane juice on exercise metabolism and sport performance of athletes in comparison to a commercially available sports drinks and plain water.

METHODS AND SUBJECTS

Subjects:

Fifteen healthy male Indian athletes in the age range of 18-25 years were participated in the present study. The physical characteristics were (Mean ± Standard Deviation) age: 19.4±0.58 yrs, Height 172.1±1.52 cms, body weight 65.2 ±1.21 kg, body fat 15.1±0.74%, lean body mass 55.0 ±1.13 kg and maximal oxygen uptake (VO_2max) 51.0± 2.10 ml.kg-1.min-1. The study was approved by Sports Authority of India Research committee. The volunteers were briefed on the purpose of the study, experimental protocol and their written consent was obtained.

Experimental Procedure:

The study had a randomized crossover counterbalance design. The subjects participated in three experimental trials, at least one week apart.

Pre Exercise Phase:

Maximal oxygen uptake (VO_2 max) was determined prior to the experimental trials [24]. The volunteers were restricted from performing routine exercise a day before each trial and were required to maintain similar training volume throughout the study. The volunteers were instructed to report to the laboratory after 10-12 hours of fast. On reporting to the laboratory, a standardized breakfast was given which comprised of two slices of bread and 500 ml of cold plain water. One hour later, the participants emptied their bladder and body weight with minimal clothing was measured. The heart rate was taken through a monitor attached to an elastic belt positioned below the pectoral muscle. A blood sample was taken to measure the hematological parameters such as blood glucose, hemoglobin, hematocrit and plasma volume.

Exercise Phase (During Exercise):

After warm up for 5 min at 50 % VO_2 max, the subjects cycled at 70% VO_2max until volitional exhaustion. In each trial subjects consumed 3ml / kg body weight of refrigerated fluid (<15^0C) at every 20 min interval [25]. The subjects were fully aware of the drinks consumed during trials. The heart rate was recorded every 5 min. At every 20 min and at exhaustion, a blood sample was taken in sitting position on bike in order to measure the hematological parameters. Perceived rate of exertion (PRE) was measured for every 10 min and fluid sensory scale was administered every 20 min to measure the gastro intestinal tolerance (GIT). All the trials were conducted at 28-30^0 C and at a relative humidity of 65 -70%.

Post Exercise Phase:

Participant's body weight with minimal clothing was measured after the trial. During recovery 9% of CHO fluid; 3ml / kg body weight was given for rehydration. A blood sample was drawn at 5, 10, 15 min to measure the hematological parameters.

Liquid Supplements:

In the present study trials were done with plain water (PW), sports drink (SpD), and Sugarcane juice (ScJ). The nutrient composition of SpD and ScJ is given in table1. Bottled mineral water (Bisleri) was used as control (PW). Glucogen Sport of Applied Nutritional Sciences, Mumbai was used as sports drink. ScJ used for the experiment was grown exclusively for research purpose from organic sources and free from pesticides. The juice was pasteurized to kill the microorganisms and to avoid bacterial contamination. To prepare a 6 % CHO solution of SpD, a 25gm sachet was dissolved in 385 ml of water, which was given during exercise and to prepare a 9% solution it was dissolved in 255 ml of water, which was given after exercise. To prepare a 6% solution, 67 ml of ScJ was mixed with 33 ml of

Table 1: Nutrient composition of sports drink and sugarcane juice

Nutrients	Sports drink(25mg)	Sugarcane Juice (100g)
Energy (k.cal)	91	39
Carbohydrate (g)	25	9.1
Vitamin A (IU)	500	188
Vitamin B1 (mcg)	-	12
Vitamin B12 * (mcg)	2	-
Vitamin –C* (mg)	60	-
Vitamin –D3* (IU)	400	-
Vitamin –E* (mg)	10	-
Calcium Pancothenate* (mg)	10	-
Potassium (mg)	100	360
Sodium (mg)	100	20
Calcium (mg)	200	74
Phosphorus (mg)	150	22
Iron (mg)	-	0.1
Zinc* (mg)	1.25	-
Magnesium* (mg)	75	-
Manganese* (mcg)	100	-
Selenium* (mcg)	20	-

* Not measured in ScJ

water, which was given during exercise and the 9% solution, in the form of pure sugarcane juice was given after exercise. Fluids were refrigerated at <15 ^{0}C.

