How Much Weight Should We Expect Someone to Lose on the Ketogenic Diet?

A Weight Loss Benchmarking Tool for the Ketogenic Diet

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Summary

Worldwide obesity has tripled over the last few decades, with over 39% of adults now being overweight, of which 13% are classified obese [1]. The tides have turned from when calories were in scarcity, such as in the paleolithic age, to a time where overnutrition in the form of overweight and obesity causes far more deaths than underweight [1].

It is therefore imperative that practitioners are equipped to bring about effective weight loss, such as with the Ketogenic Diet (KD). A problem exists however. Clients constantly ask how much weight should they expect to lose? And how fast? They can quickly become demotivated when comparing themselves to weight loss photos and stories prevalent online and on social media

Providing accurate weight loss predictions to reassure clients, and give them confidence, can thus play a key role in compliance. As a consequence of this compliance, clients are driven to achieve their weight loss goals. Evidence-based tools that accurately predict weight loss on the ketogenic diet can fill this gap - and provide this certainty for both practitioners and their clients.

This paper provides a preliminary tool developed by Ketosource to predict weight loss over a 52 week period on a ketogenic diet and illustrates its usage. The evidence-based tool is built from a review of 32 ketogenic diet weight loss studies, with a final data set including 12 studies. The studies supporting the tool, and their relevance, are also explored and summarized.

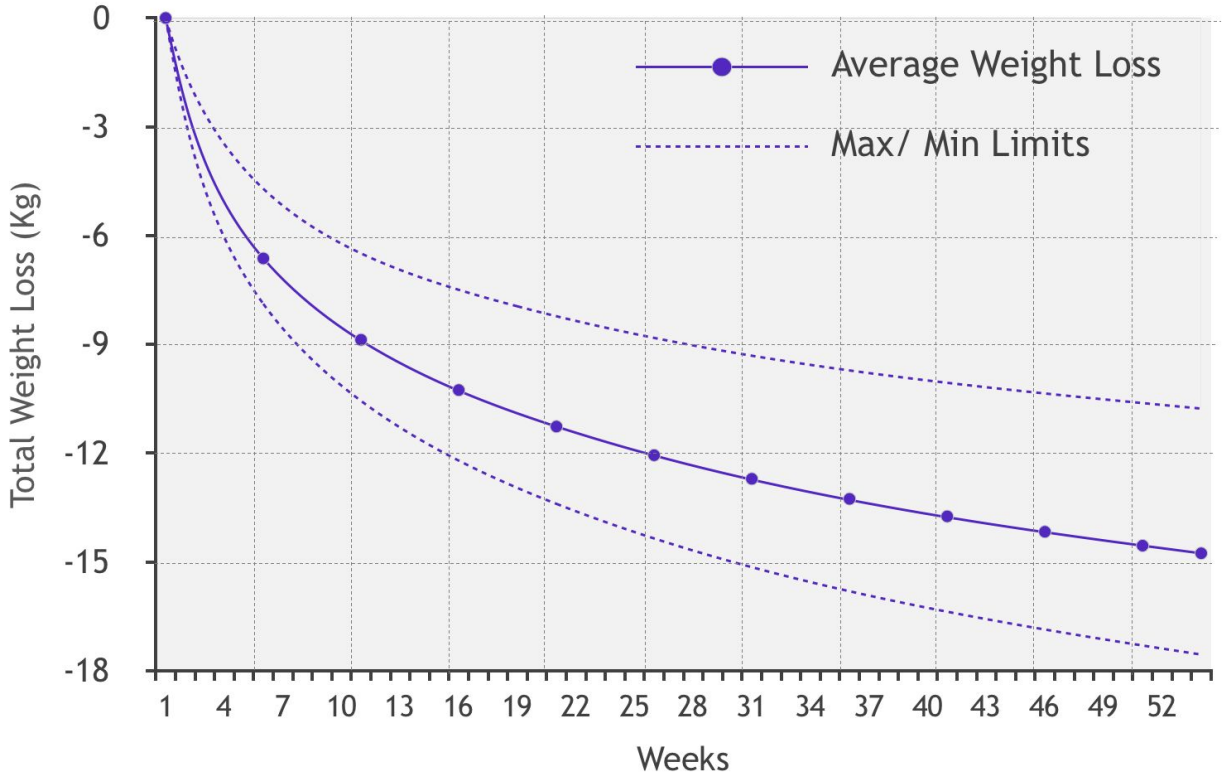
[1] WHO Obesity and Overweight Fact Sheet. World Health Organization. 2–2018. Assessed at http://www.who.int/mediacentre/factsheets/fs311/en/ on March 2018.

The Ketogenic Diet Weight Loss Benchmarking Tool

Figure 1 presents the tool (*KD Weight Loss Benchmarker*) for health practitioners to monitor weight loss for patients or clients who have been prescribed a ketogenic diet.

The chart allows the practitioner to see if weight loss is occurring at a suitable evidence-based rate from baseline. The chart is in weeks so for instance at *week 12* clients should have lost between -7kg and -11.3kg (*minimum and maximum limits*) with an average weight loss of -9.5kg.

