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A low-carbohydrate survey: Evidence for sustainable metabolic syndrome reversal

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Background: Metabolic syndrome has become a significant problem, with the American Diabetes Association estimating the cost of diabetes and pre-diabetes in the United States alone to be $322 billion per year. Numerous clinical trials have demonstrated the efficacy of low-carbohydrate diets in reversing metabolic syndrome and its associated disorders.

Aim: This study was designed to examine how voluntary adherents to a low-carbohydrate diet rate its effectiveness and sustainability using an online survey.

Setting and methods: The 57-question survey was administered online and shared internationally via social media and 'low-carb' communities. Where appropriate, chi-squared tests and paired *t*-tests were used to analyse the responses.

Results: There were 1580 respondents. The majority of respondents had consumed less than 100 g of carbohydrates per day for over a year, typically for reasons of weight loss or disease management. There was a reported decrease in waist circumference and weight with a simultaneous decrease in hunger and increase in energy level. Of those who provided laboratory values, the majority saw improvements in their HbA1c, blood glucose measurements, and lipid panel results. There was a reduction in usage of various medications, and 25% reported medication cost savings, with average monthly savings of $288 for those respondents. In particular, the usage of pain relievers and anti-inflammatories dropped with a simultaneous decreased rating of pain and increase in mobility.

Conclusion: We conclude that low-carbohydrate diets are a sustainable method of metabolic syndrome reversal in a community setting.

Introduction

The prevalence of obesity and diabetes in the United States and the world has increased dramatically over the last 40 years with no sign of correction. These diseases remain undefeated despite billions of dollars in research and health care costs.[1] Estimates from the Centers for Disease Control and Prevention (CDC) and National Health and Nutrition Examination Survey (NHANES) indicate that two-thirds of adults are overweight (body mass index (BMI) ≥25 kg/m^2),[2,3] with 36% being obese (BMI ≥30 kg/m^2).[4] The CDC's review of 2015 data reported more than 114 million Americans have diabetes or pre-diabetes.[5] While the rate of new diagnoses remains steady, the report noted that 9.4% (30.3 million of the 114 million estimated) of the US population has diabetes – an increase from 29.1 million in 2014. Countries with historically low diabetes rates are also now affected: almost half the population of China has pre-diabetes, and 10% have the diabetes.[6] The medical costs of diabetes and its complications and co-morbidities are staggering. The American Diabetes Association (ADA) estimates the cost of diabetes and pre-diabetes in the United States alone to be $322 billion a year.[7] Patients with diabetes account for one in three Medicare dollars spent and one in five overall health care dollars.[8]

At West Virginia University School of Medicine, where Dr Cucuzzella is a practising family physician and professor, outpatient and inpatient clinics are overwhelmed every day with cases of diabetes and metabolic syndrome. As of 2016, 37.7% of adults in West Virginia are obese. By best estimates, 15% have type 2 diabetes (T2D), and perhaps more than 50% have pre-diabetes.[9,10] Most of these patients are completely unaware of their condition and the impacts of a poor diet, as are many of these patients' health care providers. These patients lack the tools and support to halt or reverse their disease.

This report describes a simple approach to reversing T2D and pre-diabetes (remission is defined as normoglycaemia for 1 year without active pharmacotherapy, with the disease 'cured' after 5 years)[11] that is showing promise in the fight against this deadly and costly disease. It is based on

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survey findings from more than 1500 people from West Virginia, other parts of the United States and the world who have benefited from a low-carbohydrate diet.

Metabolic syndrome as pre-diabetes

Metabolic syndrome, or 'Syndrome X', was first identified by endocrinologist Gerald Reaven in the 1980s, and the root cause of this condition is described as 'insulin resistance'.[12] Dr Stephen Phinney and Dr Jeff Volek explain this further as a condition of 'carbohydrate intolerance'.[13] According to recent NHANES data, almost one in three Americans now have metabolic syndrome.[14] Metabolic syndrome is a sign of poor carbohydrate metabolism and hyperinsulinaemia and, if not reversed, portends an inevitable decline in overall health.[15] Markers of metabolic syndrome are abdominal obesity, high blood glucose, high triglycerides (TG), low high-density lipoprotein (HDL) cholesterol and high blood pressure. Other associated conditions are increased inflammation, vascular dysfunction, non-alcoholic fatty liver disease (NAFLD), polycystic ovary syndrome, sleep apnea and some types of cancer and dementia.[16,17,18,19,20,21,22,23,24] Obesity is commonly viewed as the cause of metabolic syndrome. However, while obesity is highly correlated with the condition, we (and others) suggest that it is the expansion of adipose stores beyond a person's individual storage capacity,[25,26] driven by and in conjunction with hyperinsulinaemia because of the overconsumption of processed dietary carbohydrates in the setting of a Western diet – so prevalent in modern society – that drives this disease process.[26,27,28] Inflammation, especially the presence of pro-inflammatory macrophages in fat stores, such as the visceral adipose tissue, is another key marker of the developing pathology.[25,29] The inflamed adipose tissue appears to lose its ability to properly respond to insulin, resulting in loss of its capacity to protectively buffer fatty acids (including sugars and starches converted to fatty acids via *de novo lipogenesis* to be 'safely' stored).[25,29] This leads to reduced capacity to clear circulating glucose, as well as greater hepatic exposure to gluconeogenic precursors from rapid fatty acid turnover occurring in the insulin-resistant adipose tissue,[30] both resulting in the persistently elevated blood glucose associated with metabolic syndrome.[31] As a population-level intervention, restriction of carbohydrates, a key contributor to the development of metabolic syndrome (especially when processed), should therefore be considered a primary intervention for those with metabolic disease.

Type 2 diabetes reversal: Is it possible?

The prospect of reversing progressive T2D is somewhat new to both the public and health care practitioners. Many assume the diagnosis is a purely progressive disease,[32,33] including an inevitable march towards worsening health and organ systems failure.[34] In the lexicon of diabetes care, 'intensive management' has superseded 'cure', 'remission' or 'reversal'. The ADA's 2017 Standards of Medical Care in Diabetes states that: 'Diabetes is a complex, chronic illness requiring continuous medical care with multifactorial risk-reduction strategies beyond glycaemic control'.[35] In line with this, the ADA's 2013 Nutrition Therapy Recommendations for the Management of Adults with Diabetes states that T2D is 'progressive' in nature and 'nutrition and physical activity interventions alone (i.e. without pharmacotherapy) are generally not adequately effective in maintaining persistent glycaemic control over time for many individuals'.[36]

In current treatment approaches, pharmacotherapy typically is the focal point and carbohydrate restriction is de-emphasised. For instance, a recent Kaiser Permanente study involving 120 000 patients concluded that prolonged T2D remission in community settings without bariatric surgery is very rare; it occurred in only 0.007% of the study population. During the 7-year study, more study participants (1.7%) died than the percentage who experienced any level of remission, and diabetes-associated medication use, health care costs and complications increased.[37] In addition, seven multinational, multicentre, randomised controlled trials aimed at achieving tight blood glucose control with medications failed to demonstrate the expected reductions in heart disease, the major killer of patients with diabetes, or in overall mortality.[38,39,40,41,42,43,44] In contrast to these outcomes, strong evidence exists for a promising alternative approach.