Biochemical Estimation:

A Venous blood sample was drawn to estimate the bio chemical parameters. Blood glucose was analyzed using glucometer (Boehringer Mannheim Germany accu check sensor). Blood lactate was analyzed using lactate analyzer (1500, YSI, USA). Cyanmet-haemoglobin method was used for the estimation of hemoglobin [26]. Micro hematocrit capillary tube coated with anticoagulant was used for the estimation of hematocrit. Plasma volume was calculated indirectly from hemoglobin and hematocrit [27].

Physiological Transients:

Exercise test was performed on an electronically operated computerized bicycle ergometer (ER 900: Erich Jaeger, Germany). $V0_2$max measurement was carried out using a portable metabolic analyzer, Cosmed K4 (Cosmed srl, Italy) using a test protocol that consisted of graded ergometry). The heart rate was recorded through a heart rate sensor (Polar HR sensor, USA). Total exercise time till exhaustion was recorded to determine the maximal endurance performance.

Measurement of PRE, GIT and Sweat loss:

The Borg's scale was administered to assess PRE [42] and fluid sensory scale was administered to measure GIT [45]. Sweat loss was calculated using the formulae: Sweat loss = (body weight before exercise- body weight after exercise) + amount of fluid intake

Statistical Analysis:

Statistical Package for Social Sciences (SPSS) version 16.0 was used for the analysis. Mean and standard error was applied for all the variables. Repeated measures analysis of variance (ANOVA) was applied to study the difference between duration and trials. Significant differences were determined by the Duncan Multiple Range Test (Post hoc). Friedman ANOVA was applied to study the significant difference between duration of exercise on PRE and GIT. Kruskal Wallis test was applied to study the significant difference in the ranks obtained for trials with PW, SpD and ScJ. Differences were considered significant at $P<0.05$.

RESULTS

The mean pre exercise heart rate (PHR) of the subjects showed no significant difference between the trials.

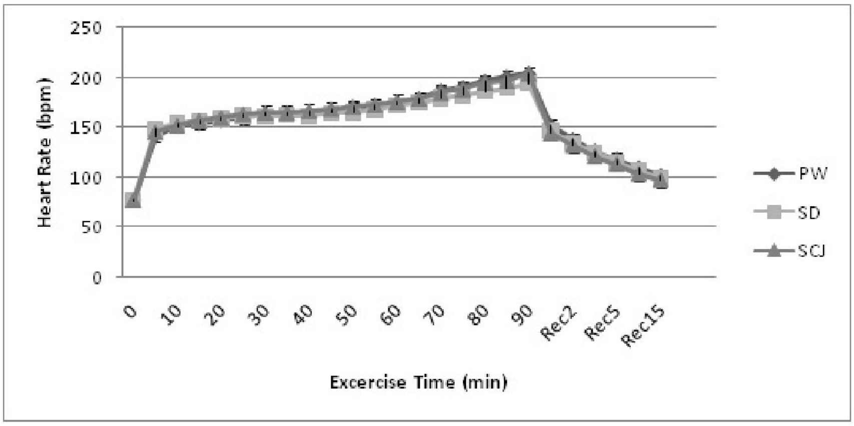

Fig. 1: Mean heart rate responses of the subjects before, during and after exercise with select liquid drinks
PW: plain water; SD: Sports Drink; ScJ: Sugarcane juice

During exercise, heart rate showed significant increase ($P<0.05$) with increasing exercise time and in post exercise, significant decrease ($P<0.05$) with increasing recovery time. There was no significant difference between the trials with PW, SpD and ScJ trials during exercise and recovery (Fig. 1). The mean total exercise time showed no significant difference between the three trials (Table 2). Most of the athletes could not exercise more than 60 min and a few athletes could exercise for about 90 min.

The subjects were in similar pre exercise blood glucose level with PW, SpD and ScJ trials. During exercise the blood glucose levels showed significant increase ($P<0.05$) with increase in exercise time ($P<0.05$). However, at each time (20, 40, 60 min) point no significant difference was observed for the blood glucose levels between the trials (Fig. 2). The post exercise blood glucose levels of the subjects in all the three trials increased significantly with the recovery time ($P<0.05$) and showed a significant difference ($P<0.05$) between the three trials. The trials with SpD and ScJ recorded significantly higher ($P<0.05$) blood glucose levels when compared with water. Sugarcane juice recorded significantly higher blood glucose levels than the sports drink trials. The mean peak blood lactate had no significant difference between the three trials (Table 2).

