# DETECTION AND EARLY LIFESTYLE INTERVENTION IN THOSE AT RISK OF TYPE 2 DIABETES

**Charlotte L. Edwardson,[1] Laura J. Gray,[2] Thomas Yates,[1] Shaun R. Barber,[2] Kamlesh Khunti,[1] *Melanie J. Davies[1]**

*1. Diabetes Research Centre, University of Leicester, Leicester, UK*
*2. Department of Health Sciences, University of Leicester, Leicester, UK*
**Correspondence to melanie.davies@uhl-tr.nhs.uk*

**Disclosure:** No potential conflict of interest.
**Received:** 21.03.14 **Accepted:** 21.07.14
**Citation:** EMJ Diabet. 2014;2:48-57.

## ABSTRACT

The prevalence of Type 2 diabetes mellitus (T2DM) has reached epidemic proportions in recent years. It is now widely recognised that T2DM is a highly preventable disease. This article highlights the evidence to date for the prevention of T2DM. In order to prevent or delay the onset of T2DM, people at high risk of developing the condition need to be identified and treated using evidenced-based and cost-effective approaches. Risk scores offer a quick, simple way of identifying those at high risk for invitation to screening programmes without the need for initial invasive tests. Best practice guidance, including those from National Institute for Health and Clinical Excellence (NICE) in the UK and the European wide IMAGE project, recommend that a two-stepped approach whereby the identification of a high-risk status through risk score technology is confirmed by a blood test. Once identified, those at high risk can be offered a lifestyle intervention programme. Landmark diabetes prevention studies show that lifestyle intervention, focusing on increases in physical activity, improvements in diet, and reductions in weight, reduces the risk of progression to T2DM by 30-60% and can have lasting benefits after the active intervention ceases. Recent pragmatic prevention programmes also demonstrate encouraging results. However, research targeted to the prevention of T2DM must continue to be expanded to find the most effective methods of T2DM prevention in various societies and cultural settings. There is also a need for research focusing on young people at high risk and novel approaches, such as targeting a reduction in sitting and use of technology, to support behaviour change.

Keywords: Type 2 diabetes, prevention, high risk, lifestyle, risk score.

## INTRODUCTION

An estimated 366 million people worldwide have diabetes, which is expected to rise to 522 million by 2030,[1,2] with death rates attributable to diabetes doubling between 2005 and 2030.[3] Prevention of Type 2 diabetes mellitus (T2DM) is therefore a public health priority. In order to prevent or delay the onset of T2DM, people at high risk of developing the condition need to be identified and treated using evidenced-based and cost-effective approaches. This article will highlight the latest evidence for the prevention of T2DM.

### Identification

Glucose is a continuum and there is a (clinically important and much researched) high-risk state where glucose levels are elevated but not over the threshold for the diagnosis of T2DM. There are a number of invasive tests, for example HbA1c or fasting blood glucose, that can be used to identify those at high risk of T2DM. Impaired Glucose Regulation (IGR) is a high-risk state where impaired glucose tolerance (IGT) and/or impaired fasting glucose (IFG) have been identified using an oral glucose tolerance test.[4] Individuals with IGR are significantly more likely to develop T2DM than

those with normal blood glucose levels; estimates of progression to T2DM within a year suggest those with isolated IGT have >5-times the risk, those with isolated IFG have 7-times the risk, and those with both IGT and IFG have >12-times the risk compared to normoglycaemic individuals.[5] There are now also recommendations that HbA1c levels raised above normal levels, but not in the range for a diagnosis of T2DM, should be classified as at high risk of diabetes.[6,7] However, there is no agreed consensus on the HbA1c range that should be classified as at high risk of diabetes, with the International Expert Committee and the UK-based National Institute for Health and Clinical Excellence (NICE) recommending it should be 6.0-6.4% (42-46 mmol/mol), whereas the American Diabetes Association suggests 5.7-6.4% (39-46 mmol/mol).[8-10] Follow-up studies have shown similar rates of progression to diabetes from the HbA1c defined as the high-risk state as seen for IFG.[11]

## RISK SCORES

Risk scores offer a quick, simple way of identifying those at high risk. The EU-wide IMAGE project recommended the use of risk scores for identifying those at risk of T2DM.[12] Risk scores generally follow one of two approaches: either being applied as questionnaires to the individual being assessed – 'self-assessment' - or as a query to a general practice database where all those 'at risk' are identified using routinely stored data. The Finnish Diabetes Risk Score (FINDRISC) is an example of a self-assessment for predicting the risk of future diabetes; it includes eight questions: age, body mass index (BMI), waist circumference, blood pressure, history of high blood glucose, family history of diabetes, physical activity, and consumption of vegetables, fruits, or berries.[13] An example of a risk score which uses routinely stored data is the UK Leicester Practice Risk Score (LPRS). This score, with accompanying software applications, ranks all individuals within a given primary care dataset for their diabetes risk status based on age, sex, ethnicity, family history of diabetes, BMI, and antihypertensive use.[14] Scores can also be categorised based on the outcome they predict. Scores which have been developed using cross-sectional data can predict prevalent disease; the LPRS detects current undiagnosed IGR and T2DM, in contrast with scores which have been developed using longitudinal data, where incidence can be predicted, such as FINDRISC. The scores developed to date tend to be for a specific population as studies have found that scores which have been developed elsewhere and used on a different population tend to have low validity.[15,16]