Trials of low-carbohydrate diets: Significant findings for a new approach to type 2 diabetes

The first well-recorded version of a low-carbohydrate diet was described in 1863 by the Englishman William Banting, who restricted starchy and sugary foods to overcome obesity on the advice of his physician.[45] The popularity of the diet as an effective weight loss regimen continued well into the 20th century, when it was common knowledge that 'sugar and starches are fattening'. By mid-20th century, studies on the low-carbohydrate diet were a rarity in the medical and nutritional literature because of a growing belief that fat, and particularly saturated fat, not carbohydrate, was the more likely dietary culprit.[46] Although resistance within the medical community persists,[47] in recent years dietary fat has slowly been exonerated, in accordance with the best available evidence.[48,49,50,51,52,53] Studies are also now emerging to show the efficacy, sustainability and other positive effects of low-carbohydrate diets, especially in those with metabolic disease.[54,55,56,57,58,59,60,61]

The definition of a low-carbohydrate diet varies in the literature, but most in the field agree that anything over 130 g – 150 g per day is not low carbohydrate.[62] An amount of less than 50 g of carbohydrate per day is considered very low carbohydrate, which would put most adults into nutritional ketosis.[63] During this state, the body relies primarily on fatty acids and ketone bodies produced from fat stores, not glucose, for energy.

Numerous randomised, controlled trials have shown that well-formulated low-carbohydrate dietary patterns are highly effective for treating obesity and improving a spectrum of risk

factors typical of patients with metabolic syndrome and diabetes who previously ate a traditional diet.[2,64,65,66,67,68,69,70,71] An example is a report by McKenzie et al. on the interim results of their 2-year outpatient trial on T2D patients adhering to a ketogenic diet (very low carbohydrate, usually < 50 g/day).[13] Although not a randomised, controlled trial, the trial demonstrates the wide-scale applicability and efficacy of carbohydrate restriction. At 10 weeks, 91% of the 262 patients remained active in the trial and had experienced an average HbA1c reduction from 7.6% to 6.5% and an average of 7.2% body weight loss. More than half of the participants (56.8%) had reduced or eliminated one or more diabetes medications. At 6 months, 89% of the participants were retained, and weight loss averaged 12%. These findings are congruent with the physiology of insulin accelerating intracellular storage of glucose and fats, whereas reduced serum insulin from a low-carbohydrate approach allows lipolysis and gives the body access to its stored fat as an energy source.[72] In contrast, intensive management of T2D with the ADA-recommended low-fat diet and standard drug regimen routinely results in minimal weight loss even when glucose control is optimised.[38]

In a critical review of the literature, Feinman et al. present 12 points of evidence (summarised below) to support the low-carbohydrate diet as the best first-line strategy for treating T2D and the most effective adjunct to pharmacology in type 1 diabetes (T1D)[55]:

1. Dietary carbohydrate restriction has the greatest effect on decreasing abnormally high blood glucose levels, the most salient feature of diabetes.
2. Increased caloric intake, the driver of the obesity and T2D epidemics, has been due almost entirely to increased carbohydrate consumption.
3. Weight loss is not required to reap the benefits of a low-carbohydrate diet, which include reversal of T2D.
4. For weight loss, no other dietary intervention has proven to be better than carbohydrate restriction.
5. For people with T2D, the low-carbohydrate diet is as effective as other dietary interventions and often significantly better.
6. Replacement of carbohydrate with protein generally improves glycaemic control.
7. Total fat and saturated fat intake do not correlate with risk of cardiovascular disease.
8. Plasma-saturated fatty acid levels are affected more by eating carbohydrates than eating fats.
9. The best predictor of microvascular, and to a lesser extent macrovascular, complications in patients with T2D is glycaemic control (as measured by HbA1c).
10. Dietary carbohydrate restriction is the most effective method (other than starvation) for reducing serum TG and increasing high-density lipoproteins.
11. Low-carbohydrate diets reduce and frequently eliminate medications for T2D patients and usually result in lower insulin doses for patients with T1D.
12. Intensive glucose lowering by carbohydrate restriction has none of the side effects associated with intensive pharmacologic therapies.

Despite a growing body of evidence for low-carbohydrate diets' superior results in the management of obesity, cardiovascular disease risk, metabolic syndrome and T2D, objections by the medical and public health communities persist.[73] This is frequently based on flawed or outdated evidence.[74] For example, misunderstanding about the body's need for glucose, in particular by the central nervous system, continues despite basic scientific knowledge to the contrary.[5] In concert, the ADA does not recommend a low-carbohydrate diet for diabetes management. While recognising that 'carbohydrate intake has a direct effect on postprandial glucose levels' and 'total amount of carbohydrate eaten is the primary predictor of glycaemic response', the ADA advises that 'a variety of eating patterns (combinations of different foods or food groups) are acceptable for the management of diabetes' and recommends adjusting carbohydrate intake to mealtime insulin dosing.[36] The ADA has refrained from making a robust recommendation for carbohydrate restriction. It posits that 'evidence is inconclusive for an ideal amount of carbohydrate intake for people with diabetes'.[36]

Aim and objectives

Although a reduced-carbohydrate approach may theoretically improve health, if it is too difficult to follow long term or if it brings with it unwanted effects, the idea that people should reduce their carbohydrates is at best irrelevant. Our hypothesis is that if one adheres to a well-formulated low-carbohydrate diet, the success and health benefits can be maintained over years and even for a lifetime. To probe the real-life utility of such an approach, previous examinations of people following some kind of carbohydrate restriction have been conducted. For example, Tim Noakes, a South African physician and low-carbohydrate diet researcher, published an analysis of more than 100 communications he had received from people following some kind of carbohydrate restriction. The participants reported reduced weight, hunger, irritable bowel syndrome symptoms, hypertension and medication needs, as well as improved glycaemic control and exercise capacity.[75] A survey of more than 2000 members of an online, low-carbohydrate support group found positive health outcomes for participants, such as decreased body weight and an improved lipid profile.[76] A survey of more than 2500 people following a low-carbohydrate diet of some type (or a paleo diet, which is often a reduced-carbohydrate diet) found a variety of positive health benefits such as reduced weight, hunger, irritable bowel syndrome symptoms, joint pain, arthritis pain, brain fog and acne, as well as improved glycaemic control, psychological well-being, athletic performance and energy.[77] About 100 people from the National Weight Control Registry, which tracks people who have long-term weight loss success, reported using a low-carbohydrate diet approach and reported long-term weight loss with reduced hunger.[78]

The purpose of this research was to gain a detailed, updated understanding of adults who were already voluntarily following a low-carbohydrate diet. Because long-term dietary trials are complex and costly, we were especially interested in the experience of long-term diet adherents. Such research is

hypothesis-generating and enables researchers to explore the actual lived experience of people following such a dietary approach.

Methods

Study design

The Low Carb Lifestyle Survey was a quality improvement project for the American Board of Family Physicians (ABFM), developed by Dr Mark Cucuzzella and with survey design assistance from collaborators in the United Kingdom (diabetes.co.uk).

Setting, study population and sampling strategy

The survey was shared with the American and international 'low-carb' community via social media and through international health care professionals who support therapeutic uses of low-carbohydrate diets. As Dr Cucuzzella has been recommending a low-carbohydrate diet as an option to his patients with T2D for 6 years, the survey was also shared with individual patients he sees and members of his local community.

Data collection

The 57-question survey was administered on Survey Monkey (an online survey company); the survey was open from December 2016 to June 2017. The survey included closed-ended, multiple-choice and open-ended questions. Responses to the survey were kept confidential. The full 57-question survey can be viewed in supplemental materials (see Appendix 1).

Data analysis

Where appropriate, we used chi-squared tests to compare proportions and paired *t*-tests to compare means and standard deviation changes within the same groups. Statistical analyses were performed using IBM SPSS software Version 22 (SPSS Inc., Chicago, IL) and GraphPad Prism version 7 (GraphPad Software, La Jolla, CA).

Ethical considerations

The American Board of Family Medicine (ABFM) peer-reviewed and approved the project before release. After results were collected, the ABFM again reviewed the project and determined that it met standards for a Quality Improvement (QI) project. A QI project relevant to the quality and standards of the ABFM is mandatory for maintenance of certification as a Board Certified Family Physician.