Figure 1: Ketogenic Diet Weight Loss Benchmarking Tool



Source: Ketosource analysis, KD studies review, internal client data

To illustrate how the KD Weight Loss Benchmarker can add value in practitioner-client interventions, let's look at some different KD and weight loss scenarios via theoretical, but common case reports.

Case 1: Patient A is on *week 5* of their ketogenic journey. So far patient A has lost 3kg from their baseline weight of 92kg. Using the KD weight loss benchmarking chart we can see that patient A is not within the range of -4.8kg and -7.8kg. At this point the practitioner can confidently identify the need to troubleshoot the low rate of weight loss with the patient.

Case 2: Patient B is on a ketogenic diet with a 16/8 fasting protocol, and performs endurance exercises 5x a week. At *week 19* patient B has lost -16kg of weight. When checking the KD weight loss benchmarking chart the practitioner can see this rate of weight loss is far above the highest rate achieved by the studies. Informed with this knowledge the practitioner finds the patient is consuming very little food due to their fasting window. The patient can be brought back to a healthier rate of weight loss by adding more healthy fat and calories back into their diet.

Case 3: Patient C is overweight and has started a ketogenic diet. At *week 3* patient A has lost -3.3kg. When looking at the KD benchmarking tool the practitioner can see their patient is clearly within range. The practitioner can confidently reassure the patient that they are on track with their weight loss an give them and estimate for what number on scales should like in the coming weeks.

The KD weight loss benchmarking tool is based on a growing data set that Ketosource has been curating. This combines data sets from weight loss studies reviewed to fit within a set of rigorous relevance criteria and our own internal client data.

At this point the data set is preliminary and thus we have left the model generic i.e. one size fits all. While the tool's prediction capability is useful in this form our goal is to develop the tool to become more nuanced, providing accurate predictions for patients based on their individual lifestyle factors.

As we add more data to the data set, in particular with our own internal and well-controlled client data, more lifestyle and individual factors will be integrated.

The rest of this paper discusses the data behind the benchmarking tool and some of the evidence-based takeaways on weight loss from the studies analysed.

What's Behind the Benchmarking Tool

Why Benchmark "Ketogenic Diet" Studies?

Again and again Low-carbohydrate high-fat (LCHF) diets have matched or outperformed other diets in obese or overweight adults [2] [3] [4] [5] [6].

Some of the studies, utilising LCHF diets, which were excluded from this paper reported significant weight loss. For example a recent 1-year RCT on 148 obese, but otherwise healthy, adults showed a significant weight loss of -5.3kg following a LCHF diet [7]. An ad libitum study by Gardner et al (2018), which started overweight participants on a KD before allowing them to move onto a LCHF diet after a few months, reported a mean weight loss of -5.99kg [8].

As can be seen on the previous charts and from meta-analysis, studies employing the KD show significantly more weight loss than just a LCHF diet [2]. A weight loss of -14.5kg after a year has been reported and illustrated on the charts above [9]. Although data point is from just one study, the strongest data we have is at 6 months with 4 KD studies giving an average weight loss of -11kg.

With 8 out of the 12 studies analysed allowing ad libitum energy intake, what are the mechanisms for superior weight loss following a KD?

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[2] Bueno NB, De Melo IS, De Oliveira SL, et al. Very-low-carbohydrate ketogenic diet v. low-fat diet for long-term weight loss: a meta-analysis of randomised controlled trials. Br J Nutr 2013;110:1178–87.

[3] Hession M, Rolland C, Kulkarni U, et al. Systematic review of randomized controlled trials of low-carbohydrate vs. low-fat/low-calorie diets in the management of obesity and its comorbidities. Obes Rev 2009;10:36–50.

[4] Santos FL, Esteves SS, Da Costa PA, et al. Systematic review and meta-analysis of clinical trials of the effects of low carbohydrate diets on cardiovascular risk factors. Obes Rev 2012;13:1048–66.

[5] Tobias DK, Chen M, Manson JE, et al. Effect of low-fat diet interventions versus other diet interventions on long-term weight change in adults: a systematic review and meta-analysis. Lancet Diabetes Endocrinol 2015;3:968–79.

[6] Mansoor, Nadia, et al. "Effects of low-carbohydrate diets v. low-fat diets on body weight and cardiovascular risk factors: a meta-analysis of randomised controlled trials." British Journal of Nutrition 115.3 (2016): 466-479.

[7] Bazzano, Lydia A., et al. "Effects of low-carbohydrate and low-fat diets: a randomized trial." Annals of internal medicine 161.5 (2014): 309-318.

[8] Gardner, Christopher D., et al. "Effect of Low-Fat vs Low-Carbohydrate Diet on 12-Month Weight Loss in Overweight Adults and the Association With Genotype Pattern or Insulin Secretion: The DIETFITS Randomized Clinical Trial." JAMA 319.7 (2018): 667-679.

