ISSN 2308-3840 (online)

World Journal of *Meta-Analysis*

World J Meta-Anal 2020 April 28; 8(2): 41-172

Published by Baishideng Publishing Group Inc

WJMA World Journal of Meta-Analysis

Contents

Bimonthly Volume 8 Number 2 April 28, 2020

OPINION REVIEW

REVIEW

MINIREVIEWS

SYSTEMATIC REVIEWS

META-ANALYSIS

SCIENTOMETRICS

Contents

World Journal of Meta-Analysis

Volume 8 Number 2 April 28, 2020

ABOUT COVER

Editor-in-Chief of *World Journal of Meta-Analysis*, Saurabh Chandan, MD, Research Fellow, Department of Gastroenterology and Hepatology, 982000 NMC Gastroenterology, University of Nebraska Medical Center, Omaha, NE 68198, United States

AIMS AND SCOPE

The primary aim of *World Journal of Meta-Analysis* (*WJMA*, *World J Meta-Anal*) is to provide scholars and readers from various fields of clinical medicine with a platform to publish high-quality meta-analysis and systematic review articles and communicate their research findings online.

WJMA mainly publishes articles reporting research results and findings obtained through meta-analysis and systematic review in a wide range of areas, including medicine, pharmacy, preventive medicine, stomatology, nursing, medical imaging, and laboratory medicine.

INDEXING/ABSTRACTING

The *WJMA* is now abstracted and indexed in China National Knowledge Infrastructure (CNKI), China Science and Technology Journal Database (CSTJ), and Superstar Journals Database

RESPONSIBLE EDITORS FOR THIS ISSUE

NAME OF JOURNAL
World Journal of Meta-Analysis

ISSN
ISSN 2308-3840 (online)

LAUNCH DATE
May 26, 2013

FREQUENCY
Bimonthly

EDITORS-IN-CHIEF
Saurabh Chandan, Sergio Machado

EDITORIAL BOARD MEMBERS
https://www.wjgnet.com/2308-3840/editorialboard.htm

PUBLICATION DATE
April 28, 2020

INSTRUCTIONS TO AUTHORS
https://www.wjgnet.com/bpg/gerinfo/204

GUIDELINES FOR ETHICS DOCUMENTS
https://www.wjgnet.com/bpg/GerInfo/287

GUIDELINES FOR NON-NATIVE SPEAKERS OF ENGLISH
https://www.wjgnet.com/bpg/gerinfo/240

PUBLICATION ETHICS
https://www.wjgnet.com/bpg/GerInfo/288

PUBLICATION MISCONDUCT
https://www.wjgnet.com/bpg/gerinfo/208

ARTICLE PROCESSING CHARGE
https://www.wjgnet.com/bpg/gerinfo/242

STEPS FOR SUBMITTING MANUSCRIPTS
https://www.wjgnet.com/bpg/GerInfo/239

ONLINE SUBMISSION
https://www.f6publishing.com

World Journal of Meta-Analysis

Submit a Manuscript: https://www.f6publishing.com

World J Meta-Anal 2020 April 28; 8(2): 119-152

DOI: 10.13105/wjma.v8.i2.119

ISSN 2308-3840 (online)

SYSTEMATIC REVIEWS

Systematic review with meta-analysis of the epidemiological evidence relating smoking to type 2 diabetes

Peter N Lee, Katharine J Coombs

ORCID number: Peter N Lee (0000-0002-8244-1904); Katharine J Coombs (0000-0003-0093-7162).

Author contributions: Lee PN conceived the study, designed and assisted in the literature searches and statistical analyses, and wrote the various drafts of the paper; Coombs KJ carried out the literature searches and statistical analyses, checked the drafts of the paper, and agreed the final version.

Supported by Japan Tobacco International, No. PO 4700389462.

Conflict-of-interest statement: The authors have carried out consultancy work for many tobacco organizations.

PRISMA 2009 Checklist statement: The guidelines of the PRISMA 2009 statement have been adopted.

Manuscript source: Invited manuscript

Received: February 5, 2020

Peter N Lee, Katharine J Coombs, Department of Statistics, P.N. Lee Statistics and Computing Ltd., Sutton SM2 5DA, Surrey, United Kingdom

Corresponding author: Peter N Lee, MA, Director, Senior Statistician, Director and Consultant Medical Statistician, Department of Statistics, P.N. Lee Statistics and Computing Ltd., 17 Cedar Road, Sutton SM2 5DA, Surrey, United Kingdom. peterLee@pnlee.co.uk

Abstract

BACKGROUND

Evidence relating tobacco smoking to type 2 diabetes has accumulated rapidly in the last few years, rendering earlier reviews considerably incomplete.

AIM

To review and meta-analyse evidence from prospective studies of the relationship between smoking and the onset of type 2 diabetes.

METHODS

Prospective studies were selected if the population was free of type 2 diabetes at baseline and evidence was available relating smoking to onset of the disease. Papers were identified from previous reviews, searches on Medline and Embase and reference lists. Data were extracted on a range of study characteristics and relative risks (RRs) were extracted comparing current, ever or former smokers with never smokers, and current smokers with non-current smokers, as well as by amount currently smoked and duration of quitting. Fixed- and random-effects estimates summarized RRs for each index of smoking overall and by various subdivisions of the data: Sex; continent; publication year; method of diagnosis; nature of the baseline population (inclusion/exclusion of pre-diabetes); number of adjustment factors; cohort size; number of type 2 diabetes cases; age; length of follow-up; definition of smoking; and whether or not various factors were adjusted for. Tests of heterogeneity and publication bias were also conducted.

RESULTS

The literature searches identified 157 relevant publications providing results from 145 studies. Fifty-three studies were conducted in Asia and 53 in Europe, with 32 in North America, and seven elsewhere. Twenty-four were in males, 10 in females and the rest in both sexes. Fifteen diagnosed type 2 diabetes from self-report by the individuals, 79 on medical records, and 51 on both. Studies varied widely in size of the cohort, number of cases, length of follow-up, and age. Overall, random-effects estimates of the RR were 1.33 [95% confidence interval (CI): 1.28-1.38] for current *vs* never smoking, 1.28 (95%CI: 1.24-1.32) for current *vs*

Peer-review started: February 5, 2020
First decision: March 21, 2020
Revised: April 8, 2020
Accepted: April 21, 2020
Article in press: April 21, 2020
Published online: April 28, 2020

P-Reviewer: Jia J, Rakhshan V
S-Editor: Tang JZ
L-Editor: A
E-Editor: Qi LL

non-smoking, 1.13 (95%CI: 1.11-1.16) for former *vs* never smoking, and 1.25 (95%CI: 1.21-1.28) for ever *vs* never smoking based on, respectively, 99, 156, 100 and 100 individual risk estimates. Risk estimates were generally elevated in each subdivision of the data by the various factors considered (exceptions being where numbers of estimates in the subsets were very low), though there was significant ($P < 0.05$) evidence of variation by level for some factors. Dose-response analysis showed a clear trend of increasing risk with increasing amount smoked by current smokers and of decreasing risk with increasing time quit. There was limited evidence of publication bias.

CONCLUSION
The analyses confirmed earlier reports of a modest dose-related association of current smoking and a weaker dose-related association of former smoking with type 2 diabetes risk.

Key words: Smoking; Type 2 diabetes; Prospective studies; Meta-analyses; Dose-response; Review

Core tip: Based on data from 145 follow-up studies of individuals free of type 2 diabetes at baseline, we confirm evidence of a modest association of smoking with subsequent onset of the disease. Meta-analysis showed relative risks of 1.33 [95% confidence interval (CI): 1.28-1.38] for current *vs* never smoking, 1.28 (95%CI: 1.24-1.32) for current *vs* non-smoking, and 1.13 (95%CI: 1.11-1.16) for former smoking. Risks increased with amount smoked and decreased with time quit. Elevated risks were consistently seen when the data were subdivided by various factors, suggesting that the associations are not a result of uncontrolled confounding.

Citation: Lee PN, Coombs KJ. Systematic review with meta-analysis of the epidemiological evidence relating smoking to type 2 diabetes. *World J Meta-Anal* 2020; 8(2): 119-152
URL: https://www.wjgnet.com/2308-3840/full/v8/i2/119.htm
DOI: https://dx.doi.org/10.13105/wjma.v8.i2.119

INTRODUCTION

Pan *et al*[1], 2015 published a meta-analysis and systematic review of the relationship of active, passive and quitting smoking with incident type 2 diabetes. Based on 88 prospective studies, they reported pooled relative risks (RRs) and 95% confidence intervals (CIs) compared to never smoking of 1.37 (95%CI: 1.33-1.42) for current smoking, 1.14 (95%CI: 1.10-1.18) for former smoking and 1.22 (95%CI: 1.10-1.25) for passive smoking, and evidence of a dose-relationship with amount smoked and years quit. This was an update of a previous review by the US Surgeon General, 2014[2], which based on 46 studies, had argued for a causal relationship. As evidence on tobacco smoking and type 2 diabetes has accumulated rapidly in the last few years, we wanted to investigate more extensively how this relationship may vary based on characteristics of the study or of the RR. We conducted our own updated review and meta-analysis, based solely on active smoking of cigarettes, with or without use of pipes, cigars or smokeless tobacco.

MATERIALS AND METHODS

Study inclusion criteria

Epidemiological prospective studies of populations without type 2 diabetes at baseline in which smoking was related to subsequent incidence of the disease.

The studies had to provide RR estimates for one or more defined major or dose-related smoking indices. The defined "major indices" compare ever, current or ex-smokers with never smokers, or current smokers with non-current smokers, and refer to smoking of any product (cigarettes, pipes, cigars and combinations) or to smoking

of cigarettes. The defined "dose related indices" concern the amount currently smoked and the duration of quitting.

Study exclusion criteria

Studies were excluded where the participants were restricted to those with diseases related to type 2 diabetes.

Literature searches

This was carried out in five steps.

Step 1 identified relevant papers from four previously published reviews of evidence from relevant prospective studies. The review in the 2014 United States Surgeon-General Report[2], presented an analysis based on 46 prospective studies, taking into account studies reported in an earlier review by Willi *et al*[3], 2007 and adding additional studies. Since that Report, which included studies published up to 2010, two further meta-analyses have been published. That by Pan *et al*[1], 2015 included 88 studies, all but five of those considered by the United States Surgeon-General, along with many other studies published up to May 3, 2015. Another review by Akter *et al*[4], 2017 was limited to studies in Japan, and also considered studies up to 2015.

Step 2, carried out on January 31, 2019, repeated the Medline searches described by Pan *et al*[1], 2015, but with the search date restricted to January 1, 2015 onwards.

Step 3 was based on a search on our in-house reference system for papers with keywords DIABETES.

Step 4, carried out on March 1, 2019, repeated the Embase searches described by Pan *et al*[1], 2015, with the search restricted to papers not on Medline.

Finally, Step 5 was based on reference lists of papers identified in Steps 2, 3 and 4, looking for additional potentially relevant papers published from 2015.

In Steps 2 and 4, abstracts were examined first, with full texts obtained only for papers which appeared likely to be relevant. This step was initially carried out by Coombs KJ, with a 20% check made by Lee PN.

At each step, papers (or abstracts) examined for potential relevance were only those not previously considered.

At the end of this process, a set of potentially relevant papers was obtained. Subsequently, more detailed examination of the full texts at the data entry stage revealed that some papers did not actually meet the inclusion criteria, leading to a reduction in the list of relevant papers.

Data recorded

Relevant information was entered onto a publication database and a linked RR database.

The publication database contains a record for each publication describing the following aspects: In-house reference ID of the publication; first author; publication year; location (continent/country); study name; study title; population studied; beginning and end year of baseline; end year of follow-up; length of follow-up; definition of type 2 diabetes (for both baseline exclusion and subsequent incidence) and source of diagnosis; cohort size; number of type 2 diabetes cases; age at baseline; sexes considered; races considered; definition of smoking; results available (current, former, ever, amount smoked, and years quit); details of results available for specific subsets [sex, age, body mass index (BMI), physical activity, alcohol, family history of type 2 diabetes, education, diet, and others]; and details of factors adjusted for in analyses (sex, age, BMI, physical activity, alcohol, family history of type 2 diabetes, education, diet, blood pressure, cholesterol, glucose, triglycerides, waist size, and others).

The RR database holds the detailed results, typically containing multiple records for each publication. Each record is linked to the relevant publication and refers to a specific comparison. The record includes details of the publication reference ID, study name, sex, age range at baseline, length of follow-up, BMI range, definition of smoking, and smoking status of the numerator (current, former or ever), and of the denominator (never or non). Where the smoking status is former, the range of years quit is entered. The range of amount smoked is also entered. For unadjusted RR estimates, the numbers of cases and at risk (or person years) are entered for both the numerator and denominator.