Results

Survey respondent characteristics

The survey was completed by 1580 respondents. Respondents were required to answer all questions, with the exception of the open-ended items. The majority of respondents resided in the United States, with the rest residing elsewhere (Table 1).

TABLE 1: Survey respondent characteristics.

Characteristic	*N* (%)
Gender	
Female	982 (62.2)
Male	598 (37.9)
Age	
< 20	2 (0.1)
20–29	34 (2.2)
30–39	223 (14.1)
40–49	483 (30.6)
50–59	524 (33.2)
60–69	266 (16.9)
> 70	48 (3.0)
Race/ethnicity	
American Indian or Alaskan Native	12 (0.8)
Asian or Pacific Islander	36 (2.3)
Black or African American	25 (1.6)
Hispanic or Latino	58 (3.7)
White/Caucasian	1435 (90.1)
Prefer not to answer	10 (0.6)
Other	44 (2.8)
Place of residence	
USA	919 (58.2)
Canada	128 (8.1)
South and Central America	15 (0.9)
Europe	289 (18.3)
South Africa	43 (2.7)
Middle East	16 (1.0)
Asia and India	18 (1.1)
Australia and New Zealand	152 (9.6)
Occupational status	
Full-time employment	994 (63.0)
Part-time employment	171 (11.0)
Currently not working	146 (9.2)
Retired	238 (15.1)
Student	31 (2.0)
How learned about low-carbohydrate diet	
Internet	616 (39.0)
Medical professional	168 (10.6)
Family member or friend	315 (19.9)
Book	240 (15.2)
Community group	22 (1.4)
Other	10 (13.2)
Reason for starting low-carbohydrate diet	
To improve chronic health condition	696 (44.1)
For weight loss	1184 (75.0)
To enhance athletic performance	211 (13.4)
To have more energy throughout day	498 (31.5)
Friend or family member on low-carbohydrate diet	89 (5.6)
No specific reason – just curious	37 (2.3)
Other	334 (21.1)
Length of time on low-carbohydrate diet	
< 1 month	34 (2.2)
1–3 months	185 (11.8)
3–6 months	180 (11.4)
6 months–1 year	298 (18.9)
1–2 years	347 (22.0)
> 2 years	536 (34.0)
Amount of carbohydrates consumed daily	
< 30 g	780 (49.4)
30 g–50 g	502 (31.8)
50 g–100 g	252 (16.0)
100 g–200 g	42 (2.7)
200 g–300 g	4 (0.3)
Physical activity	
Minutes per week - Min (SD)	164 (192)

Most of the respondents were female, white, middle-aged and working full time. Of the survey respondents, 97% said that they considered themselves to be adherent to a low-carbohydrate diet. More than half of the respondents said that they had been on a low-carbohydrate diet for at least 1 year. The most commonly reported way respondents had learned about the low-carbohydrate diet was through the Internet. Respondents were allowed to choose more than one reason for starting a low-carbohydrate diet. Three out of four respondents said they started the diet for weight loss, but chronic disease improvement and a desire for more energy were also common responses.

Almost half (49%) of the respondents reported a very restricted average carbohydrate intake of less than 30 g per day. Almost one-third (32%) reported an average carbohydrate intake of 30 g – 50 g per day, 16% reported 50 g – 100 g per day and the remaining 3% reported more than 100 g per day. Average carbohydrate intake was inversely associated with amount of time spent on the diet; that is, of those adherents for less than 6 months, 65% reported an average daily carbohydrate intake of less than 30 g. For participants adherent from 6 months to 2 years, daily consumption of less than 30 g daily still comprised the majority response, but had declined with time. By 2 years, those consuming less than 30 g daily and those consuming 30 g – 50 g daily were even at 38% each. This is consistent with one approach to carbohydrate restriction, starting with a very low-carbohydrate intake and then gradually increasing the carbohydrate level as time goes on.[79] The amount of weekly physical activity reported was an average of 164 min, with 18% reporting no regular physical activity.

Weight loss and lab test values

The large majority of respondents reported weight loss and waist circumference reduction with a low-carbohydrate diet (Table 2). Three out of four reported weight loss of 10 pounds or more, with more than one-third of respondents reporting a weight loss of more than 30 pounds. Similarly, 81% respondents reported some reduction in waist size, with 17% reporting a reduction of 5 inches or more. Decreases in weight and waist circumference correlated inversely with daily carbohydrate intake, with a greater proportion of participants (those consuming less than 30 g of carbohydrate per day) reporting more than 3 inches lost from the waist or more than 20 pounds total weight loss (Figure 1).

TABLE 2: Weight and waist circumference change with low-carbohydrate diet.

Type of Change	*N* (%)
Change in weight	
Did not weigh	32 (2.0)
Weight stayed within 2 pounds of starting weight	74 (4.7)
Gained 2 or more pounds	46 (2.9)
Lost 2–10 pounds	254 (16.1)
Lost 10–30 pounds	555 (35.1)
Lost 30–50 pounds	346 (21.9)
Lost > 50 pounds	273 (17.3)
Change in waist circumference	
Did not measure	280 (17.7)
Gained waist circumference	18 (1.1)
Lost < 1 inch	111 (7.0)
Lost 1–3 inches	512 (32.4)
Lost 3–5 inches	387 (24.5)
Lost > 5 inches	272 (17.2)

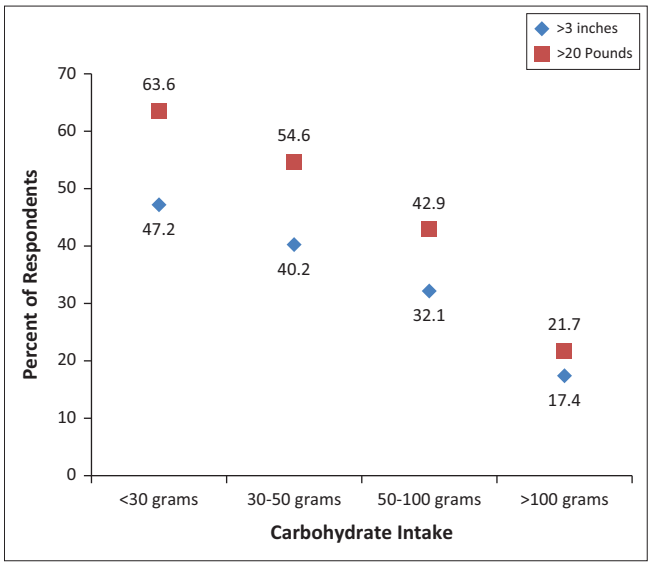

FIGURE 1: Weight and waist circumference loss in relation to carbohydrate intake.

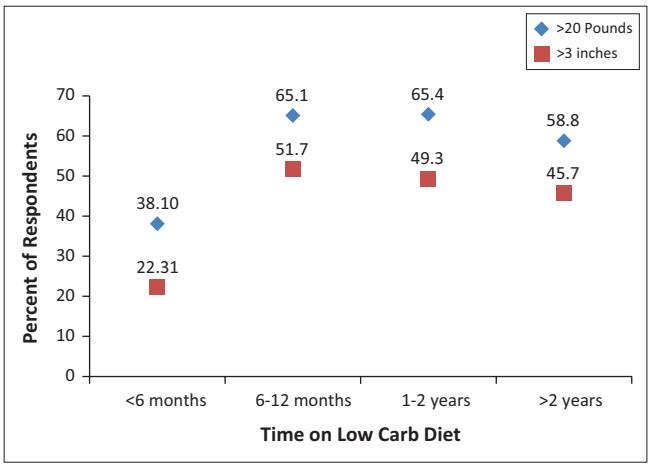

FIGURE 2: Weight and waist circumference loss in relation to time on a low-carbohydrate diet.

