EFFECTIVENESS OF APPLE CIDER VINEGAR ON POSTPRANDIAL SUGAR LEVELS: A RETROSPECTIVE CROSS-OVER STUDY ON INDIVIDUALS WITH TYPE 2 DIABETES

Introduction:

Type 2 Diabetes is one of the most common metabolic disorders. India is known as the Diabetes capital of the world. According to International Diabetes Federation's findings in 2019 the top 3 countries with the highest number of individuals with Diabetes are China (116.4 million), India (77 million) and the United States of America (31 million). [1]

Type 2 Diabetes is one of the leading endocrine disorders at present.One of the root causes for Type 2 Diabetes is Insulin resistance in the body[2]. The major contributing factors studied as a risk factor to develop Type 2 Diabetes are unhealthy lifestyles leading to high fat storage mainly in the abdomen region. The various lifestyle factors that cause the onset of diabetes are sedentary lifestyle, physical inactivity [3], smoking, alcohol consumption [2] and unhealthy diet. Foods that are rich sources of refined flour, oil and excessive sugars lead to fluctuations in the plasma blood sugar levels. When healthy people eat food containing carbohydrates, the digestive system breaks them into smaller particles and releases Glucose, which enters the blood. When glucose enters the blood, pancreas secrete the hormone- Insulin. This hormone prompts the cells to absorb glucose for generating energy. Glucose is absorbed into the liver, muscles and adipose tissues. Muscle accounts for a major percentage of glucose absorption about 60-70% [4] in the form Glycogen. This is utilised during the intense workout 10% of glucose absorption happens in the adipose tissue [4]. During the prolonged starvation these tissues produce ketone bodies via lipogenesis pathways that provide an alternate energy substrate to the brain.Liver accounts for 30% of glucose uptake[4]. During the insulin deficiency and Insulin resistance,the hepatics via gluconeogenesis pathway leads to production of hepatic glucose.

In a person with Type 2 Diabetes, when carbohydrates are consumed, due to Insulin resistance and reduced secretion of Insulin from the pancreas, absorption of glucose is decreased. This eventually leads to an increase in the plasma glucose levels. (Insulin is a hormone which helps to control the amount of sugar in the blood). With Insulin resistance glucose absorption by the skeletal muscle cells, adipose tissue and liver is significantly less compared to healthy individuals [5].

The main goal in the management of diabetes is to achieve near normal levels of fasting and post prandial sugar levels throughout the day [6]. The total amount of carbohydrate consumption has the strongest impact on glycemic responses. American Diabetes Associations in their 2019 position statement states that eating low carbohydrate meals have resulted in better glycemic control and has the potential to reduce the antihyperglycemic medications for the Type 2 Diabetics [7].

Carbohydrates are the chief source of energy contributing 70-80% of total calories [8]. A 10 year follow up study on urban Indians in Chennai showed that higher diet risk score which included larger intake of refined grains and reduced intake of vegetables and fruits, dairy and nuts doubled the incidence of new-onset T2D [9]. In a cohort where bringing down the total carbohydrate intake can be challenging, health care professionals might have to look for alternative methods to bring down food's impact on blood glucose (postprandial levels). There are several foods and beverages that can bring a positive impact on our digestive system. One such example is Apple Cider Vinegar (ACV).

Apple cider vinegar is the part of fruit apple extracted by the biotechnological process of double fermentation, alcoholic and acetic.This acidic solution is used throughout the world as a flavouring solution or preservative for foods. Apple cider vinegar contains various flavonoids, it also contains chemicals like Gallic acid, catechin, caffeic acid, and ferulic acid [10] Apple cider vinegar has the various health benefits like Antioxidants, Anti-Diabeic, Anti-inflammatory , Antihypertensive and anti hypercholesterolemia properties [11]. Due to anti-diabetic properties of Apple cider vinegar, it helps in suppressing disaccharides activities in the intestine. The active chemical composition Apple Cider Vinegar is Acetic acid that interferes with digestion of molecules of starch which reduces the amount of glucose absorption in the plasma of blood after meals [12].

