UNIVERSITI PUTRA MALAYSIA

BAYESIAN LOGISTIC REGRESSION MODEL ON RISK FACTORS OF TYPE 2 DIABETES MELLITUS

EMENYONU SANDRA CHIAKA

FS 2016 45

BAYESIAN LOGISTIC REGRESSION MODEL ON RISK FACTORS OF TYPE 2 DIABETES MELLITUS

By

SANDRA CHIAKA EMENYONU

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

April 2016

DEDICATIONS

To my wonderful father and mother, for their prayers and supports.
To my lovely siblings, for their patience and encouragements.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

BAYESIAN LOGISTIC REGRESSION MODEL ON RISK FACTORS OF TYPE 2 DIABETES MELLITUS

By

EMENYONU SANDRA CHIAKA

April 2016

Chairman : Associate professor Mohd Bakri Adam, PhD
Institute : Institute For Mathematical Research

Logistic regression model has long been known and it is commonly used in analysing a binary outcome or dependent variable and connects the binary dependent variable to several independent variables. Estimates of the coefficients for the variables are obtained via the method of maximum likelihood based on the frequentist point of view. However, Bayesian analysis allows the incorporation of the prior information and the coefficients of the logistic regression model are estimated by assuming prior distribution for each of the coefficient of interest, which then combines with the likelihood function for the posterior distribution to be obtained.

The Bayesian logistic regression methods made use of the metropolis hasting (Random walk algorithm) and the Gibbs sampler with the incorporation of non-informative flat prior and non-informative non-flat prior distributions to obtain the posterior distribution for each coefficient of the variables. Although we incorporated the flat prior distribution, it has been shown to be widely used in different fields of study. However, this work also incorporated a non-flat prior, which is our main research and to the best of our knowledge has not been incorporated on any T2DM dataset in Malaysia.

This study evaluates the risk factors such as age, ethnicity, gender, physical activity, hypertension, body mass index, family history of diabetes and waist circumference. The coefficients of the variables mentioned above were estimated by the method of maximum likelihood and significant variables were further identified. The significant variables determined by maximum likelihood method were then estimated using the BLR method. The BLR approach via Gibbs sampler and the random walk metropolis algorithm suggests that family history of diabetes, waist circumference and the body mass index are the significant risk factors associated with the type 2 diabetes mellitus. The model results also show a slight decrease in the posterior standard deviation associated with the parameters generated from the Bayesian analysis with the non-flat prior distribution compared to the results generated from the Bayesian analysis incorporating the non-informative prior. Having seen that the

difference between the models is not much, consequently from all indications, all the models are good and they exhibited model fit.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

MODEL LOGISTIK REGRASI BAYESIAN TERHADAP FAKTOR RISIKO KENCING MANIS JENIS 2

Oleh

EMENYONU SANDRA CHIAKA

April 2016

Pengerusi : **Profesor Madya Mohd Bakri Adam, PhD**
Institut : **Institut Penyelidikan Matematik**

Model regrasi logistik telah lama dikenali dan ia biasanya digunakan bagi menganalisis hasil binari atau pembolehubah bersandar dan menghubungkan pembolehubah bersandar binari kepada beberapa pembolehubah bebas. Anggaran pekali bagi pembolehubah diperolehi melalui kaedah kebarangkalian maksimum berdasarkan daripada pemerhatian yang telah diguna pakai sebelum ini. Walau bagaimanapun, analisis Bayesian membolehkan penggabungan maklumat prior dan pekali model regrasi logistik dianggar dengan pengandaian taburan prior bagi setiap pekali, yang kemudiannya digabungkan dengan fungsi kebarangkalian untuk mendapatkan taburan posterior.

Kaedah Bayesian regrasi logistik menggunakan metropolis hasting (algoritma berjalan secara rawak) dan Gibbs sampler yang menggabungkan taburan prior rata tidak bermaklumat dan prior tidak rata yang tidak bermaklumat untuk mendapatkan taburan posterior bagi setiap pekali pembolehubah. Meskipun kajian ini telah menggunakan prior rata, namun ia juga telah menunjukkan penggunaannya secara meluas dalam pelbagai bidang pengajian. Walau bagaimanapun, kajian ini juga berkait dengan prior tidak rata dimana ia merupakan penyelidikan utama kami dan daripada pengetahuan kami ianya masih belum digunakan di mana-mana dataset T2DM di Malaysia.

Kajian ini menilai faktor-faktor risiko seperti umur, etnik, jantina, aktiviti fizikal, tekanan darah tinggi, indeks jisim badan, sejarah keluarga diabetes dan lilitan pinggang. Pekali pembolehubah yang dinyatakan di atas telah dianggarkan dengan menggunakan kaedah kebarangkalian maksimum dan seterusnya pembolehubah yang berperanan penting akan dikenal pasti dengan lebih teliti. Pembolehubah yang berperanan penting ini ditentukan dengan kaedah kebarangkalian maksimum yang kemudiannya dianggar menggunakan kaedah BLR. Pendekatan BLR melalui Gibbs sampler dan algoritma berjalan secara rawak menunjukkan bahawa sejarah keluarga diabetes, lilitan pinggang dan indeks jisim badan adalah faktor risiko utama yang berkait rapat dengan penyakit kencing manis jenis 2. Hasil keputusan daripada model juga menunjukkan terdapat sedikit penurunan pada sisihan piawai bagi

posterior yang berhubung kait dengan parameter yang dihasilkan daripada analisis Bayesian dengan taburan prior tidak-rata berbanding dengan keputusan yang dihasilkan daripada analisis Bayesian yang menggabungkan prior tidak-bermaklumat. Setelah melihat kepada perbezaan yang tidak ketara di antara model-model, dengan kesinambungan dari semua petunjuk, semua model adalah berkeadaan baik dan ia telah menunjukkan model yang sesuai.

ACKNOWLEDGEMENTS

Firstly, my thanks and praise to God for the wisdom, understanding and knowledge he granted me, I would like to express my deepest and warmest gratitude to my wonderful supervisor, Dr. Mohd Bakri Adam, for his support, guidance and constant encouragement which made me to have focus and direction in my research.

A big thank you to Dr. Isthrinayagy Krishnarajah and Dr. Shamarina Shohaimi for their assistance and motivation, I would not have been able to do this research without you. Also I wish to thank the principal investigators Prof. Dr. Anis Safura Ramli, Dr Jamaiyah Haniff, MPH and all the staff of the clinical research centre Kuala Lumpur for providing the data I used in this thesis.

My unending gratitude and appreciation go to my parents (Mr and Mrs D.O Emenyonu), to my siblings (Chidi, Ekeoma, Soro and Ogechi), my cousin brother (Ifeanyi), my nephew (Chisom) and for their support, encouragement, prayers and for believing in me. Finally, thanks to all my friends in mathematics department who contributed in one way or the other, God bless you all.

