Diabetes Ther
https://doi.org/10.1007/s13300-023-01495-1

ORIGINAL RESEARCH

Optimizing Diabetes Management Using a Low-Calorie Diet in Saudi Arabia: A Cost-Benefit Analysis

Saud Al Sifri · Raed Aldahash · Daniel-Antonio de Luis Roman · Ahmed Amin · María Camprubi-Robles · Kirk W. Kerr · Alina Juusti-Hawkes · Ariel Beresniak

Received: August 4, 2023 / Accepted: October 11, 2023

ABSTRACT

Background: Low-calorie diets, high in protein and low in carbohydrates, are commonly recommended for patients with pre-diabetes and type 2 diabetes. The objective of this study was to carry out a cost-benefit analysis (CBA) of a low-calorie versus a standard diet from the perspective of the Saudi Arabian health system.
Methods: The CBA compares costs and benefits of the two diet strategies over a 1-year time horizon. Costs included diet and diabetes treatment-related resources while benefits were measured in terms of the costs of diabetes complications avoided. Data on costs and benefits were collected from published literature and subject matter experts. Incremental costs were estimated as the cost difference between low-calorie and standard diet. Incremental benefits were estimated as cost difference from medical complications when following a low-calorie or standard diet. The incremental absolute cost-benefit ratio was calculated to show the difference between the costs and benefits of the low-calorie diet. Incremental relative cost-benefit ratio was calculated to show the cost per dollar of benefit obtained. Monte Carlo simulation modeled variability in outcomes due to variation in costs and uncertainty of diabetes complications.

Prior Presentation: Preliminary version of this analysis was presented at the Virtual Endocrine Diabetes and Obesity Congress (VEDOC2022) May 2022.

S. Al Sifri
Department of Endocrinology and Diabetes, Alhada Armed Forces Hospital, Taif, Saudi Arabia

R. Aldahash
Department of Medicine, Ministry of National Guard-Heath Affairs, Riyadh, Saudi Arabia

R. Aldahash
King Abdullah International Medical Research Center, Riyadh, Saudi Arabia

R. Aldahash
King Saud Bin Abdulaziz for Health Science, Riyadh, Saudi Arabia

D.-A. de Luis Roman
Servicio Endocrinología y Nutrición Hospital Clínico Universitario Valladolid, Valladolid, Spain

D.-A. de Luis Roman
Centro de Investigación de Endocrinologia y Nutrición. Facultad de Medicina, Valladolid, Spain

A. Amin · K. W. Kerr (✉)
Abbott Nutrition, Columbus, OH, USA
e-mail: Kirk.kerr@abbott.com

M. Camprubi-Robles
Abbott Nutrition, Research and Development, Granada, Spain

A. Juusti-Hawkes · A. Beresniak
Data Mining International, Geneva, Switzerland

Published online: 27 October 2023

Results: The 1 year cost of standard diet was US$2515 ± 156 compared to US$2469 ± 107 per patient for a low-calorie diet. Incremental benefit is estimated at US$21,438 ± 7367 per patient. The estimated incremental absolute cost-benefit ratio was US$ − 21,360 establishing that benefits are greater than costs, while the estimated incremental relative cost-benefit ratio is 0.0037, establishing that benefits are 270 times greater than costs.
Conclusion: The low-calorie diet was the dominant strategy compared to the standard diet in modeled scenarios. These findings highlight the importance of a low-calorie diet as part of diabetes management programs for outpatients with type 2 diabetes.

Keywords: Cost-benefit analyses; Diabetes complications; Low-calorie diet; Type 2 diabetes

Key Summary Points
With the increasing prevalence of diabetes worldwide, new treatments to manage diabetes, such as low-calorie and very low-calorie diets, are being studied
This study models the impact of a low-calorie diet using oral nutrition supplements as meal replacements on healthcare costs from diabetes complications
The study finds that low-calorie diets have a mean incremental benefit of US$21,438 ± 7367 compared to a standard diet
Low-calorie diets may be a cost-effective intervention for reducing costs from diabetes complications