[9] Brinkworth, Grant D., et al. "Long-term effects of a very low-carbohydrate diet and a low-fat diet on mood and cognitive function." Archives of internal medicine 169.20 (2009): 1873-1880.

There are two proposed mechanisms at play here: Firstly a metabolic advantage using fat metabolism [10] [11] [12]; Secondly reduced hunger and appetite suppression bringing about lower voluntary energy intake [13].

KD cause greater weight loss than other isocaloric diets [14]. This could be via the use of more protein for gluconeogenesis, a loss of energy from ketone excretion, and/or an increased level of lipolysis with a simultaneous reduction of adipose creation from reduced plasma insulin[15] [16] [17]. With most of the studies allowing unlimited energy intake whilst adhering to the KD guidelines, ketones may have appetite suppressant properties [18] [19].

Indeed, this theory has been given more credence as it has been shown that exogenous ketones may directly suppress appetite by lowering plasma ghrelin levels [20].

The rate of daily weight loss would be expected to slow down as participants near their ideal weight. This curtailing of daily weight loss is illustrated in Figure 3. However as Yancy (2004) illustrates, a rapid weight loss of 200g per day is achievable in the first few weeks of starting the KD [21].

Brinkworth (2009) on the other hand shows a lower rate of around 50-70g a day. This could be explained by participants having another feature of metabolic syndrome other than obesity and a lower starting baseline weight than that of Participants within Yancy (2004). At *10 weeks* there are more studies, and one could conceive a daily rate of weight loss between 25-140g per day. At *week 20* anywhere from 10-70g per day of weight loss could occur depending on how much weight clients have left to lose before their ideal weight.

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[10] Feinman, Richard D., and Eugene J. Fine. "Thermodynamics and metabolic advantage of weight loss diets." Metabolic syndrome and related disorders 1.3 (2003): 209-219.
[11] Feinman RD, Fine EJ. 'A calorie is a calorie' violates the second law of thermodynamics. Nutr J 2004;3:9.
[12] Forsythe, Cassandra E., et al. "Comparison of low fat and low carbohydrate diets on circulating fatty acid composition and markers of inflammation." Lipids 43.1 (2008): 65-77.
[13] Nickols-Richardson, Sharon M., et al. "Perceived hunger is lower and weight loss is greater in overweight premenopausal women consuming a low-carbohydrate/high-protein vs high-carbohydrate/low-fat diet." Journal of the American Dietetic Association 105.9 (2005): 1433-1437.
[14] Harcombe, Z., and T. Noakes. "The universities of Stellenbosch/Cape Town low-carbohydrate diet review: Mistake or mischief?." SAMJ: South African Medical Journal 106.12 (2016): 1179-1182.
[15] Feinman RD, Fine EJ. 'A calorie is a calorie' violates the second law of thermodynamics. Nutr J 2004;3:9.
[16] Webster, Christopher C., et al. "Gluconeogenesis during endurance exercise in cyclists habituated to a long-term low carbohydrate high-fat diet." The Journal of physiology 594.15 (2016): 4389-4405.
[17] Paoli A, Grimaldi K, Bianco A, et al. Medium term effects of a ketogenic diet and a Mediterranean diet on resting energy expenditure and respiratory ratio. BMC Proc 2012;6:P37.
[18] Johnstone AM, Horgan GW, Murison SD, et al. Effects of a high-protein ketogenic diet on hunger, appetite, and weight loss in obese men feeding ad libitum. Am J Clin Nutr 2008;87:44–55.
[19] Paoli A, Bosco G, Camporesi EM, et al. Ketosis, ketogenic diet and food intake control: a complex relationship. Front Psychol 2015;6:27.
[20] Stubbs, Brianna J., et al. "A ketone ester drink lowers human ghrelin and appetite." Obesity 26.2 (2018): 269-273.
[21] Yancy, William S., et al. "A low-carbohydrate, ketogenic diet versus a low-fat diet to treat obesity and hyperlipidemia: a randomized, controlled trial." Annals of internal medicine 140.10 (2004): 769-777.

LCHF diets consistently outperform other diets for weight loss in the overweight population [14]. As to be expected KDs, with their greater level of carbohydrate restriction, show an even greater level of weight loss at various time points. The weight loss is substantial without limiting energy intake due to a potential metabolic advantage.