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Associate professor Mohd Bakri Adam, PhD
Assosiate Professor
Faculty of Science
Universiti Putra Malaysia
(Chairperson)

Isthrinayagy Krishnarajah, PhD
Faculty of Science
Universiti Putra Malaysia
(Member)

Shamarina Shohaimi, PhD
Assosiate Professor
Faculty of Science
Universiti Putra Malaysia
(Member)

BUJANG KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature:________________________ Date:________________________

Name and Matric No: Sandra Chiaka Emenyonu, GS34475

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

Signature: ______________________________
Name of Chairman of Supervisory Committee
Associate professor Dr. Mohd Bakri Adam

Signature: ______________________________
Name of Member of Supervisory Committee
Dr Isthrinayagy Krishnarajah

Signature: ______________________________
Name of Member of Supervisory Committee
Dr Shamarina Shohaimi

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BA	Bayesian Approach
BMI	Body Mass Index
BLR	Bayesian Logistic Regression
C.I	Credible Interval
CVDs	CardioVascular Diseases
DIC	Deviance Informatiom Criterion
FA	Frequentist Approach
FDM	Family History of Diabetes
FLR	Frequentist Logistic Regression
FPG	Fasting Plasma Glucose
GDM	Gestational Diabetes Mellitus
GLMS	Generalized Linear Models
HbAIC	Glycated Hemoglobin
2HPG	2Hours Plasma Glucose
HYPERT	Hypertension
IFG	Impaired Fasting Glycemia
IGT	Impaired Glucose Tolerance
MCMC	Markov Chain Monte Carlo
MLE	Maximum Likelihood Estimation
OR	Odds Ratio
PA	Physical Activity
POST DIST	Posterior Distribution
STD	Standard Deviation
SSR	Soybean Sclerotinia Stem Rot
T2DM	Type 2 Diabetes Mellitus
WC	Waist Circumference
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Section

Alberti et al. (1998) define diabetes mellitus as a class of metabolic disorders characterized by excess sugar in the blood over a long period of time which is caused by inadequate secretion of insulin, insulin activity or the two. In a study on global prevalence of diabetes, Wild et al. (2004) estimate the total number of people with type 2 diabetes mellitus (T2DM) in the year 2000 at 171 million and anticipate it to rise to 366 million in 2030. The rise in the prevalence of diabetes has been of great concern globally but is higher in the developing nations compared to the developed nations. This rapid rise in the prevalence of diabetes has been reported to be more in Asia, especially the South East Asian countries like Malaysia. With Mafauzy (2006) revealing that the prevalence of diabetes in Malaysia within the period of 1986 to 1996 showed a rise from 6.3 percent to 8.2 percent. Further predictions by the world health organization, suggests that there will be a total number of 2.48 million people with diabetes by 2030 as compared to 2000, where a figure of 0.94 million was estimated thus, showing a 164 percent increase in prevalance rate. Similarly, Mafauzy et al. (2011) predict that by 2025, the prevalence of diabetes will be higher by 170 percent in the developing world, compared to a 42 percent increase in prevalence rate in the developed nations. In conclusion, T2DM is seen to be the commonest form of diabetes which has taken hold of over 90% of the diabetic community through out the world and the fast upswing in the number of people with diabetes is prominent in the urban and rural regions Valliyot et al. (2013).

Diabetes consists of type 1 diabetes, type 2 diabetes mellitus, and gestational diabetes mellitus (GDM). For type 1, which is known as insulin dependent occurs when no insulin is produced at all because the insulin producing cell in the pancreas has been destroyed. While the T2DM occurs when the body either does not produce enough insulin or the insulin being produced cannot be used by the body, also known as insulin resistance. GDM occurs during pregnancy, but can be resolved after the baby has been delivered, and if not taken care of, can result to type 2 diabetes. Moreover, diabetes type 2 has different symptoms. American diabetes association et al. (2013) reveal that the symptoms of high blood sugar include polyuria which is frequent urination, polydipsia, which is an increase in thirst, polyphagia also known as increased hunger, weight loss and blurred vision, and these symptoms of the type 2 diabetes are shown in Figure 1.1.

Diagnosis of diabetes can be done through a test of Glucose level. Organization (1999) investigates several ways for the measurement of glucose which have been built, and the standard measurement for diabetes have been reconsidered for more than ten years. Consequently the following test are used to this effect.

- **Fasting Plasma Glucose Test:** The fasting plasma glucose test (fasting blood sugar) measures the glucose level from a blood sample of an individual for atleast eight hours