INTRODUCTION

Diabetes mellitus is the most common chronic endocrine disorder, and its prevalence is quickly rising around the world. In Saudi Arabia and many other countries, diabetes is reaching epidemic proportions. The World Health Organization (WHO) reported that Saudi Arabia had the second highest rate of diabetes in the Middle East and seventh highest in the world in 2016 [1]. Over 10% of the Saudi population is now living with this condition, and according to the recent report by the International Diabetes Federation (IDF), the prevalence is due to almost double by 2045 [2]. It must also be noted that while over 4 million Saudi citizens out of the population of just under 35 million have diabetes, almost 2 additional million have the disease but are not yet diagnosed [2]. The prevalence of both diabetes and prediabetes increases significantly with age. According to several surveys run in Saudi Arabian communities, almost half of people aged 50 and older suffer from diabetes and another 10–15% have prediabetes [3]. The share of the population age 30 and older with prediabetes may be as high as 25.5%, meaning that there are more than 3 million people at risk of diabetes mellitus [4, 5].

Globally, most people living with diabetes have type 2 diabetes. Key contributors to the increase in people with diabetes are urbanization, an aging population and lifestyle choices leading to increasing rates of overweight and obesity, such as an unhealthy diet and the lack of exercise. The major socio-economic changes that have occurred over the past 40 years in Saudi Arabia have significantly contributed to the rapid growth of diabetes among its population. The rise in prosperity and technological advances have greatly modified the way of life and moved it from the traditional dependence on grown natural produce towards the increased consumption of fast foods and sweet beverages as well as from a physically active life inherited from the Bedouin tradition to a more sedentary culture and over-dependence on modern comfort and gadgets [6]. In addition, the indigenous Saudi population appears to have a specific genetic predisposition to develop type 2 diabetes, which is aggravated by a rise in obesity rates, a high rate of consanguinity and the presence of other variables linked to the insulin resistance syndrome [7]. In fact, the escalation propensity of diabetes in Saudi Arabia has been particular worrying in the recent past—e.g., in the past 3 years alone diabetes has

registered an almost ten-fold increase in the country [1].

High blood sugar levels over a prolonged period can lead to significant health complications. The most common consequences of diabetes are cardiovascular and neurological conditions, diabetic retinopathy and diabetic nephropathy [1]. As a result, diabetes has a significant economic impact on the Saudi healthcare system through both the cost of diabetes medications and the treatment of comorbidities as well as the indirect costs related to loss of productivity, disability and early mortality by disease [6]. The current trend in the diabetes statistics indicates that the healthcare utilization and medical care costs in Saudi Arabia will rise to unsustainable levels unless an efficient and wide-ranging epidemic control program is introduced and incorporated throughout the country [1]. Contrary to its perception as an incurable, chronic disease with potentially life-threatening complications, diabetes symptoms can be managed with proper treatment, control measures and prevention techniques [1].

The awareness campaigns and prevention programs centered on education around the risk factors and complications linked to the progression of the disease are critical for diabetes care and management. As overweight and obesity are among the main contributors to the development of diabetes [8], weight loss could be seen as the primary approach for nutritional management of the disease. Compared to standard care, restricting the dietary energy intake by following a low-calorie diet—together with other approaches—may lead to superior weight loss, improvement of glycemic control and reversal of diabetes symptoms [9]. The DiRECT trial used a 3-month (extendable up to 5 months if desired by participant) total diet replacement phase to induce weight loss [10]. During this phase, intervention group participants consumed 825–853 kcal/day consisting of 59% carbohydrate, 13% fat, 26% protein and 2% fiber. Intervention group participants lost an average of 14.5 kg during the total diet replacement while control group patients lost 1 kg bodyweight. Participants in the intervention group experienced an average weight regain of 2.9 kg in subsequent study phases. Average HbA1c fell by − 0.9% in the intervention group, but increased by 0.1% in the control group.

This study conducted a cost-benefit analysis (CBA) of following a low-calorie diet, high in protein and low in carbohydrates, to manage diabetes, versus a standard diet. The analysis was conducted from the perspective of the Saudi Arabia health system. In the proposed low-calorie diet scenario, one to two meals per day were replaced by a meal replacement product (Glucerna® SR). Diet- and treatment-related costs and benefits from avoiding diabetes-related costs and complications were modeled to identify an efficient strategy through which outpatients with type 2 diabetes may experience fewer diabetes-related complications, require fewer diabetes medications and rely less on healthcare resource use.