For adjusted RR estimates, the RR and 95%CI are entered, taken directly from the publication, or estimated using standard methods[5], with details also entered of the factors adjusted for.

Numbers of cases and at risk, or RRs and 95%CIs, are only entered for the whole population or for subgroups defined by sex, age group or BMI group. As noted above, the availability of results by other factors is recorded in the publication database, but

the detailed results have not so far been entered. Results are also only entered unadjusted for potential confounding variables and adjusted for the most confounding variables for which results were available.

All data were entered by Coombs KJ and checked by Lee PN, with any disagreements discussed and resolved.

Multiple publications for the same study

Once the data were entered, the list of publications was sorted into studies. Where the RRs from only one publication needed to be used in analysis, with the others providing no useful extra data (*e.g.*, providing similar data for a shorter follow-up), these "other" publications were rejected, with the reasons for rejection noted. Where more than one publication from the same study provided useful data (*e.g.*, for different aspects of smoking), one publication was nominated as the main reference for the study (typically, the publication providing the most detailed results) and others were nominated as subsidiary references. Thus, it was possible to have main, subsidiary and rejected references from the same study. Another possibility is that a publication may give a pooled analysis of several individual studies, including useful data for aspects not covered in the main publications of the separate studies. These pooled publications are also nominated as subsidiary references.

Meta-analyses

Fixed-effect and random-effects meta-analyses were conducted using the method of Fleiss and Gross, 1991[6], with heterogeneity quantified by H, the ratio of the heterogeneity chisquared to its degrees of freedom. H is directly related to the statistic I^2[7] by the formula $I^2 = 100\ (H-1)/H$. For all meta-analyses, Egger's test of publication bias[8] was included.

The major smoking indices

Meta-analyses were conducted using the available data for current *vs* never, current *vs* non, ever *vs* never, and former *vs* never smoking. Where there was a choice of estimates for a study, preference was given to results that were for the full range of amount smoked, the longest follow-up, the most adjusted, the widest age range, and the preferred product, with preference being given, in order to results for: Cigarettes; smoking excluding exclusive pipe/cigar; smoking; and tobacco; but not exclusive cigar, pipe or smokeless tobacco. For a study of both sexes, preference was also given to separate estimates for the two sexes, if available. While in most studies, the choice of estimates was straightforward, in others it was not (*e.g.*, between an unadjusted RR for a longer follow-up from one publication and an adjusted RRs for a shorter follow-up from another). Here Coombs KJ and Lee PN agreed and recorded the most relevant RR to choose (disregarding its magnitude). For a particular exposure (*e.g.*, current *vs* never) each study could provide only the estimate or two sex-specific estimates for inclusion in the meta-analysis.

Effect estimates were derived based on all the selected RRs as well as for those subdivided by various categorical variables: Sex (male, female, and sexes combined); continent (Asia, Europe, Americas, and Oceania); publication year (before 2005, 2005-14, 2015 or later); diagnosis of type 2 diabetes (self-reported, medical data only, both); population (general, pre-diabetics only, excludes pre-diabetics); total number of adjustment factors (0, 1-5, 6-10, 11+); cohort size (< 5000, 5000-20000, > 20000); number of type 2 diabetes cases (< 500, 500-999, 1000-2000, 2001+); highest baseline age (< 60, 60-74, 75+ years); length of follow-up (< 5, 5-10, > 10 years); definition of smoking [cigarettes, smoking (whether or not excluding exclusive pipe/cigar), tobacco]; and whether each of a range of different variables were adjusted for.

The dose-related smoking indices

When comparing RRs by amount currently smoked (with a reference group of never smokers) or non-smokers, or by years quit (with a reference group of never smokers), a study typically provides a set of non-independent RRs for each dose-category, expressed relative to a common base. To avoid double-counting, it is necessary to include only one in any one meta-analysis.

For amount smoked, three methods were used. One method used only for studies that reported results for two levels of amount smoked, was to compare results for 1-19 and 20+ cigs/d, the most common subdivision used. The second, used only for studies that reported results for three levels of amount smoked was to compare results for low, medium and high cigs/d regardless of the levels selected. The third involved defining a set of key values (10, 20 and 40 cigs/d) and carrying out a separate meta-analysis for each key value. For an RR to be allocated to a key value its dose category had to include that key value and no other. This method was only applied for studies reporting results by three or more levels, with all three key value

results available. These methods were used for data on current *vs* never smoking, and for current *vs* non-smoking.

For years quit, two methods were used. One simply used the shortest and longest categories. The other used the key values approach with values of 3, 7 and 12 years quit.

Results by BMI

For each of the studies that reported independent RR estimates separately for different subdivisions of the population by level of BMI, estimates were made, for each smoking index for which data were available, of the ratio of the RR for highest *vs* lowest BMI group, these ratios then also being meta-analysed.

Avoidance of overlap

When conducting meta-analyses care was taken to minimize overlap of cases. Thus, results from subsidiary papers were used only when the main paper did not provide the result required for the particular meta-analysis. Also, if an RR was available from three separate studies, and also from a combined analysis from the three studies, the individual results were preferred, only using the combined RR for a smoking index for which results were not reported in all the different studies.

RESULTS

Publications and studies identified

As summarized in Table 1[9-15], 221 publications were originally identified as likely to be relevant, with 42 later rejected during data entry, the reasons for rejection being given in Supplementary File 1. As seven of the publications provided results for two independent data sets (either presenting separate results for two studies or for two non-overlapping follow-up periods), data entry was carried out initially for 186 publication records. On investigation of studies with multiple records, 29 records were rejected as providing no useful information extra to those provided in other records) and 12 were classified as subsidiary, providing some limited extra information for records classified as main. This meant that there were 145 studies, 144 separate studies plus the combined analysis of three studies (HPFUS, NHS and NHSII). Table 2[9-14,16-161] summarizes some characteristics of these studies, while Supplementary file 1 also gives information on why some publications were rejected or only provided subsidiary information.

All stages of the identification of relevant papers, classification of papers with studies, and data entry were conducted initially by Coombs KJ and checked by Lee PN. Exceptionally, Lee PN only checked 20 percent of the abstracts for the Medline and Embase searches. This 20 percent check, of a total of 8798 hits, only resulted in four extra full-text papers being examined, only one of which proved to have relevant data. Given the very limited extra information obtained, and the time spent, it was decided not to extend this to a 100 percent check.

Study characteristics

Location: As shown in Table 2, 53 of the 145 studies were conducted in Asia (including 23 in Japan, 10 in South Korea, nine in China and 11 in other countries). Fifty-three were conducted in Europe (eight in Great Britain, eight in Finland, seven in Germany, six in Sweden, five in Spain, and 19 in other countries), with 32 in North America (all in the United States), six in Australia and one in Brazil.

Population: Ten of the studies were in females, 24 in males and 111 in both sexes. About half were of the relevant general population, with Table 2 showing further details.

Time: There was a clear increase in study frequency with time, with 17 starting before 1980, 23 starting in the 1980s, 47 in the 1990s, 42 in 2000-2005, and 16 from 2006 onwards.

Years follow up: Twenty-four studies involved less than 5 years follow-up; 62 studies involved 5-9.9 years follow-up; 36 studies involved 10-14.9 years follow-up; and 23 studies involved 15 years or more years follow-up, with the longest (NOVAK) involving 35 years.

Diagnosis: Fifteen of the studies diagnosed type 2 diabetes only on the basis of self-report of the individuals, 79 only on medical records, and 51 on both.

Size: The numbers in the cohorts studied varied from 182 to over eight million. Sixty-

Table 1 Literature searching

Step		Papers originally selected as probably relevant[1]	Papers rejected during data entry[2]	Papers providing separate results for multiple studies[3]
1	Previous reviews	98	10	3[9-11]
2	Medline search	74 (from 3365 hits)	23	4[12-15]
3	In-house database	1	0	0
4	Embase search	33 (from 5433 hits)	7	0
5	Secondary references[4]	15 (of 30 identified)	2	0
Total		221	42	7

[1]Numbers of papers originally selected exclude those already identified in a previous step.
[2]Reasons for rejection are summarized in Supplementary file 1.
[3]Or for separate periods of follow-up.
[4]From papers identified in steps 2 to 4.

three were under 5000, 39 in the range 5000 to 20000 and 43 larger than this.

Type 2 diabetes cases: The number of type 2 diabetes cases varied from 27 to almost 180000. Eighty-two involved fewer than 500 cases, 21 involved 500-999 cases, 13 involved 1000-2000 cases, and 28 involved more than this. The number was not available for one study.

Age: Most of the studies included some individuals of age 75 or older at baseline. However, 24 were restricted to those aged less than 60 and 30 more were restricted to those aged less than 74.

Meta-analyses

Current *vs* never smoking: The studies provided 99 RR estimates from 80 studies for the comparison of current *vs* never smoking. Nineteen studies provided estimates for both sexes, six for females only, 17 for males only and 38 only for sexes combined. Of the 99 estimates, 12 were below 1, 10 were above 2, with the remaining 77 in the range 1 to 2. The overall fixed-effect RR estimate was 1.25 (95%CI: 1.24-1.26) with highly significant heterogeneity between the estimates (Chisq. 816.8 on 98 df, $P < 0.001$, I^2 = 88.0%). The random-effects estimate was somewhat higher at 1.33 (95%CI: 1.28-1.38). There was limited evidence of publication bias ($0.01 < P < 0.05$).

Table 3 presents the overall random-effects estimate, together with a breakdown of the estimates by various factors, with fuller details given in Supplementary file 2. There was evidence ($P < 0.05$) that the estimates varied by population type with both the estimates from studies restricted to pre-diabetics exceeding 3. There was also evidence that estimates were higher in those that were more adjusted ($P < 0.05$) or adjusted for various other individual factors (age, alcohol, family history of diabetes, cholesterol, triglycerides – all $P < 0.05$ - and glucose – $P < 0.01$), but were lower in those that were adjusted for education ($P < 0.05$). It is notable, however, that with the exception of two estimates based on less than five RRs, all the RR estimates shown in Table 3 were significantly ($P < 0.05$) increased.

For the analysis subdivided by sex, Figure 1 (females), Figure 2 (males) and Figure 3 (sexes combined) summarize the data in forest plots, while Figure 4 (females), Figure 5 (males) and Figure 6 (sexes combined) present funnel plots to illustrate possible publication bias. No marked publication bias was evident.

Table 4 (and Supplementary file 3) summarizes the results of the dose-response analysis for current *vs* never smoking. Whichever of the three methods of dose-response grouping was used, the RR estimates clearly rose with increasing amount smoked, and the increase at each level remained significant ($P < 0.05$). Note that the sets of estimates are not independent, with all the studies providing results for the key value analysis also contributing to the low/medium/high split.

Current *vs* non-smoking: There were 156 RR estimates from 133 studies for the comparison of current *vs* non- smoking. Twenty-three studies provided estimates for both sexes, eight for females only, 24 for males only and 78 for sexes combined.