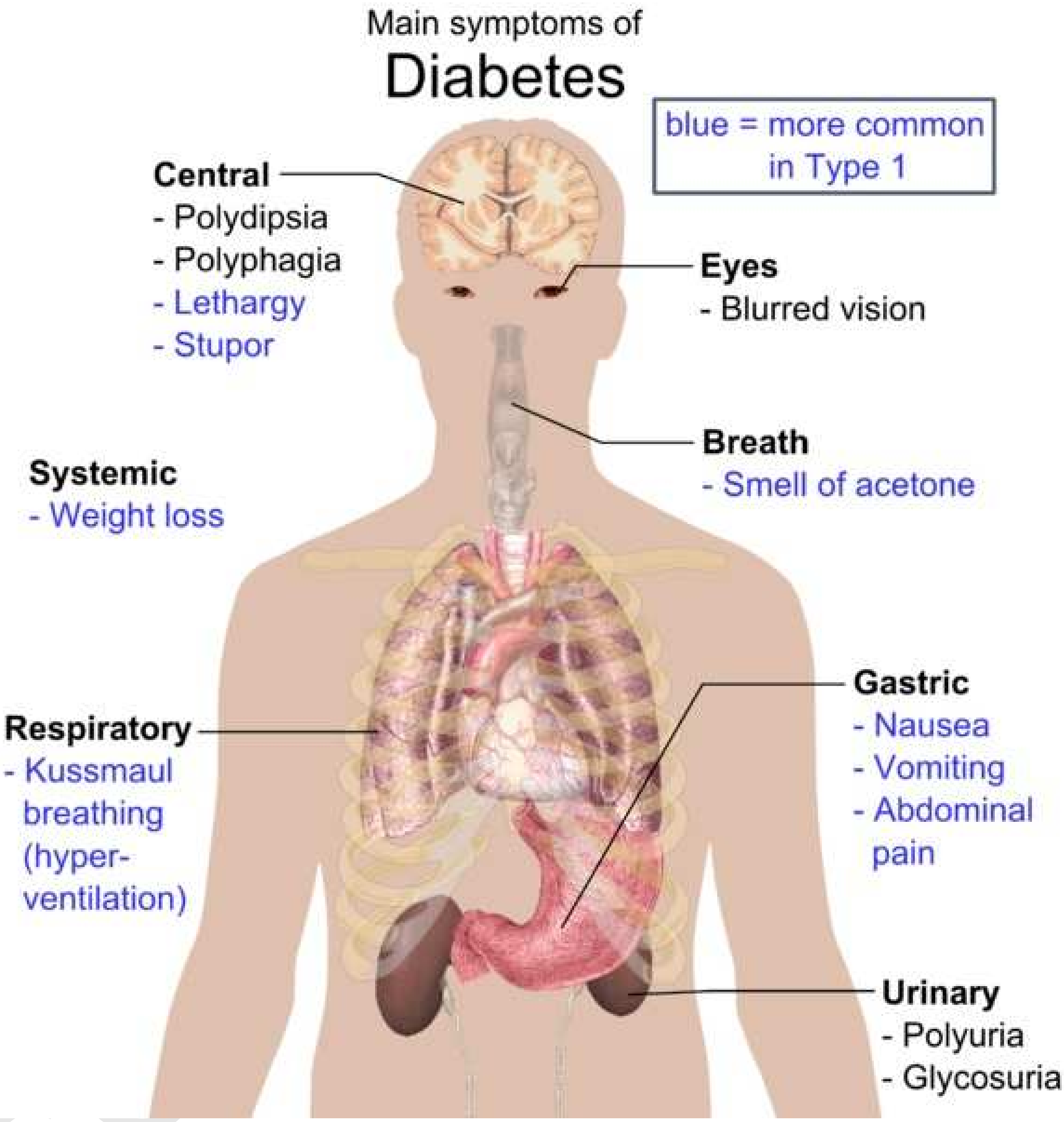

Figure 1.1: Symptoms of type 2 diabetes mellitus (T2DM)
(Mikael Häggström, 2014)

of not eating. It is frequently used to check for prediabetes and diabetes. National diabetes data group et al. (1979) reveal that both fasting plasma glucose and the 2-hour plasma glucose concentration have been approved to check for diabetes and impaired glucose tolerance (IGT) since the year 1979.

- **Glycated Haemoglobin (HbA1C):** Nathan et al. (2007) show that HbAIC measures the amount of glucose in the red blood cells for the last 2 -3 months and can be used to detect the presence of diabetes.

- **Oral Glucose Tolerance Test (OGTT)** measures the blood glucose after a person fasts not less than eight hours, then 2 hours after the person consumes glucose dissolved in water. American diabetes association et al. (2013) recommend the test to be done as reported by the world health organisation, using a glucose solution which contains 75 grams of anhydrous glucose dissolved in water. This test can be used in diagnosing pre-diabetes and diabetes.

Confirmation using a second test should be carried out on a different day, if the test result indicates that a subject has diabetes. Reason being that, the repeated test serves as a confirmatory test, which when done is checked with the previous test result to know if the two different test results available are above the diagnostic cut-off points and having seen that affirms the diagnosis of diabetes.

This study evaluates both the frequentist and Bayesian approaches on logistic regression model. Frequentist Logistic regression model has long been known and it is commonly used in analyzing a binary outcome. However, one of the major difference between the Bayesian and the frequentist is that, the Bayesian allows the incorporation of prior information.

The estimation of the coefficients of the variables being considered, will be estimated via the method of maximum likelihood and Bayesian logistic regression method making use of the Gibbs sampler and the Random walk Metropolis algorithm. Further, these variables which include both the significant and non-significant being considered in the present study, have been considered in some literatures but mostly from the frequentist point of view. Although, some of these variables, in different studies were found to be significant risk factors of type 2 diabetes mellitus. Therefore, we decided to consider these variables in our work to see if they are also significant risk factors of type 2 diabetes mellitus.

On the other hand several fields of study in different countries have applied the Bayesian logistic regression model via the Gibbs sampler and the Random walk metropolis algorithm, incorporating mostly the non- informative prior (flat) distribution. However, there have not been many studies on the risk factor of type 2 diabetes mellitus employing the Bayesian logistic regression model via the Gibbs sampler and the Random walk metropolis algorithm, assuming a non-flat prior distribution. In as much as the flat prior will be incorporated, it has been shown to be widely used in different fields of study. However, this work suggests a new prior distribution, which is our main research and to the best of our knowledge has not been incorporated on any T2DM dataset in Malaysia.

In other words, the Bayesian logistic regression method incorporating our suggested prior distribution will be applied on the significant risk factors associated with type 2 diabetes melitus to obtain the posterior distribution for each parameter of the variables.

Therefore, our research's main contributions are

- estimating the parameters of the variables of T2DM, that is those factors that can influence the development of type 2 diabetes mellitus,

- different methods were employed in estimating of these risk factors and these are the Frequentist and the Bayesian methods,

- the frequentist approach made use of the method of maximum likelihood, while the Bayesian analysis was via two MCMC approaches incorporating the flat and non-flat prior distribution. for the non-flat prior distribution, a weakly informative prior was specified which is our newly suggested prior for the estimation of the coefficients of varaibles of T2DM.

1.2 Problem Statement

The Frequentist Logistic Regression (FLR) method has been applied in different fields of study. However, the Bayesian Logistic Regression (BLR) method can also be used to analyse various distributions. One of the key advantage of the Bayesian over Frequentist approach is the incorporation of the prior information. Further, the non-informative flat prior distribution has been incorporated and applied to different fields of research. For instance, Bayesian logistic regresssion model via Random walk metropolis algorithm incorporating a non-informative prior distribution has been applied in economic related field, like the study carried out by Acquah (2013). Similarly, the Bayesian logistic regression method has also been applied in environmental related field using a non-informative prior distribution. This Bayesian analysis was performed via the Gibbs sampler as reported by Das et al. (2012). However, to the best of the author's knowledge, there have not been studies incorporating non-flat prior distributions on T2DM dataset in Malaysia. Thus, this research aims at carrying out the Bayesian analysis via the Metropolis algorithm and the Gibbs sampler incorporating our newly suggested prior distributions.

1.3 Objectives of the Research

The objectives of this study are

- to determine risk factors associated with T2DM using maximum likelihood estimation,

- to determine risk factors associated with type 2 diabetes mellitus via the Gibbs sampler using flat and non-flat prior distribution, and

- to determine risk factors associated with type 2 diabetes mellitus via Random walk metropolis algorithm using flat and non-flat prior distribution.

1.4 Expected Outcome

After the completion of this research, we expect to achieve the following:

1. The development of model from this research can be used in real life situations in

determining probability. More so, the systematic use of prior information can improve long term accuracy.

2. The result will provide information on the application of Bayesian logistic regression method incorporating a non-informative prior and a non-flat prior distribution in several fields of research.

3. This research can enable analyst and decision makers to establishing a consistent set of decision about the assesment of risks and how to manage them properly.

1.5 Limitations of the Study

Due to time and financial constraints, two Markov Chain Monte Carlo (MCMC) methods of estimation were considered, also few variables were chosen in this study, as the capacity to explore other variables and the use of other MCMC approaches being considered in other studies were limited.