METHODS

Types of CBA Analyses

The CBA compares costs and benefits of the two diet strategies expressed in monetary value over a 1-year time horizon [12]. Costs measured included diet- and diabetes treatment-related costs. Benefits were measured in terms of costs avoided by the reduction of diabetes-related complications. This analysis focused on two comparisons of costs and benefits. First, the incremental absolute cost-benefit (IACB) shows the difference between the incremental costs and incremental benefits of the low-calorie diet and is a measure of whether benefits are greater than costs. Second, the incremental relative cost-benefit ratio (IRCB) is the ratio of incremental costs to incremental benefits and shows the cost per dollar of benefit obtained. Incremental costs were estimated by the difference in costs for the low-calorie and the standard diets. Incremental benefits were estimated by the difference in costs from diabetes complications when following a standard diet and costs from diabetes complications from following a low-calorie diet.

Costs

All costs in the model were expressed in US$ (2021).

Information on healthcare resource utilization, probability of complications and use of diabetes medications under a standard diet and under a low-calorie diet was obtained from the available scientific literature, statistical reports and professional experience of clinical experts in Saudi Arabia (S.A.S., R.A.).

The cost of the standard diet for an individual in Saudi Arabia was estimated by "average monthly household expenditure on food and beverage in Saudi Arabia 2018" [11] divided by the average household size. Assuming a diet of three meals of equal costs, the cost of the low-calorie diet was estimated by replacing the cost of one to two thirds of monthly food and beverage expenditures by the cost of using a meal replacement product (Glucerna® SR) for those meals. Average diet cost in Saudi Arabia was estimated to be US$1708 over 1 year for a standard diet and a between US$1912–2115 for a low-calorie diet, depending on whether just one or two meals were replaced [11].

The costs of diabetes-specific medications were obtained from Saudi Arabian experts and based on the disclosed public price. The reduced need for diabetes medication leading to smaller medication costs under a low-calorie diet was based on the experts' clinical experience and on the data from an internal audit performed in a tertiary diabetes center (Diabetes center in Alhada & Taif Armed Forces Hospital). Specific diabetes medication costs were estimated to range between US$540–1080 under a standard diet and between US$300–612 under a low-calorie diet. It was estimated that, on average, patients with type 2 diabetes are mostly taking 2–3 diabetes-specific medications such as metformin, sulfonylureas and dipeptidyl peptidase type IV (DPP-4) DPP-4 inhibitors. Some patients are also receiving basal insulin (glargine) or premixed insulin analogs. A small number of patients might take more expensive medications such as glut-2 transporter inhibitors (SGLT-2 inhibitors) or glucagon-like peptide 1 receptor agonists (GLP-1 RA), which have not been included in these costs.

Benefits

As noted previously, benefits were estimated by the difference in costs of diabetes complications under a standard diet and the costs of complications under a low-calorie diet. Diabetes complications considered in the model were:

- Limb amputation (from toe amputations to below knee amputations),
- Diabetic retinopathy,
- Coronary heart disease,
- Ischemic stroke,
- Peripheral artery disease,
- Peripheral diabetic neuropathy,
- Heart failure, and
- Chronic renal failure.

As with the costs of the standard diet and diabetes medication, data on the probability of diabetes-related complications and the costs of managing these complications were collected through available scientific literature [12] and consultation with local experts (diabetologists, ophthalmologists, cardiologists, internists, neurologists and nephrologists). Costs and incidence of complications over 1 year are presented in Table 1.

Monte Carlo Simulation

Monte Carlo simulation was used to incorporate variability of input data in the estimates of the benefits and costs of the two strategies. The model was simulated 100,000 times using estimates drawn from the potential data distributions of input variables [13]. This modeling approach manages uncertainty by considering the distribution of each variable parameter. For instance, for each strategy, resource utilization (such as low-calorie diet costs, prescription drugs costs, management of diabetes complications, etc.) is estimated across the distribution ranges for each parameter. The simulation model was programmed to account for the entire distribution of costs for each pre-defined parameter. Costs and probabilities were assumed to be uniformly distributed between minimum and maximum values.