Of the 156 estimates, 27 were below 1, 11 were above 2, with the remaining 118 in the range 1 to 2. The overall fixed-effect RR estimate was 1.20 (95%CI: 1.20-1.21), with highly significant heterogeneity (Chisq. 1986.7 on 155 df, $P < 0.001$, I^2 = 92.2%), and the random-effects estimate was 1.28 (95%CI: 1.24-1.32), slightly lower than the

Table 2 Some characteristics[1] of the 145 studies of smoking and type 2 diabetes

Study Ref.	Main/ Other Ref.	Continent	Country, location[2]	Study Population[3]	Sex	Baseline	Follow-up (yr)[4]	Diagnosis code[5]	Cohort size	Diabetes cases	Age
3 studies[6]	[16]	North America	United States	Medical professionals	M+F	1984-1991	19.6	3	162807	12384	25-75
AICHI	[17]/[18]	Asia	Japan, Aichi	Civil servants	M+F	2002	9.0	3	3338	225	35-66
AIZAWA	[19]	Asia	Japan, Matsumoto	Participants from hospital (not otherwise defined)	M+F	2005	4.9	2	4159	279	Any
ALEIN	[20]	Asia	Taiwan (China), A-Lein	Persons undergoing community wide screening for hepatitis	M+F	1996-1997	8.0	2	3539	423	40-69
ALSWH	[21]	Oceania	Australia	General population	F	1998	12.0	1	12367	871	47-52
ANSAN	[22]/[23,24]	Asia	South Korea, Ansun and Ansan	Community based	M+F	2001-2002	4.0	2	4041	329	40-69
ARIC	[25]/[26]	North America	United States, North Carolina, Mississippi, Maryland	Probability sample from 4 US communities with exclusive sampling of African Americans in one of the four sites, Black or White	M+F	1987-1989	9.0	3	10892	1254	45-64
ASAN	[27]	Asia	South Korea, Asan	Attending voluntary medical check-ups	M+F	2000	5.0	2	5372	234	20-79
ATTICA	[28]	Europe	Greece, Athens	General population	M+F	2001-2002	10.0	2	1485	191	18-89
Ausdiab	[29]	Oceania	Australia	General population	M+F	1990-2000	5.0	2	5842	244	25+
BEDFORD	[30]	Europe	England, Bedford	Borderline diabetics with a 2h fasting glucose of 6.7-11.1 mmol/L	M+F	1962-1964	10.0	2	241	36	18+
BIP	[31]	Asia	Israel	Subjects with impaired functional capacity (New York Heart Association class II and III)	M+F	1990-1993	6.2	2	630	98	45-74
BMES	[32]	Oceania	Australia, West of Sydney	Non institutionalised residents	M+F	1992-1994	10.0	3	2123	165	49+

BOGA-LUSA	[33]	North America	United States, Bogalusa	General population	M+F	1973-2010	9.1	2	7725	176	< 18
BOTNIA	[9]/[34]	Europe	Finland, Botnia	Family members of diabetics	M+F	1990	7.6	2	2770	138	Any
BRHS	[35]	Europe	Britain	General population	M	1978-1980	16.8	3	7124	290	40-59
BRU-NECK	[36]	Europe	Italy, Bruneck	General population, White	M+F	1990	10.0	2	837	64	40-79
BURKE	[37]	Oceania	Australia Kimberley	General population, Aboriginal	M+F	1988-1989	12.9	2	493	104	15-88
BWHS	[38]	North America	United States	African American subscribers to magazine targeted at black women	F	1995	16.0	3	43003	4387	21-69
CASSAN	[39]	North America	United States	Majority were veterans, 98% Caucasian	M	1963	18.0	2	1972	226	20-80
CCHS	[40]	North America	United States, Cleveland	General population	M+F	2008	5.0	2	5084	872	18+
CDCdeC	[41]	Europe	Spain, Canaries	General population	M+F	2000-2005	3.5	3	5521	146	18-75
CEHSC	[42]	Asia	Hong Kong (China)	General population volunteers	M+F	1998-2001	9.8	2	53905	806	65+
CKB	[43]	Asia	China	General population	M+F	2004-2008	7.2	2	461211	8784	30-79
CoLaus	[44]	Europe	Switzer-land, Lausanne	General population	M+F	2003-2006	5.5	2	3166	47	35-75
CPSI	[45]	North America	United States	General Population	M+F	1959-1960	12.0	3	709827	25397	30+
CRISPS	[46]	Asia	Hong Kong (China)	General population, Chinese	M+F	2000-2004	9.0	2	1380	123	Any
CURES	[47]	Asia	India, Chennai	General population	M+F	2001-2003	9.1	2	1376	385	20+
DAQING	[48]	Asia	China	Care clinic patients with pre-diabetes, part of diabetes prevention inter-vention	M+F	1986	23.0	3	568	436	Any
DEHGHA	[49]	Europe	Nether-lands, Ommoord	General population	M+F	1990-1993	10.8	2	6935	645	55+
DE-PLAN	[11]	Europe	Spain, Navarra, Reus and Barcelona	Partici-pants in clinical trial on Mediter-ranean diet, Caucasian	M+F	2006	4.2	2	552	124	45-75
DESIR	[50]	Europe	France, Western	Volunteers for periodic health checks	M+F	1998	9.0	2	3817	203	30-64

DLCS	[51]	Europe	Nether-lands, Northern	General population, Western Europe	M+F	2007-2013	4.0	3	72880	1056	18-90
DNC	[52]	Europe	Denmark	Nurses	F	1993-1999	15.3	2	24174	1137	44+
DONGFENG	[53]	Asia	China, Da Qing	Retired employees	M+F	2008-2010	4.0	3	17690	1390	Any
DWECS	[54]	Europe	Denmark	Workers	M+F	1995-2005	5.0	2	6823	NA	30-59
EPIC-IN	[55]	Europe	8 countries[7]	Subset of partici-pants in EPIC-InterAct cohort	M+F	1991	11.7	3	23501	10327	Any
ESTHER	[56]	Europe	Germany, Saarland	General population	M+F	2000-2002	8.0	3	7462	718	50-75
FAGERB	[57]	Europe	Sweden, Göteborg	General population, Caucasian	F	2001-2004	5.5	2	341	69	64
FINNMARK	[58]	Europe	Norway, Finnmark	General population	M+F	1997-1978	12.0	2	11654	162	35-52
GLOSTRUP	[59]	Europe	Denmark, Glostrup	General population	M	1982-2001	18.9	2	5350	211	30-70
GNHIES	[60]	Europe	Germany	General population (non institutionalized)	M+F	1997-1999	5.0	2	3625	82	18-79
HDNNCDS	[12]	Asia	China, Harbin	General population, Chinese	M+F	2010	4.2	3	7133	578	20-74
HEALTH 2000	[10]	Europe	Finland	General population	M+F	2000-2001	7.0	2	4110	81	40-79
HEINZN	[61]/[62]	Europe	Germany, Western	General population	M+F	2000-2003	5.1	3	3547	319	45-75
HENAN	[63]	Asia	China, Henan	General population, N Chinese ancestry	M+F	2007-2008	6.0	3	12272	775	18+
HIPOP-OHP	[64]	Asia	Japan	Employees	M+F	1999	3.4	3	6498	229	Any
HIPPIS1	[65]	Europe	England and Wales	Primary care patients	M+F	1993-2008	8.0	2	2540753	78081	25-79
HIPPIS2	[66]	Europe	England	Primary care patients	M+F	2005-2016	3.9	2	8186705	178314	25-84
HISAYAMA	[67]	Asia	Japan, Hisayama	General population	M+F	1988	11.8	2	1935	286	40-79
HPFUS	[68]	North America	United States	Health profes-sionals	M	1986	6.0	3	41810	509	40-75
HPHS	[12]	Asia	China, Harbin	General population, Chinese	M+F	2008	4.2	3	3350	244	20-74
HUNT	[69]	Europe	Norway, Nord-Trøndelag	General population	M+F	1984-1997	11.0	3	90819	1860	20+
ICARIA	[70]	Europe	Spain	Spanish workers	M+F	2004-2007	4.1	3	380366	9960	18-65
ICS	[71]	Asia	Iran, Isfahan, Arak and Najafabad	General population	M+F	2001	7.0	2	2980	389	35+

IPC	[72]	Europe	France, Paris	Workers and those seeking employment who had undergone 2 health checks	M+F	1998-2010	5.3	2	22567	527	18+
IRAS	[73]	North America	United States, 4 areas[8]	General population	M+F	1992-1993	5.0	2	906	148	40-69
IWHS	[74]	North America	United States, Iowa	Community based	F	1986	13.2	1	36839	3281	55-69
JACC	[75]	Asia	Japan	Community based	M+F	1988-1990	5.0	1	16160	396	40-79
J-ECOH	[76]/[77]	Asia	Japan	Employees	M+F	2008-2010	3.9	2	53930	2441	15-83
JHS	[78]	North America	United States, Mississippi	General population, Black	M+F	2000-2004	8.0	2	2991	479	21-84
JPHC	[79]	Asia	Japan	General population	M+F	1990	10.0	1	28893	1183	40-59
JPHC2	[80]	Asia	Japan	General population	M+F	1995-1998	5.0	1	59834	1100	45-74
KANGBUK	[81]	Asia	South Korea, Seoul	Individuals undergoing health screening	M+F	2002	5.6	3	174314	5544	18+
KAWAHA	[82]	Asia	Japan, Kitakyushu City	City workers	M+F	2008	3.7	2	52781	4369	20-89
KAWAKA	[83]	Asia	Japan, electrical company	Employees of large electrical company	M	1984	8.0	2	2312	41	18-53
KMIC	[84]	Asia	South Korea	Government and school employees	M	1990-1986	8.0	2	27635	1170	35-44
KoGES-K	[85]/[86]	Asia	South Korea, Kangwha	Community based	M+F	2006-2011	4.0	2	2079	142	40+
KORA F4/FF4	[87]	Europe	Germany, Augsburg	General population	M+F	2006-2008	7.0	2	504	76	62-81
KORA S4/F4	[88]	Europe	Germany, Augsburg	General population	M+F	1999-2001	7.0	2	887	93	55-74
KPNW	[89]	North America	United States, Portland	Health care members	M+F	1997-2000	6.8	2	46578	1854	40+
LEICESTER	[90]	Europe	England, Leicester	With clinical diagnosis of polycystic ovary syndrome	F	1988-2009	5.2	2	2164	138	16-79
LIETO	[91]	Europe	Finland, Leito	General population	M	1998-1999	9.0	2	430	30	64+
LINDBE	[92]	Europe	Denmark, Copenhagen	General population	M+F	2001-2003	8.5	2	5349	136	20-94
LLP	[93]	Europe	England, Liverpool	General population	M+F	1998-2008	10.0	2	8753	763	45-79
MAILES	[94]	Oceania	Australia, Adelaide	General population	M	2002-2006	4.9	3	1597	232	35-80
MANSON	[95]	North America	United States	Physicians in randomized trial	M	1982	12.0	1	21068	770	40-84

MECC	[96]	North America	United States, Hawaii and California	General population, African American and Latino	M+F	1993-1996	14.0	3	48995	15833	50-75
MECH	[97]	North America	United States, Hawaii	General population, Caucasian, Hawaiian, Japanese, American	M+F	1993-1996	12.1	3	74970	8559	45-75
MESA	[98]/[99]	North America	United States, 6 states[9]	General population, White, Black, Hispanic or Chinese	M+F	2000-2002	10.2	2	5931	359	45-84
MFH	[10]	Europe	Finland	General population	M+F	1978-1980	10.0	2	4517	145	40-79
MJH	[100]	Asia	Taiwan (China)	Paid members of private health screening program, Chinese	M+F	2001-2014	6.7	3	147908	4781	18+
MONI-CAG	[101]	Europe	Germany, Augsburg	General population	M+F	1984-1995	12.5	3	10892	672	25-74
MONI-CAS	[102]	Europe	Sweden, Northern	General population	M	1986-1994	8.7	3	1275	27	25-74
MORIMO	[103]/[104]	Asia	Japan, Nagano prefecture	Volunteers in Nagano Prefecture	M+F	1990-1992	10.1	3	5872	595	40-69
MOZAFF	[105]	North America	United States, 4 states[10]	Ambulatory, noninstitutionalized subjects	M+F	1989-1992	10.0	2	4883	337	65+
MPBB	[106]	North America	United States, Michigan	Subjects who had injected food contaminated with polybrominated biphenyls, 99.8% White	M+F	1976	25.0	3	1384	180	20+
MPP	[9]	Europe	Sweden, Malmo	General population	M+F	1974-1992	24.8	2	16061	2063	Any
MUTUAL	[107]	Asia	Japan	Civil servants	M+F	2000	6.5	2	5848	287	30-59
MYHUS	[108]	Asia	Japan	Employees	M+F	2004	5.0	3	13700	408	36-55
NAGALA	[109]/[110]	Asia	Japan, Gifu	Subjects receiving medical check-ups	M+F	2004-2015	5.1	3	17810	804	Any
NAGAYA	[111]	Asia	Japan, Nagoya	Volunteer attendants of annual health check ups	M	1988-1990	7.4	3	16829	869	30-59
NAKANI	[112]	Asia	Japan, Osaka	Employees	M	1994	5.0	2	1266	54	35-59
NCDS	[113]	Europe	Britain	Birth cohort from March 1958	M+F	1974	17.0	1	4945	28	16
NHANES	[114]	North America	United States	General population	M+F	1971-1975	18.0	3	4830	443	25-74