1.6 Organization of the Thesis

The thesis is classified under five chapters. Chapter 1 deals with the background of the thesis, objective, expected outcome and limitations of the study. Relevant literature reviews including different approaches used in this thesis are discussed in Chapter 2. Chapter 3 explains the mathematical methods applied, data type, data source and procedures for the data analysis. Chapter 4 introduces the Bayesian inference. Chapter 5 includes results and discussion. While the findings, conclusion and future work are in Chapter 6.

BIBLIOGRAPHY

Abate, N., Chandalia, M., Snell, P. G., and Grundy, S. M. (2004). Adipose tissue metabolites and insulin resistance in nondiabetic asian indian men. *Journal of Clinical Endocrinology and Metabolism*, 89(6):2750–2755.

Acquah, H. (2013). Bayesian logistic regression modelling via markov chain monte carlo algorithm. *Journal of Social and Development Sciences*, 4(4):193–197.

Adwere-Boamah, J. (2011). Multiple logistic regression analysis of cigarette use among high school students. *Journal of Case Studies in Education*, 1:1–9.

Aguilar-Salinas, C. A., Monroy, O. V., Gómez-Pérez, F. J., Chávez, A. G., Esqueda, A. L., Cuevas, V. M., Rull-Rodrigo, J. A., and Conyer, R. T. (2003). Characteristics of patients with type 2 diabetes in méxico results from a large population-based nationwide survey. *Diabetes Care*, 26(7):2021–2026.

Aksu, H., Pala, K., and Aksu, H. (2006). Prevalence and associated risk factors of type 2 diabetes mellitus in nilufer district, bursa, turkey. *International Journal of Diabetes and Metabolism*, 14(2):98–102.

Akter, S., Rahman, M. M., Abe, S. K., and Sultana, P. (2014). Prevalence of diabetes and prediabetes and their risk factors among bangladeshi adults: a nationwide survey. *Bulletin of the World Health Organization*, 92(3):204–213A.

Alberti, K., Davidson, M. B., DeFronzo, R. A., Drash, A., Genuth, S., Harris, M. I., Kahn, R., Keen, H., Knowler, W. C., Lebovitz, H., et al. (1998). Report of the expert committee on the diagnosis and classification of diabetes mellitus. *Diabetes Care*, 21:5–20.

American diabetes association, A. D. A. et al. (2013). Diagnosis and classification of diabetes mellitus. *Diabetes Care*, 36(Supplement 1):67–74.

Amoah, A. G., Owusu, S. K., and Adjei, S. (2002). Diabetes in ghana: a community based prevalence study in greater accra. *Diabetes research and clinical practice*, 56(3):197–205.

Anderson, D. R., Burnham, K. P., Gould, W. R., and Cherry, S. (2001). Concerns about finding effects that are actually spurious. *Wildlife Society Bulletin*, 29(1):311–316.

Arslanian, S. A., Bacha, F., Saad, R., and Gungor, N. (2005). Family history of type 2 diabetes is associated with decreased insulin sensitivity and an impaired balance between insulin sensitivity and insulin secretion in white youth. *Diabetes Care*, 28(1):115–119.

Aspray, T. J., Mugusi, F., Rashid, S., Whiting, D., Edwards, R., Alberti, K. G., Unwin, N. C., et al. (2000). Rural and urban differences in diabetes prevalence in tanzania: the role of obesity, physical inactivity and urban living. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 94(6):637–644.

Badran, M. and Laher, I. (2012). Type ii diabetes mellitus in arabic-speaking countries. *International Journal of Endocrinology*, 2:1–11.

Banerji, M. A., Faridi, N., Atluri, R., Chaiken, R. L., and Lebovitz, H. E. (1999). Body composition, visceral fat, leptin, and insulin resistance in asian indian men 1. *Journal of Clinical Endocrinology and Metabolism*, 84(1):137–144.

Barnett, K. N., McMurdo, M. E., Ogston, S. A., Morris, A. D., and Evans, J. M. (2006). Mortality in people diagnosed with type 2 diabetes at an older age: a systematic review. *Age and ageing*, 35(5):463–468.

Belsey, D. A., Kuh, E., and Welsch, R. E. (1980). *Regression diagnostics: Identifying influential data and sources of collinearity*. John Wiley.

Bjørnholt, J. V., Erikssen, G., Liestøl, K., Jervell, J., Thaulow, E., and Erikssen, J. (2000). Type 2 diabetes and maternal family history: an impact beyond slow glucose removal rate and fasting hyperglycemia in low-risk individuals? results from 22.5 years of follow-up of healthy nondiabetic men. *Diabetes Care*, 23(9):1255–1259.

Blatná, D. (2006). Outliers in regression. *Trutnov*, 30:1–6.

Bollen, K. A. and Jackman, R. W. (1985). Regression diagnostics an expository treatment of outliers and influential cases. *Sociological Methods & Research*, 13(4):510–542.

Boutayeb, A., Lamlili, M. E., Boutayeb, W., Maamri, A., Ziyyat, A., and Ramdani, N. (2012). The rise of diabetes prevalence in the arab region. 2(2):55–60.

Box, G. E. (1980). Sampling and bayes' inference in scientific modelling and robustness. *Journal of the Royal Statistical Society. Series A (General)*, 143(4):383–430.

Carlin, B. P. and Louis, T. A. (2000). *Bayes and empirical Bayes methods for data analysis*. Chapman and Hall, London.

Cederberg, H., Stančáková, A., Kuusisto, J., Laakso, M., and Smith, U. (2015). Family history of type 2 diabetes increases the risk of both obesity and its complications: is type 2 diabetes a disease of inappropriate lipid storage? *Journal of Internal Medicine*, 277(5):540–551.

Chamnan, P., Simmons, R., Sharp, S., Griffin, S., and Wareham, N. (2009). Cardiovascular risk assessment scores for people with diabetes. *Diabetologia*, 52(10):1–14.

Chandalia, M., Lin, P., Seenivasan, T., Livingston, E. H., Snell, P. G., Grundy, S. M., and Abate, N. (2007). Insulin resistance and body fat distribution in south asian men compared to caucasian men. *PLoS One*, 2(8):1–7.

Chen, H., Deng, L., and Li, J. (2013). Prevalence of osteoporosis and its associated factors among older men with type 2 diabetes. *International Journal of Endocrinology*, 2013:1–9.

Chen, L., Magliano, D. J., and Zimmet, P. Z. (2012). The worldwide epidemiology of type 2 diabetes mellituspresent and future perspectives. *Nature Reviews Endocrinology*, 8(4):228–236.

Chew, B. H., Shariff Ghazali, S., Ismail, M., Haniff, J., and Bujang, M. A. (2013). Age 60years was an independent risk factor for diabetes-related complications despite good control of cardiovascular risk factors in patients with type 2 diabetes mellitus. *Experimental Gerontology*, 48(5):485–491.