The PREDICT-2 group have summarised the currently available risk scores worldwide, and this is hosted on the International Diabetes Federation website (http://www.idf.org/risk-prediction-tools-predict-2).[17] A number of risk scores have been developed for use in Europe and these are summarised in Table 1. Additionally, the FINDRISC has been validated for use in Greece, Bulgaria, Italy, Spain, and Sweden. Although many risk scores exist,[18-21] relatively few are currently used in practice.[22] One review stated that this could be because the way in which the risk score will be used is not considered in the development stage.[20] A systematic review of the implementation of risk scores reported a number of barriers to the uptake of risk scores by healthcare professionals which included: attitudes toward the tools; impracticality of using the tools; and lack of reimbursement and regulatory support. As previously introduced, the LPRS was derived for population level screening within primary care.[14]

The developers of this tool have tried to overcome these barriers by developing a piece of software which runs alongside the practices' electronic medical records to make the score easy to use, in practice. This software was used across 54 general practices in two large prevention studies[23,24] where it was used to identify and invite the top 10% at highest risk within each practice for screening.[25] Of the 21,741 invited, 4,282 attended (20%). Of these, 25.7% were found to have IGR, with 4.2% having undiagnosed T2DM. These rates were significantly higher than when a population screening approach was taken in the same vicinity.[26] This risk score also has regulatory support and is recommended by NICE.[27] Risk scores incorporating invasive measures also exist, i.e. biomarkers or genetic factors.[28] These generally do not out-perform their non-invasive counterparts and are not routinely used. Using non-invasive risk scores allows people to assess their own risk, and therefore might engage people who do not routinely visit their GP.

### Stepped Approach

Best practice guidance, including those from the IMAGE project, recommend that a two-stepped approach - whereby the identification of a high-risk status through risk score technology - is confirmed by blood test.[9,29] This type of stepped approach

has been shown to be the most cost-effective method of identifying risk status.[30] A recent study estimated that using a one-step screening strategy where everyone receives an HbA1c, costs around €1,084 per case of T2DM detected. This is reduced to around €658 per case, if a two-stage strategy, employing a risk score, is used.[31] Risk scores avoid the need for universal screening and the subsequent blood tests, ensuring that metabolically healthy individuals are not subject to intervention, and that those with undiagnosed T2DM are picked up earlier.

## LIFESTYLE INTERVENTIONS FOR THOSE AT RISK OF T2DM

Observational research has consistently shown that 80-90% of all cases of T2DM result from an unhealthy lifestyle.[32,33] Over the past two decades there have been several landmark diabetes prevention randomised controlled trials (RCTs) that have been conducted across diverse countries and populations,[34-38] which have consistently shown that lifestyle intervention can reduce the risk of progression to T2DM by 30-60% in those with IGT. The Finnish Diabetes Prevention Study (DPS)[34] and the American Diabetes Prevention Program (DPP)[35] found that the risk of T2DM was reduced by 58% in people with IGT or IFG, given lifestyle counselling over a 3-year period. Similar findings were also seen in India,[37] Japan,[36] and China.[38] Table 2 summarises the design and main findings from the major lifestyle intervention trials.

Lifestyle intervention in the prevention of T2DM has typically been focused on achieving a weight reduction, usually prescribed as a percentage of initial body weight (e.g. at least 5%) until a desirable BMI was achieved, increasing moderate intensity aerobic physical activity to at least ≥150 minutes per week (one study also offered supervised resistance training), and diet modifications such as a reduction in total calories, total and saturated fat and sugar intake, and an increase in fibre, vegetables, and wholegrain products. These recommendations were delivered during one-to-one counselling sessions, and behaviour modification techniques such as motivational interviewing, self-monitoring, and individualised short and long-term goals were employed.

**Table 1: Risk scores developed for use in Europe.**

| Score | Country | Outcome | Use |
|---|---|---|---|
| Inter99[73] | Denmark | Undiagnosed T2DM | Self-assessment |
| DESIR[74] | France | Incident T2DM | Primary care* |
| PROCAM[75] | Germany | Incident T2DM in males only | Primary care |
| German diabetes risk score[76] | Germany | Incident and undiagnosed T2DM | Self-assessment |
| FINDRISC[13] | Finland | Incident T2DM | Self-assessment |
| Hoorn[77] | Netherlands | Undiagnosed T2DM | Self-assessment |
| Rotterdam scores[78] | Netherlands | Undiagnosed T2DM | (1) Primary care;<br>(2) Self-assessment |
| SUNSET study[79] | Netherlands | Known and undiagnosed T2DM | Self-assessment |
| PORMETS[80] | Portugal | Undiagnosed IFG and T2DM | Self-assessment |
| Canary islands[81] | Spain | Known and undiagnosed T2DM | Primary care |
| PREDIMED[82] | Spain | Incident T2DM | Self-assessment |
| Cambridge[83] | UK | Known and undiagnosed T2DM | Primary care |
| QD Score[84] | UK | Incident T2DM | Primary care |
| Leicester risk scores[14,85] | UK | Undiagnosed IGR and T2DM | (1) Primary care;<br>(2) Self-assessment |

*Those marked primary care are for population screening on medical records or require the results from invasive tests.
T2DM: Type 2 diabetes mellitus; IGR: impaired glucose regulation; IFG: impaired fasting glucose.