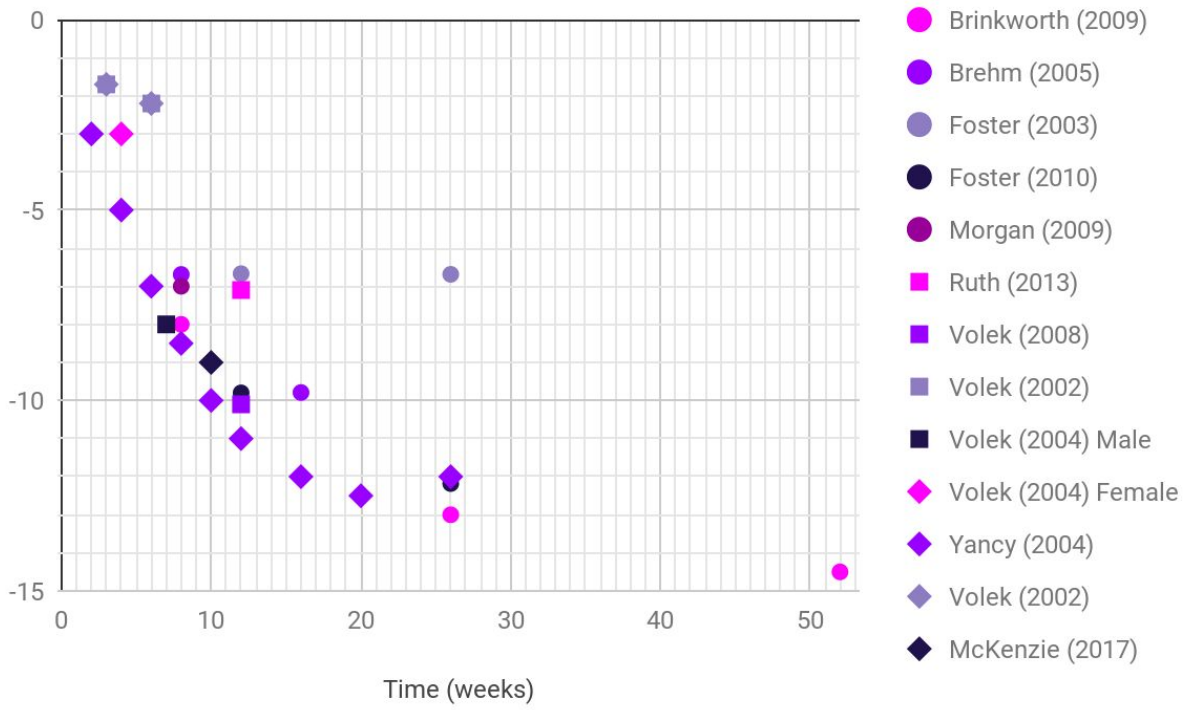
When participants are given unlimited access to food they unconsciously reduce their calories due to increased satiety and reduced hunger [20]. Therefore the practitioner can allow ad libitum eating on a ketogenic diet whilst being confident weight loss with ensue. Daily rate of weight loss will decrease over time which is in line with most diets as people reach their ideal weight [5] [6]. There is always the option for practitioners to prescribe a restricted calorie KD if a more aggressive rate of weight loss is required.

The Data Set: Benchmark Points from Studies

After a review of the KD studies available, we narrowed down the data set from 32 to 12 studies.

The data points taken from these are shown in Figure 2.

Figure 2: Comparison of Weight Loss on KD Over Time (12 Aggregated Studies)



Many of the studies were randomised control trials (RCTs) with ad libitum energy consumption, following ketogenic guidelines of a carbohydrate (CHO) intake of 20–50g per day or under 10% of daily calories if on a 2000 kcal diet [22].

From the data points in Figure 2, Figure 1 was created after the following adjustments were made:

At *week 3* a new high value was entered using the highest rate of weight loss per week at a rate of -1kg as recorded by Yancy's (2004) study in 2 week intervals. At the same time point Volek's (2002) paper represents the lowest expected weight loss as the participants were healthy, normal-weight men [23].

At *week 6* Volek's (2002) paper gave a very reduced weight loss value of -2.2kg, as seen pointed icon in Figure 2. This has been treated as an anomaly due to the participants already being at a healthy weight and thus weight loss would not be expected to continue. Therefore this low data point was adjusted to follow the trend of the other studies.

At *week 10* both Mckenzie (2017) and Yancy (2004) showed very high rates of weight loss. Increased weight loss was the result of greater participant adherence from the studies extensive counselling, routine monitoring and ketone tracking [2, 24]. Since both study conditions are hard to replicate in free-living individuals, a new low value for *week 10* was estimated for clients.

Foster's (2003) study did not follow the trend at *week 12* due to minimal counselling and guidance leading to poor adherence [25]. Therefore the low value at *week 12* was adjusted.

The only studies at *week 16* were both high on the weight loss scale. Both Brehm (2005) and Yancy (2004) had a high rate of weight loss due to routine counselling and food journaling at *week 16* [2 26]. Therefore a new low value for weight loss was estimated.

Only one study, Brinkworth (2009) was a year in length whilst also maintaining participant adherence to a KD [9]. Therefore both high and low values were extrapolated from the last available studies at *week 26* of the timeline.

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[22] Noakes, Timothy David, and Johann Windt. "Evidence That Supports the Prescription of Low-Carbohydrate High-Fat Diets: A Narrative Review." *British Journal of Sports Medicine*, vol. 51, no. 2, 2017, pp. 133–39, doi:10.1136/bjsports-2016-096491.

[23] Volek, Jeff S., et al. "Body composition and hormonal responses to a carbohydrate-restricted diet." Metabolism-Clinical and Experimental 51.7 (2002): 864-870.