Chib, S. and Greenberg, E. (1995). Understanding the metropolis-hastings algorithm. *The American Statistician*, 49(4):327–335.

Cnop, M., Landchild, M. J., Vidal, J., Havel, P. J., Knowles, N. G., Carr, D. R., Wang, F., Hull, R. L., Boyko, E. J., Retzlaff, B. M., et al. (2002). The concurrent accumulation of intra-abdominal and subcutaneous fat explains the association between insulin resistance and plasma leptin concentrations distinct metabolic effects of two fat compartments. *Journal of Diabetes*, 51(4):1005–1015.

Colagiuri, S., Borch-Johnsen, K., Glümer, C., and Vistisen, D. (2005). There really is an epidemic of type 2 diabetes. *Diabetologia*, 48(8):1459–1463.

Congdon, P. (2003). *Applied bayesian modelling*. John Wiley & Sons, New York.

Connolly, V., Unwin, N., Sherriff, P., Bilous, R., and Kelly, W. (2000). Diabetes prevalence and socioeconomic status: a population based study showing increased prevalence of type 2 diabetes mellitus in deprived areas. *Journal of Epidemiology and Community Health*, 54(3):173–177.

Cook, R. D. (1986). Assessment of local influence. *Journal of the Royal Statistical Society. Series B (Methodological)*, 48(2):133–169.

Cooney, M. T., Cooney, H. C., Dudina, A., and Graham, I. M. (2011). Total cardiovascular disease risk assessment: a review. *Current Opinion in Cardiology*, 26(5):429–437.

Cowie, C. C., Rust, K. F., Byrd-Holt, D. D., Eberhardt, M. S., Flegal, K. M., Engelgau, M. M., Saydah, S. H., Williams, D. E., Geiss, L. S., and Gregg, E. W. (2006). Prevalence of diabetes and impaired fasting glucose in adults in the us population national health and nutrition examination survey 1999–2002. *Diabetes Care*, 29(6):1263–1268.

D'Agostino, R. B., Hamman, R. F., Karter, A. J., Mykkanen, L., Wagenknecht, L. E., and Haffner, S. M. (2004). Cardiovascular disease risk factors predict the development of type 2 diabetes the insulin resistance atherosclerosis study. *Diabetes Care*, 27(9):2234–2240.

Das, I., Stein, A., Kerle, N., and Dadhwal, V. K. (2012). Landslide susceptibility mapping along road corridors in the indian himalayas using bayesian logistic regression models. *Geomorphology*, 179:116–125.

Davis, C. L., Pollock, N. K., Waller, J. L., Allison, J. D., Dennis, B. A., Bassali, R., Meléndez, A., Boyle, C. A., and Gower, B. A. (2012). Exercise dose and diabetes risk in overweight and obese children: a randomized controlled trial exercise and diabetes risk in overweight children. *Journal of the American Medical Association*, 308(11):1103–1112.

Diabetes, U. (2012). Diabetes in the uk 2011-2012. *Diabetes-in-the-UK-2011/Last accessed 28th September*, pages 1–22.

Donnelly, J. E., Blair, S., Jakicic, J., Manore, M., Rankin, J., Smith, B., et al. (2009). American college of sports medicine position stand. appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults. *Medicine and Science in Sports and Exercise*, 41(2):459–471.

Dunson, D. B. (2001). Commentary: practical advantages of bayesian analysis of epidemiologic data. *American Journal of Epidemiology*, 153(12):1222–1226.

Dunstan, D. W., Zimmet, P. Z., Welborn, T. A., De Courten, M. P., Cameron, A. J., Sicree, R. A., Dwyer, T., Colagiuri, S., Jolley, D., Knuiman, M., et al. (2002). The rising prevalence of diabetes and impaired glucose tolerance the australian diabetes, obesity and lifestyle study. *Diabetes care*, 25(5):829–834.

Ellison, A. M. (2004). Bayesian inference in ecology. *Ecology letters*, 7(6):509–520.

Evans, J., Newton, R. W., Ruta, D. A., MacDonald, T. M., and Morris, A. D. (2000). Socio-economic status, obesity and prevalence of type 1 and type 2 diabetes mellitus. *Diabetic Medicine*, 17(6):478–480.

Ford, E. S., Giles, W. H., and Dietz, W. H. (2002). Prevalence of the metabolic syndrome among us adults: findings from the third national health and nutrition examination survey. *Journal of the American Medical Association*, 287(3):356–359.

Fridlyand, L. and Philipson, L. (2006). Reactive species and early manifestation of insulin resistance in type 2 diabetes. *Diabetes, Obesity and Metabolism*, 8(2):136–145.

Gelfand, A. E. and Smith, A. F. (1990). Sampling-based approaches to calculating marginal densities. *Journal of the American Statistical Association*, 85(410):398–409.

Gelman, A. (2004). Prior distribution. *Encyclopedia of Environmetrics*, 3:1634–1637.

Gezawa, I., Puepet, F., Mubi, B., Uloko, A., Bakki, B., Talle, M., Haliru, I., et al. (2015). Socio-demographic and anthropometric risk factors for type 2 diabetes in maiduguri, north-eastern nigeria. *Sahel Medical Journal*, 18(5):1–7.

Gillies, C. L., Abrams, K. R., Lambert, P. C., Cooper, N. J., Sutton, A. J., Hsu, R. T., and Khunti, K. (2007). Pharmacological and lifestyle interventions to prevent or delay type 2 diabetes in people with impaired glucose tolerance: systematic review and meta-analysis. *British Medical Journal*, 334(7588):299.

Green, A., Støvring, H., Andersen, M., and Beck-Nielsen, H. (2005). The epidemic of type 2 diabetes is a statistical artefact. *Diabetologia*, 48(8):1456–1458.

Greenberg, E. (2012). *Introduction to Bayesian econometrics*. Cambridge University Press.

Grøntved, A., Rimm, E. B., Willett, W. C., Andersen, L. B., and Hu, F. B. (2012). A prospective study of weight training and risk of type 2 diabetes mellitus in men weight training and risk of type 2 diabetes. *Archives of Internal Medicine*, 172(17):1306–1312.

Gu, D., Reynolds, K., Duan, X., Xin, X., Chen, J., Wu, X., Mo, J., Whelton, P., He, J., Group, I. C., et al. (2003). Prevalence of diabetes and impaired fasting glucose in the chinese adult population: International collaborative study of cardiovascular disease in asia (interasia). *Diabetologia*, 46(9):1190–1198.

Guariguata, L., Whiting, D., Hambleton, I., Beagley, J., Linnenkamp, U., and Shaw, J. (2014). Global estimates of diabetes prevalence for 2013 and projections for 2035. *Diabetes research and clinical practice*, 103(2):137–149.