**Table 2: Characteristics of the primary lifestyle interventions that have been tested in the prevention of Type 2 diabetes.**

| Country<br><br>Study name | Sample size (men/women) | Inclusion criteria | Interventions | Lifestyle intervention targets | Study duration (weeks) | Risk reduction at end of intervention period* |
|---|---|---|---|---|---|---|
| China<br><br>The Da Qing IGT and Diabetes Study[38] | 530 (283/247) | IGT, Age ≥25 years | 1. Control<br>2. Diet<br>3. Exercise<br>4. Diet and Exercise | **Diet group:** Weight maintenance for normal weight. Weight reduction for those with a BMI ≥25 kg/m$^2$ through reduced energy intake<br>**Exercise group:** Participants were encouraged to increase their physical activity by at least one prescribed unit per day (such as slow walking for 30 minutes, or fast walking for 20 minutes) and by two units per day where possible<br>**Diet-plus-exercise group:** Combination of above | 6 | Diet: 31<br>Exercise: 46<br>Exercise and Diet: 42 |
| USA<br><br>Diabetes Prevention Research Group[35] | 3,234 (1,043/2,191) | IGT, Age ≥25 years, BMI ≥24 kg/m$^2$ (≥22 kg/m$^2$ if Asian), fasting plasma glucose ≥5.3 mmol/l | 1. Control<br>2. Lifestyle<br>3. Metformin | 150 minutes per week of MVPA and weight reduction (7% of initial body mass) through a healthy, high fibre, low-energy, fat controlled diet | 2.8 | 58 |
| Finland<br><br>Finish Diabetes Prevention Study[34] | 522 (172/350) | IGT, age 40 to 64 years old, BMI ≥25 | 1. Control<br>2. Lifestyle | 30 minutes per day of MVPA and weight reduction (5% of initial body mass) through a healthy diet based on reduced saturated fat (10% of energy intake), reduced fat (30% of total energy intake), and high fibre | 3 | 58 |
| India<br><br>Indian Diabetes Prevention Programme[37] | 531 (420/111) | IGT | 1. Control<br>2. Lifestyle<br>3. Metformin<br>4. Lifestyle plus Metformin | 30 minutes per day of MVPA and healthy diet based on reduced energy intake with fibre rich foods low in refined carbohydrates and fats | 3 | Lifestyle: 29<br>Lifestyle and Metformin: 28 |
| Japan[36] | 458/0 | IGT | 1. Control<br>2. Lifestyle | 30 minutes per day of MVPA and weight reduction through a healthy diet | 4 | 67 |

***% reduction compared to controls.**

IGT: impaired glucose tolerance; BMI: body mass index; MVPA: moderate-to-vigorous physical activity.

Overall, tested lifestyle interventions based on these targets have been shown to be equally or more effective than most pharmaceutical interventions in the prevention of T2DM.[39] Importantly, successful lifestyle interventions have also been shown to have lasting benefits, even after the active intervention ceases. For example, in the DPS study, the intervention effect was sustained at 7 years[40] and in the DPP, a relative reduction of 34% in diabetes incidence was maintained 10 years

after randomisation (7 years after the intervention ended).[41] Furthermore, the China Da Qing Diabetes Prevention trial[42] showed that a relative risk reduction of 43% was maintained at 20 years (14 years after the intervention ended).

Although highly successful and shown to be potentially cost-effective in the longer term for 'high risk' individuals,[43] these landmark intervention studies used intensive behaviour change strategies relying on multiple and lengthy one-to-one patient contacts which would be incompatible and unsustainable in a routine healthcare setting. For example, the DPS had a median of 20 one-to-one counselling sessions over a 4-year period. Several countries including the UK, US, Finland, Germany, and Australia responded to this limitation by developing, evaluating, and implementing diabetes prevention programmes that have been tailored to the needs of their specific healthcare settings.[44] Although these pragmatic programmes have varied in context and scope, they have tended to centre on utilising group-based health educational programmes as the primary vehicle for promoting behaviour change. Evidence suggests that group-based programmes can be delivered successfully by a range of staff including nurses, dieticians, exercise specialists, and lay people.[45]

In the UK it has been shown that a 3-hour group-based, theory-driven, structured education programme - combined with personalised pedometer use - can be highly successfully when delivered in a healthcare setting, with significant changes to health behaviour and improved metabolic health over a 12 and 24 month period in those with a high risk of T2DM.[46,47] This brief group-based programme was refined into the Walking Away from T2DM programme, which includes a fully operational commissioning pathway for healthcare providers,[23] including a standardised and accredited educator training and quality assurance programme. In Finland, population approaches to diabetes and cardiovascular disease prevention, that incorporate all elements of the healthcare profession, local government, and community partners, including offering individuals group-based lifestyle educational programmes, have been found to be effective.[48] Similar approaches have also been introduced within other regions of Europe, including in Germany and countries involved in DEPLAN (diabetes in Europe-prevention using lifestyle, physical activity and nutritional intervention).[49] Beyond Europe, the Centres for Disease Control in the United States have led the way in developing and evaluating components of a multi-faceted stepped approach to prevention that includes working with health insurance companies and referring high-risk individuals to community-led group-based diabetes prevention programmes run through YMCA facilities.[49,50]