Long-term weight loss and waist circumference reduction

Among respondents who knew their weight and waist circumference before and after diet initiation, at 6–12 months on the diet (Figure 2), 65% reported a weight loss of 20 pounds or more and 52% reported a waist circumference reduction of 3 inches or more. We found similar results for people who reported following a reduced carbohydrate diet for even longer. For example, for those on the diet 2 years or more, 59% reported a weight loss of 20 pounds or more and 46% reported a waist circumference reduction of 3 inches or more. Providing laboratory values was optional in the survey. Lab test values of respondents who knew their values before diet initiation and after are shown in Tables 3 and 4. Improvements were reported for fasting blood

TABLE 3: Lab test values before and after low-carbohydrate diet initiation.

Lab test values	*N*	Before, mean (SD)	After, mean (SD)	Difference, mean (SD)	*p*
Fasting blood glucose	352	143 mg/dL (58.2)	99 mg/dL (72.5)	44.4 (66.2)	< 0.001
Postprandial blood glucose	267	175 mg/dL (45.8)	107 mg/dL (22.9)	69.3 (67.6)	< 0.001
Total cholesterol	221	210 mg/dL (47.5)	232 mg/dL (59.9)	21.9 (62.2)	< 0.001
LDL cholesterol	221	127 mg/dL (44.0)	144 mg/dL (55.6)	16.9 (53.9)	< 0.001
HDL cholesterol	221	57 mg/dL (21.1)	71 mg/dL (24.4)	14.6 (17.7)	< 0.001
Triglycerides	221	149 mg/dL (144.3)	82 mg/dL (55.3)	-67.7 (144.0)	< 0.001
Triglyceride/HDL ratio	221	3.49 (4.62)	1.37 (1.21)	-2.11 (4.44)	< 0.001

Note: Statistical results determined by paired *t*-tests. This includes only participants with before and after values.
SD, Standard deviation; LDL, low-density lipoprotein; HDL, high-density lipoprotein.

TABLE 4: Proportion of participants with HbA1c levels in the normal, pre-diabetes or type 2 diabetes ranges before and after initiation of a low-carbohydrate diet (*N* = 495).

HbA1c	Before, *N* (%)	After, *N* (%)	*p*
< 5.5 (Normal)	82 (16.6)	241 (65.3)	< 0.001
5.5–6.4 (Pre-diabetes)	173 (34.9)	137 (27.7)	< 0.001
> 6.5 (Type 2 diabetes)	240 (48.5)	35 (7.1)	< 0.001

Note: Statistical results determined by chi-squared tests for proportion of people in each category. This includes only participants with before and after values.

TABLE 5: HbA1c values stratified by carbohydrate intake.

HbA1c value per carbohydrate intake level	Before initiation *N* (%)	After initiation *N* (%)	Chi-square statistic (*p*)
< 30 g			
6.5 or more	139 (53.9)	16 (6.2)	203.5 (< 0.0001)
5.5–6.4	88 (34.1)	65 (25.2)	
Under 5.5	31 (12.0)	177 (68.6)	
30 g–50 g			
6.5 or more	69 (45.1)	14 (9.2)	71.8 (< 0.0001)
5.5–6.4	55 (35.9)	45 (29.4)	
Under 5.5	29 (19.0)	94 (61.4)	
50 g–100 g			
6.5 or more	28 (36.8)	4 (5.3)	30.7 (< 0.0001)
5.5–6.4	28 (36.8)	23 (30.3)	
Under 5.5	20 (26.3)	49 (64.5)	
> 100 g			
6.5 or more	4 (50.0)	1 (12.5)	2.7 (0.26)
5.5–6.4	2 (25.0)	4 (50.0)	
Under 5.5	2 (25.0)	3 (37.5)	

Note: Calculated using a 3 × 2 contingency table and chi-squared test.

glucose, postprandial blood glucose and triglyceride/HDL (TG/HDL) ratio (Table 3).

Glycaemic control

We also examined the proportion of participants reporting HbA1c levels in the normal range or in the ranges diagnostic of pre-diabetes or T2D (Table 4). We noticed large improvements. For example, the proportion of participants reporting an HbA1c below 5.5 increased almost fourfold (17% to 65%). Almost half (49%) reported an HbA1c of 6.5 or more before diet initiation. After initiation, fewer than one in 10 (7%) reported an HbA1c that high. Absolute increase in participants reporting a normal HbA1c (< 5.5; 48.7% increase) and absolute decrease in participants reporting a diabetic HbA1c (≥ 6.5; 41.4%) were both greatest in the group eating less than 30 g of carbohydrate per day, with smaller absolute improvements with increasing carbohydrate intake (Table 5).

Medication use

Respondents reported declines in use of medications (e.g., antidepressant, anti-anxiety, sleep aids, pain relief, anti-inflammatory and phosphodiesterase type 5 inhibitors for erectile dysfunction) after starting the diet (Table 6). The use of all types of medications (except for erectile dysfunction) reduced by more than 50%.

Small minorities of respondents reported current use of medications for diabetes, high blood pressure and hyperlipidaemia, with some reporting having reduced or completely discontinued such medications after initiating the diet (Table 7). While more than half of the respondents said that medication costs were not relevant for them, (e.g. NHS on no medication costs or not on medication) 25% reported a savings, with the average reported savings in medications cost being $288 per month.

Energy, mobility, pain, physical and emotional well-being, and between-meal state

Respondents reported improvements in energy level (see Figure 3), ability to perform usual activities (such as housework or leisure activities), pain and emotional health after starting a low-carbohydrate diet (Table 8). For example, before initiation, 59% of respondents reported low energy levels and only 4% reported high energy levels, compared to 3% and 51%, respectively, after initiation. The numbers of respondents reporting moderate to extreme problems with mobility, pain or symptoms of anxiety or depression declined after diet initiation (Table 8). Respondents reported improvement in a variety of aspects of physical and psychological well-being after starting a low-carbohydrate diet. For example, at least eight out of 10 respondents reported improvement in outlook, happiness and self-esteem, and six out of 10 reported improved confidence in controlling blood sugar (Table 9). Similarly, before initiating a low-carbohydrate diet, the great majority of respondents reported negative between-meal experiences, such as intense hunger, tiredness and difficulty concentrating (Table 10). Fewer than one in five respondents reported having such experiences after diet initiation.

Other health changes, challenges and knowledge gained

Respondents were invited to answer three open-ended questions about their experiences on a low-carbohydrate

TABLE 6: Medication use before and after low-carbohydrate diet initiation.

Medication type	Used before, *N* (%)	Used after, *N* (%)	*p*
Antidepressant	195 (12.5)	90 (5.8)	< 0.001
Anti-anxiety	112 (7.3)	52 (3.4)	< 0.001
Sleep aids	176 (11.4)	74 (4.8)	< .001
Painkillers	342 (22.1)	77 (5.0)	< 0.001
Anti-inflammatory	417 (27.1)	101 (6.8)	< 0.001
Erectile dysfunction	17 (1.1)	13 (0.86)	0.46

Note: Statistical results determined by chi-squared tests.

TABLE 7: Medication use.