Guariguata, L., Whiting, D., Weil, C., and Unwin, N. (2011). The international diabetes federation diabetes atlas methodology for estimating global and national prevalence of diabetes in adults. *Diabetes research and clinical practice*, 94(3):322–332.

Gupta, A., Mukherjee, B., and Upadhyay, S. (2008). Weibull extension model: a bayes study using markov chain monte carlo simulation. *Reliability Engineering & System Safety*, 93(10):1434–1443.

Henriksen, E. J., Diamond-Stanic, M. K., and Marchionne, E. M. (2011). Oxidative stress and the etiology of insulin resistance and type 2 diabetes. *Free Radical Biology and Medicine*, 51(5):993–999.

Hosmer, D. W., Jovanovic, B., and Lemeshow, S. (1989). Best subsets logistic regression. *Biometrics*, 45(4):1265–1270.

Houstis, N., Rosen, E. D., and Lander, E. S. (2006). Reactive oxygen species have a causal role in multiple forms of insulin resistance. *Nature*, 440(7086):944–948.

Imon, A. (2006). Identification of high leverage points in logistic regression. *Pakistan Journal of Statistics-All Series-*, 22(2):147.

Imon, A. R. and Hadi, A. S. (2008). Identification of multiple outliers in logistic regression. *Communications in Statistics-Theory and Methods*, 37(11):1697–1709.

Isomaa, B., Forsén, B., Lahti, K., Holmström, N., Wadén, J., Matintupa, O., Almgren, P., Eriksson, J., Lyssenko, V., Taskinen, M.-R., et al. (2010). A family history of diabetes is associated with reduced physical fitness in the prevalence, prediction and prevention of diabetes (ppp)–botnia study. *Diabetologia*, 53(8):1709–1713.

Item, F. and Konrad, D. (2012). Visceral fat and metabolic inflammation: the portal theory revisited. *Obesity Reviews*, 13(S2):30–39.

Ivers, R. Q., Cumming, R. G., Mitchell, P., and Peduto, A. J. (2001). Diabetes and risk of fracture the blue mountains eye study. *Diabetes Care*, 24(7):1198–1203.

Jakicic, J. M., Marcus, B. H., Gallagher, K. I., Napolitano, M., and Lang, W. (2003). Effect of exercise duration and intensity on weight loss in overweight, sedentary women: a randomized trial. *Journal of the American Medical Association*, 290(10):1323–1330.

Jakicic, J. M., Wing, R. R., and Winters-Hart, C. (2002). Relationship of physical activity to eating behaviors and weight loss in women. *Medicine & Science in Sports & Exercise*, 34(10):1653–1659.

Jaynes, E. T. (1957). Information theory and statistical mechanics. *Physical Review*, 106(4):620–630.

Kerlinger, F. and Pedhazur, E. (1973). Multiple regression in behavioral research. *Holt, Rinehart and Winston, New York.*

Kim, S., Lee, J., Lee, J., Na, J., Han, J., Yoon, D., Baik, S., Choi, D., and Choi, K. (2006). Prevalence of diabetes and impaired fasting glucose in korea korean national health and nutrition survey 2001. *Diabetes Care*, 29(2):226–231.

King, H., Keuky, L., Seng, S., Khun, T., Roglic, G., and Pinget, M. (2005). Diabetes and associated disorders in cambodia: two epidemiological surveys. *The Lancet*, 366(9497):1633–1639.

Knowler, W. C., Barrett-Connor, E., Fowler, S. E., Hamman, R. F., Lachin, J. M., Walker, E. A., and Nathan, D. M. (2002). Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. *The New England Journal of Medicine*, 346(6):393–403.

Koo, H., Robert, S., Hamid Jan, J., et al. (2013). Which is a better anthropometric indicator of cardiovascular risk factors in type 2 diabetes mellitus patients? waist hip ratio or body mass index? *Malaysian Journal of Nutrition*, 19(2):163–172.

Kosaka, K., Noda, M., and Kuzuya, T. (2005). Prevention of type 2 diabetes by lifestyle intervention: a japanese trial in igt males. *Diabetes Research and Clinical Practice*, 67(2):152–162.

Kumar, P., Hayati, K., and Rampal, L. (2014). Prevalence of type 2 diabetes mellitus and its associated factors among a public university staff in selangor. *International Journal of Public Health and Clinical Sciences*, 1(1):118–130.

Lemeshow, S. and Hosmer, D. (2000). *Applied logistic regression (Wiley Series in Probability and Statistics*. Wiley-Interscience; 2 Sub edition.

Letchuman, G., Wan Nazaimoon, W., Wan Mohamad, W., Chandran, L., Tee, G., Jamaiyah, H., Isa, M., Zanariah, H., Fatanah, I., and Ahmad Faudzi, Y. (2010). Prevalence of diabetes in the malaysian national health morbidity survey iii 2006. *Med J Malaysia*, 65(3):180–6.

Lindström, J., Peltonen, M., Eriksson, J., Ilanne-Parikka, P., Aunola, S., Keinänen-Kiukaanniemi, S., Uusitupa, M., and Tuomilehto, J. (2013). Improved lifestyle and decreased diabetes risk over 13 years: long-term follow-up of the randomised finnish diabetes prevention study (dps). *Diabetologia*, 56(2):284–293.

Lynch, S. M. (2007). *Introduction to applied Bayesian statistics and estimation for social scientists*. Springer Science & Business Media.

Ma, S., Cutter, J., Tan, C. E., Chew, S. K., and Tai, E. S. (2003). Associations of diabetes mellitus and ethnicity with mortality in a multiethnic asian population: data from the 1992 singapore national health survey. *American Journal of Epidemiology*, 158(6):543–552.

Mafauzy, B. M. (2006). Diabetes mellitus in malaysia. *Medical Journal of Malaysia*, 61(4):397–398.

Mafauzy, M., Hussein, Z., and Chan, S. (2011). The status of diabetes control in malaysia: results of diabcare 2008. *Medical Journal of Malaysia*, 66(3):175–181.

Majgi, S. (2012). Risk factors of diabetes mellitus in rural puducherry. *Online Journal of Health and Allied Sciences*, 11(1):1–7.

Malek, R., Belateche, F., Laouamri, S., Hamdi-Cherif, M., Touabti, A., Bendib, W., Nechadi, A., Mekideche, F., and Hanat, S. (2001). [prevalence of type 2 diabetes mellitus and glucose intolerance in the setif area (algeria)]. *Diabetes & metabolism*, 27(2 Pt 1):164–171.

Malik, M., Bakir, A., Saab, B. A., Roglic, G., and King, H. (2005). Glucose intolerance and associated factors in the multi-ethnic population of the united arab emirates: results of a national survey. *Diabetes research and clinical practice*, 69(2):188–195.

Mason, A., Richardson, S., and Best, N. (2010). Using dic to compare selection models with non-ignorable missing responses. 13:1–29.