Evidence from several recent systematic reviews[51-53] on the effectiveness of translational diabetes prevention programmes, suggests that a mean waist measurement reduction of around 4.5 cm[52] and a mean weight reduction of around 2 kg is achievable over 12 months.[52] This is lower than the amounts achieved by the intervention arms, the Finnish DPS (~4.2 kg) and the US DPP (~6.7 kg), at the same time point.[34,35] However, a 2 kg weight loss is still clinically meaningful, with findings from the US DPP study suggesting that future diabetes incidence may be reduced by as much as 16% for each kilogram of weight lost.[54] Whilst these results are encouraging, more research is needed to assess the longer-term (>12 months) effectiveness and cost-effectiveness of diabetes prevention programmes that have been implemented into routine care.

## Guidelines for Diabetes Prevention

Recent evidence-based guidelines for diabetes prevention, compiled by NICE[9] and the IMAGE project (Development and Implementation of a European Guideline and Training Standards for Diabetes prevention),[12] make clearly defined recommendations for the essential components to include in any lifestyle programmes in order to maximise their effectiveness. Table 3 summarises the recommendations for design and content of lifestyle change programmes for preventing T2DM. These recommendations were informed by robust reviews of the relevant literature, and supplemented by expert opinion. It has recently been demonstrated that adherence to guideline recommendations on intervention content and delivery are associated with greater weight loss in a dose-dependent manner, with greater adherence leading to greater effect.[52]

## The Future of Diabetes Prevention Lifestyle Research

Recently, there has been increasing political recognition that diabetes prevention should be a major worldwide priority. For example, in 2011, the United Nations adopted a political declaration on

the prevention and control of non-communicable diseases (NCDs) that acknowledged the global burden and threat of NCDs including diabetes, and recognised that prevention must be the cornerstone of the global response to NCDs (http://www.un.org/ga/search/view_doc.asp?symbol=A/66/L.1).

**Table 3: Recommendations for design and content of lifestyle-change programmes for preventing T2DM.**

| Essential components of lifestyle programmes | | Details |
|---|---|---|
| **Content** | Establish motivation for behaviour change | Exploration of perceptions of risk for developing T2DM, exploration and reinforcement of reasons for wanting to change, confidence about making changes and expectations |
| | Information provision | Raise awareness of the benefits of lifestyle changes (and changes needed) |
| | Lifestyle changes - aim to promote changes in both diet and physical activity | • ≥150 minutes/week of MVPA<br>• Weight loss to reach and maintain a 'healthy' BMI<br>• Consume wholegrain food products, at least five portions of fruit and vegetables, limit sugar and salt intake, increase consumption of dietary fibre, consume fish regularly, alcohol in moderation, reduce total amount of fat, and eat less saturated fat |
| | Behaviour change and self-regulatory techniques – utilise established, well defined techniques | • Self-monitoring of physical activity and eating (e.g. with use of diet or pedometer)<br>• Action plan of short and long-term goals (SMART goals)<br>• Providing feedback on performance<br>• Problem solving<br>• Reflection<br>• Relapse prevention<br>• Overcoming barriers<br>• Motivational interviewing<br>• Prompting self-talk<br>• Prompting practice<br>• Individual tailoring<br>• Time management |
| | Social support | Facilitate/encourage social support (family, friends, and colleagues) for the planned behaviour change |
| **Design** | Contact time | • Maximise the frequency or number of contacts (within the resources available)<br>• Provide at least 16 hours of contact time over the first 9-18 months |
| | Group versus individual | To balance cost and effectiveness - use group-based interventions with around 10-15 people where feasible |
| | Person-centred approach | • Ensure programmes adopt an empathy-building approach. Supports person to become the expert and puts them in control |
| | Time between sessions | • Ensure sessions are spread over a period of time - to allow people to make gradual changes to their lifestyle and reflect and learn from experiences<br>• Allow time during group sessions for people to share this learning with others |
| | Training and quality assurance | • Ensure lifestyle programmes have a systematic and accredited method of training educators and regularly assessing compliance and competency; this is crucial for the professional development of health care professionals and standardisation of delivery when implemented over multiple sites |

T2DM: Type 2 diabetes mellitus; MVPA: moderate-to-vigorous physical activity; BMI: body mass index.
*Summarised from IMAGE[12] and NICE[9] guidance.*