The mean hemoglobin and hematocrit level of the subjects before and during and after exercise was not significantly different between the trials. During

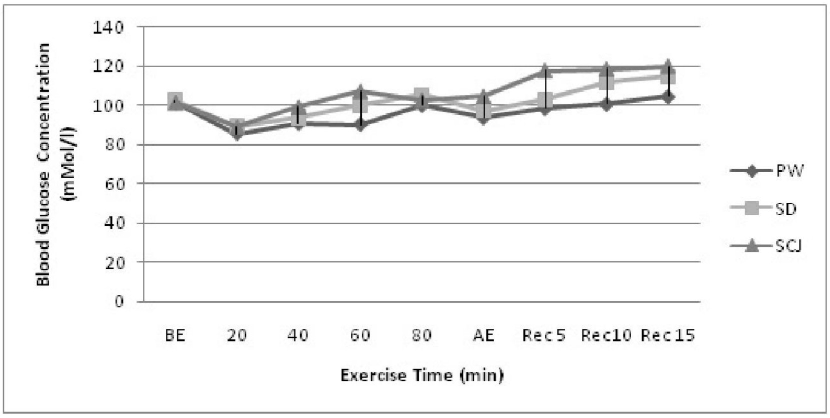

Fig. 2: Blood glucose concentration of the subjects before, during and after exercise with select liquid drinks
PW: plain water; SD: Sports Drink; ScJ: Sugarcane juice

Table 2: Total exercise time and peak blood lactate concentration of athletes with select liquid drinks

Parameter	Liquid Supplements	Total Exercise Time (min) (Mean ± Standard Error)	ANOVA value
Total exercise time	Plain Water	62.0 (5.29)	F= 0.07NS
	Sports Drink	64.3 (5.63)	
	Sugarcane Juice	63.4 (5.54)	
Peak Blood Lactate Concentration	Water	12.0 (0.66)	F= 0.01NS
	Sports Drink	12.0 (0.57)	
	Sugarcane Juice	12.1 (0.68)	

NS: Not significant

exercise, the mean hemoglobin and hematocrit level was increased with increase in exercise time (*P*<0.05) and decreased during recovery (*P*<0.05). During exercise with increasing exercise time the mean plasma volume decreased for all the trials. However, the difference between the trials was not significant. In post exercise, the mean plasma volume significantly increased (*P*<0.05) in all the three trials with increase in recovery time. However, no significant difference was found (Fig. 3). The sweat loss showed no significant difference between the three trials.

In the present study the percent change in body weight with PW, SpD and ScJ trials shows marginal dehydration with test fluids. The total amount of fluid ingested and sweat loss was almost similar in all the trials, indicating similar level of hydration with the test fluids (Table 3). The PRE significantly increased with the time of exercise in all the three trials. However, there was no significant difference between the trials during exercise for PRE (Table 4). During exercise, at different time points and during recovery no significant difference was observed for thirst, stomach upsets and nausea in PW, SpD and ScJ trials. However, significant difference (*P*<0.05) was observed for fullness and sweetness (Table 5). Feeling of fullness and sweetness was more in ScJ trial than SpD trial.

DISCUSSION

In the present context, HR responses were not significantly different during and after exercise with ingestion of plain water, sports drink and sugarcane juice. Owen et al[28] reported that no significant difference in heart rate was noticed with the ingestion of either plain water or CHO beverages during prolonged exercise in the hot environment.

The time to exhaustion showed no significant

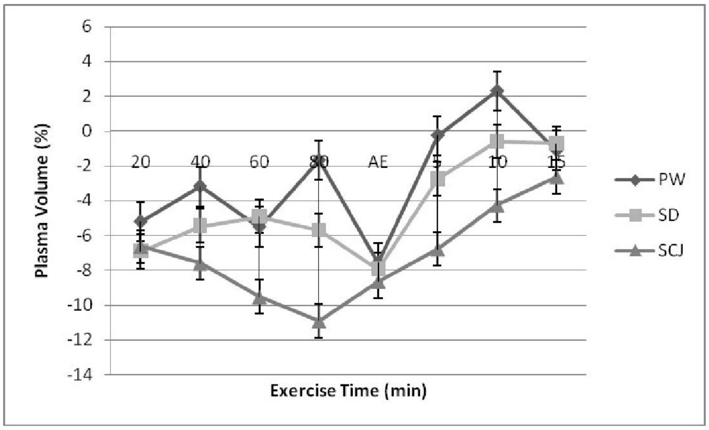

Fig. 3: Plasma volume level of the subjects before, during and after exercise with select liquid drinks
PW: plain water; SD: Sports Drink; ScJ: Sugarcane juice