[24] McKenzie, Amy L., et al. "A novel intervention including individualized nutritional recommendations reduces hemoglobin A1c level, medication use, and weight in type 2 diabetes." JMIR Diabetes 2.1 (2017): e5.

[25] Foster, Gary D., et al. "A randomized trial of a low-carbohydrate diet for obesity." New England Journal of Medicine 348.21 (2003): 2082-2090.

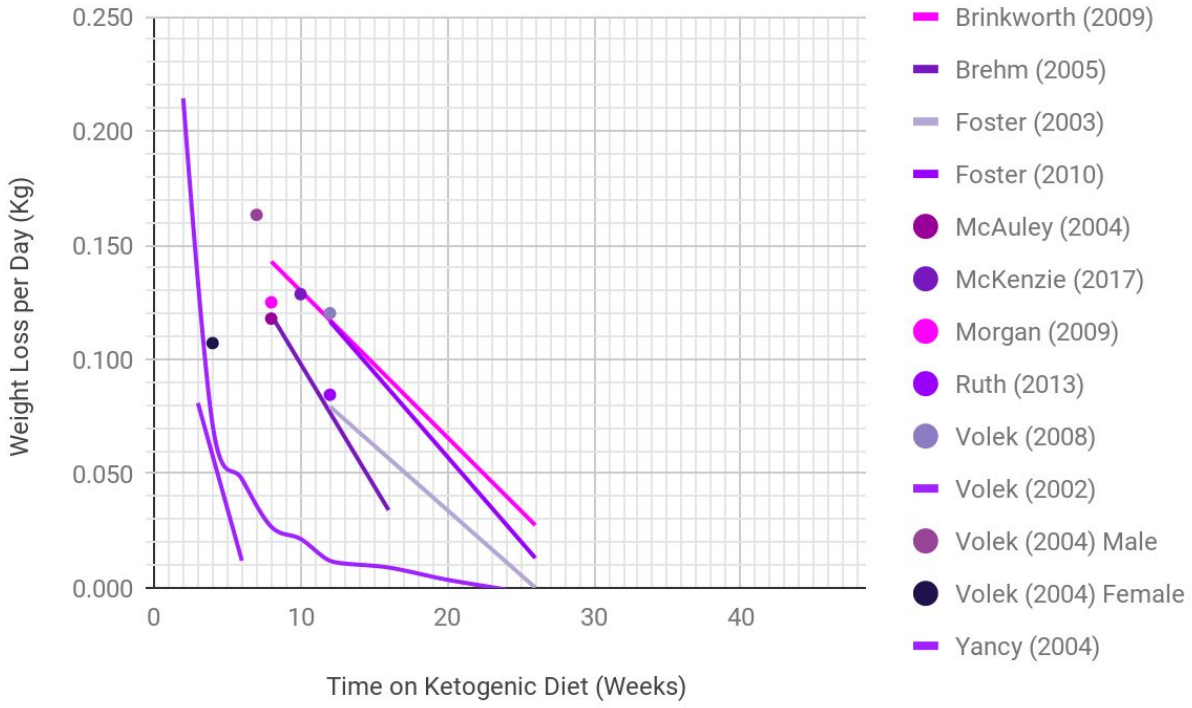
[26] Brehm, Bonnie J., et al. "The role of energy expenditure in the differential weight loss in obese women on low-fat and low-carbohydrate diets." The Journal of Clinical Endocrinology & Metabolism 90.3 (2005): 1475-1482.

Rate of Weight Loss Slows Over Time on the KD

The studies paint a clear picture of a declining rate of weight loss over time, as illustrated in Figure 3 showing the daily rate of weight loss.

The longer a person stays on the ketogenic diet, the lower the rate of weight loss per day (or per week) should be expected to be.

Figure 3: Comparison of Rate of Weight Loss on KD Over Time (12 Aggregated Studies)



As benchmark points, weight loss starts between 100 to 200 grams per day (700 to 1400 grams per week) and drops over time to around 50 grams per day (350 grams per week).

How the 12 Studies in Our Data Set Were Selected

Of the 32 studies which warranted analysis, only 12 met the correct KD criteria.

Studies, both in entirety and partially, were excluded if participants were given dietary advice above 10% of total daily energy intake or 50g of carbohydrate [22]. Records were also excluded if participants were <18 years of age, did not adhere to the ketogenic diet restrictions or if no dietary analysis data was given.

To try and reduce heterogeneity between studies only the periods when participants followed the KD, to the best of our knowledge, were included for each of the studies in the table (*Appendix 1*).

For instance, participants in the Foster (2010) [27] study followed the KD diet for 6 months before the dietary advice allowed carbohydrates in excess of 50g per day, whilst both Morgan (2009) [28] and McAuley (2004) [29] participants followed a KD diet for 8 weeks.Therefore, the duration of the studies in table 1 refers only to this time frame within each study. All three studies used the *Dr. Atkins' New Diet Revolution* guidelines

Of other note, the Volek (2004) [30] study used different intervention lengths for male and female participants to account for changes in weight due to the female menstrual cycle. This study was therefore split into two results for the analysis behind the graphs.