Research targeted to the prevention of T2DM must continue to be expanded to find the most effective methods of T2DM prevention in various settings.[55] It is promising that major funding bodies have responded to this need. For example, the EU in general, especially through the Horizon 20/20 study,[56] has put the prevention of chronic diseases at the heart of their agenda, with a range of calls from societal interventions to healthcare reorganisation and technological innovation. Ongoing EU funded work is also set to significantly advance knowledge. The PREVIEW study will include a multicentre RCT comparing two diet and two exercise strategies for 2,500 individuals with IGT and other risk factors. This study targets participants across the age spectrum, from children to the elderly (http://preview.ning.com/). This is timely since the sharp rise in the levels of obesity and sedentary lifestyles witnessed in younger age groups has resulted in up to a 10-fold increase in the prevalence of T2DM in younger adults and youth.[57] If left unconsidered, T2DM in the young will become one of the primary clinical priorities within the next couple of decades.[58] This need also prompted the European Commission to set up tenders for pilot projects aimed at the development and implementation of successful prevention strategies for T2DM among children. Furthermore, diabetes prevention studies focusing on children are also ongoing in the US.[59-61]

Individual countries have also recognised the need for effective diabetes prevention strategies and have funded research and policy change accordingly. For example, in England the National Institute for Health Research has committed substantial resources to funding research aimed at the prevention of T2DM and related chronic conditions across the translational spectrum, from experimental studies to implementation within primary care (http://www.nihr.ac.uk/Pages/default.aspx). However, at a national level, policy and research innovation tends to be very country-specific, reflecting the cultural and healthcare norms of the country in question. In order for diabetes prevention to be truly effective, it is likely that shared learning across countries will need to be actively promoted and supported. For example, the high-risk strategies currently promoted in the UK will only be effective if they are also combined with the societal, population-wide approaches that have been effective in Finland. Grassroots learning platforms have been set up to help disseminate international best practice, such as the network of diabetes prevention (http://nebel.tumainiserver.de/dp/); such initiatives should be commended and actively supported.

It is also clear that along with these broader issues, diabetes prevention will also be influenced by other areas of importance, such as technology and targeted health behaviours. In recent years, it has been acknowledged that modern technology is likely to be of fundamental importance in providing a pragmatic and cost-effective avenue for self-management and behaviour change in the prevention and management of highly prevalent chronic diseases; the most ubiquitous of such approaches are based on mobile or smart phones. A recently published systematic review revealed that text messaging or smartphone applications are well accepted by participants, and may provide beneficial effects on reducing weight, decreasing waist circumference, decreasing BMI, decreasing fat mass, increasing physical activity, decreasing sugar-sweetened beverage intake, decreasing screen time, and encouraging healthier eating patterns.[62] Furthermore, mobile phones have been used successfully in the prevention and management of T2DM. Results from recently published meta-analyses provide strong evidence that mobile phone interventions led to statistically significant improvements in glycaemic control and self-management in patients with T2DM.[63,64] Researchers in India also demonstrated that in comparison to standard care, a mobile phone text messaging intervention reduced the incidence of T2DM in a high-risk population.[65] Similar studies are also ongoing in Canada and the UK.[66,67]

Lifestyle interventions used in the prevention of T2DM are also likely to receive innovation through the targeting of new behaviours. Over the past decade, sedentary behaviour (defined as non-exercise sitting) has emerged as an independent risk factor for chronic disease, including for T2DM.[68] Indeed, recent studies in high-risk populations have shown that sedentary time actually has stronger associations with various markers of cardiometabolic health when compared with moderate-to-vigorous physical activity (MVPA).[69,70] Furthermore, emerging experimental research demonstrates that reducing sitting time by regularly (e.g. every 20 or 30 minutes) performing short bouts (e.g. 2 minutes) of light ambulation throughout the day, significantly decreases postprandial glycaemia and insulinaemia compared to prolonged sitting.[71,72] These studies

suggest that focusing on sedentary time and total movement throughout the day may be a more effective behavioural approach than solely promoting increased MVPA. The emerging evidence around sedentary behaviour has been picked up by several high profile international groups who are investigating the effectiveness of integrating interventions aimed at reducing daily sitting time into prevention initiatives. If successful, it is likely that diabetes prevention programmes in the future will include a strong focus on reducing daily sitting time in addition to the traditional behavioural targets.

## CONCLUSION

In conclusion, those at high risk of T2DM can be readily identified as part of routine care, and the development of T2DM in such populations can be slowed or prevented through lifestyle intervention. However, further work is needed to effectively translate and embed this knowledge into routine clinical care throughout Europe and worldwide. Healthcare policy and law, research, technological innovation, and shared international learning are all central to ensuring the epidemic of T2DM is effectively addressed for future generations.


### Acknowledgements

We acknowledge support from the National Institute for Health Research Collaboration for Leadership in Applied Health Research and Care – East Midlands (NIHR CLAHRC – EM), the Leicester Clinical Trials Unit, and the NIHR Leicester-Loughborough Diet, Lifestyle, and Physical Activity Biomedical Research Unit, which is a partnership between University Hospitals of Leicester NHS Trust, Loughborough University, and the University of Leicester.


## REFERENCES


1. International Diabetes Federation. IDF Diabetes Atlas (2011) 5th edition, Brussels: International Diabetes Federation.

2. Whiting DR et al. IDF diabetes atlas: global estimates of the prevalence of diabetes for 2011 and 2030. Diabetes Res Clin Pract. 2011;94(3):311-21.