Methodology:

This is a crossover study retrospectively evaluated on participants who enrolled in the Sugarfit's diabetes reversal program (SDRP). SDRP is a personalized intervention program that uses technology-enabled clinical management, dedicated human coach-led diabetes, and nutrition experts to provide customized nutrition, progressive fitness, and behavioural modification for the holistic management of Type 2 diabetes. Continuous Glucose Monitor is a device which continuously monitors glucose levels. This device records fluctuations in every 15 minutes intervals helping to capture glucose levels from interstitial fluid with trends in real-time. This crossover study was done between a) a meal without ACV and b) a meal with ACV during the 14 day continuous glucose monitoring (CGM) period. One of the most commonly used interventions in SDRP is advice on consuming a teaspoon of apple cider vinegar diluted in 150 ml water half an hour before major meals. Participants on CGM were observed for the first 3 days for post meal spikes. Then advised to have apple cider vinegar before consuming the meal. They were also expected to log their meal intake and activity details on the Sugarfit's app to track the CGM progress. Those who were allergic to ACV, did not tolerate the taste of ACV, were not interested in trying, saw any other adverse effects like vomiting/diarrhoea/constipation, or did not continue the intervention for 3 successful days were excluded from the study. A total of 40 participants' data was collected from the food log recorded during the CGM period. The participants' baseline average Hba1c was 8.3% with an average weight of 77 kgs. They were between the age group 22 to 67 years and in that male participants were 25 while female participants were 15 in number.

The outcomes analysed were a) first hour postprandial spike, b) second hour postprandial spike, c) highest spike value, d) duration of highest spike seen and e) duration it took to come back to baseline, with and without ACV.

Table 1: Baseline characteristics of study participants

Age in years	22-67
Sex	Male n=25 Female n=15
Hba1c in %	8.3
Weight in kgs	77

Results:

Baseline characteristics including age, gender, starting Hba1c and weight of the participants are given in Table 1. All the participants were diagnosed with type 2 diabetes and self enrolled in sugarfit's diabetes reversal program. Data of 40 such participants who adhered to the intervention of including apple cider vinegar in their diets before meals were analysed during the CGM period. Since the recorded data was collected on the same participants for 3 days without an ACV meal and next 3 days with ACV before meals, baseline sugar values were not significantly different. 1st hour post meal sugars without ACV was 48 mg/dl from baseline while with ACV it was 35 mg/dl. Interestingly, 2nd hour post meal sugars without ACV still remained an average of 48 mg/dl from baseline while with ACV it was reduced further down to 28 mg/dl. (Refer Table 2a).

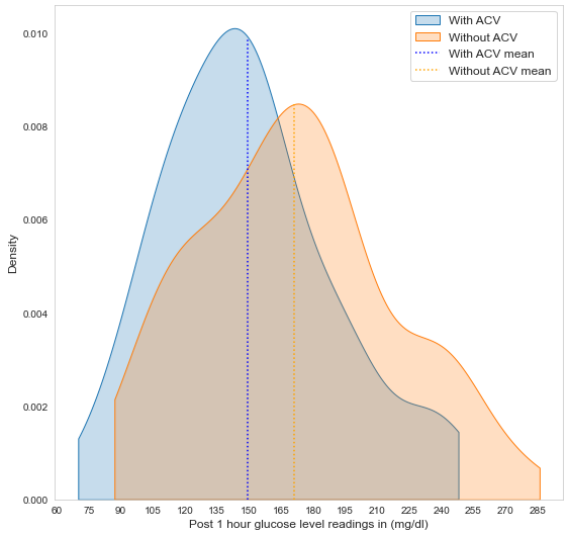
Highest spike value in 2 hours after the meal without ACV was 190 mg/dl while with ACV it was 165 mg/dl. Highest spike was observed with the meal without ACV at 93 minutes while with ACV it was observed at 74 minutes. It was observed that only 14% of values came back to baseline sugars without ACV meal while with ACV 28% of values came back to baseline within the next 120 minutes. (Refer Table 2b).

Results were plotted on graphs using python's mathplotlib and seaborn library. Kernel density estimation charts [Figure 1a, 1b, 2a, 2b and 3] were plotted to understand first and second hour glucose levels with spike analysis and glucose back to baseline analysis respectively.