Table 1 Costs of diabetes complications (in US$ 2021) and incidence (minimum-maximum) with standard diet and low-calorie diet (source: local practices in Saudi Arabia)

	Min costs	Max costs	Min-max prob Standard diet	Min-max prob Low-calorie diet	Sources
Limb amputation	12,000	18,000	15–40%	5–20%	Non-published local public/private practices records and expert opinions (co-authors SAS, RA, DALR)
Diabetic retinopathy	8000	21,000	20–45%	10–25%	Mata-Cases et al.; Alharbi et al.; non-published local public/private practices records and expert opinions (co-authors SAS, RA, DALR)
Coronary heart disease	35,000	60,000	30–55%	20–40%	Mata-Cases et al.; Diabetes Care 2021;44(Suppl. 1):S125–S150; Diabetes Care 2021;44(Suppl. 1):S111–S124; non-published local public/private practices records and expert opinions (co-authors SAS, RA, DALR)
Ischemic stroke	18,000	23,000	15–25%	10–15%	Mata-Cases et al.; al-Rajeh et al.; Awada et al.; Diabetes Care 2021;44(Suppl. 1):S125–S150; Diabetes Care 2021;44(Suppl. 1):S111–S124; non-published local public/private practices records and expert opinions (co-authors SAS, RA, DALR)
Peripheral artery disease	12,000	20,000	25–60%	10–25%	Mata-Cases et al.; Badran et al.; Diabetes Care 2021;44(Suppl. 1):S125–S150; Diabetes Care 2021;44(Suppl. 1):S111–S124; non-published local public/private practices records and expert opinions (co-authors SAS, RA, DALR)
Peripheral diabetic neuropathy	2500	3400	40–70%	30%–40%	Mata-Cases et al.; Wang et al.; Almohisen AA et al.; Diabetes Care 2021;44(Suppl. 1):S151–S167; non-published local public/private practices records and expert opinions (co-authors SAS, RA, DALR)
Heart failure	15,000	25,000	20%–30%	15–25%	Mata-Cases et al.; Diabetes Care 2021;44(Suppl. 1):S125–S150; Diabetes Care 2021;44(Suppl. 1):S111–S124; non-published local public/private practices records and expert opinions (co-authors SAS, RA, DALR)
Chronic renal failure	10,000	25,000	30–60%	10–35%	Mata-Cases et al.; Al-Rubeaan et al.; Diabetes Care 2021;44(Suppl. 1):S111–S124; non-published local public/private practices records and expert opinions (co-authors SAS, RA, DALR)

Ethical Approval

Ethics committee approval was not required for this article. It is a modeling activity based on existing data. No new data from human participants were collected. This study was performed in accordance with the Helsinki Declaration of 1964 and its later amendments.

RESULTS

The model estimated mean costs from diabetes-related complications of US$54,427 ± 6051 under a standard diet (see Fig. 1), with minimum and maximum costs of US$34,564 and US$80,246, respectively. Under a low-calorie diet, mean costs from diabetes-related complications were estimated to be US$32,996 ± 4209 with minimum and maximum costs of US$19,861 and US$49,757, respectively (Fig. 1). The estimated mean cost of a standard diet was US$2,515 ± 156 while the estimated mean cost of a low-calorie diet was US$2469 ± 107.

Using these estimates, the mean incremental benefit (costs of complications under a low-calorie diet minus costs of complications under a standard diet) was estimated to be US$21,438 ± 7367, and the estimated incremental cost (total costs of low-calorie diet minus total costs of standard diet) was US − $48 ± 189. This results in an estimated incremental absolute cost-benefit ratio of US$ − 21,360, establishing that benefits are greater than costs. Estimated incremental relative cost-benefit ratio is 0.0037, indicating that benefits are 270 times greater than costs.

DISCUSSION

The cost-benefit analysis approach used in this study has several advantages in the analysis of diet programs and their impact on diabetes. The present CBA compares interventions and their consequences in which both costs and resulting benefits are expressed in monetary terms. An adequate diet for patients with type 2 diabetes minimizes complications, serving as a crucial prevention strategy called “tertiary prevention” in public health, which complements the primary and secondary prevention efforts. Primary prevention focuses on preventing the disease from occurring in the first place, while secondary prevention aims to detect the disease in its early stages. CBA analyses are particularly relevant in these three levels of prevention. The approach in this study underlines that diabetes treatments utilizing diet are efficient strategies. Additionally, calculating the costs of diabetes complications avoided provides a robust approach to estimating benefits without using willingness-to-pay surveys, which are often inconsistent across populations and over time. In addition, the CBA methodology avoids the limitations and fragile assumptions of cost-utility analyses (CUA) based on the inconsistent Quality Adjusted Life Years (QALY) indicator strategies [14, 15].