3. World Health Organisation. Diabetes. Fact sheet no 312. 2011.

4. World Health Organisation. Definition, diagnosis, and classification of diabetes mellitus and its complications. Report of a WHO consultation. Part 1: Diagnosis and classification of diabetes mellitus (1999), Geneva: World Health Organisation.

5. Gerstein HC et al. Annual incidence and relative risk of diabetes in people with various categories of dysglycemia: a systematic overview and meta-analysis of prospective studies. Diabetes Res Clin Pract. 2007;78(3):305-12.

6. John WG et al. Use of haemoglobin A1c (HbA1c) in the diagnosis of diabetes mellitus. The implementation of World Health Organisation (WHO) guidance 2011. Pract Diab. 2012;29(1):12-12a.

7. World Health Organisation. Use of glycated haemoglobin (HbA1c) in the diagnosis of diabetes mellitus (2011), Geneva: World Health Organisation.

8. The International Expert Committee. International Expert Committee Report on the role of the A1C assay in the diagnosis of diabetes. Diabetes Care. 2009;32(7): 1327-34.

9. National Institute for Health and Clinical Excellence. Preventing type 2 diabetes: risk identification and interventions for individuals at high risk (PH38). 2012.

10. American Diabetes Association. Standards of Medical Care in Diabetes—2010. Diabetes Care. 2010;33(Suppl. 1):S11-S61.

11. Morris DH et al. Progression rates from HbA1c 6.0-6.4% and other prediabetes definitions to type 2 diabetes: a meta-analysis. Diabetologia. 2013;56(7):1489-93.

12. Paulweber B et al. A European evidence-based guideline for the prevention of type 2 diabetes. Horm Metab Res. 2010;42 Suppl 1:S3-S36.

13. Lindström J, Tuomilehto J. The diabetes risk score: a practical tool to predict type 2 diabetes risk. Diabetes Care. 2003;26(3):725-31.

14. Gray LJ et al. Detection of impaired glucose regulation and/or type 2 diabetes mellitus, using primary care electronic data, in a multiethnic UK community setting. Diabetologia. 2012;55(4):959-66.

15. Rathmann W et al. Performance of screening questionnaires and risk scores for undiagnosed diabetes: the KORA Survey 2000. Arch Intern Med. 2005;165(4):436-41.

16. Witte DR et al. Performance of existing risk scores in screening for undiagnosed diabetes: an external validation study. Diabet Med. 2010;27(1):46-53.

17. Lee CM, Colagiuri S. Risk scores for diabetes prediction: the International Diabetes Federation PREDICT-2 project. Diabetes Res Clin Pract. 2013;100(2): 285-6.

18. Buijsse B et al. Risk assessment tools for identifying individuals at risk of developing type 2 diabetes. Epidemiol Rev. 2011;33(1):46-62.

19. Collins GS et al. Developing risk prediction models for type 2 diabetes: a systematic review of methodology and reporting. BMC Med. 2011;9:103.

20. Noble D et al. Risk models and scores for type 2 diabetes: systematic review. BMJ. 2011;343:d7163.

21. Barber SR et al. Risk assessment tools for detecting those with pre-diabetes: a systematic review. Diabetes Res Clin Pract. 2014: in press.

22. Dhippayom T et al. How diabetes risk assessment tools are implemented in practice: a systematic review. Diabetes Res Clin Pract. 2014;104(3):329-42.

23. Yates T et al. Walking away from type 2 diabetes: trial protocol of a cluster randomized controlled trial evaluating a structured education programme in those at high risk of developing type 2 diabetes. BMC Fam Pract. 2012;13:46.

24. Gray LJ et al. Let's prevent diabetes: study protocol for a cluster randomised controlled trial of an educational

intervention in a multi-ethnic UK population with screen detected impaired glucose regulation. Cardiovasc Diabetol. 2012;11:56.

25. Gray LJ et al. Implementation of the automated Leicester Practice Risk Score in two diabetes prevention trials provides a high yield of people with abnormal glucose tolerance. Diabetologia. 2012;55(12): 3238-44.

26. Webb DR et al. Screening for diabetes using an oral glucose tolerance test within a western multi-ethnic population identifies modifiable cardiovascular risk: the ADDITION-Leicester study. Diabetologia. 2011;54(9):2237-46.

27. Chatterton H et al. Risk identification and interventions to prevent type 2 diabetes in adults at high risk: summary of NICE guidance. BMJ. 2012;345:e4624.

28. Echouffo-Tcheugui JB et al. Added value of novel circulating and genetic biomarkers in type 2 diabetes prediction: a systematic review. Diabetes Res Clin Pract. 2013;101(3):255-69.

29. Schwarz PE et al. Nonpharmacological interventions for the prevention of type 2 diabetes mellitus. Nat Rev Endocrinol. 2012;8(6):363-73.

30. Chamnan P et al. Estimating the potential population impact of stepwise screening strategies for identifying and treating individuals at high risk of Type 2 diabetes: a modelling study. Diabet Med. 2012;29(7):893-904.

31. Khunti K et al. A comparison of cost per case detected of screening strategies for type 2 diabetes and impaired glucose regulation: modelling study. Diabetes Res Clin Pract. 2012;97(3):505-13.

32. Mozaffarian D et al. Lifestyle risk factors and new-onset diabetes mellitus in older adults: the cardiovascular health study. Arch Intern Med. 2009;169(8):798-807.