Medication type	Currently use, *N* (%)	Reduced or stopped since diet initiation, *N* (%)
Diabetes	140 (8.9)	107 (6.8)
Blood pressure	221 (14.0)	178 (11.3)
Cholesterol	82 (5.2)	93 (5.9)

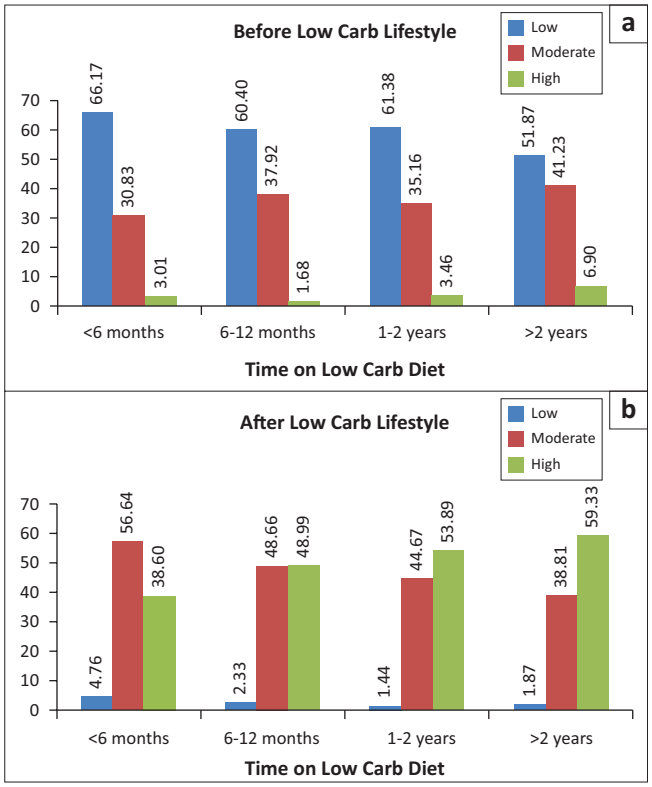

FIGURE 3: Energy level before and after a low-carb diet broken down by amount of time following a low-carb lifestyle.

diet. Common responses are summarised in Table 11. Commonly reported health changes were improvements on a wide spectrum: breathing and allergies, markers of NAFLD, libido and reproductive health, mental clarity and digestion. Commonly reported challenges related to a low-carbohydrate diet included negative reactions from family, friends and health professionals; dining out, special occasions and travelling; flu-like symptoms associated with transitioning to a low-carbohydrate diet; and desires for certain foods. Common reports of the important learning or information gained from being on a low-carbohydrate diet pertained to insulin resistance and metabolic syndrome; the difference between nutritional ketosis and ketoacidosis; and awareness about how different foods affect satiety, weight gain and how one feels.

TABLE 8: Energy and activity, physical and emotional well-being before and after low-carbohydrate diet initiation.

Indicator	Before *N* (%)	After *N* (%)	*p*
Energy level			
Low	935 (59.2)	41 (2.6)	< 0.001
Moderate	579 (36.7)	734 (46.5)	< 0.001
High	66 (4.2)	805 (51.0)	< 0.001
Usual activities			
Slight or no problem	1224 (77.5)	1535 (97.2)	< 0.001
Moderate or severe problem	347 (22.0)	43 (2.7)	< 0.001
Unable to perform	0 (0.6)	2 (0.1)	> 0.15
Mobility			
Slight or no problem	1302 (82.4)	1531 (96.9)	< 0.001
Moderate or severe problem	272 (17.2)	47 (3.0)	< 0.001
Unable to walk	6 (0.4)	2 (0.1)	> 0.15
Pain or discomfort			
Slight or no pain or discomfort	906 (57.3)	1502 (95.1)	< 0.001
Moderate or severe	650 (41.1)	78 (4.9)	< 0.001
Extreme pain	24 (1.5)	0 (0)	< 0.001
Emotional health			
Slight or no anxiety or depression	1053 (66.7)	1519 (96.1)	< 0.001
Moderate or severe anxiety or depression	485 (30.7)	60 (3.8)	< 0.001
Extreme anxiety or depression	42 (2.7)	1 (0.1)	< 0.001

Note: Statistical results determined by chi-squared tests for proportion of people in each category.

TABLE 9: Changes in physical and psychological well-being after starting low-carbohydrate diet.

Indicator	Improved, *N* (%)	No change, *N* (%)	Worsened, *N* (%)
General quality of life	1461 (92.5)	105 (6.7)	14 (0.9)
Quality of sleep	1094 (69.2)	433 (27.4)	53 (3.4)
Confidence in controlling blood sugar	1019 (64.5)	551 (34.9)	10 (0.6)
Motivation to maintain changes made in lifestyle	1482 (93.8)	87 (5.5)	11 (0.7)
Confidence in food choices	1509 (95.5)	57 (3.6)	14 (0.9)
Outlook on life	1385 (87.7)	184 (11.7)	11 (0.7)
Self-esteem	1335 (84.5)	240 (15.2)	5 (0.3)
Happiness	1318 (83.4)	247 (15.6)	15 (1.0)

TABLE 10: Between-meal experiences.

Indicator	Experienced before, *N* (%)	Experienced after, *N* (%)	*p*
Intense hunger	1375 (87.1)	55 (3.5)	< 0.001
Tiredness	1480 (93.9)	305 (19.3)	< 0.001
Difficulty concentrating	1300 (83.0)	177 (11.3)	< 0.001
Mood swings	1160 (74.3)	154 (9.8)	< 0.001
Irritability	1251 (79.9)	255 (16.3)	< 0.001
Anxiety	925 (59.4)	207 (13.3)	< 0.001

Note: Statistical results determined by chi-squared tests.

Discussion

To date, few studies have been published on the efficacy of low-carbohydrate diets for weight loss or reversal of metabolic syndrome and T2D beyond 2 years in duration.[80] Our survey offers a unique perspective on this issue. It garnered a large, international cohort of individuals, with more than 500 of them being adherent to a low-carbohydrate diet for more than 2 years. Because respondents were overwhelmingly people succeeding on the diet, the data give

TABLE 11: Commonly reported free-response answers.

Have there been any other changes to your health that we have not already covered? (838 responses)	What is the most challenging aspect of the low carbohydrate lifestyle? (1302 responses)	What is the most important piece of information or learning that you have taken from the low carbohydrate lifestyle? (1226 responses)
Improvement in allergy symptoms and breathing quality	Holidays and special occasions	Insulin resistance and metabolic syndrome
Improvement in athletic performance	Vacations and travelling	Sugar content of food
Improvement in libido	Social occasions and dining out	Food's effect on satiety
Improvement in mental clarity	Negative reactions from family and friends	Self-importance
Improvement in irritable bowel syndrome	Negative reactions from health professionals	Importance of non-scale victories
Improvement in heartburn and acid reflux	Criticism and misunderstanding	Eating fat does not cause you to be fat
Improvement in immune function	Initial 'carbohydrate flu' symptoms	Eating three meals a day is unnecessary
Improvement in integument and dental quality	Leg cramps and electrolyte balance	Nutritional ketosis is different from ketoacidosis
Improvement in polycystic ovary syndrome and menstruation	Work, financial and other life stressors	Eating meat is not something to feel guilty about
Improvement in migraine frequency	Concerns about cholesterol	To pay attention to how one feels in response to food
Improvement in joint pain and chronic pain	Desire for certain foods	Carbs are not needed to train for endurance races
Improvement in NAFLD	None	Sugar cravings occur only when eating sugar

NAFLD, non-alcoholic fatty liver disease.

an undiluted view of what is possible when a low-carbohydrate approach is successful. The reversals in lab values, body weight and waist circumference that were reported in the survey are striking. In addition, reductions in medication use, pain and mental health concerns along with improved energy and mobility after diet initiation were commonly reported. As would be expected with such improvements in physical health, the cohort reported overwhelmingly that their physical and psychological well-being also improved after starting a low-carbohydrate diet.