NHIC	[115]	Asia	South Korea	Recipients of biennial medical check-ups	M+F	1992-1995	14.0	2	1236443	89422	30-95
NHIS-HEALS	[116]	Asia	South Korea	Recipients of national health screen test	M+F	2002-2003	10.8	2	359349	37678	40-79
NHIS-NCS	[117]	Asia	South Korea	Nationally represen-tative	M+F	2002	6.8	2	51405	2749	20+
NHS	[118]	North America	United States	Registered Nurses	F	1976-1982	24.0	3	100526	5392	30-55
NHSII	[13]	North America	United States	Registered Nurses	F	1989-1991	23.0	3	88086	5441	25-42
NIH - AARP	[119]	North America	United States, 6 states[11]	General population	M+F	1995-1996	11.0	1	207479	18000	50-71
NOMAS	[120]	North America	United States, North Manhattan	General population, White, Black or Hispanic	M+F	1993-2001	11.0	3	2430	449	40+
NOVAK	[121]	Europe	Sweden, Gothen-burg	General population (interven-tion group in ineffective trial)	M	1970-1973	35.0	2	6828	899	47-56
OLMS-TED	[122]	North America	United States, Rochester	General population who also took at least one medication	M+F	1999-2004	6.0	2	13508	1182	18+
ONAT	[123]	Asia	Turkey	Partici-pants in nationwide survey	M+F	1997-1998	5.9	3	3385	216	28+
OSAKA	[124]	Asia	Japan, Osaka	General population undergoing basic health check-ups	M+F	2001	4.0	2	9327	171	40-74
OSLO	[125]	Europe	Norway, Oslo	General population	M	1972-1973	28.0	3	6382	584	40-49
OSTENS	[126]	Europe	Sweden, Stockholm	General population	M	1992-1994	10.0	2	2383	99	35-56
PARK	[127]	Asia	South Korea, not known	Under-going health examina-tions	M	2002	4.0	2	1717	50	Any
PATJA	[128]	Europe	Finland, North Karelia and Kuopio	General population	M+F	1972-1992	21.0	2	41372	2770	25-64
PINGLIANG	[129]	Asia	China, Ping Liang	General population pre-diabetic at baseline	M+F	2002-2003	10.8	2	334	98	Any
PMMJS	[130]	Asia	China, Jiangsu	General population	M+F	2000-2004	5.0	2	3598	160	35-74

PREDI-MED	[11]	Europe	Spain, Navarra, Reus and Barcelona	Partici-pants in clinical trial on Mediter-ranean diet, Caucasian	M+F	2003-2009	4.8	2	1381	155	55-80
PREDI-MERC	[131]	Europe	Spain, Madrid	General population	M+F	2007	6.4	2	2048	44	30-74
PRE-VEND	[132]	Europe	Nether-lands, Groningen	General population	M+F	1997-1998	11.4	3	7953	447	Any
REGA-RDS	[133]	North America	United States	General population, Black or White	M+F	2003-2007	9.5	2	7758	891	45+
SABE	[134]	South America	Brazil, Sào Paulo	General population	M+F	2000	6.0	1	914	72	60+
SAIREN	[135]	Asia	Japan, Ibaraki-ken	General population undergoing annual health check-ups	M+F	1993	5.0	2	128141	7990	40-79
SALSA	[136]	North America	United States, Sacramento	General population, Latino	M+F	1998-1999	10.0	3	782	144	60+
SAM-SUNG	[137]	Asia	South Korea, Seoul	Under-going health examina-tions, Korean	M	2006	6.0	3	1774	180	20+
SAPA-LDIA	[138]	Europe	Switzer-land	General population	M+F	2002	8.3	3	2631	110	18+
SAWADA	[139]	Asia	Japan, Tokyo	Employees of Tokyo Gas Company	M	1985	14.0	3	4745	280	20-41
SAX45	[140]	Oceania	Australia, New South Wales	General population	M+F	2006-2008	3.4	1	54997	888	45+
SCCS	[14]	North America	United States, Southern	General population, Black or White	M+F	2002-2009	4.5	1	35892	3439	40-79
SCCS2	[14]	North America	United States, Southern	General population, Black or White	M+F	2012[12]	3.0	1	20712	1708	43-82
SHFS	[141]	North America	United States, 4 states[13]	Members of multiplex families, American Indians	M+F	2001-2003	5.5	2	431	133	14+
SHIP	[142]	Europe	Germany, Augsburg	Caucasian German citizens	M+F	1997-2001	11.1	2	2034	206	20-81
SMHS	[143]	Asia	China, Shanghai	General population	M	2002-2006	5.4	3	51464	1304	40-74
STILLW	[144]	Europe	Finland	Employees of Finnish Company	M	1986	17.0	2	5827	313	18-65
STRAND	[145]	Europe	Finland, Helsinki	Volunteer executives and busines-smen	M	1974-1975	20.0	3	1802	94	40-56

STRING	[146]/[147]	Europe	England, London	Civil service employees	M+F	1985-2002	23.7	2	8270	1286	50
SUGIMO	[148]	Asia	Japan, Tokyo	Partici-pants in MHTS	M+F	1976	16.0	2	2573	296	18-69
SULA-WESI	[149]	Asia	Indonesia, South Sulawesi	Three tribes	M+F	2013	3.0	2	182	58	16+
SWAN	[150]	North America	United States, Michigan	Partici-pants in study of menopause transition, Black or White	F	1996	16.0	3	424	157	42-52
TCS	[151]	Asia	Thailand	Students at Sukothai Thammi-thirat Open University	M+F	2005	8.0	1	39507	698	15-88
TERATA	[152]	Asia	Japan, Chiba	Steel-workers	M	2002	8.0	2	8423	464	Any
TLSA	[153]	Asia	Taiwan (China), Non-aboriginal areas	Partici-pants in ongoing survey on aging, Taiwanese	M+F	1999	4.0	1	2995	277	53+
TOPICS6	[154]	Asia	Japan, Toranomon	Govern-ment employees and some general population	M+F	1997-2002	5.0	3	7654	289	40-75
TROMSO	[155]	Europe	Norway, Tromsø	General population	M+F	1994-1995	10.8	3	26168	522	25-98
UCHIMO	[156]	Asia	Japan, Osaka	Employees of large company	M	1981-1991	10.0	2	6250	450	35-60
VETE-RAN	[157]	North America	United States	Veterans	M+F	2002-2003	4.0	2	239057	33453	18-99
VIP	[158]	Europe	Sweden, Västerbo-tten County	General population	M+F	1990-2012	9.9	3	32120	2211	35-55
WHI	[159]	North America	United States	Postmenop ausal women in a clinical trial or an observa-tional study	F	1993-1998	11.0	1	135906	15076	50-79
YOUNGF	[160]	Europe	Finland	Population based	M+F	1980	24.0	3	2298	79	3-18
ZUT-PHEN	[161]	Europe	Nether-lands, Zutphen	General population	M	1960	25.0	2	841	58	40-59

[1]Where relevant, characteristics are shown for the main reference, given first in the column Main/Other Ref.
[2]If location not stated, then national.
[3]All races are included unless stated otherwise.
[4]NA means not available. Some studies provided results for more than one follow-up time. Here the longest follow-up is indicated. The follow-up times are presented as means, medians or averages to various numbers of decimal places. The values shown are the best estimate available.
[5]1 = self-report only; 2 = medical records only; 3 = both.
[6]Studies HPFUS, NHS and NHSII.
[7]France, Italy, Spain, United Kingdom, Netherlands, Germany, Sweden and Denmark.
[8]Los Angeles, Oakland, San Antonio and San Juis Valley.
[9]Maryland, Illinois, North Carolina, California, New York and Minnesota.
[10]North Carolina, California, Maryland and Pennsylvania.
[11]California, Florida, Louisiana, New Jersey, North Carolina and Pennsylvania.
[12]Subset of SCCS who were diabetes free at end of SCCS follow-up. Unclear what the baseline date range of SCCS2 actually was.

[13]Arizona, North and South Dakota and Oklahoma. M: Male; F: Female.

estimate for current *vs* never smoking. As for current smoking, there was limited evidence of publication bias ($0.01 < P < 0.05$).

Table 3 also presents the overall random-effects estimate for current *vs* non-smoking, as well as a breakdown of the estimates by different factors (see also Supplementary file 4). As for current *vs* never smoking, the random-effects estimate was elevated in all subdivisions of the data, significantly so except where based on very few estimates. There was little evidence of variation in the RR in subdivisions of the data by level of the various factors studied, the most notable exceptions being the somewhat higher estimate in studies adjusted rather than unadjusted for family history of diabetes, and the variation by continent.

Table 4 (and Supplementary file 5) summarizes the results of the dose-response analysis for current *vs* non-smoking. As for current *vs* never smoking, there was clear evidence that risk rises with amount smoked, whichever dose-response grouping is used.

Forest and funnel plots for the analysis subdivided by sex are shown in Supplementary file 6.

Former *vs* never smoking: There were 100 RR estimates from 81 studies for the comparison of former *vs* never smoking. Nineteen provided estimates for both sexes, seven for females only, 17 for males only and 38 for sexes combined.

Of the 100 estimates, 18 were below 1, 7 were above 2, with the remaining 75 in the range 1 to 2. The overall fixed-effect estimate was 1.09 (95%CI: 1.08-1.10), with highly significant heterogeneity (Chisq. 263.6 on 99 df, $P < 0.001$, $I^2 = 62.4\%$). The random-effects estimate was 1.13 (95%CI: 1.11-1.16). Somewhat stronger evidence of publication bias ($0.001 < P < 0.01$) was seen than for current smoking.

Table 5 presents the overall random effects estimate, together with a breakdown of the estimates by different factors (see also Supplementary file 7). There was no strong evidence ($P < 0.01$) of variation in the RR by level of any factor, with estimates slightly elevated in all subgroupings except where based on very few estimates.

Table 6 (and Supplementary file 8) summarizes the results of the dose-response analysis for former *vs* never smoking. These showed clear evidence that the RR declined with increasing time since quitting.

Again, forest and funnel plots are shown in Supplementary file 6.

Ever *vs* never smoking: One hundred RRs were available from 82 studies. The overall fixed-effect RR estimate was 1.17 (95%CI: 1.16-1.18) with evidence of considerable heterogeneity (Chisq. 897.37 on 99 df, $P < 0.001$, $I^2 = 89.0\%$), the random-effect estimate being 1.25 (95%CI: 1.21-1.28). There was some evidence of publication bias ($0.001 < P < 0.01$). RRs were generally elevated in all subgroups, the strongest evidence of variation by any factor ($P < 0.001$) relating to adjustment for education, unadjusted estimates (RR = 1.29, 95%CI: 1.24-1.34) being higher than adjusted ones (RR = 1.17, 95%CI: 1.12-1.21). There was also weaker evidence ($P < 0.05$) that RRs were somewhat higher in Asia, and somewhat lower in populations with a baseline upper age limit of 75 or more, or if the RRs were unadjusted for glucose. See Table 8 and Supplementary File 9 for fuller details.

Only one of the studies provided information on risk by amount smoked, so no dose-response meta-analyses were possible.

Again, forest and funnel plots are shown in Supplementary file 6.

Ratio of RRs for highest to lowest BMI groupings: Six studies provided results by level of BMI, three of these giving results for each sex separately. One study provided data only for current *vs* never and former *vs* never smoking, while the others also provided data for current *vs* non-smoking and ever *vs* never smoking. None of the meta-analyses provided any evidence of variation in RR by level of BMI, the random effects meta-analysis estimate of the highest to lowest ratio being 1.20 (95%CI: 0.92-1.57) for current *vs* never smoking, 1.06 (95%CI: 0.82-1.36) for current *vs* non-smoking, 1.12 (0.95-1.32) for former *vs* never smoking, and 1.03 (95%CI: 0.87-1.23) for ever *vs* never smoking, based on, respectively, 9, 7, 9 and 7 estimates. (See Supplemen-tary file 10).

Supplementary files

Supplementary file 1 gives further details of the literature search, including a list of the 42 publications rejected during data entry, giving the reasons for rejection, and a description of how multiple publications from a study were dealt with.