What Explains The Gap Between High and Low Rates of Weight Loss?

Our KD weight loss benchmarking tool incorporates various rates of weight loss between low and high case scenarios. This was driven by the variation of values found in the data set but we believe a lot more can be done to reduce the variance in client outcomes.

There is still much to learn about optimizing rates of weight loss on the ketogenic diet. As we learn more about the factors that increase or reduce weight loss rates, these can be incorporated into the tool, allowing practitioners to better optimize outcomes for clients.

Analysis of Potential Drivers of Differing Weight Loss Rates in Studies

The ketogenic diet guidelines employed by each study varied which could explain differences in the weight loss observed between studies. Half of the studies used a protocol based on *Dr. Atkins' New Diet Revolution* book guidelines which prescribes an increase in carbohydrate intake over time [31].

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[27] Foster, Gary D., et al. "Weight and metabolic outcomes after 2 years on a low-carbohydrate versus low-fat diet: a randomized trial." Annals of internal medicine 153.3 (2010): 147-157.
[28] Morgan, L. M., et al. "Comparison of the effects of four commercially available weight-loss programmes on lipid-based cardiovascular risk factors." Public health nutrition 12.6 (2009): 799-807.
[29] McAuley, K. A., et al. "Comparison of high-fat and high-protein diets with a high-carbohydrate diet in insulin-resistant obese women." Diabetologia 48.1 (2005): 8-16.
[30] Volek, Jeff S., et al. "Comparison of energy-restricted very low-carbohydrate and low-fat diets on weight loss and body composition in overweight men and women." Nutrition & metabolism 1.1 (2004): 13.
[31] Atkins, RC. Dr. Atkins' New Diet Revolution. New York: Avon Books; 1998.

However this does not seem to be a major factor in some of the differences observed. For instance at *week 26* Foster (2003)[32], Foster (2010) and Yancy (2004) all used these guidelines but the average weight loss was inconsistent with -6.7, -12.1 and -12kg respectively.

On the other hand, Brinkworth (2009) had the highest weight loss at *week 26* of -13kg, which is not significantly different to that of Foster (2010) and Yancy (2004).

This leads us on to compliance and actual macronutrient intake. The studies with the best results consistently showed better adherence, lower carbohydrate amounts and/or a greater ketone presence.

Although energy intake played a part, not all the calorie restricted studies showed greater weight loss. For instance at *week 12*, Ruth (2013) [33] had a -500 kcal deficit and mean weight loss of -7.1kg . Foster (2010) and Yancy (2004) however, were ad libitum and reported greater weight loss at *week 12*. Likewise Volek (2008) [34] had a whopping -1500 kcal deficit but saw a weight loss similar to Foster (2010) and Yancy (2004).

The main variables of note are compared in the table (*appendix 1*). Many other factors could have affected the KD studies analysed but were out of the scope of this paper. The KD studies included here showed heterogeneity in starting weight, energy consumption, duration and macronutrient proportions of the prescribed KDs.

Study Case 1: The Minimum Rate of Weight Loss

McAuley (2004) had the worst results for short-term weight loss. The participants in the McAuley (2004) trail consumed a greater CHO content, ~ 41g / 11%, than other studies whilst also being insulin resistant, which would impair weight loss due to greater circulating insulin attenuating lipase activity in adipose tissue [22].

Foster (2003) for longer term 26 week weight loss. Foster (2003) had minimal professional contact which led to poor adherence and a high attrition rate. Whilst Volek (2002) saw minimal weight loss due to participants being healthy normal weight men.

Study Case 2: The Maximum Rate of Weight Loss

Yancy (2004) showed the best result which was comparable to Foster (2010) at week 26 with a rate of daily weight loss of 66g and 67g respectively.

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[32] Foster, Gary D., et al. "A randomized trial of a low-carbohydrate diet for obesity." New England Journal of Medicine 348.21 (2003): 2082-2090.
[33] Ruth, Megan R., et al. "Consuming a hypocaloric high fat low carbohydrate diet for 12 weeks lowers C-reactive protein, and raises serum adiponectin and high density lipoprotein-cholesterol in obese subjects." Metabolism-Clinical and Experimental 62.12 (2013): 1779-1787.
[34] Volek, Jeff S., et al. "Carbohydrate restriction has a more favorable impact on the metabolic syndrome than a low fat diet." Lipids 44.4 (2009): 297-309.

The results of Yancy (2004) could be due to dietary counselling which occurred twice monthly for 3 months then monthly for 3 months. Participants were instructed to complete 5 consecutive days, including a weekend, food diaries before each meeting which would have made participants more aware of their food choices and possibly a reduction in energy intake as seen in previous studies [35].

Similarly Foster (2010) participants were to complete regular food records and received comprehensive behavioural treatment weekly for 20 weeks, then every other week for 20 weeks. Protein was not measured in Foster (2010) but the participants in Yancy (2004) consumed 25% total daily energy intake as protein.