Mazerolle, M. (2004). Making sense out of akaikes information criterion: its use and interpretation in model selection and inference from ecological data. *Mouvements et Reproduction des Amphibiens en Tourbières Perturbées*, pages 174–190.

McEvoy, C. T., Cardwell, C. R., Woodside, J. V., Young, I. S., Hunter, S. J., and McKinley, M. C. (2014). A posteriori dietary patterns are related to risk of type 2 diabetes: Findings from a systematic review and meta-analysis. *Journal of the Academy of Nutrition and Dietetics*, 114(11):1759–1775.

Meigs, J. B., Cupples, L. A., and Wilson, P. (2000). Parental transmission of type 2 diabetes: the framingham offspring study. *Diabetes*, 49(12):2201–2207.

Midi, H. and Ariffin, S. B. (2013). Modified standardized pearson residual for the identification of outliers in logistic regression model. *Journal of Applied Sciences*, 13(6):828–836.

Mila, A. L., Yang, X. B., and Carriquiry, A. L. (2003). Bayesian logistic regression of soybean sclerotinia stem rot prevalence in the US north-central region: accounting for uncertainty in parameter estimation. *Phytopathology*, 93(6):758–764.

Mohan, V., Shanthirani, C., Deepa, M., Datta, M., Williams, O., and Deepa, R. (2006). Community empowerment-a successful model for prevention of non-communicable diseases in india-the chennai urban population study (cups-17). *Journal of the Association of Physicians of India*, 54:858–862.

Mook-Kanamori, M. J., Selim, M. M. E.-D., Takiddin, A. H., Al-Mahmoud, K. A., Al-Homsi, H., McKeon, C., Al Muftah, W. A., Kader, S. A., Mook-Kanamori, D. O., and Suhre, K. (2014). Elevated hba1c levels in individuals not diagnosed with type 2 diabetes in qatar: a pilot study. *Qatar Medical Journal*, 2(2):106–113.

Mostafa, S. A., Davies, M. J., Webb, D. R., Srinivasan, B. T., Gray, L. J., and Khunti, K. (2012). Independent effect of ethnicity on glycemia in south asians and white europeans. *Diabetes Care*, 35(8):1746–1748.

Mutshinda, C. M. (2009). Markov chain monte carlo based bayesian analysis of binary response regression, with illustration in dose-response assessment. *Modern Applied Science*, 3(4):p19.

Nathan, D., Turgeon, H., and Regan, S. (2007). Relationship between glycated haemoglobin levels and mean glucose levels over time. *Diabetologia*, 50(11):2239–2244.

National diabetes data group, N. D. D. G. et al. (1979). Classification and diagnosis of diabetes mellitus and other categories of glucose intolerance. *Diabetes*, 28(12):1039–1057.

Nor Jr, S. M., Suzana, S., Hanis, M. Y., Lim, C., Teh, S., Mohd, F. M., Lim, H., Dahlia, S., and Norliza, M. (2010). Assessment of physical activity level among individuals with type 2 diabetes mellitus at cheras health clinic, kuala lumpur. *Malaysian Journal of Nutrition*, 16(1):101–112.

Ntzoufras, I. (2011). *Bayesian modeling using WinBUGS*, volume 698. John Wiley & Sons.

Nurunnabi, A., Rahmatullah Imon, A., and Nasser, M. (2010). Identification of multiple influential observations in logistic regression. *Journal of Applied Statistics*, 37(10):1605–1624.

Nyamdorj, R. (2008). Body mass index compared with central obesity indicators in relation to diabetes and hypertension in asians. *Obesity*, 16(7):1622–1635.

Nyamdorj, R., Pitkäniemi, J., Tuomilehto, J., Hammar, N., Stehouwer, C., Lam, T., Ramachandran, A., Janus, E., Mohan, V., Söderberg, S., et al. (2010). Ethnic comparison of the association of undiagnosed diabetes with obesity. *International Journal of Obesity*, 34(2):332–339.

Obrien, R. M. (2007). A caution regarding rules of thumb for variance inflation factors. *Quality & Quantity*, 41(5):673–690.

Organization, W. H. (1999). Diagnosis and classification of diabetes mellitus and its complications. *Geneva: World Health Organization*, 1:1–66.

Park, H. (2013). An introduction to logistic regression: from basic concepts to interpretation with particular attention to nursing domain. *Journal of Korean Academy of Nursing*, 43(2):154–164.

Paul, R. K. (2006). Multicollinearity: Causes, effects and remedies. *IASRI, New Delhi*, pages 1–14.

Pavkov, M. E., Hanson, R. L., Knowler, W. C., Bennett, P. H., Krakoff, J., and Nelson, R. G. (2007). Changing patterns of type 2 diabetes incidence among pima indians. *Diabetes Care*, 30(7):1758–1763.

Peng, C.-Y. J., Lee, K. L., and Ingersoll, G. M. (2002). An introduction to logistic regression analysis and reporting. *The Journal of Educational Research*, 96(1):3–14.

Qatanani, M. and Lazar, M. A. (2007). Mechanisms of obesity-associated insulin resistance: many choices on the menu. *Genes & development*, 21(12):1443–1455.

Ramachandran, A., Chamukuttan, S., Shetty, S. A., Arun, N., and Susairaj, P. (2012). Obesity in asia–is it different from rest of the world. *Diabetes/Metabolism Research and Reviews*, 28(s2):47–51.

Ramachandran, A., Snehalatha, C., Kapur, A., Vijay, V., Mohan, V., Das, A., Rao, P., Yajnik, C., Kumar, K. P., Nair, J. D., et al. (2001). High prevalence of diabetes and impaired glucose tolerance in india: National urban diabetes survey. *Diabetologia*, 44(9):1094–1101.

Rashwan, N. I. and El dereny, M. (2012). The comparison between results of application bayesian and maximum likelihood approaches on logistic regression model for prostate cancer data. *Applied Mathematical Sciences*, 6(23):1143–1158.

Reinehr, T. (2013). Type 2 diabetes mellitus in children and adolescents. *World Journal of Diabetes*, 4(6):270–281.

Roberts, G. O., Gelman, A., Gilks, W. R., et al. (1997). Weak convergence and optimal scaling of random walk metropolis algorithms. *The annals of applied probability*, 7(1):110–120.

Ruta, L., Magliano, D., LeMesurier, R., Taylor, H., Zimmet, P., and Shaw, J. (2013). Prevalence of diabetic retinopathy in type 2 diabetes in developing and developed countries. *Diabetic Medicine*, 30(4):387–398.

Sadikot, S., Nigam, A., Das, S., Bajaj, S., Zargar, A., Prasannakumar, K., Sosale, A., Munichoodappa, C., Seshiah, V., Singh, S., et al. (2004). The burden of diabetes and impaired glucose tolerance in india using the who 1999 criteria: prevalence of diabetes in india study (podis). *Diabetes research and clinical practice*, 66(3):301–307.