Discussion of key findings

An important marker of metabolic health and adverse long-term outcomes is a large waist circumference and visceral fat.[81,82] Although we had to rely on participants' self-report of pounds and inches gained or lost, in light of the fact that sustained weight loss is universally difficult, our dramatic findings deserve consideration. A weight loss of 20 pounds or more was reported by 65.1% of those on the diet for 6–12 months and by 58.8% of those on the diet for 2 years or more (Figure 2).

Although fewer than half (44.1%) of respondents reported that their reason for following a low-carbohydrate diet was to improve a chronic condition, we collected robust data for diabetes and glucose control. Of the entire cohort, 495 knew their HbA1c before diet initiation and 413 knew their value post-diet initiation. By definition, people with T2D have an HbA1c of ≥ 6.5, and pre-diabetes is defined by an HbA1c of 5.7–6.4. Many studies suggest that an HbA1c around 5.0–5.5 is likely to be the ideal.[83,84,85,86] Of those reporting their after-initiation values, the proportion with an HbA1c < 6.5 nearly doubled, and nearly four times as many reported an HbA1c of < 5.5. Most importantly, those with an HbA1c in the diabetic range (≥ 6.5) decreased from 48.5% to 7.1%.

Active management of diabetes requires measuring fasting and post-meal blood glucose levels. Average pre-diet values (143 mg/dL fasting and 175 mg/dL post-meal) reflected poor glucose tolerance (Table 3). At the time of the survey, the average blood glucose values were 99 mg/dL for fasting and 107 mg/dL for post-meal, which is a significant improvement.

It is clear in the literature that the most powerful predictor in a basic lipid panel of insulin resistance and cardiovascular health is the ratio of TG and HDL-cholesterol.[87,88,89,90] As low-density lipoprotein (LDL) cholesterol (which is calculated as the measurement of cholesterol mass within LDL particles) is made up of small (atherogenic) and large (healthy) particles, there is controversy about total LDL role as a predictor of cardiovascular events.[74] A low TG/HDL ratio reflects 'pattern A' (large LDL particles) and a high TG/HDL ratio reflects 'pattern B' (small LDL particles), the latter being more closely associated with both carbohydrate (particularly refined) intake and cardiovascular disease risk.[90,91] Because of its association with a less atherogenic lipid profile, a TG/HDL ratio close to 1.0 is regarded as predictive of low cardiovascular risk.[92] A higher TG/HDL ratio is also associated with hyperinsulinaemia,[93] which is an independent risk factor for cardiovascular disease.[94] One concern about a low-carbohydrate diet is the typical slight rise in LDL cholesterol, although no study has shown its adverse outcome. Dietary interventions that lower LDL have also failed to show reductions in disease risk.[95,96] In fact, evidence has shown overall cardiovascular risk to improve on a well-formulated low-carbohydrate diet.[97] Higher LDL-C has been associated with longevity in one review of 68 000 patients.[98] Among study respondents who knew their values, after starting a low-carbohydrate diet, average HDL increased and average TG decreased. Most significantly, the pre-diet TG/HDL ratio was 3.5. After diet initiation, the average TG/HDL ratio was 1.4, which reflects a much lower cardiovascular risk.

Our survey showed marked reductions in medication use and costs, which is an important finding not only for consumers but also for insurance companies and taxpayers. While more than half of the respondents said drug costs were not relevant for them, a quarter of respondents were able to reduce their individual costs, and in those with a specific amount cited, the average reduction was $288 a month.

Decreased strength and difficulty in mobility are associated with poor health outcomes and increased mortality.[99,100,101] The ability to rise from the floor and have a strong walking speed is associated with healthy ageing.[102] The number of survey respondents reporting moderate or severe mobility problems or being unable to walk declined from 278 to 49 individuals after diet initiation, and the number reporting moderate to severe pain declined dramatically after diet

initiation, from 674 to 78. It is reasonable to conclude that the reported improvements in mobility were at least in part associated with reductions in pain. Chronic pain is a major reason why patients seek primary care, and our current approach to pain management has resulted in unintended consequences, contributing to the current opioid crisis.[103] Safe and natural methods for pain management need to be explored, and we are just beginning to learn the potential of nutritional therapy. This finding suggests further work needs to be conducted on dietary interventions for pain.

Similarly, anxiety and depression are common primary care symptoms.[104] Pharmaceutical management of these conditions has shown marginal benefit (confounded by significant misreporting of trials in the literature),[105,106] especially in those with mild or moderate symptoms where dietary or lifestyle interventions are likely to have a greater impact.[107,108] Antidepressant medications also carry significant side effects, especially in elderly patients already under a burden of iatrogenic polypharmacy.[109] Our survey respondents reported marked improvements in symptoms of anxiety and depression after starting a low-carbohydrate diet. These findings support low-carbohydrate nutrition as an alternative therapeutic approach for some mental health conditions and warrant continued research.[110] How one feels between meals in mood and cravings is also critical to sustain any nutritional lifestyle plan. One well-known claim of low-carbohydrate diets is that one can lose weight and not be hungry.[111,112,113] Our survey respondents, more than one-third of whom had been on a low-carbohydrate diet over 2 years, strongly affirmed this. Table 10 shows the dramatic differences before and after low-carbohydrate diet initiation in self-reported symptoms of hunger, fatigue, poor concentration, mood swings, blood sugar swings, irritability and anxiety. Furthermore, participants also reported an increase in energy levels despite the lower caloric intake that naturally occurs with a low-carbohydrate diet.[114]

In this sample of successful, mostly long-term low-carbohydrate diet followers, the diet led to improvements in physical and psychological well-being for most of our study respondents. Feelings of emotional well-being are hypothesised to be important components for sustainable lifestyle change.[115] These overwhelmingly positive changes suggest that a low-carbohydrate diet may be especially sustainable. In addition, 18% of participants reported no regular physical activity, supporting the idea that people do not need to exercise excessively to lose fat and improve metabolism.

Moreover, participants reported improvements in a variety of health conditions after initiating a low-carbohydrate diet, some of which have been studied before, at least preliminarily (improvements in symptoms related to migraines,[116] irritable bowel syndrome,[117] heartburn,[118] polycystic ovary syndrome,[119] NAFLD[120] and pain[121]), and some of which have not been studied well or much at all (e.g., libido, immune function and allergies). More research is needed on these topics.

Limitations

This study was not without limitations. This was a retrospective study assessing a host of biomedical indicators reliant on self-reported data subject to recall bias. Although we believe that the questions we used are face valid, we did not use validated self-report scales. Therefore, some answers may not be as reliable and accurate as they would have been if we had used validated instruments. A detailed survey like this also lends itself to those who are highly engaged in the topic. Like any survey, the respondents may not be representative of all patients. Furthermore, in our appeal for participants, we did not differentiate between people who are followers of one of the many types of carbohydrate-restricted approaches such as low-carbohydrate, high-fat and low-carbohydrate, high-protein (although most of the practitioners who supported the survey favoured a low-carbohydrate, high-fat approach). As to the small sample of minorities, we feel this reflects, at least in part, the bias inherent in snowballing sampling. Many of the initial contacts when the survey was launched were not minority (non-white people comprise about 6% of the population of the state of West Virginia). As the survey was largely shared through social networks, it could be that race played a role in who was invited to take part.

Furthermore, this study lacked the rigour of a randomised, controlled trial. However, our goal was not to compare the results of a low-carbohydrate diet with some other dietary approach. Instead, we were interested in what people who were voluntarily choosing to follow some kind of carbohydrate-reduced nutritional approach would report about their lived experience.

Implications

The results of our survey support pursuit of other pertinent questions around myriad aspects of low-carbohydrate diets: long-term health effects, factors that facilitate success and overcoming of barriers, age-related differences in response to the diet and parameters of the optimal low-carbohydrate diet for overall health and well-being.