Mckenzie (2017) [24] ensured ketosis of all the diabetic patients included in the study by routinely monitoring BOHB which may have led to greater adherence or a true metabolic advantage of staying in ketosis.

The patients in this study also had access to the Virta Clinic which utilises a technology-enabled, full-service clinic model for metabolic recovery from type 2 diabetes. This included extensive education, accountability and monitoring services.

However, the patients in this study had the greatest mean starting weight of 117 kg so more weight loss would be expected. This account must be approached with some caution because it should be noted that this was a non-randomised, parallel arm, outpatient intervention.

Brinkworth (2009) achieved a very high weight loss of -13kg at 6 months. This is due to multiple factors including a hypocaloric diet of ~1500 kcal, a low carbohydrate threshold of under 36.5g and regular consultations with participants.

What Else Could Explain the Differences?

The specific body composition of the weight lost has not been presented in this paper due to the inaccuracy of available tools with which clients measure their own body fat percentage.

In the studies there were differences in the loss of lean mass vs fat mass for instance McAuley (2004) retained more lean mass. Heterogeneity existed between body composition measuring tools used such as DEXA or Bioelectrical impedance (BIA).

Other variances between studies are daily protein intake, risk factors and exercise recommendations. Most of the studies had a high protein intake, around 30% total energy intake.

[35] TURNER-MCGRIEVY, G.M., BEETS, M.W., MOORE, J.B., KACZYNSKI, A.T., BARR-ANDERSON, D.J. and TATE, D.F., 2013. Comparison of traditional versus mobile app self-monitoring of physical activity and dietary intake among overweight adults participating in an mHealth weight loss program. Journal of the American Medical Informatics Association, 20(3), pp. 513-518.

Confounding factors that may have altered results but were missed out in the studies are the composition of fatty acids consumed in the diet, individual exercise, genetics and sleep. Data of these variables were not presented in the majority of the studies analysed.

Takeaways

The data set taken from our review of 12 ketogenic diet weight loss studies found:

- In most studies there is a voluntary reduction in energy intake when allowed to eat ad libitum within the CHO limit.
- Studies show a decreasing rate of weight loss over time starting with between 100 to 200 grams per day (700 to 1400 grams per week) and dropping over time to around 50 grams per day (350 grams per week).
- The better the adherence, and the lower carbohydrate intake is, the greater the weight loss appears to be.

Ketosource proposes a KD Weight Loss Benchmarking tool for nutritionists and physicians to evaluate if their clients are losing weight at an appropriate rate (or if some troubleshooting may be required to find out why not).

The Ketosource tool should be considered to be at a ‘preliminary’ stage. More research and data is required to reinforce the benchmarking tool’s benchmarks, and to understand individual factors that will bias the rate of weight loss for an individual.

To improve upon the tool Ketosource plans to investigate the following points:

- *Controlling for distance from ideal weight (e.g. based on WHtR):* Does the rate of weight loss predictably slow based on distance from an optimum WHtR? Or body fat %?
- *Other factors leading to different rates of weight loss:* e.g. sleep, exercise, genetics, dietary fat composition, insulin resistance, exercise and other lifestyle factors.
- *The definition of a ketogenic diet:* Most studies used KDs based on the *Dr. Atkins’ New Diet Revolution guidelines*. What would the results look like using Phinney’s Well Formulated Ketogenic Diet definition?

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Appendix

TABLE: Comparison of KD Weight Loss Studies

Lead Author (reference no.)	Year	Duration (KD)	N (% female)	Study type	Diet type	Diet Guidance (per day)	Energy consumption	Dietary Compliance (per day)	Risk Factor	Mean Baseline Weight (kg)	Keto Mean Weight Loss (kg)
Brehm	2005	2 months (Keto)	20 (100)	RCT	KD–> LC	20g CHO increase to 40-60g after 2 weeks (only if urinary ketones positive); Dr. Atkins' *New Diet Revolution* guidelines	Ad libitum	48.3g/15%CHO; 28% protein, Counselling for 2 months	Obesity	90.60	-6.69
Brinkworth	2009	12 months	33 (67)	RCT	KD	24% CHO, 35% Protein; 61% Fat. <20g CHO for the first 8 weeks and then 40g for remainder of the study.	Hypocaloric (~1434 kcal/d women; ~1673 kcal/d men)	<36.5g / <10% CHO; 35% protein; Consultation with dietitian bi-weekly for first 8 weeks then monthly basis.	Obesity + one more metabolic syndrome feature	93.90	-14.50
Foster	2003	6 months	33 (64)	RCT	KD–> LC	20g CHO then gradual increase; *Dr. Atkins' New Diet Revolution* guidelines	Ad libitum	20g CHO; Professional contact minimal.	Obesity	98.00	-6.69
Foster	2010	6 months	153 (6)	RCT	KD–> LC	20g CHO then gradual increase; Dr. Atkins' *New Diet Revolution* guidelines	Ad libitum	20g CHO Comprehensive group behavioral treatment weekly until 20 weeks the bi-weekly.	Obesity	103.30	-12.18