Supplementary Files 2, 4, 7 and 9 give full details of the results for the main

Table 3 Meta-analysis random effect relative risks for current smoking

Grouping[1]		Current *vs* never smoking			Current *vs* non-smoking		
		n[2]	RR (95%CI)	*P*	*n*	RR (95%CI)	*P*
Overall		99	1.33 (1.28-1.38)	$P < 0.001$, $P < 0.05$	156	1.28 (1.24-1.32)	$P < 0.001$, $P < 0.05$
Sex	Female	25	1.30 (1.23-1.37)		31	1.26 (1.21-1.31)	
	Male	36	1.40 (1.32-1.49)		47	1.30 (1.24-1.36)	
	Combined	38	1.28 (1.18-1.39)	NS[3]	78	1.26 (1.18-1.34)	NS
Continent	Asia	44	1.36 (1.30-1.43)		57	1.36 (1.29-1.43)	
	Europe	32	1.34 (1.27-1.42)		60	1.25 (1.20-1.30)	
	North and South America	19	1.27 (1.18-1.37)		34	1.18 (1.12-1.25)	
	Oceania	4	1.05 (0.68-1.62)	NS	5	1.54 (1.28-1.85)	$P < 0.001$
Publication year	Up to 2005	13	1.41 (1.27-1.56)		23	1.24 (1.16-1.33)	
	2005-2014	47	1.36 (1.30-1.43)		66	1.31 (1.27-1.35)	
	2015 or later	39	1.27 (1.20-1.35)	NS	67	1.23 (1.17-1.30)	NS
Basis of diagnosis	Self-report only	12	1.32 (1.25-1.40)		17	1.34 (1.25-1.44)	
	Medical records only	49	1.32 (1.25-1.38)		86	1.29 (1.23-1.34)	
	Both	38	1.36 (1.27-1.46)	NS	53	1.24 (1.17-1.32)	NS
Population	General	93	1.32 (1.28-1.37)		147	1.28 (1.24-1.32)	
	Pre-diabetics only	2	3.29 (1.51-7.21)		3	1.23 (0.79-1.90)	
	Pre-diabetics excluded	4	1.61 (1.30-1.99)	$P < 0.05$	6	1.38 (1.15-1.67)	NS
Number of adjustment factors	0	17	1.15 (1.00-1.33)		33	1.19 (1.08-1.31)	
	1 to 5	18	1.36 (1.25-1.47)		30	1.38 (1.27-1.51)	
	6 to 10	43	1.40 (1.32-1.48)		64	1.29 (1.25-1.33)	
	11 or more	21	1.28 (1.20-1.37)	$P < 0.05$	29	1.22 (1.15-1.30)	$P < 0.1$
Cohort size	< 5000	35	1.36 (1.19-1.56)		58	1.31 (1.20-1.42)	
	5000 to 20000	20	1.38 (1.25-1.53)		43	1.24 (1.17-1.32)	
	> 20000	44	1.32 (1.26-1.37)	NS	55	1.29 (1.24-1.35)	NS
Number of type 2 diabetes cases	< 500	44	1.37 (1.23-1.52)		78	1.27 (1.19-1.35)	
	500-999	18	1.50 (1.34-1.67)		24	1.40 (1.27-1.55)	
	1000-2000	10	1.26 (1.15-1.38)		17	1.20 (1.11-1.30)	
	2001+	27	1.29 (1.22-1.35)	$P < 0.1$	37	1.26 (1.20-1.33)	NS
Highest age at baseline	< 60	13	1.36 (1.23-1.51)		22	1.24 (1.16-1.32)	
	60-74	27	1.44 (1.32-1.56)		38	1.36 (1.27-1.45)	

	75+	59	1.29 (1.24-1.35)	$P < 0.1$	96	1.26 (1.21-1.31)	NS
Length of follow-up (yr)	< 5	14	1.27 (1.19-1.35)		25	1.24 (1.15-1.34)	
	5-10	55	1.38 (1.30-1.47)		81	1.34 (1.28-1.40)	
	> 10	30	1.31 (1.22-1.39)	NS	50	1.22 (1.17-1.28)	$P < 0.05$
Definition of smoking	Cigarette	47	1.32 (1.27-1.38)		63	1.25 (1.21-1.29)	
	Smoking	50	1.36 (1.26-1.46)		89	1.30 (1.23-1.37)	
	Tobacco	2	1.10 (0.94-1.29)	$P < 0.1$	4	1.16 (1.06-1.27)	$P < 0.1$
Adjusted for age	No	20	1.17 (1.04-1.32)		41	1.22 (1.12-1.33)	
	Yes	79	1.35 (1.31-1.41)	$P < 0.05$	115	1.29 (1.25-1.33)	NS
Adjusted for sex	No	72	1.35 (1.29-1.41)		107	1.27 (1.23-1.32)	
	Yes	27	1.29 (1.20-1.39)	NS	49	1.29 (1.20-1.38)	NS
Adjusted for BMI	No	29	1.24 (1.11-1.38)		55	1.22 (1.13-1.32)	
	Yes	70	1.35 (1.30-1.41)	NS	101	1.30 (1.26-1.34)	NS
Adjusted for physical activity	No	41	1.27 (1.20-1.35)		87	1.27 (1.21-1.33)	
	Yes	58	1.36 (1.30-1.43)	$P < 0.1$	69	1.28 (1.23-1.33)	NS
Adjusted for alcohol consumption	No	42	1.26 (1.19-1.34)		87	1.26 (1.20-1.32)	
	Yes	57	1.37 (1.31-1.43)	$P < 0.05$	69	1.29 (1.25-1.33)	NS
Adjusted for family history of diabetes	No	61	1.28 (1.22-1.35)		99	1.23 (1.17-1.29)	
	Yes	38	1.41 (1.33-1.49)	$P < 0.05$	57	1.34 (1.29-1.40)	$P < 0.01$
Adjusted for education	No	63	1.37 (1.31-1.44)		115	1.29 (1.24-1.35)	
	Yes	36	1.28 (1.21-1.34)	$P < 0.05$	41	1.23 (1.18-1.28)	$P < 0.1$
Adjusted for diet	No	74	1.35 (1.29-1.41)		126	1.29 (1.24-1.34)	
	Yes	25	1.30 (1.22-1.38)	NS	30	1.23 (1.18-1.28)	$P < 0.1$
Adjusted for blood pressure	No	53	1.31 (1.24-1.40)		88	1.27 (1.21-1.34)	
	Yes	46	1.35 (1.29-1.41)	NS	68	1.28 (1.24-1.33)	NS
Adjusted for cholesterol	No	72	1.30 (1.25-1.35)		115	1.26 (1.22-1.31)	
	Yes	27	1.40 (1.32-1.48)	$P < 0.05$	41	1.32 (1.25-1.39)	NS
Adjusted for glucose	No	79	1.30 (1.25-1.35)		116	1.26 (1.22-1.31)	
	Yes	20	1.44 (1.35-1.54)	$P < 0.01$	40	1.34 (1.27-1.41)	NS
Adjusted for triglycerides	No	80	1.30 (1.25-1.36)		124	1.27 (1.22-1.31)	
	Yes	19	1.45 (1.33-1.58)	$P < 0.05$	32	1.34 (1.24-1.44)	NS
Adjusted for waist circumference	No	82	1.34 (1.29-1.40)		136	1.28 (1.24-1.32)	
	Yes	17	1.29 (1.19-1.41)	NS	20	1.25 (1.16-1.35)	NS

Adjusted for any other factors	No	37	1.30 (1.19-1.42)		62	1.28 (1.18-1.38)	
	Yes	62	1.34 (1.29-1.40)	NS	94	1.27 (1.23-1.30)	NS

[1]For sex, publication year, basis of diagnosis, number of adjustment factors, definition of smoking and age adjusted the grouping relates to characteristics of the relative risk. For other factors it relates to characteristics of the study.
[2]Number of estimates combined.
[3]NS means not significant, $P \geq 0.1$. For the overall analysis, the first P value relates to heterogeneity between estimates and the second to publication bias. For the other analyses it relates to a test of heterogeneity between the random-effects estimates at each level. Information on publication bias by level of each factor studied is given in Supplementary Files 2 and 4. NS: Not significant; CI: Confidence interval; RR: Relative risk.

analysis of, respectively, current *vs* never smoking, current *vs* non-smoking, former *vs* never smoking and ever *vs* never smoking. Each file is laid out similarly. Introductory pages describe the content and layout of the output, and explain the abbreviations used and the decisions made where multiple results were available for a single study. Table 1 of each Supplementary File then gives details of each candidate RR selected from the main and subsidiary publications for each study, while Table 2 of each file gives details of the RRs actually used in the analyses, and Tables 3-27 of each file give full results of the meta-analyses subdivided by each of the 25 factors considered (sex, continent, *etc*.).

Supplementary Files 3, 5 and 8 give full details of the dose-response analysis of respectively, current *vs* never smoking (by amount smoked), current *vs* non- smoking (by amount smoked) and former *vs* never smoking (by year quit). Each file includes separate blocks of description and results, similar to those for Supple-mentary Files 2, 4 7 and 9 , but only including Tables 1-3 of those files, with Table 3 only showing results subdivided by sex. Each block relates to a specific dose-response level (*e.g*., about 10 for amount smoked).

Supplementary file 6 presents forest and funnel plots for current *vs* non-smoking, former *vs* never smoking and ever *vs* never smoking, similar to those shown in Figures 1-6 of the paper for current *vs* never smoking.

Supplementary file 10 gives the results of meta-analyses of ratios of relative risks for the highest to lowest BMI groupings available.

DISCUSSION

According to the United States National Institute of Diabetes and Digestive and Kidney Diseases Health Information Center[162], risk factors for type 2 diabetes include overweight/obesity, age, a family history of diabetes, high blood pressure, low high-density lipoprotein cholesterol, high triglycerides, a history of gestational diabetes, giving birth to a baby weighing 9 pounds or more, physical inactivity, a history of heart disease or stroke, as well as being in certain ethnic groups or having certain diseases. Smoking is not mentioned as a risk factor.

The meta-analyses we conducted indicate a modest relationship of smoking to risk of type 2 diabetes. This can be seen for current smoking (whether compared with never or non-smokers), former smoking and ever smoking. While there was clear evidence of heterogeneity in the RRs, the random-effects RRs showed increased risks in males and females, in younger and older subjects, in all continents studied, regardless of the basis of diagnosis, and regardless of the definition of smoking used. Despite the evidence of heterogeneity between the individual estimates, a striking feature of the results presented in Tables 3 and 5 was the fact that the estimates were elevated in virtually every subdivision of the data, whichever factor the subdivision was based on. There was also clear evidence (see Tables 4 and 6) of an increasing risk with increasing amount smoked by current smokers and of decreasing risk with increasing time quit by former smokers. Though there was some evidence of variation in risk by level of some factors, this did not suggest that the elevation in risk was unique to some populations or could be explained by adjustment for specific confounding variables. Nor did the fact that some studies did not report an elevation affect the overall conclusion. With a relatively weak association (with RRs about 1.3 for current smoking and about 1.13 for former smoking) it might be expected that some smaller studies would not detect an elevated risk. However, this did not affect the overall conclusion. Indeed, it was notable that, of the 12 RR estimates for current *vs* never smoking that were below 1.0, only one was statistically significant (at $P < 0.05$), whereas, of the 87 estimates above 1.0, as many as 63 were.

Given the weight of evidence from this review and others, smoking may be a contributory factor to type 2 diabetes. Publication bias, for which some evidence was

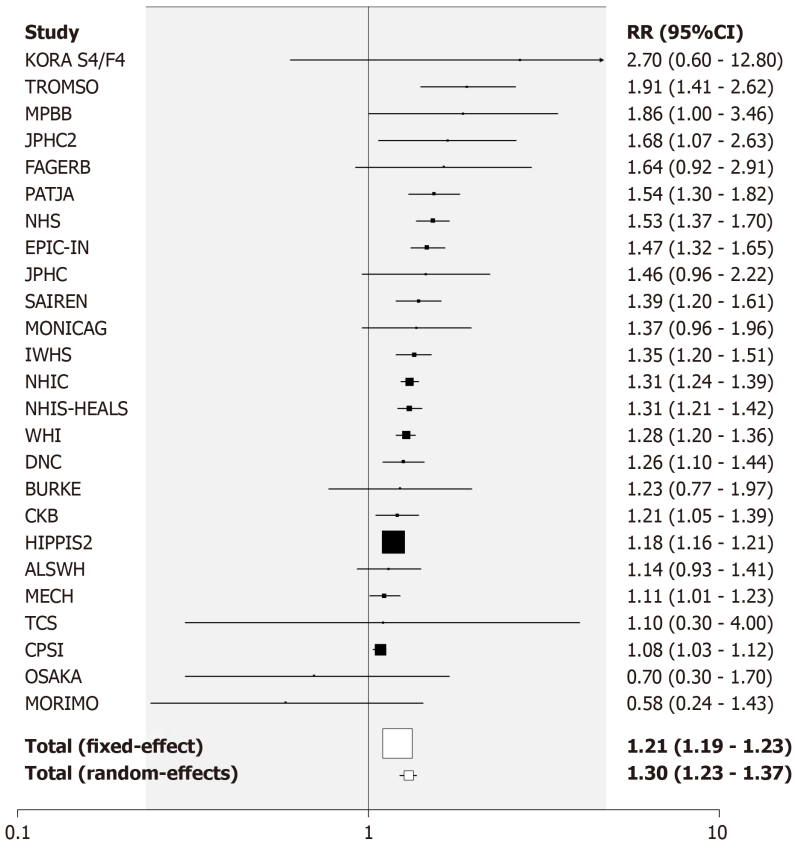

Figure 1 Forest plot for current *vs* never smoking, results for females. For each selected relative risk (RR), the figure shows the study ref. (see Table 2) and the RR and 95% confidence interval, both numerically and plotted as a line on a log scale from 0.1 to 10. The RRs are plotted from highest to lowest, with the RR estimate shown in the centre of the line as a square, with area proportional to the weight of the estimate. Lines showing RRs with wide confidence intervals may be truncated, as indicated by an arrow head at the truncated end. Also shown are the overall fixed-effect and random-effects estimates. The vertical line is at RR = 1 with an increased risk indicated by a preponderance of squares to its right. RR: Relative risk; CI: Confidence interval.

detected, might have led to some over-estimation of the association, due to some studies finding no relationship not presenting their results. Bias due to misclassification of smoking status would only tend to bias the observed relationship down, not produce an association that did not truly exist. Failure to control properly for diet, BMI or related factors would not seem to be an explanation of the association as elevated risks were seen in studies that adjusted for these factors. That said, it is clear from Table 3 that many of the studies did not adjust for various factors listed in the first paragraph of the discussion, so that the association seen between smoking and type 2 diabetes may have suffered from uncontrolled confounding to some extent.