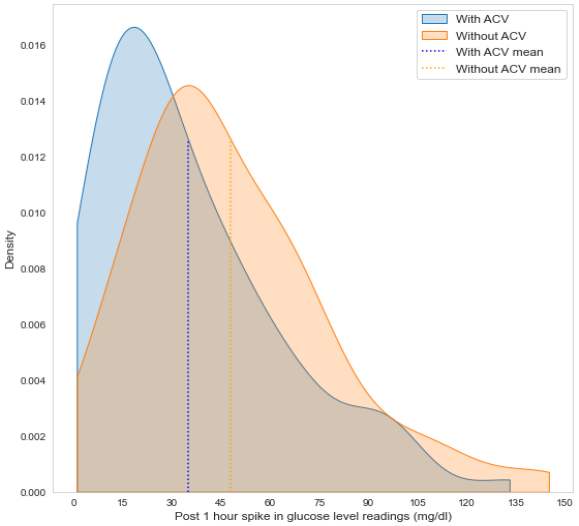
Table 2a: Spike Analysis

	Baseline Sugars (mg/dl)	1st Hour postprandial (mg/dl)	Spike (mg/dl)	2nd Hour postprandial (mg/dl)	Spike (mg/dl)
Without ACV	123	171	48	171	48
With ACV	115	149	35	143	28

Figure-1:

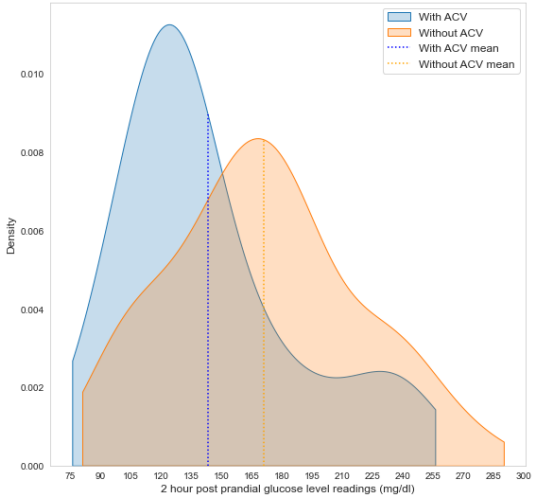


1a) Post 1 hour glucose with and without ACV

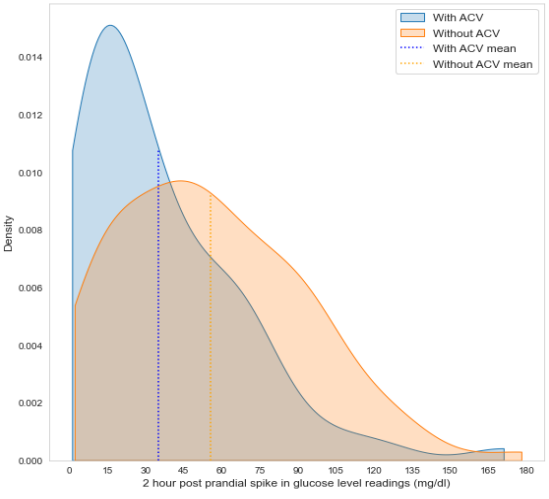


1b) 1st hour spike with and without ACV

Figure-2:



2a) Post 2 hour glucose with and without ACV



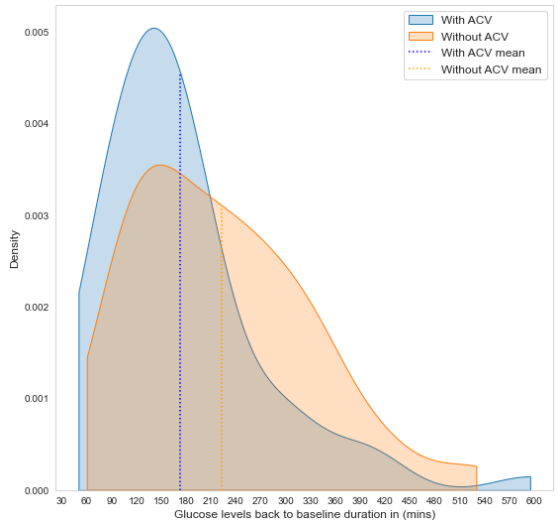
2b) 2nd hour spike with and without ACV

Table 2b: Spike Analysis

	Highest spike value (mg/dl)	Highest spike duration (minutes)	Back to baseline in %
Without ACV	191	93	14
With ACV	166	74	28

The primary outcome of Sugarfit's diabetes reversal program is reduction in Hba1c. In this study, with 40 participants on ACV as the intervention, baseline Hba1c of 8.3% was brought down to 7% with an average drop of 1.3% over the span of 3 months. Apart from that, there was also a drop in weight, where the baseline weight in kgs was 77 and dropped to 74.3 kgs with a change in an average of 2.7 kgs. (Refer Table 3a and 3b).