Although type 2 diabetes has been on the rise for a number of years in Saudi Arabia [1], there does not seem to be a standardized approach in either studying its prevalence and progression or the treatment through medication or nutritional strategies [1]. Depending on the geographical region, the level of care can differ quite significantly across geographic regions with some medical centers providing support ranging from primary care to an endocrinologist and a dietitian or a nutritional therapist where in other locations patients are treated mainly by family physicians, with the medication being the first and only line of treatment, and do not have access to a dietitian. As a result, recommendations and general awareness regarding the importance of the diet, physical exercise and the role of lifestyle patterns in type 2 diabetes prevention and management lack consistency [16, 17]. Even for those who do speak to dietitians, the obvious challenge lies in achieving long-term adherence to healthier eating patterns. While adherence to medication commitment activities is among the most practiced self-care attributes, adherence to major lifestyle modifications such as healthy diet and physical exercise is often poor [18]. An additional challenge is the place food occupies in Saudi culture as an important symbol of hospitality [16]. There is, however, a growing trend in the public health awareness and self-management programs, both globally and in

the Gulf countries like Saudi Arabia, that aim to promote and implement multidisciplinary diabetes care including education, attending check-ups at specialized clinics, dietary guidelines and physical exercise [16, 19, 20].

In terms of nutritional strategies for diabetes management, the concept of a low-calorie diet has not been regularly practiced. Using meal replacement products such as Glucerna®, as was used in this study's modeled scenarios, which are low in calories and carbohydrates but rich in protein and other nutritional elements, may provide an alternative and act as a potential transition phase towards consuming healthier foods on a more regular basis. In addition to the balanced nutritional profile, the benefit of such products lies in the ease with which most patients can adhere to using them as opposed to bringing immediate and radical changes in their daily cooking and eating routines to shift their diet towards healthier alternatives. By reducing the number of carbohydrates in the patients' diet, low-calorie meal replacement products may also reduce the fat mass and increase lean body mass, leading naturally to weight loss and improvements in the metabolic parameters [21]. While results from trials employing a low-calorie diet have varied, it is clear that such programs should be seen as part of a permanent lifestyle change rather than a temporary intervention [22].

Increasing levels of diabetes prevalence and economic burden around the world, often due to factors discussed here, suggest that a diet-based approach to diabetes management would have wide applicability. Even in areas following traditionally health-promoting Mediterranean-style diets, the growing popularity of fast food has led to many health problems, including diabetes, among their populations. A Spanish study looked at the impact of two meal replacement strategies on cardiovascular risk parameters in patients with obesity and osteoarthritis. The study showed that at 3 months patients using meal replacement products had lost weight and had a clear improvement in the lipid parameters, glycemic control and systolic blood pressure [23]. The multinational PREVIEW trial, initiated in 2013, examined type 2 diabetes prevention in adults with prediabetes through changes in nutrition and increase in physical activity over 3 years. The study demonstrated that combining an initial low-calorie diet to lose weight and a long-term maintenance diet accompanied by a physical activity program could achieve longer term weight loss and reduce the risk of developing type 2 diabetes [24].

Limitations

The approach used in this study does have several limitations. First, this study measures and quantifies the benefits of low-calorie diet in diabetes using an economic evaluation approach, assuming patient adherence and results similar to those identified in published studies. Second, this study was based on observational data rather than a head-to-head comparative trial, leaving open the potential for confounding bias. However, cost assessments conducted alongside clinical trials lead to protocol-driven criteria that may not be generalizable to a non-study setting. Third, the information regarding healthcare resource utilization was obtained from the literature, reports, or clinical expert experience, which may not be as generalizable as insurance claims data. However, such data were not available for this analysis.