This review has limitations, some unavoidable. Lack of access to individual person data limited the detail of the meta-analyses that can be carried out, but obtaining such data was not practical. Obtaining a reliable definition of outcome, exposure and adjustment variables was sometimes hindered by incomplete information in the source papers. Some studies involved relatively few type 2 diabetes cases, but associations were evident both in studies with small and large numbers. It is possible that our analyses did not make full use of all the data collected, but this is inevitable in a paper of reasonable length. We would be willing to make our database available to bona fide researchers for further analysis.

Our results are consistent with those of the earlier review by Pan *et al*[1] based on 88 prospective studies. Although our analyses were based on a considerably larger number of studies, 145, our estimated random-effect RRs of 1.33, 1.28 and 1.13 for current *vs* never, current *vs* non, and former *vs* never smoking were similar to their corresponding estimates of 1.40, 1.35 and 1.14. Like us, they also found dose-response relationships with amount smoked and years since quitting. The interested reader is referred to that paper for further discussion of limitations of the data and interpretation of the results.

That paper refers to "the high prevalence of smoking in many countries and the

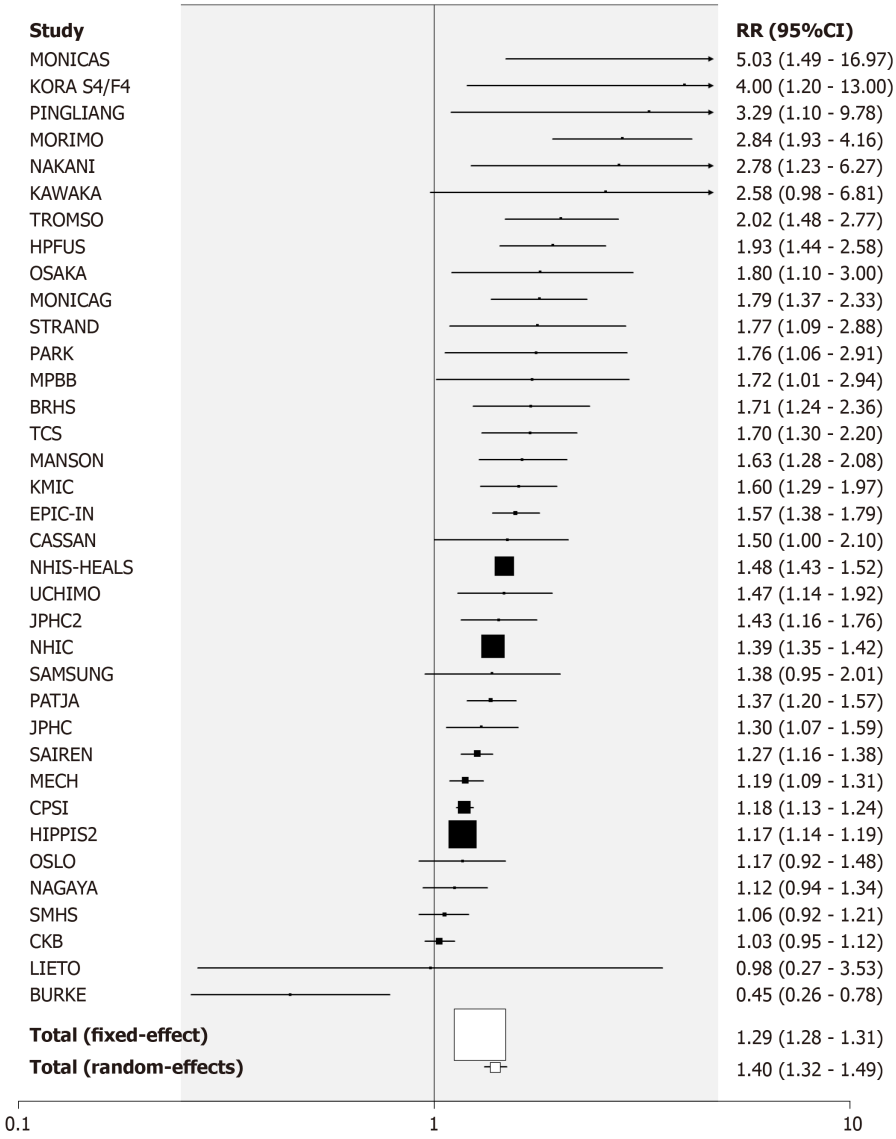

Figure 2 Forest plot for current *vs* never smoking, results for males. For each selected relative risk (RR) the figure shows the study ref. (see Table 2) and the RR and 95% confidence interval, both numerically and plotted as a line on a log scale from 0.1 to 10. The RRs are plotted from highest to lowest, with the RR estimate shown in the centre of the line as a square, with area proportional to the weight of the estimate. Lines showing RRs with wide confidence intervals may be truncated, as indicated by an arrow head at the truncated end. Also shown are the overall fixed-effect and random-effects estimates. The vertical line is at RR = 1 with an increased risk indicated by a preponderance of squares to its right. RR: Relative risk; CI: Confidence interval.

increasing number of diabetes worldwide" and considers that "reducing tobacco use should be prioritized as a key public health strategy to prevent and control global epidemic of diabetes". Though reduction of smoking is clearly important to limit a range of diseases such as lung cancer, chronic obstructive pulmonary disease and cardiovascular disease, one must question this prioritization, in the light of the range of other risk factors for type 2 diabetes noted above, and the evidence that diabetes incidence is rising fast worldwide[56], while smoking is declining[2]. As a strategy, controlling diet may be much more beneficial. The work of Taylor *et al*[163] suggests that, in many people, type 2 diabetes can be completely reversed quite rapidly by appropriate diet and weight loss.

In conclusion, the analyses confirm earlier reports of a modest dose-related association of current smoking and a weaker dose-related association of former smoking with risk of type 2 diabetes.

Table 4 Dose-response analyses for current smoking

Grouping[1]	Current *vs* never smoking		Current *vs* non-smoking	
	n[2]	RR (95%CI)	*n*	RR (95%CI)
Using key values:				
About 10 cigs/d	13	1.10 (1.03-1.18)	13	1.04 (0.98-1.10)
About 20 cigs per d	13	1.31 (1.19-1.44)	13	1.27 (1.16-1.39)
About 40 cigs per d	13	1.55 (1.39-1.72)	13	1.54 (1.37-1.72)
Low	23	1.17 (1.11-1.23)	22	1.13 (1.07-1.19)
Medium	23	1.30 (1.22-1.39)	22	1.26 (1.18-1.34)
High	23	1.53 (1.41-1.65)	22	1.48 (1.37-1.60)
1-19 cigs/d	18	1.32 (1.20-1.45)	17	1.20 (1.10-1.30)
20+	18	1.58 (1.42-1.76)	17	1.44 (1.31-1.59)

[1]The key value analysis is based on all studies which provide estimates for each key value (*i.e.*, for a range which included the key value and no other key value). The low/medium/high analysis is based on all studies which provide estimates for exactly three levels. The 1-19, 20+ analysis is based on those studies which reported results only for these two levels.
[2]Number of estimates combined. CI: Confidence interval; RR: Relative risk.

Table 5 Meta-analysis random effects relative risks for former (*vs* never) smoking

Grouping[1]		*n*[2]	RR (95%CI)	*P*
Overall		100	1.13 (1.11-1.16)	$P < 0.001$, $P < 0.01$
Sex	Female	26	1.13 (1.08-1.18)	
	Male	36	1.12 (1.08-1.16)	
	Combined	38	1.16 (1.09-1.22)	NS[3]
Continent	Asia	44	1.16 (1.10-1.22)	
	Europe	32	1.13 (1.09-1.18)	
	North and South America	20	1.11 (1.07-1.16)	
	Oceania	4	1.07 (0.93-1.23)	NS
Publication year	Up to 2005	13	1.13 (1.06-1.21)	
	2005-2014	47	1.16 (1.11-1.22)	
	2015 or later	40	1.11 (1.08-1.15)	NS
Basis of diagnosis	Self-report only	12	1.17 (1.05-1.29)	
	Medical records only	49	1.11 (1.08-1.13)	
	Both	39	1.16 (1.11-1.22)	$P < 0.1$
Population	General	94	1.13 (1.11-1.16)	
	Pre-diabetics only	2	0.97 (0.08-12.64)	
	Pre-diabetics excluded	4	1.11 (0.86-1.44)	NS
Number of adjustment factors	0	18	1.11 (1.01-1.23)	
	1 to 5	18	1.20 (1.11-1.30)	
	6 to 10	42	1.12 (1.08-1.17)	
	11 or more	22	1.13 (1.09-1.17)	NS
Cohort size	< 5000	35	1.21 (1.11-1.32)	
	5000 to 20000	20	1.19 (1.09-1.29)	
	> 20000	45	1.12 (1.09-1.15)	NS
Number of type 2 diabetes cases	< 500	44	1.21 (1.12-1.30)	
	500 to 999	18	1.11 (1.03-1.20)	
	1000 to 2000	10	1.26 (1.10-1.45)	
	2001+	28	1.11 (1.08-1.14)	$P < 0.1$
Highest age at baseline	< 60	14	1.20 (1.10-1.30)	
	60-74	27	1.19 (1.10-1.29)	
	75+	59	1.11 (1.09-1.14)	NS
Length of follow-up (yr)	< 5	14	1.13 (1.08-1.19)	
	5-10	55	1.16 (1.10-1.23)	

	> 10	31	1.11 (1.08-1.15)	NS
Definition of smoking	Cigarette	48	1.12 (1.09-1.15)	
	Smoking	50	1.15 (1.10-1.21)	
	Tobacco	2	0.95 (0.83-1.08)	$P < 0.05$
Adjusted for age	No	21	1.13 (1.05-1.22)	
	Yes	79	1.13 (1.10-1.16)	NS
Adjusted for sex	No	75	1.13 (1.10-1.16)	
	Yes	25	1.13 (1.07-1.19)	NS
Adjusted for BMI	No	31	1.15 (1.07-1.24)	
	Yes	69	1.12 (1.10-1.15)	NS
Adjusted for physical activity	No	41	1.15 (1.11-1.20)	
	Yes	59	1.12 (1.09-1.16)	NS
Adjusted for alcohol consumption	No	43	1.15 (1.10-1.19)	
	Yes	57	1.13 (1.09-1.16)	NS
Adjusted for family history of diabetes	No	61	1.13 (1.10-1.17)	
	Yes	39	1.13 (1.09-1.17)	NS
Adjusted for education	No	65	1.16 (1.12-1.19)	
	Yes	35	1.09 (1.05-1.14)	$P < 0.05$
Adjusted for diet	No	75	1.14 (1.11-1.17)	
	Yes	25	1.12 (1.07-1.16)	NS
Adjusted for blood pressure	No	54	1.14 (1.10-1.19)	
	Yes	46	1.13 (1.09-1.16)	NS
Adjusted for cholesterol	No	73	1.13 (1.10-1.16)	
	Yes	27	1.14 (1.08-1.20)	NS
Adjusted for glucose	No	80	1.13 (1.10-1.16)	
	Yes	20	1.15 (1.07-1.23)	NS
Adjusted for triglycerides	No	81	1.12 (1.10-1.15)	
	Yes	19	1.17 (1.08-1.27)	NS
Adjusted for waist circumference	No	83	1.13 (1.10-1.16)	
	Yes	17	1.14 (1.05-1.24)	NS
Adjusted for other factors	No	38	1.15 (1.08-1.23)	
	Yes	62	1.13 (1.10-1.15)	NS

[1]For sex, publication year, basis of diagnosis, number of adjustment factors, definition of smoking and age adjusted the grouping relates to characteristics of the RR. For other factors it relates to characteristics of the study.
[2]Number of estimates combined.
[3]NS means not significant, $P \geq 0.1$. For the overall analysis, the first P value relates to heterogeneity between estimates and the second to publication bias. For the other analyses it relates to a test of heterogeneity between the random-effects estimates at each level. Information on publication bias by level of each factor studied is given in Supplementary file 6. CI: Confidence interval; RR: Relative risk; NS: Not significant; BMI: Body mass index.