Table 3: Pre and post exercise changes in body weight and sweat loss of subjects in the trials with select liquid drinks

Hydration Indicators	Mean ± Standard Error			ANOVA Value
	Plain Water	Sports drink	Sugarcane juice	
Pre exercise body weight (kg)	63.7(1.52)	64.0(1.48)	63.7(1.52)	F=0.01^{NS}
Post exercise body weight (kg)	63.5(1.56	63.7(1.49)	63.5(1.54)	F= 0.00^{NS}
Change in body weight (%)	0.4(0.07)	0.5(0.08)	0.4(0.07)	F= 0.15^{NS}
Sweat loss (ml)	797.6(58.83)	799.6(100.82)	759.6(102.77)	F=0.04^{NS}

NS: Not significant

difference between three trials viz; SpD, ScJ and PW, but the mean values showed that the subjects performed exercise for a longer time with SpD and ScJ than PW. The primary reason for the difference in cycling time was due to presence of CHO and electrolyte sources in SpD & ScJ which were able to maintain blood glucose at a higher level for oxidation by muscle thus sparing the muscle glycogen stores [29-31]. In a competitive sport the margin between victory and defeat is small. This small difference might sway the result. Athletes may improve their exercise performance with consumption of CHO fluids during exercise for the winning edge.

Ingestion of CHO during endurance exercise results in maintenance of blood glucose levels and a concomitant increase in the rate of CHO oxidation during the later stages of the exercise and spares muscle glycogen [8,32-35]. In the present context at different points of exercise time (20, 40, 60, 80 minutes) the glucose values significantly increased in SpD, ScJ and PW trials and no significant difference was found between the trials. The exogenous CHO source might have resulted in the increases observed in blood glucose levels in both SpD and ScJ trials. The subjects performing with water might have depended for glucose on the internal mobilization of muscle glycogen, glycogenolysis, lactate conversion and free fatty acids.

This increase in glucose concentrations with CHO beverages in this study was also similar to the responses found in studies conducted by Owen et al [28] and Ivy et al [36]. Both studies showed increased performance endurance with the increase of blood glucose concentration. In the present context a trend of increased exercise performance with SpD and ScJ trials compared to water was evident, however the differences were not significant.

Muscle glycogen resynthesis is enhanced if CHO beverages are ingested immediately following an exercise bout [15,16,37]. The rate of resynthesis is dependent on the amount of CHO ingested [38] and the addition of sodium to CHO solutions results in increased replenishment of muscle glycogen. In recovery, significantly increased blood glucose concentration was observed in the SpD, ScJ compared to PW trials. The increase in blood glucose concentration with SpD and ScJ indicates that perhaps this increase in blood glucose was because of exogenous CHO and in PW trial free fatty acids (FFA) may have contributed. Seidman et al [39] haveobserved similar results with glucose polymer and water which shows increased blood glucose with glucose polymer and increased FFA with water.

The lactate levels showed no significant difference between the three trials. This shows that blood lactate concentration was not affected either by ingestion of

Table 4: Kruskals wallis test results for perceived rate of exertion of the subjects during exercise with select liquid drinks

Trial	Exercise Time (min) (Mean Ranks)								
	10	20	30	40	50	60	70	80	90
Plain Water	24.9	24.4	23.1	19.5	15.2	16.1	10.1	8.0	3.0
Sport Drink	21.7	21.5	20.6	16.7	15.6	13.6	8.9	6.0	3.0
Sugarcane juice	22.3	23.0	22.1	17.6	15.6	11.6	10.7	5.5	3.0
Chi- square	0.57^{NS}	0.41^{NS}	0.3^{NS}	0.48^{NS}	0.01^{NS}	1.55^{NS}	0.39^{NS}	1.23^{NS}	0.00^{NS}

* Significant at P<0.05; NS: Not significant

Table 5: Kruskals wallis test results for gastro intestinal tolerance of the subjects during exercise and recovery with select liquid drinks