33. Ford ES et al. Healthy living is the best revenge: findings from the European Prospective Investigation into Cancer and Nutrition-Potsdam study. Arch Intern Med. 2009;169(15):1355-62.

34. Tuomilehto J et al. Prevention of type 2 diabetes mellitus by changes in lifestyle among subjects with impaired glucose tolerance. N Engl J Med. 2001;344(18): 1343-50.

35. Knowler WC et al. Reduction in the incidence of type 2 diabetes with lifestyle intervention or metformin. N Engl J Med. 2002;346(6):393–403.

36. Kosaka K et al. Prevention of type 2 diabetes by lifestyle intervention: a Japanese trial in IGT males. Diabetes Res Clin Pract. 2005;67(2):152-62.

37. Ramachandran A et al. The Indian Diabetes Prevention Programme shows that lifestyle modification and metformin prevent type 2 diabetes in Asian Indian subjects with impaired glucose tolerance (IDPP-1). Diabetologia. 2006;49(2):289-97.

38. Pan XR et al. Effects of diet and exercise in preventing NIDDM in people with impaired glucose tolerance. The Da Qing IGT and Diabetes Study. Diabetes Care. 1997;20(4):537-44.

39. Gillies CL et al. Pharmacological and lifestyle interventions to prevent or delay type 2 diabetes in people with impaired glucose tolerance: systematic review and meta-analysis. BMJ. 2007;334(7588):299.

40. Lindström J et al. Sustained reduction in the incidence of type 2 diabetes by lifestyle intervention: follow-up of the Finnish Diabetes Prevention Study. Lancet. 2006;368(9548):1673-9.

41. Knowler WC et al. 10-Year follow-up of diabetes incidence and weight loss in the Diabetes Prevention Program Outcomes Study. Lancet. 2009;374(9702):1677–86.

42. Li G et al. The long-term effect of lifestyle interventions to prevent diabetes in the China Da Qing Diabetes Prevention Study: a 20-year follow-up study. Lancet. 2008;371(9626):1783-9.

43. Gillies CL et al. Different strategies for screening and prevention of type 2 diabetes in adults: cost effectiveness analysis. BMJ. 2008;336(7654):1180-5.

44. Yates T et al. Prevention of diabetes: a reality in primary care? Prim Care Diabetes. 2007;1(3):119-21.

45. Greaves CJ et al. Systematic review of reviews of intervention components associated with increased effectiveness in dietary and physical activity interventions. BMC Public Health. 2011;11:119.

46. Yates T et al. The Pre-diabetes Risk Education and Physical Activity Recommendation and Encouragement (PREPARE) programme study: are improvements in glucose regulation sustained at two years? Diabet Med. 2011;28(10):1268-71.

47. Yates T et al. Effectiveness of a pragmatic education program designed to promote walking activity in individuals with impaired glucose tolerance: a randomized controlled trial. Diabetes Care. 2009;32(8):1404-10.

48. Saaristo T et al. National type 2 diabetes prevention programme in Finland: FIN-D2D. Int J Circumpolar Health. 2007;66(2):101-12.

49. Albright A. Navigating the sea of diabetes. Diabetes Spectrum. 2009;22(1):38-42.

50. Green LW et al. Primary prevention of type 2 diabetes: integrative public health and primary care opportunities, challenges and strategies. Fam Pract. 2012;29 Suppl 1:i13-23.

51. Johnson M et al. Can diabetes prevention programmes be translated effectively into real-world settings and still deliver improved outcomes? A synthesis of evidence. Diabet Med. 2013;30(1):3-15.

52. Cardona-Morrell M et al. Reduction of diabetes risk in routine clinical practice: are physical activity and nutrition interventions feasible and are the outcomes from reference trials replicable? A systematic review and meta-analysis. BMC Public Health. 2010;10:653.

53. Dunkley AJ et al. Diabetes prevention in the real world: effectiveness of pragmatic lifestyle interventions for the prevention of type 2 diabetes and of the impact of adherence to guideline recommendations. A systematic review and meta-analysis. Diabetes Care. 2014;37(4):922-33.

54. Hamman RF et al. Effect of weight loss with lifestyle intervention on risk of diabetes. Diabetes Care. 2006;29(9): 2102-7.

55. Tuomilehto J et al. Long-term benefits from lifestyle interventions for type 2 diabetes prevention: time to expand the efforts. Diabetes Care. 2011;34 Suppl 2:S210-4.

56. European Commission. Horizon 2020 in brief. The EU Framework Programme for Research & Innovation. 2014. Available at: http://ec.europa.eu/programmes/horizon2020/en/news/horizon-2020-brief-eu-framework-programme-research-innovation.

57. Wilmot EG et al. Type 2 diabetes in younger adults: the emerging UK epidemic. Postgrad Med J. 2010;86(1022):711-8.

58. Blüher S et al. Who should we target for diabetes prevention and diabetes risk reduction? Curr Diab Rep. 2012;12(2): 147-56.

59. Vivian EM. Lessons learned from a community based lifestyle intervention for youth at risk for type 2 diabetes. J Obes Weight Loss Ther. 2013;3(5):doi:10.4172/2165-7904.1000191. [Epub ahead of print].