Table 6 Dose-response analyses for former *vs* never smoking (years quit)

Grouping[1]		*n*[2]	RR (95%CI)
Using key values:	About 3 yr quit	8	1.39 (1.21-1.60)
	About 7 yr quit	8	1.17 (1.07-1.27)
	About 12 yr quit	8	1.11 (1.01-1.22)
Shortest		14	1.46 (1.31-1.63)
Longest		14	1.13 (1.01-1.27)

[1]The key value analysis is based on all studies which provide estimates for each key value (*i.e.*, for a range which included the key value and no other key value). The shortest/longest analysis is based on all studies which provide estimates by years quit.
[2]Number of estimates combined. CI: Confidence interval; RR: Relative risk.

Table 7 Meta-analysis random effects relative risks for ever (*vs* never) smoking

Grouping[1]		*n*[2]	RR (95%CI)	*P*
Overall		100	1.25 (1.21-1.28)	$P < 0.001$, $P < 0.01$
Sex	Female	24	1.25 (1.18-1.31)	
	Male	36	1.25 (0.20-1.31)	
	Combined	40	1.22 (1.14-1.31)	$P < 0.05$
Continent	Asia	41	1.30 (1.25-1.36)	
	Europe	36	1.21 (1.17-1.26)	
	North and South America	20	1.19 (1.13-1.26)	
	Oceania	3	0.87 (0.48-1.57)	$P < 0.05$
Publication year	Up to 2005	13	1.25 (1.16-1.34)	
	2005-2014	47	1.26 (1.20-1.33)	
	2015 or later	40	1.23 (1.18-1.28)	NS[3]
Basis of diagnosis	Self-report only	10	1.35 (1.17-1.56)	
	Medical records only	51	1.22 (1.18-1.27)	
	Both	39	1.26 (1.19-1.33)	NS
Population	General	95	1.24 (1.21-1.28)	
	Pre-diabetics only	1	3.30 (1.24-8.77)	
	Pre-diabetics excluded	4	1.43 (1.17-1.76)	$P < 0.1$
Number of adjustment factors	0	23	1.18 (1.06-1.32)	
	1 to 5	16	1.28 (1.20-1.36)	
	6 to 10	40	1.24 (1.19-1.30)	
	11 or more	21	1.22 (1.16-1.28)	NS
Cohort size	< 5000	39	1.26 (1.14-1.38)	
	5000 to 20000	17	1.27 (1.17-1.38)	
	> 20000	44	1.24 (1.20-1.28)	NS
Number of type 2 diabetes cases	< 500	46	1.26 (1.16-1.36)	
	500 to 999	17	1.32 (1.19-1.47)	
	1000 to 2000	9	1.28 (1.14-1.43)	
	2001+	28	1.22 (1.17-1.26)	NS
Highest age at baseline	< 60	13	1.35 (1.23-1.47)	
	60-74	27	1.32 (1.23-1.41)	
	75+	60	1.21 (1.17-1.25)	$P < 0.05$
Length of follow-up (yr)	< 5	14	1.21 (1.15-1.26)	
	5-10	56	1.29 (1.22-1.35)	
	> 10	30	1.21 (1.15-1.28)	NS
Definition of smoking	Cigarette	48	1.22 (1.18-1.26)	
	Smoking	50	1.28 (1.20-1.36)	
	Tobacco	2	1.09 (0.94-1.25)	$P < 0.1$
Adjusted for age	No	27	1.19 (1.09-1.31)	
	Yes	73	1.24 (1.20-1.28)	NS
Adjusted for sex	No	77	1.26 (1.22-1.30)	
	Yes	23	1.20 (1.13-1.27)	NS
Adjusted for BMI	No	35	1.23 (1.13-1.34)	
	Yes	65	1.24 (1.20-1.28)	NS
Adjusted for physical activity	No	43	1.26 (1.20-1.32)	
	Yes	57	1.24 (1.19-1.29)	NS
Adjusted for alcohol consumption	No	46	1.24 (1.19-1.30)	
	Yes	54	1.25 (1.20-1.30)	NS
Adjusted for family history of diabetes-	No	62	1.22 (1.17-1.27)	
	Yes	38	1.28 (1.23-1.33)	NS
Adjusted for education	No	67	1.29 (1.24-1.34)	
	Yes	33	1.17 (1.12-1.21)	$P < 0.001$
Adjusted for diet	No	76	1.26 (1.22-1.31)	

	Yes	24	1.21 (1.15-1.26)	NS
Adjusted for blood pressure	No	57	1.25 (1.19-1.32)	
	Yes	43	1.23 (1.19-1.27)	NS
Adjusted for cholesterol	No	75	1.24 (1.20-1.28)	
	Yes	25	1.27 (1.19-1.36)	NS
Adjusted for glucose	No	79	1.23 (1.19-1.27)	
	Yes	21	1.31 (1.25-1.37)	$P < 0.05$
Adjusted for triglycerides	No	83	1.23 (1.20-1.27)	
	Yes	17	1.31 (1.22-1.41)	NS
Adjusted for waist circumference	No	84	1.25 (1.21-1.30)	
	Yes	16	1.21 (1.12-1.31)	NS
Adjusted for other factors	No	42	1.24 (1.15-1.33)	
	Yes	58	1.23 (1.20-1.28)	NS

[1]For sex, publication year, basis of diagnosis, number of adjustment factors, definition of smoking and age adjusted the grouping relates to characteristics of the relative risk. For other factors it relates to characteristics of the study.
[2]Number of estimates combined.
[3]NS means not significant, $P \geq 0.1$. For the overall analysis, the first P value relates to heterogeneity between estimates and the second to publication bias. For the other analyses it relates to a test of heterogeneity between the random-effects estimates at each level. Information on publication bias by level of each factor studied is given in Supplementary file 8. CI: Confidence interval; RR: Relative risk; NS: Not significant.

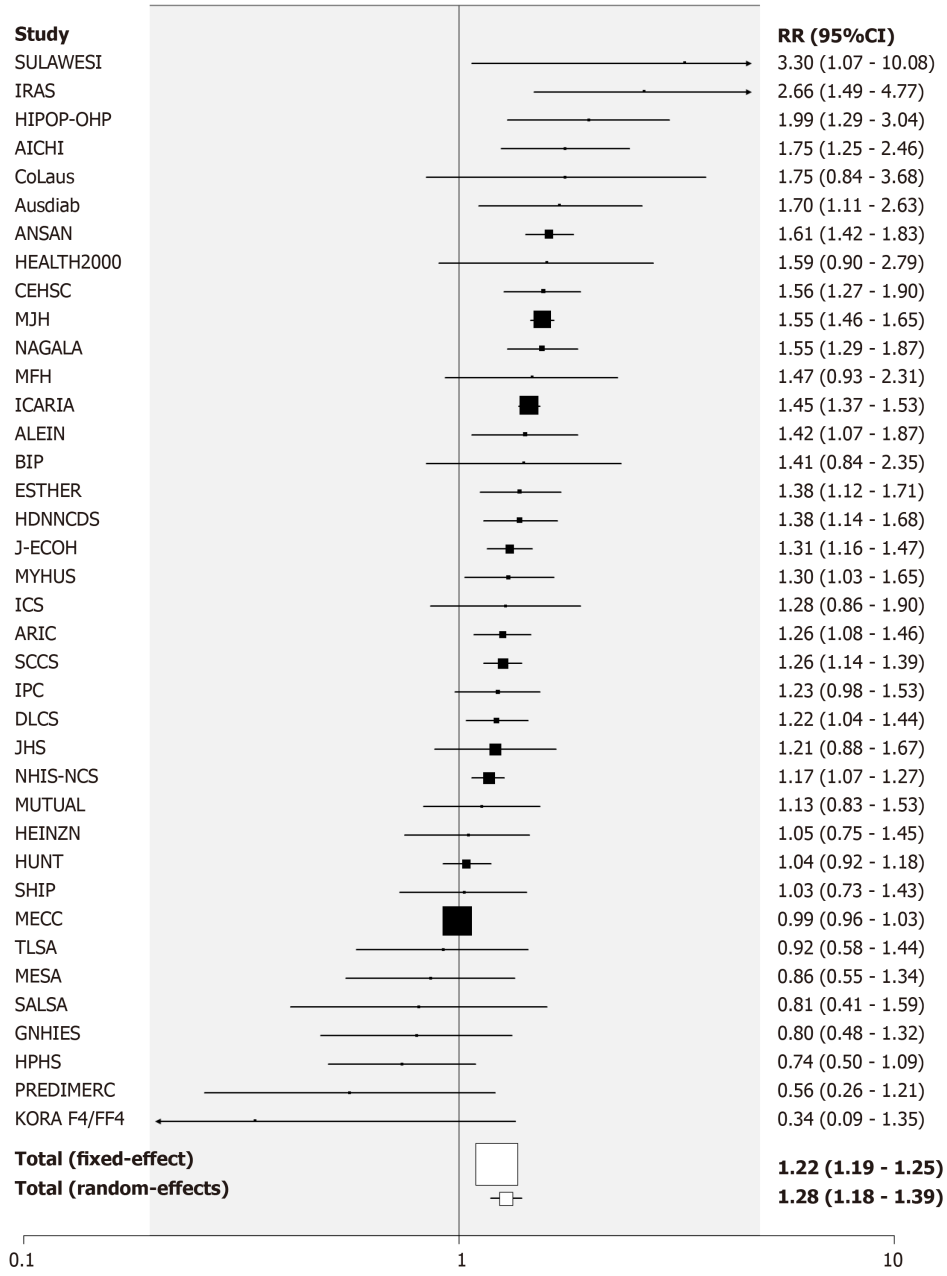

Figure 3 Forest plot for current *vs* never smoking, results for sexes combined. For each selected relative risk (RR), the figure shows the study ref. (see Table 2) and the RR and 95% confidence interval, both numerically and plotted as a line on a log scale from 0.1 to 10. The RRs are plotted from highest to lowest, with the RR estimate shown in the centre of the line as a square, with area proportional to the weight of the estimate. Lines showing RRs with wide confidence intervals may be truncated, this being indicated by an arrow head at the truncated end. Also shown are the overall fixed-effect and random-effects estimates. The vertical line is at RR = 1 with an increased risk indicated by a preponderance of squares to its right. RR: Relative risk; CI: Confidence interval.

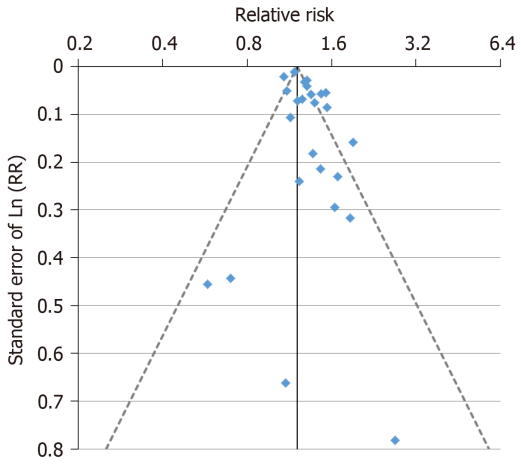

Figure 4 Funnel plot for current *vs* never smoking, results for females. Each of the selected relative risks (RRs) is shown as a diamond, plotted against its value on the x-axis (on a log scale) and the standard error of $\log_e$ RR on the y-axis. The vertical line indicates the overall fixed-effect estimate, while the diagonals indicate where 95% of the values should lie, given the standard error of $\log_e$ RR. Evidence of publication bias is indicated by a tendency for the smaller (high standard error) studies to show larger treatment effects. RR: Relative risk.