Salas-Salvadó, J., Martinez-Gonzalez, M., Bullo, M., and Ros, E. (2011). The role of diet in the prevention of type 2 diabetes. *Nutrition, Metabolism and Cardiovascular Diseases*, 21:B32–B48.

Sánchez-Castillo, C. P., Velásquez-Monroy, O., Lara-Esqueda, A., Berber, A., Sepulveda, J., Tapia-Conyer, R., and T James, W. P. (2005). Diabetes and hypertension increases in a society with abdominal obesity: results of the mexican national health survey 2000. *Public Health Nutrition*, 8(1):53–60.

Sarkar, S. K., Midi, H., Rana, M., et al. (2011). Detection of outliers and influential observations in binary logistic regression: An empirical study. *Journal of Applied Sciences*, 11(1):26–35.

Sentell, T. L., He, G., Gregg, E. W., Schillinger, D., et al. (2012). Racial/ethnic variation in prevalence estimates for united states prediabetes under alternative 2010 american diabetes association criteria: 1988-2008. *Ethnicity and Disease*, 22(4):451–458.

Shaw, J. E., Sicree, R. A., and Zimmet, P. Z. (2010). Global estimates of the prevalence of diabetes for 2010 and 2030. *Diabetes research and clinical practice*, 87(1):4–14.

Sherlock, C., Fearnhead, P., and Roberts, G. O. (2010). The random walk metropolis: linking theory and practice through a case study. *Statistical Science*, 25(2):172–190.

Siren, R., Eriksson, J. G., and Vanhanen, H. (2012). Waist circumference a good indicator of future risk for type 2 diabetes and cardiovascular disease. *BioMed Central Public Health*, 12(1):1–6.

Smith, A. F. and Spiegelhalter, D. J. (1980). Bayes factors and choice criteria for linear models. *Journal of the Royal Statistical Society. Series B (Methodological)*, 42(2):213–220.

Snijder, M. B., Dekker, J. M., Visser, M., Bouter, L. M., Stehouwer, C. D., Kostense, P. J., Yudkin, J. S., Heine, R. J., Nijpels, G., and Seidell, J. C. (2003). Associations of hip and thigh circumferences independent of waist circumference with the incidence of type 2 diabetes: the hoorn study. *The American Journal of Clinical Nutrition*, 77(5):1192–1197.

Spiegelhalter, D. J., Best, N. G., Carlin, B. P., and Van Der Linde, A. (2002). Bayesian measures of model complexity and fit. *Journal of the Royal Statistical Society: Series B (Statistical Methodology)*, 64(4):583–639.

Sta Romana, M. and Li-Yu, J. T. (2007). Investigation of the relationship between type 2 diabetes and osteoporosis using bayesian inference. *Journal of Clinical Densitometry*, 10(4):386–390.

Tazi, M. A., Abir-Khalil, S., Chaouki, N., Cherqaoui, S., Lahmouz, F., Sraïri, J. E., and Mahjour, J. (2003). Prevalence of the main cardiovascular risk factors in morocco: results of a national survey, 2000. *Journal of hypertension*, 21(5):897–903.

Tektas, D. and Günay, S. (2008). A bayesian approach to parameter estimation in binary logit and probit models. *Hacettepe Journal of Mathematics and Statistics*, 37(2):167–176.

Tieh, P. and Dreimane, D. (2014). Type 2 diabetes mellitus in children and adolescents. *The Indian Journal of Pediatrics*, 81(2):165–169.

Tiew, K. F., Chan, Y. M., Lye, M. S., and Loke, S. C. (2014). Factors associated with dietary diversity score among individuals with type 2 diabetes mellitus. *Journal of Health, Population, and Nutrition*, 32(4):665–676.

Tuomilehto, J. (2004). Impact of age on cardiovascular risk: implications for cardiovascular disease management. *Atherosclerosis Supplements*, 5(2):9–17.

Valliyot, B., Sreedharan, J., Muttappallymyalil, J., Valliyot, S. B., et al. (2013). Risk factors of type 2 diabetes mellitus in the rural population of north kerala, india: a case control study. *Diabetologia Croatica*, 42(1):33–40.

Valverde, J. C., Tormo, M.-J., Navarro, C., Rodríguez-Barranco, M., Marco, R., Egea, J.-M., Pérez-Flores, D., Ortolá, J.-B., González-Sicilia, L., Tébar, J., et al. (2006). Prevalence of diabetes in murcia (spain): a mediterranean area characterised by obesity. *Diabetes Research and Clinical Practice*, 71(2):202–209.

Van Dongen, S. (2006). Prior specification in bayesian statistics: three cautionary tales. *Journal of Theoretical Biology*, 242(1):90–100.

Velleman, P. F. and Welsch, R. E. (1981). Efficient computing of regression diagnostics. *The American Statistician*, 35(4):234–242.

Wan Nazaimoon, W., Md Isa, S., Wan Mohamad, W., Khir, A., Kamaruddin, N., Kamarul, I., Mustafa, N., Ismail, I., Ali, O., and Khalid, B. (2013). Prevalence of diabetes in malaysia and usefulness of hba1c as a diagnostic criterion. *Diabetic Medicine*, 30(7):825–828.

Wang, Y., Rimm, E. B., Stampfer, M. J., Willett, W. C., and Hu, F. B. (2005). Comparison of abdominal adiposity and overall obesity in predicting risk of type 2 diabetes among men. *The American Journal of Clinical Nutrition*, 81(3):555–563.

Wareham, N. and Forouhi, N. (2005). Is there really an epidemic of diabetes? *Diabetologia*, 48(8):1454–1455.

West, M., Harrison, P. J., and Migon, H. S. (1985). Dynamic generalized linear models and bayesian forecasting. *Journal of the American Statistical Association*, 80(389):73–83.

Whiting, D. R., Guariguata, L., Weil, C., and Shaw, J. (2011). Idf diabetes atlas: global estimates of the prevalence of diabetes for 2011 and 2030. *Diabetes Research and Clinical Practice*, 94(3):311–321.

Wild, S., Roglic, G., Green, A., Sicree, R., and King, H. (2004). Global prevalence of diabetes estimates for the year 2000 and projections for 2030. *Diabetes Care*, 27(5):1047–1053.

Wulan, S., Westerterp, K., and Plasqui, G. (2010). Ethnic differences in body composition and the associated metabolic profile: a comparative study between asians and caucasians. *Maturitas*, 65(4):315–319.

Xue, H., Wang, C., Li, Y., Chen, J., Yu, L., Liu, X., LI, J., Cao, J., Deng, Y., Guo, D., et al. (2015). Incidence of type 2 diabetes and number of events attributable to abdominal obesity in china: A cohort study. *Journal of Diabetes*, 8(2):1–9.