Appendix

McAuley	2004	8 week (keto)	31 (100)	RCT	KD–> LC	20g CHO 2 weeks then gradual increase 5g/day per week up to 50g at week 8; Dr. Atkins' *New Diet Revolution* guidelines	Ad libitum	41g/11% CHO 29% Protein at week 8. Supervision for 16 weeks	Obesity, insulin-resistance	96.00	-6.60
McKenzie	2017	10 weeks	232 (67)	Non-randomized, parallel arm, outpatient intervention	KD	<30g CHO; 1.5g/kg protein; 3-5 servings non-starchy vegetable, adequate fluid and mineral intake for a ketogenic state	Ad libitum	Mean BOHB (ketones) 0.6mmol/L	T2D	117.00	-9.00
Morgan	2009	8 weeks	57 (74)	RCT	KD–> LC	20g increased to 91g gradual 5g CHO; *Dr. Atkins' New Diet Revolution* guidelines	Ad libitum	49.6g/12% CHO, 37% Protein at week 8, 7d dairies	Overweight/Obesity	92.10	-7.00
Ruth	2013	12 weeks	15 (90)	RCT	KD	500 kcal deficit; ≤40g CHO; 60% (<7% SFA) fat; ~35% protein	Hypocaloric (-500 kcal)	Good: 39.4g/9.6% CHO. 33.5% Protein, Fat 56% (SFA 20.7%) Bi-weekly consultation with the study dietitian.	Obesity	100.50	-7.14
Volek	2002	6 weeks	12 (0)	Case-control dietary intervention study	KD	5-10% CHO, 60% Fat	Ad libitum	Good: 46g/8% CHO; 30% protein; 61% Fat (25% SFA)		79.20	-2.20

Appendix

Volek	2004	50 days (Male); 30 days (Women)	28 (46)	Cross-over randomised trial	KD	<10% CHO, ~30% protein, ~60% fat	Hypocaloric (-500 kcal)	~9% CHO; ~63% Fat; 28% protein; Urinary ketones measured positive	Overweight/Obesity	Men 109.1; Female 76.3; Total 92.7	Male -8; female -3
Volek	2008	12 weeks	20 (50)	RCT	KD	12% CHO; 59% Fat; 28% Protein	Hypocaloric (~-1500 kcal)	45g/12% CHO; 59% Fat; Protein 28%. Weeks 2–12 Urinary ketones above trace on 85% of days.	Overweight/Obesity	96.50	-10.10
Yancy	2004	6 months	45 (71)	RCT	KD–> LC	<20g increased by 5g/day per week until reaching a body weight maintenance level; Dr. Atkins' *New Diet Revolution* guidelines	Ad libitum	29.5g/8% CHO; 68% Fat; 25% Protein; Urinary ketones present	Overweight/Obesity, Hyperlipidemic	98.10	-12.00

- KD – Ketogenic diet (20–50g CHO/day or <10% of daily kcal of 2000 kcal/day diet)[1]
- LC – LCHF diet (<26% of total energy intake or <130 g CHO/day)[1]

[1] Noakes, Timothy David, and Johann Windt. "Evidence That Supports the Prescription of Low-Carbohydrate High-Fat Diets: A Narrative Review." *British Journal of Sports Medicine*, vol. 51, no. 2, 2017, pp. 133–39, doi:10.1136/bjsports-2016-096491.

Appendix

Studies Exclusion list

Benoit (1965) – Male Navy personnel, restricted to a 1000 kcal ketogenic diet.
Brehm (2003) – Poor adherence, no nutritional or urinary ketone data before 3 months. Diet composed of 15% carbohydrate 3 months.
Dashti (2005) No dietary adherence data given
Dansinger (2005) – Low carbohydrate diet
Gardner (2007) – Low carbohydrate diet
Gardner (2018) – Low carbohydrate diet
Iqbal (2010) – Low carbohydrate diet
Lim (2009) – Low carbohydrate diet, no KD duration measured.
McAuley (2006) – Low carb not keto, continuation of McAuley (2005)
Samaha (2003) – Low carb not keto due to poor adherence
Stern (2004) – Poor adherence to a KD
Truby (2006), Truby (2008) – No Dietary adherence data just “reported portions of carbohydrate foods fell from 40 each day at baseline to five at two months and seven at six months”. Dietary adherence 12% CHO, missing data.
Tsai 2005 – Simply a rehash of Stern (2004)[2] but for cost effectiveness of a KD.
Willi (1998) Based on children aged 12-15 using a low-fat ketogenic diet
Young (1971) Study not on free-living participants, special meals made for them.

[2] Seshadri, Prakash, et al. "A randomized study comparing the effects of a low-carbohydrate diet and a conventional diet on lipoprotein subfractions and C-reactive protein levels in patients with severe obesity." *The American journal of medicine* 117.6 (2004): 398-405.

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