CONCLUSION

The management of diabetes and diabetes-related complications imposes a significant economic burden on the Saudi Arabian healthcare system. The scenarios modeled in this study illustrate that the patients with type 2 diabetes adhering to a low-calorie diet with one to two meal replacements per day have significantly lower healthcare resource use than patients following a standard diet, making the low-calorie diet the dominant strategy compared to the standard diet. While many physicians have long been aware of the positive results that could be achieved by patients with diabetes following a low-calorie diet, this study underlines the benefits gained and costs avoided through comparison of a standard diet and a

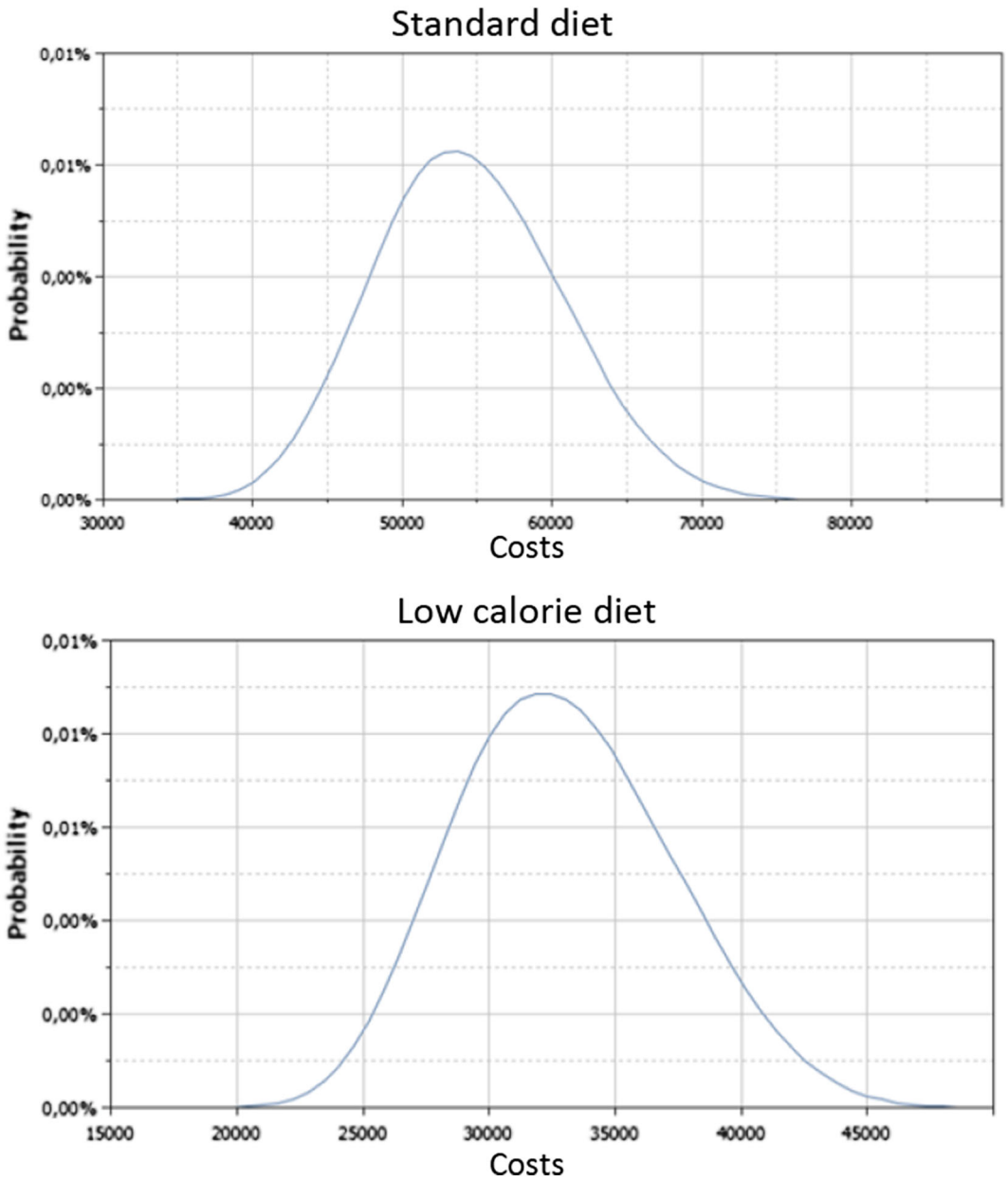

Fig. 1 Distribution of costs of diabetes complications under standard diet and low-calorie diet (US$)

low-calorie diet and highlights the importance of a low-calorie diet as part of diabetes management programs for outpatients with type 2 diabetes. The results of this model can provide evidence-based data to inform the decision-making process of governmental and healthcare bodies and raise awareness about the nutritional solutions for patients with diabetes.