Gastrointestinal tolerance	Trial	Exercise Time (min) (Mean Ranks)				Recovery
		20	40	60	80	
Thirst	Plain Water	16.5	16.0	11.5	7.5	22.0
	Sport Drink	27.0	16.0	14.5	6.0	20.5
	Sugarcane juice	25.5	22.3	16.5	6.0	26.5
	Chi- square Value	9.09*	9.57 NS	4.10 NS	2.00 NS	2.63 NS
Sweetness	Plain Water	9.0	9.0	5.5	3.0	8.2
	Sport Drink	26.9	21.5	17.8	9.0	29.3
	Sugarcane juice	33.1	27.5	19.2	10.0	31.4
	Chi- square Value	31.9*	24.9*	21.9*	11.0*	30.9*
Stomach Upset	Plain Water	23.0	18.0	13.5	5.0	22.5
	Sport Drink	23.0	18.0	15.0	6.5	24.0
	Sugarcane juice	23.0	18.0	13.5	8.0	22.5
	Chi- square Value	0.00 NS	0.00 NS	2.00 NS	2.44 NS	2.00 NS
Fullness	Plain Water	19.5	15.5	10.5	3.0	18.5
	Sport Drink	22.5	18.9	15.7	7.5	21.4
	Sugarcane juice	27.0	22.0	17.5	9.0	29.0
	Chi- square Value	6.28*	3.98 NS	6.32*	8.17*	10.72*
Nausea	Plain Water	23.0	18.5	15.5	6.50	23.0
	Sport Drink	23.0	18.5	15.5	6.50	23.0
	Sugarcane juice	23.0	18.5	15.5	6.50	23.0
	Chi- square Value	0.00 NS	0.00 NS	0.00 NS	0.00 NS	0.00 NS

* Significant at $P<0.05$; NS: Not significant

water or by sports drink or sugarcane juice. Fritzsche et al [40] found similar results with ingestion of water and a CHO drink.

The precent change in body weight with PW, SpD and ScJ trials shows marginal dehydration with test fluids. The total amount of fluid ingested and sweat loss was almost similar in all the trials, indicating similar level of hydration was observed with the test fluids. Owen et al [28] have reported that sweat rates remain the same with different CHO beverages during exercise in the heat. Sweating rates were reported to be similar with a 10% glucose polymer, 10% glucose or water.

The major target of fluid replacement during exercise and recovery is to maintain plasma volume, so that circulation and sweating can progress at optimum level [27]. Progressive, uncompensated reduction in plasma volume result in increased heart rate and cardiac stroke volume and eventually in the hearts ability to maintain its output [41].

In this study, the mean values showed increased haemoglobin and hematocrit and decreased plasma volume at different time points of exercise with PW, SpD and ScJ trials. This shows an insufficient amount of fluid ingestion with sweat loss. This also is evident from change in body weight. The post exercise mean values showed decreased haemoglobin and hematocrit level and increased plasma volume than the pre exercise levels with PW, SpD and ScJ. This could be due to fluid replacement post exercise.

Exercise intensity is interpreted via oxygen uptake, relative values such as heart rate and in terms of ratings of subjective intensity as perceived by the subject [42]. The perception of exertion may be looked upon as a kind of gestalt, or configuration of sensations: strain, aches and fatigue from the peripheral muscles and the pulmonary system, and some other sensory cues [43]. The increased rate of PRE in the present study indicates that ingestion of CHO drink can make the task of exercise easier. Carter et al [44] also noticed that the PRE was significantly lower during the CHO ingestion trials compared to the plain water trials.

Gastric emptying rates and intestinal absorption may have impact on actual performance. There was a significant difference in sweetness and fullness with ScJ when compared with SpD. This may be due to the composition of sugarcane juice. Cool water, at a temperature of 5 to 15^{0}C empties quicker than warmer solutions [46]. In this study beverages were served were at a temperature of 13-15^{0}C.

Limitations:

The researchers could assess the rehydration status only up to 15 min. We could not assess the serum electrolyte status during and after exercise, blood lactate level during exercise, total body water and plasma free fatty acids.

CONCLUSION

ScJ may be equally effective as SpD and PW during exercise in a comfortable environment (<30^{0}C) and as effective a rehydration drink as SpD and PW. Reduction of the feeling of fullness with ScJ and maintenance of plasma volume may be achieved with modification through addition of NaCl.

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Conflict of interests: None

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