Conclusion

Currently recommended drug treatments, nutritional guidelines and behavioural interventions have had limited to no success in halting the obesity and diabetes epidemics. This has resulted in exorbitant health care costs[122] and indirect costs from lower quality of life[123] and lost productivity[124] for a growing proportion of the population. The premise of this research project is that excess carbohydrate intake in the Western diet is a major driver of the obesity and diabetes epidemics, and that restricting dietary carbohydrate to a level that permits utilisation of fat as the primary fuel will yield substantial weight loss and improvement in diabetes and metabolic syndrome, other health conditions and overall quality of life. Moreover, we show that for many, a low-carbohydrate diet is satisfying and sustainable.

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Competing interests

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Authors' contributions

M.T.C. was responsible for project conception, design and implementation. J.T. assisted with project implementation, performed calculations and created figures and graphs. M.T.C. and J.T. wrote the initial draft. N.E.D. made conceptual and editorial contributions. L.S. was responsible for the aims section and made conceptual and editorial contributions. T.R.W. made conceptual and editorial contributions and reviewed calculations as well as directed the reference section.

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Apppendix 1

Low Carb Lifestyle Survey

Thanks for being part of the Low Carb Lifestyle Survey. This is a project for the American Board of Family Physicians and developed in partnership with Dr. Mark Cucuzzella, Professor West Virginia University School of Medicine, and our partners in the United Kingdom [www.diabetes.co.uk]. Your responses to this survey are confidential and will help us learn how to help you and medical professionals as we gain knowledge and experience with the low carbohydrate lifestyle. Thank you for your time to answer the important questions in this survey. Survey will take approximately 10 minutes. Share with others who have adopted the Low Carb Lifestyle to help us understand and evolve in the therapeutic benefits and the challenges.

*** 1. What is your gender?**

- ◯ Female
- ◯ Male

*** 2. What is your age?**

- ◯ less than 20
- ◯ 20-29
- ◯ 30-39
- ◯ 40-49
- ◯ 50-59
- ◯ 60-69
- ◯ over 70

*** 3. What is your ethnicity? (Please select all that apply.)**

- ☐ American Indian or Alaskan Native
- ☐ Asian or Pacific Islander
- ☐ Black or African American

- [ ] Hispanic or Latino
- [ ] White / Caucasian
- [ ] Prefer not to answer
- [ ] Other (please specify)

*** 4. In what country do you currently reside?**

- ◯ United States
- ◯ Other (please specify)

5. IF IN THE USA- In what ZIP code is your home located? (enter 5-digit ZIP code; for example, 00544 or 94305).Skip if not in USA

*** 6. What is your occupational status?**

- ◯ Student
- ◯ Full-time employment
- ◯ Part-time employment
- ◯ Currently not working
- ◯ Retired

*** 7. How many months have you been doing the Low Carb Lifestyle?**

- ◯ less than a month
- ◯ 1-3 months
- ◯ 3-6 months
- ◯ 6 months - 1 year
- ◯ 1-2 years
- ◯ More than 2 years

*** 8. How did you hear about the Low Carb Lifestyle?**

- ◯ Friend
- ◯ Family Member
- ◯ Medical Professional
- ◯ Community Group
- ◯ Internet
- ◯ Book

- ◯ Seminar in your Community
- ◯ Other (please specify)

*** 9. Why did you start on Low Carb Lifestyle? You can select more than one answer**

- ☐ Hope to improve a chronic health conditions such as diabetes or high blood pressure
- ☐ For Weight loss
- ☐ Enhance athletic performance
- ☐ To have more energy through the day
- ☐ A friend or family member was doing this
- ☐ No specific reason just curious about it
- ☐ Other (please specify)

*** 10. Do you consider yourself to be currently adherent to a Low Carb Lifestyle?**

- ◯ Yes
- ◯ No

11. If you stopped the Low Carb Lifestyle- Why?

*** 12. How many grams of carbohydrate on average do you eat daily ? For an online calculator http://www.carb-counter.org/ . (note- use total carbs not "net" carbs)**

*** 13. How many minutes of exercise/physical activity you do per week? If you don't do any physical activity a week, please enter 0.**

*** 14. What was your HbA1c before starting Low Carb Lifestyle ?**

*** 15. What is your current HbA1c?**

16. What were your cholesterol levels before Low Carb Lifestyle ?

Total cholesterol (mg/dl):

LDL cholesterol (mg/dl):

HDL cholesterol (mg/dl):

Triglyceride (mg/dl):

Don't know- place "?" in box

17. What are your current cholesterol levels since starting Low Carb Lifestyle?

Total cholesterol (mg/dl):

LDL cholesterol (mg/dl):

HDL cholesterol (mg/dl):

Triglyceride (mg/dl):

Don't know- place "?" in box

*** 18. How has your waist circumference changed since starting Low Carb Lifestyle? instructions on measuring https://www.cdc.gov/healthyweight/assessing/**

if you have reduced more than 5 inches/12.7 cm please specify

*** 19. What units do you use to measure your weight?**

- ◯ Pounds (lbs)
- ◯ Kilograms (Kg)

*** 20. Have you lost weight since starting the Low Carb Lifestyle?**

- ◯ Yes
- ◯ No

*** 21. How has your weight changed since starting Low Carb Lifestyle?**

if greater than 50 pounds/ 22.7 Kg please specify

*** 22. Did you buy a blood glucose meter to help you on the Low Carb Lifestyle?**

- ◯ Yes
- ◯ No

◯ No - I already had one

*** 23. Did you buy a blood pressure meter to help you on the Low Carb Lifestyle?**

◯ Yes

◯ No

◯ No- I already had one

The following questions are on blood glucose monitoring . If you do not check glucose skip to question 27. This data should be available on your meter. If you don't know precisely, just give a rough average.

24. IF YOU CHECK YOUR BLOOD GLUCOSE- Before starting Low Carb Lifestyle what was your:

Fasting (morning) blood glucose level (mg/dl) [ ]

Blood glucose level 1-2 hours after a typical meal (mg/dl) [ ]

25. IF YOU CHECK YOUR BLOOD GLUCOSE- Currently what is your:

Fasting blood glucose level (mg/dl) [ ]

Blood glucose level 1-2 hours after a typical meal (mg/dl) [ ]

26. Are you happy with your blood glucose control?

◯ Yes

◯ No

*** 27. Do you currently take medication for high blood pressure? (may have more than one answer)**

☐ Yes

☐ No

☐ I have come off some/all of my blood pressure medication since starting Low Carb Lifestyle

*** 28. Do you currently take medication for high cholesterol? (may have more than one answer)**

☐ Yes

☐ No

☐ I have come off some/all of my high cholesterol medication since starting Low Carb Lifestyle

*** 29. Do you currently take medication for diabetes? (may have more than one answer)**

- [ ] Yes
- [ ] No
- [ ] I have come off some/all of my diabetes medication(s) since starting Low Carb Lifestyle

30. Before Low Carb Lifestyle did you regularly take:

	Yes	No
Anti-depressants	○	○
Anti-anxiety medication	○	○
Sleeping tablets	○	○
Painkillers	○	○
Anti-inflammatory medication	○	○
Phosphodiesterase type 5 inhibitors (medication for erectile dysfunction)	○	○

31. NOW- Since Starting Low Carb Lifestyle do you regularly take:

	Yes	No
Anti-depressants	○	○
Anti-anxiety medication	○	○
Sleeping tablets	○	○
Painkillers	○	○
Anti-inflammatory medication	○	○
Phosphodiesterase type 5 inhibitors (medication for erectile dysfunction)	○	○

*** 32. Prior to Low Carb Lifestyle select the option that best describes your mobility:**

- ○ I had no problems with walking about
- ○ I had slight problems with walking about
- ○ I had moderate problems with walking about
- ○ I had severe problems with walking about
- ○ I was unable to walk about