Medical Writing/Editorial Assistance No medical writing or editorial assistance was used for this article.

Author Contribution. All authors (Ariel Beresniak, Alina Juusti-Hawkes, Saud Al Sifri, Raed Aldahash, Daniel-Antonio de Luis Roman, and Ahmed Amin, Maria Camprubi and Kirk W. Kerr) contributed to project conceptualization

and design. Ariel Beresniak, Alina Juusti-Hawkes, Saud Al Sifri, Raed Aldahash, Daniel-Antonio de Luis Roman and Ahmed Amin performed data collection. Model development and analysis were performed by Ariel Beresniak and Alina Juusti-Hawkes. The first draft of the manuscript was written by Ariel Beresniak and Alina Juusti-Hawkes. Kirk W. Kerr and Maria Camprubi revised the manuscript. All authors (Ariel Beresniak, Alina Juusti-Hawkes, Saud Al Sifri, Raed Aldahash, Daniel-Antonio de Luis Roman, and Ahmed Amin, Maria Camprubi and Kirk W. Kerr) provided comments on the manuscript and read and approved the final manuscript.

Funding. Data analysis and model development by Data Mining International (A Beresniak and A Juusti-Hawkes) was funded by an unrestricted grant from Abbott. No funding was provided to Saud Al Sifri, Raed Aldahash or Daniel-Antonio de Luis Roman for their work on this project. Abbott funded the journal's Rapid Service Fee.

Data Availability. The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Conflict of interest. Saud Al Sifri has nothing to disclose. Raed Aldahash has nothing to disclose. Ahmed Amin, Maria Camprubi-Robles, and Kirk W. Kerr are employees and stockholders of Abbott. Daniel-Antonio de Luis Roman has nothing to disclose. Ariel Beresniak and Aline Juusti-Hawkes (Data Mining International) received an unrestricted grant from Abbott for data analyses and manuscript development.

Ethical Approval. Ethics committee approval was not required for this article. It is a modeling activity based on existing data. No new data from human participants was collected. This study was performed in accordance with the Helsinki Declaration of 1964 and its later amendments.

REFERENCES

1. Al Dawish M, Robert A, Braham R, Al Hayek A, Al Saeed A, Ahmed R, et al. Diabetes mellitus in Saudi Arabia: a review of the recent literature. Curr Diabetes Rev. 2016;12(4):359–68.

2. Bell J. Prevalence of diabetes in Saudi Arabia to almost double by 2045: Report [Available from: https://english.alarabiya.net/News/gulf/2021/11/15/Prevalence-of-diabetes-in-Saudi-Arabia-to-almost-double-by-2045-Report]. Accessed 30 Dec 2021.

3. Bahijri SM, Jambi HA, Al Raddadi RM, Ferns G, Tuomilehto J. The prevalence of diabetes and prediabetes in the adult population of Jeddah, Saudi Arabia—a community-based survey. PLoS ONE. 2016;11(4): e0152559.

4. Al-Rubeaan K, Al-Manaa H, Khoja T, Ahmad N, Al-Sharqawi A, Siddiqui K, et al. Epidemiology of abnormal glucose metabolism in a country facing its epidemic: SAUDI-DM study. J Diabetes. 2015;7(5):622–32.

5. Robert AA, Al Dawish MA, Braham R, Musallam MA, Al Hayek A, Al Kahtany NH. Type 2 diabetes mellitus in Saudi Arabia: major challenges and possible solutions. Curr Diabetes Rev. 2016;13:59–64.

6. Naeem Z. Burden of Diabetes Mellitus in Saudi Arabia. Int J Health Sci. 2015;9(3):V–VI.

7. Elhadd TA, Al-Amoudi AA, AS A. Epidemiology, clinical and complications profile of diabetes in Saudi Arabia: a review. Ann Saudi Med. 2007;27(4): 241–50.