Figure-3:



Glucose back to baseline with and without ACV

Table 3a: Hba1c Analysis

Baseline Hba1c in %	Hba1c after 3 months in %	Hba1c changes in %
8.3	7	1.3 ↓

Table 3b: Weight Analysis

Baseline weight in kgs	Weight after 3 months in kgs	Weight changes in kgs
77	74.3	2.7 ↓

Discussion:

Postprandial levels are largely influenced by the meal consumed. In a healthy person, insulin starts working immediately and blood sugar levels return to pre meal or baseline within 2 hours [13]. In a diabetic individual, this mechanism is influenced by many other contributing factors like, anti-diabetic agents, insulin therapy, insulin resistance, insulin sensitivity, physical activity, etc. This was a cross-over study done on 40 participants with type 2 diabetes to observe their postprandial response in 1st and 2nd hour without apple cider vinegar for 3 days and later again with apple cider vinegar consumption for 3 days. Inclusion of ACV has shown to reduce postprandial blood glucose [14].. The intake of apple vinegar ameliorates the insulin sensitivity and increases the uptake of glucose in the skeletal muscles [15]. The above hypothesis was also proved in this study where the postprandial spike in both 1st and 2nd hours reduced with the consumption of ACV. It was also observed that with ACV the highest spike duration was quicker in 74 minutes compared to 93 minutes without ACV and less about 25mg/dl compared to the value without ACV. With the values analysed, 14% came back to baseline or pre meal values without ACV while 28% came back to baseline with ACV consumption. Although the type of food consumed was kept constant in terms of its carbohydrate content and glycemic load, there might be missed logging and/or false reporting expected. It is however also possible that the data collected from the food log were not entirely correct, as the accuracy and performance of CGM systems are yet to be tested for its performance as the values are taken from interstitial fluid and not taken from capillary or plasma blood. Hba1c and weight were also compared from baseline to after 3 months in the SDRP, and were analysed in this study as well. Though ACV was not the only intervention given for all the 40 participants evaluated for this study, it was definitely an intervention which was adhered by all the participants and has positively contributed in bringing down Hba1c and weight in these individuals with type 2 diabetes.

Conclusion:

Type 2 Diabetes is one of the major metabolic disorders for mankind. It is characterised by high blood sugar levels(impairment in the insulin secretion), insulin resistance and excessive production of the hepatic sugar levels.The main aim of management of Diabetes is to achieve nearly normal values of post prandial and fasting sugar levels.

Post-meal hyperglycemia is an independent risk factor for cardiovascular problems. Recent studies have shown that post-meal spikes and glucose variability have been associated with diminished brain function and an increased risk of dementia. The American Diabetes Association recommends a goal of <180 mg/dl as a postprandial glucose level target for type 2 diabetic individuals. To achieve the best Hba1c targets, along with pre-meal glucose levels, having strict postprandial targets becomes imperative.

The amount of carbohydrate we consume has a huge impact on post prandial sugar levels. For the healthy individual, insulin secretion happens as soon as a person consumes food. The sugar levels will return to baseline in around 2 hours and inturn maintain the plasma sugar levels at the normal range. On the contrary, for a person with Type 2 diabetes, (due to impairment in the insulin secretion and insulin sensitivity) fluctuations are observed in postprandial sugar levels. There are some liquid supplements that are proven to help manage postprandial blood sugar levels. Apple cider vinegar is one among them of its acetic acid component. This current study shows the positive impact of apple cider vinegar on controlling postprandial sugar levels.

This retrospective cross-over study concludes that this simple and easy-to-implement intervention helps in controlling the post prandial blood sugar levels without any side-effects. Although the duration of peak blood sugar level depends on the glycemic index of the grains being consumed and the quantity of proteins and fibres, the blood sugar level normalisation was shorter in case of ACV.

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