*** 33. NOW - Since starting Low Carb Lifestyle select the option that best describes your mobility :**

- ◯ I have no problems with walking about
- ◯ I have slight problems with walking about
- ◯ I have moderate problems with walking about
- ◯ I have severe problems with walking about
- ◯ I am unable to walk about

*** 34. Prior to Low Carb Lifestyle select the option that best describes your ability to perform your usual activities (e.g. work, study, housework, family or leisure activities):**

- ◯ I had no problems with doing my usual activities
- ◯ I had slight problems with doing my usual activities
- ◯ I had moderate problems with doing my usual activities
- ◯ I had severe problems with doing my usual activities
- ◯ I was unable to do my usual activities

*** 35. NOW- Since starting Low Carb Lifestyle select the option that best describes your ability to perform your usual activities (e.g. work, study, housework, family or leisure activities):**

- ◯ I have no problems with doing my usual activities
- ◯ I have slight problems with doing my usual activities
- ◯ I have moderate problems with doing my usual activities
- ◯ I have severe problems with doing my usual activities
- ◯ I am unable to do my usual activities

*** 36. Prior to Low Carb Lifestyle select the option that best describes your discomfort levels:**

- ◯ I had no pain or discomfort
- ◯ I had slight pain or discomfort
- ◯ I had moderate pain or discomfort
- ◯ I had severe pain or discomfort
- ◯ I had extreme pain or discomfort

*** 37. NOW- Since starting Low Carb Lifestyle select the option that best describes your discomfort levels :**

- ◯ I have no pain or discomfort
- ◯ I have slight pain or discomfort
- ◯ I have moderate pain or discomfort
- ◯ I have severe pain or discomfort

- ◯ I have extreme pain or discomfort

*** 38. Prior to Low Carb Lifestyle select the option that best describes your emotional health:**

- ◯ I was not anxious or depressed
- ◯ I was slightly anxious or depressed
- ◯ I was moderately anxious or depressed
- ◯ I was severely anxious or depressed
- ◯ I was extremely anxious or depressed

*** 39. NOW- Since starting Low Carb Lifestyle select the option that best describes your emotional health:**

- ◯ I am not anxious or depressed
- ◯ I am slightly anxious or depressed
- ◯ I am moderately anxious or depressed
- ◯ I am severely anxious or depressed
- ◯ I am extremely anxious or depressed

*** 40. How good or bad was your health prior to Low Carb Lifestyle? On a scale of 0 to 100, where 100 means the best health you can imagine and 0 means the worst health you can imagine:**

[ ]

*** 41. How good or bad is your health NOW? On a scale of 0 to 100, where 100 means the best health you can imagine and 0 means the worst health you can imagine:**

[ ]

*** 42. Prior to Low Carb Lifestyle how would you describe your energy levels :**

- ◯ Low
- ◯ Moderate
- ◯ High

*** 43. NOW since starting the Low Carb Lifestyle how would you describe your energy levels :**

- ◯ Low
- ◯ Moderate
- ◯ High

44. Since starting the Low Carb Lifestyle, how have you found:

Easy Moderately easy Difficult

	Easy	Moderately easy	Difficult
Managing changes to your diet?	○	○	○
Managing changes to increase your physical activity?	○	○	○
Managing your medication(s)? [if applicable]	○	○	○
Checking your blood sugar levels? [if applicable]	○	○	○
Coping mentally/emotionally?	○	○	○
Knowing what to eat?	○	○	○

*** 45. Since starting the Low Carb Lifestyle, what changes have you noticed in your wellbeing:**

	Significantly improved	Improved	No change	Worsened	Significantly worsened
Quality of life	○	○	○	○	○
Quality of sleep	○	○	○	○	○
Confidence in controlling my blood glucose levels	○	○	○	○	○
Motivation to maintain the changes that you've made to your lifestyle	○	○	○	○	○
Confidence in my food choices	○	○	○	○	○
Outlook on life	○	○	○	○	○
Self esteem	○	○	○	○	○
Happiness	○	○	○	○	○

*** 46. Since starting the Low Carb Lifestyle, do you know:**

	Yes	No
which foods a healthy diet contains	○	○
the different effects of carbohydrate, protein and fat on my blood glucose levels	○	○

	Yes	No
which foods tend to contain the most carbohydrate	○	○
alternative recipes to high-carb dishes	○	○
which foods contain healthy fats, and which contain unhealthy fats	○	○
the difference between "real" and "processed" food	○	○
three or more examples of healthy, filling snacks	○	○
the effects of alcoholic drinks on my blood sugar levels	○	○
what portion control is	○	○

*** 47. Prior to the Low Carb Program, on average, how often per week did you:**

	Never	Once per week	2-3 times per week	4-5 times per week	6+ times per week
eat home-cooked food for dinner (not a ready meal)	○	○	○	○	○
have takeout for dinner	○	○	○	○	○
buy your lunch (rather than preparing it at home)	○	○	○	○	○
get 5 services of non-starchy veggies a day	○	○	○	○	○

*** 48. NOW- Since starting the Low Carb Program, on average, how often per week do you:**

	Never	Once per week	2-3 times per week	4-5 times per week	6+ times per week
eat home-cooked food for dinner (not a ready meal)	○	○	○	○	○

	Never	Once per week	2-3 times per week	4-5 times per week	6+ times per week
have takeout for dinner	○	○	○	○	○
buy your lunch (rather than preparing it at home)	○	○	○	○	○
get 5 services of non-starchy veggies a day	○	○	○	○	○

*** 49. Prior to the Low Carb Lifestyle, did you regularly experience any of the following between meals?**

	Yes	No
Intense hunger	○	○
Tiredness	○	○
Difficulty concentrating	○	○
Spikes in blood glucose levels	○	○
Mood swings	○	○
Irritability	○	○
Anxiety	○	○

*** 50. NOW- Since starting the Low Carb Lifestyle, do you regularly experience any of the following between meals?**

	Yes	No
Intense hunger	○	○
Tiredness	○	○
Difficulty concentrating	○	○
Spikes in blood glucose levels	○	○
Mood swings	○	○
Irritability	○	○
Anxiety	○	○

51. Have there any been any other changes to your health that we haven't already covered?

52. What's the most important piece of information or learning that you've taken from the Low Carb Lifestyle?

53. What's the most challenging aspect of the Low Carb Lifestyle?

*** 54. We want to improve resources for a Low Carb Lifestyle, would any of the following be useful to you? (you can select more than one answer)**

- [ ] Interviews with health professionals
- [ ] Recipe videos
- [ ] More recipes
- [ ] Recipe plans (i.e. a 30 day plan)
- [ ] The latest research into low-carb
- [ ] Low carb food lists
- [ ] More infographics
- [ ] A mentor to speak to over email
- [ ] A mentor to speak to over phone
- [ ] Emotional support
- [ ] A doctor to ask questions to
- [ ] Quick and easy low carb foods
- [ ] I do not need any more resources

*** 55. Have you been able to reduce your monthly life insurance premiums by using the Low Carb Lifestyle to improve your health?**

- ◯ Yes
- ◯ No
- ◯ Not relevant to me

If so much per month in US Dollars

*** 56. Have you been able to reduce your monthly medication costs by using the Low Carb Lifestyle to improve your health?**

- ◯ Yes
- ◯ No
- ◯ Not relevant to me

If so how much per month in US Dollars

57. Thank you for completing the Low Carb Lifestyle Survey. We're looking for low carb champions to support others on their low carb journey and/or case studies for teaching the next generation of medical professionals. If you'd be interested, please leave your email address and/or telephone number and a note of interest.