8. Al-Sumaih I, Johnston B, Donnelly M, O'Neill C. The relationship between obesity, diabetes, hypertension and vitamin D deficiency among Saudi Arabians aged 15 and over: results from the Saudi health interview survey. BMC Endocr Disord. 2020;20(1):81.

9. Hallberg S, Gershuni V, Hazbun T, Athinarayanan S. Reversing type 2 diabetes: a narrative review of the evidence. Nutrients. 2019;11(4):766.

10. Lean ME, Leslie WS, Barnes AC, Brosnahan N, Thom G, McCombie L, et al. Primary care-led weight management for remission of type 2 diabetes (DiRECT): an open-label, cluster-randomised trial. Lancet. 2018;391:541–51.

11. Average monthly household expenditure in Saudi Arabia in 2018, by major expenditure group [Available from: https://www.statista.com/statistics/614679/average-monthly-household-expenditure-in-saudi-arabia-by-major-expenditure-group/.

12. American Diabetes Association. Standards of medical care in diabetes—2021. Diabetes Care. 2021;44(Supplement 1):S1–222.

13. Andronis L, Barton P, Bryan S. Sensitivity analysis in economic evaluation: an audit of NICE current practice and a review of its use and value in decision-making. Health Technol Assess. 2009;13(29): iii; ix-xi, 1–61.

14. Beresniak A, Medina-Lara A, Auray JP, De Wever A, Praet JC, Tarricone R, et al. Validation of the underlying assumptions of the quality-adjusted life-years outcome: results from the ECHOUTCOME European project. Pharmacoeconomics. 2015;33(1): 61–9.

15. Langley PC. Great expectations: cost-utility models as decision criteria. Inov Pharm. 2016;7(2):14.

16. Sami W, Ansari T, Butt NS, Hamid MRA. Effect of diet on type 2 diabetes mellitus: a review. Int J Health Sci (Qassim). 2017;11(2):65–71.

17. Alanazi FK, Alotaibi JS, Paliadelis P, Alqarawi N, Alsharari A, Albagawi B. Knowledge and awareness of diabetes mellitus and its risk factors in Saudi Arabia. Audi Med J. 2018;39(10):981–9.

18. Alhaiti AH, Senitan M, Dator WLT, Sankarapandian C, Baghdadi NA, Jones LK, et al. Adherence of type 2 diabetic patients to self-care activity: tertiary care setting in Saudi Arabia. J Diabetes Res. 2020;6: 4817637.

19. Al Slamah T, Nicholl B, Alslail F, Harris L, Kinnear D, Melville C. Correlates of type 2 diabetes and glycaemic control in adults in Saudi Arabia a secondary data analysis of the Saudi health interview survey. BMC Public Health. 2020;20(1):515.

20. Alshareef SM, Alkhathlan MA, Alwabel AA, Al-Bawardi AA, Alqarni AH, Almuryidi AS, et al. How does the utilization of diabetes dietitian and educator service in Saudi Arabia affect glycemic outcomes? J Family Community Med. 2018;25(2): 108–13.

21. Basciani S, Costantini D, Contini S, Persichetti A, Watanabe M, Mariani S, et al. Safety and efficacy of a multiphase dietetic protocol with meal replacements including a step with very low calorie diet. Endocrine. 2015;48(3):863–70.

22. Maula A, Kai J, Woolley AK, Weng S, Dhalwani N, Griffiths FE, et al. Educational weight loss interventions in obese and overweight adults with type 2 diabetes: a systematic review and meta-analysis of randomized controlled trials. Diabetic Med. 2020;37(4):623–35.

23. López-Gómez JJ, Izaola-Jauregui O, Primo-Martín D, Torres-Torres B, Gómez-Hoyos E, Ortolá-Buigues A, et al. Effect of two meal replacement strategies on cardiovascular risk parameters in advanced age patients with obesity and osteoarthritis. Nutrients. 2020;12(4):976.

24. Fogelholm M, Larsen T, Westerterp-Plantenga M, Macdonald I, Martinez J, Boyadjieva N, et al. Prevention of Diabetes through Lifestyle Intervention and Population Studies in Europe and around the World. Design, Methods, and Baseline Participant Description of an Adult Cohort Enrolled into a Three-Year Randomised Clinical Trial. Nutrients. 2017;9(6):632.