60. Savoye M et al. Reversal of early abnormalities in glucose metabolism in obese youth: results of an intensive lifestyle randomized controlled trial. Diabetes Care. 2014;37(2):317-24.

61. Healthy Study Group. A school-based intervention for diabetes risk reduction. N Engl J Med. 2010;363(5):443-53.

62. Stephens J, Allen J. Mobile phone interventions to increase physical activity and reduce weight: a systematic review. J Cardiovasc Nurs. 2013;28(4):320-9.

63. Liang X et al. Effect of mobile phone intervention for diabetes on glycaemic control: a meta-analysis. Diabet Med. 2011;28(4):455-63.

64. Liu L, Ogwu SM. A meta-analysis of mobile health and risk reduction in patients with diabetes mellitus: challenge and opportunity. Journal MTM. 2012;1(3):17-24.

65. Ramachandran A et al. Effectiveness

of mobile phone messaging in prevention of type 2 diabetes by lifestyle modification in men in India: a prospective, parallel-group, randomised controlled trial. Lancet Diabetes Endocrinol. 2013;1(3):191-8.

66. Leicester Diabetes Centre. The PRomotion Of Physical activity through structured Education with differing Levels of ongoing Support for those with pre-diabetes: randomised controlled trial in a diverse multi-ethnic community. 2012. Available at: http://www.controlled-trials.com/ISRCTN83465245.

67. Stuckey MI et al. A lifestyle intervention supported by mobile health technologies to improve the cardiometabolic risk profile of individuals at risk for cardiovascular disease and type 2 diabetes: study rationale and protocol. BMC Public Health. 2013;13:1051.

68. Wilmot EG et al. Sedentary time in adults and the association with diabetes, cardiovascular disease and death: systematic review and meta-analysis. Diabetologia. 2012;55(11):2895-905.

69. Henson J et al. Associations of objectively measured sedentary behaviour and physical activity with markers of cardiometabolic health. Diabetologia. 2013;56(5):1012-20.

70. Cooper AR et al. Sedentary time, breaks in sedentary time and metabolic variables in people with newly diagnosed type 2 diabetes. Diabetologia. 2012;55(3):589-99.

71. Dunstan DW et al. Breaking up prolonged sitting reduces postprandial glucose and insulin responses. Diabetes Care. 2012;35(5):976-83.

72. Duvivier BM et al. Minimal intensity physical activity (standing and walking) of longer duration improves insulin action and plasma lipids more than shorter periods of moderate to vigorous exercise (cycling) in sedentary subjects when energy expenditure is comparable. PLoS One. 2013;82(2):e55542.

73. Glümer C et al. A Danish diabetes risk score for targeted screening: the Inter99 study. Diabetes Care. 2004;27(3):727-33.

74. Balkau B et al. Predicting diabetes: clinical, biological, and genetic approaches: data from the Epidemiological Study on the Insulin Resistance Syndrome (DESIR). Diabetes Care. 2008;31(10):2056-61.

75. von Eckardstein A et al. Risk for diabetes mellitus in middle-aged Caucasian male participants of the PROCAM study: implications for the definition of impaired fasting glucose by the American Diabetes Association. Prospective Cardiovascular Münster. J Clin Endocrinol Metab. 2000;85(9):3101-8.

76. Schulze MB et al. An accurate risk score based on anthropometric, dietary, and lifestyle factors to predict the development of type 2 diabetes. Diabetes Care. 2007;30(3):510-5.

77. Ruige JB et al. Performance of an NIDDM screening questionnaire based on symptoms and risk factors. Diabetes Care. 1997;20(4):491-6.

78. Baan CA et al. Performance of a predictive model to identify undiagnosed diabetes in a health care setting. Diabetes Care. 1999;22(2):213-9.

79. Bindraban NR et al. Prevalence of diabetes mellitus and the performance of a risk score among Hindustani Surinamese, African Surinamese and ethnic Dutch: a cross-sectional population-based study. BMC Public Health. 2008;8:271.

80. Gray LJ et al. The development and validation of the Portuguese risk score for detecting type 2 diabetes and impaired fasting glucose. Prim Care Diabetes. 2013;7(1):11-8.

81. Cabrera de León A et al. A simple clinical score for type 2 diabetes mellitus screening in the Canary Islands. Diabetes Res Clin Pract. 2008;80(1):128-33.

82. Guasch-Ferré M et al. A risk score to predict type 2 diabetes mellitus in an elderly Spanish Mediterranean population at high cardiovascular risk. PLoS One. 2012;7(3):e33437.

83. Griffin SJ et al. Diabetes risk score: towards earlier detection of type 2 diabetes in general practice. Diabetes Metab Res Rev. 2000;16(3):164-71.

84. Hippisley-Cox J et al. Predicting risk of type 2 diabetes in England and Wales: prospective derivation and validation of QDScore. BMJ. 2009;338:b880.

85. Gray LJ et al. The Leicester Risk Assessment score for detecting undiagnosed Type 2 diabetes and impaired glucose regulation for use in a multiethnic UK setting. Diabet Med. 2010;27(8):887-95.