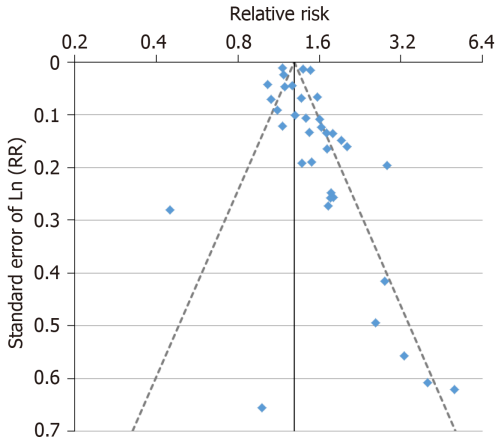

Figure 5 Funnel plot for current *vs* never smoking, results for males. Each of the selected relative risks (RRs) is shown as a diamond, plotted against its value on the x-axis (on a log scale) and the standard error of $\log_e$ RR on the y-axis. The vertical line indicates the overall fixed-effect estimate, while the diagonals indicate where 95% of the values should lie, given the standard error of $\log_e$ RR. Evidence of publication bias is indicated by a tendency for the smaller (high standard error) studies to show larger treatment effects. RR: Relative risk.

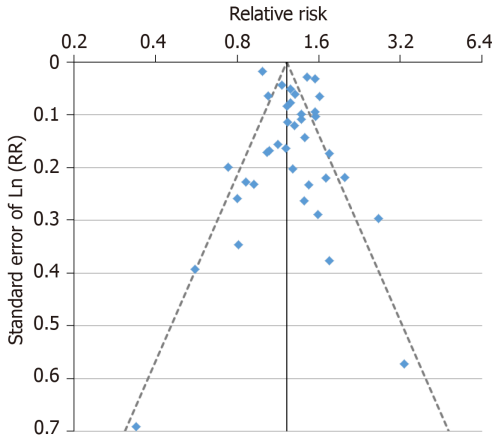

Figure 6 Funnel plot for current *vs* never smoking, results for sexes combined. Each of the selected relative risks (RRs) is shown as a diamond, plotted against its value on the x-axis (on a log scale) and the standard error of $\log_e$ RR on the y-axis. The vertical line indicates the overall fixed-effect estimate, while the diagonals indicate where 95% of the values should lie, given the standard error of $\log_e$ RR. Evidence of publication bias is indicated by a tendency for the smaller (high standard error) studies to show larger treatment effects. RR: Relative risk.

ARTICLE HIGHLIGHTS

Research background

A systematic review of the relationship between smoking and incident type 2 diabetes, based on 88 epidemiological prospective studies, was published in 2015. Much new evidence on this relationship has become available since then.

Research motivation

To obtain up-to-date evidence relating smoking to type 2 diabetes.

Research objectives

To systematically review available evidence from prospective studies on the relationship of type 2 diabetes onset to ever, current or former smoking of cigarettes or of any tobacco product, including dose-response data.

Research methods

Attention was restricted to prospective studies of populations free of type 2 diabetes at baseline which related subsequent incidence of the disease to one or more defined major or dose-related smoking indices. The major indices compared ever, current or former smokers to never smokers and current smokers to non-current smokers. The dose-related indices concerned amount currently smoked and years quit. Literature searches identified relevant papers from previous reviews, from Medline searches and from references lists of relevant papers identified. Data were extracted on study details and on the relative risks required, estimated if required using standard methods. Care was taken to avoid overlap of data from the same study from multiple publications. Fixed-effect and random-effects meta-analyses were conducted, including tests of heterogeneity and publication bias. Where a study provided multiple estimates, a preference scheme was used involving factors such as level of adjustment for confounding factors, length of follow-up and age range considered. Sex-specific results were used, if available. Effect estimates were derived based on all the selected RRs, and also for those subdivided by various categorical variables – sex, continent, year of publication, basis of diagnosis of diabetes, initial diabetes status of the population, age, length of follow-up, definition of smoking, and whether a range of different variables were adjusted for.

Research results

The literature searches identified 157 relevant publications providing results from 145 studies. Overall random-effect RR estimates were 1.33 [95% confidence interval (CI): 1.28-1.38] for current *vs* never smoking, 128 (95%CI: 1.24-1.32) for current *vs* non-smoking, 1.13 (95%CI: 1.11-1.16) for former *vs* never smoking and 1.25 (95%CI: 1.21-1.28) for ever *vs* never smoking, each combined estimate being based on at least 99 individual estimates. Estimates were generally elevated in each subdivision of the data by the categorical variables considered, though in some cases RR estimates varied significantly ($P < 0.05$) by level. The dose-response analysis showed that risk increased with increasing amount smoked, and reduced with increasing time quit.

Research conclusions

Our analyses confirmed and extended reports of a modest dose-related association of current smoking and a weaker dose-related association of former smoking with risk of type 2 diabetes. The evidence suggests smoking may contribute to the risk of type 2 diabetes, though our estimates may be affected by publication bias and some uncontrolled confounding. Although reduction of smoking is clearly important to limit risk of diseases such as lung cancer, chronic obstructive pulmonary disease and cardiovascular disease, the worldwide rise in incidence of type 2 diabetes, coupled with a decline in smoking, suggests that control of other factors, such as diet, may be much more beneficial in reducing type 2 diabetes risk.

Research perspectives

Our analyses suggest strongly that there is a modest increased risk of type 2 diabetes associated with current smoking which is greater in heavier smokers and reduced following quitting. Further large prospective studies could characterize this more precisely by more detailed assessment of smoking history and by more fully accounting for the range of other factors known to be related to type 2 diabetes. Care should be taken to determine the accuracy of all the data used, and to assess the effect that any possible inaccuracy might have on the estimated association.

ACKNOWLEDGEMENTS

We thank Barbara Forey for assistance with classification of studies, Jan Hamling, John Hamling and John Fry for assistance in conducting the analyses described and producing the figures, and Yvonne Cooper and Diane Morris for typing various drafts of this paper.

REFERENCES

1 **Pan A**, Wang Y, Talaei M, Hu FB, Wu T. Relation of active, passive, and quitting smoking with incident type 2 diabetes: a systematic review and meta-analysis. *Lancet Diabetes Endocrinol* 2015; **3**: 958-967 [PMID: 26388413 DOI: 10.1016/S2213-8587(15)00316-2]

2 **National Center for Chronic Disease Prevention and Health Promotion (US) Office on Smoking and Health**. The Health Consequences of Smoking—50 Years of Progress: A Report of the Surgeon General. Atlanta (GA): Centers for Disease Control and Prevention (US) 2014; 944

3 **Willi C**, Bodenmann P, Ghali WA, Faris PD, Cornuz J. Active smoking and the risk of type 2 diabetes: a systematic review and meta-analysis. *JAMA* 2007; **298**: 2654-2664 [PMID: 18073361 DOI: 10.1001/jama.298.22.2654]

4 **Akter S**, Goto A, Mizoue T. Smoking and the risk of type 2 diabetes in Japan: A systematic review and meta-analysis. *J Epidemiol* 2017; **27**: 553-561 [PMID: 28716381 DOI: 10.1016/j.je.2016.12.017]

5 **Lee PN**, Forey BA, Coombs KJ. Systematic review with meta-analysis of the epidemiological evidence in the 1900s relating smoking to lung cancer. *BMC Cancer* 2012; **12**: 385 [PMID: 22943444 DOI: 10.1186/1471-2407-12-385]

6 **Fleiss JL**, Gross AJ. Meta-analysis in epidemiology, with special reference to studies of the association between exposure to environmental tobacco smoke and lung cancer: a critique. *J Clin Epidemiol* 1991; **44**: 127-139 [PMID: 1995774 DOI: 10.1016/0895-4356(91)90261-7]

7 **Higgins JP**, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *BMJ* 2003; **327**: 557-560 [PMID: 12958120 DOI: 10.1136/bmj.327.7414.557]

8 **Egger M**, Davey Smith G, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. *BMJ* 1997; **315**: 629-634 [PMID: 9310563 DOI: 10.1136/bmj.315.7109.629]

9 **Lyssenko V**, Jonsson A, Almgren P, Pulizzi N, Isomaa B, Tuomi T, Berglund G, Altshuler D, Nilsson P, Groop L. Clinical risk factors, DNA variants, and the development of type 2 diabetes. *N Engl J Med* 2008; **359**: 2220-2232 [PMID: 19020324 DOI: 10.1056/NEJMoa0801869]

10 **Laaksonen MA**, Knekt P, Rissanen H, Härkänen T, Virtala E, Marniemi J, Aromaa A, Heliövaara M, Reunanen A. The relative importance of modifiable potential risk factors of type 2 diabetes: a meta-analysis of two cohorts. *Eur J Epidemiol* 2010; **25**: 115-124 [PMID: 20012885 DOI: 10.1007/s10654-009-9405-0]

11 **Guasch-Ferré M**, Bulló M, Costa B, Martínez-Gonzalez MÁ, Ibarrola-Jurado N, Estruch R, Barrio F, Salas-Salvadó J; PREDI-PLAN Investigators. A risk score to predict type 2 diabetes mellitus in an elderly Spanish Mediterranean population at high cardiovascular risk. *PLoS One* 2012; **7**: e33437 [PMID: 22442692 DOI: 10.1371/journal.pone.0033437]

12 **Du S**, Wu X, Han T, Duan W, Liu L, Qi J, Niu Y, Na L, Sun C. Dietary manganese and type 2 diabetes mellitus: two prospective cohort studies in China. *Diabetologia* 2018; **61**: 1985-1995 [PMID: 29971528 DOI: 10.1007/s00125-018-4674-3]

13 **Shan Z**, Li Y, Zong G, Guo Y, Li J, Manson JE, Hu FB, Willett WC, Schernhammer ES, Bhupathiraju SN. Rotating night shift work and adherence to unhealthy lifestyle in predicting risk of type 2 diabetes: results from two large US cohorts of female nurses. *BMJ* 2018; **363**: k4641 [PMID: 30464025 DOI: 10.1136/bmj.k4641]

14 **Conway BN**, Han X, Munro HM, Gross AL, Shu XO, Hargreaves MK, Zheng W, Powers AC, Blot WJ. The obesity epidemic and rising diabetes incidence in a low-income racially diverse southern US cohort. *PLoS One* 2018; **13**: e0190993 [PMID: 29324894 DOI: 10.1371/journal.pone.0190993]

15 **Frisard C**, Gu X, Whitcomb B, Ma Y, Pekow P, Zorn M, Sepavich D, Balasubramanian R. Marginal structural models for the estimation of the risk of Diabetes Mellitus in the presence of elevated depressive symptoms and antidepressant medication use in the Women's Health Initiative observational and clinical trial cohorts. *BMC Endocr Disord* 2015; **15**: 56 [PMID: 26458393 DOI: 10.1186/s12902-015-0049-7]

16 **Hu Y**, Zong G, Liu G, Wang M, Rosner B, Pan A, Willett WC, Manson JE, Hu FB, Sun Q. Smoking Cessation, Weight Change, Type 2 Diabetes, and Mortality. *N Engl J Med* 2018; **379**: 623-632 [PMID: 30110591 DOI: 10.1056/NEJMoa1803626]

17 **Hilawe EH**, Yatsuya H, Li Y, Uemura M, Wang C, Chiang C, Toyoshima H, Tamakoshi K, Zhang Y, Kawazoe N, Aoyama A. Smoking and diabetes: is the association mediated by adiponectin, leptin, or C-reactive protein? *J Epidemiol* 2015; **25**: 99-109 [PMID: 25400076 DOI: 10.2188/jea.JE20140055]

18 **Yatsuya H**, Li Y, Hirakawa Y, Ota A, Matsunaga M, Haregot HE, Chiang C, Zhang Y, Tamakoshi K, Toyoshima H, Aoyama A. A Point System for Predicting 10-Year Risk of Developing Type 2 Diabetes Mellitus in Japanese Men: Aichi Workers' Cohort Study. *J Epidemiol* 2018; **28**: 347-352 [PMID: 29553059 DOI: 10.2188/jea.JE20170048]

19 **Miyakoshi T**, Oka R, Nakasone Y, Sato Y, Yamauchi K, Hashikura R, Takayama M, Hirayama Y, Hirabayashi K, Koike H, Aizawa T. Development of new diabetes risk scores on the basis of the current definition of diabetes in Japanese subjects [Rapid Communication]. *Endocr J* 2016; **63**: 857-865 [PMID: 27523099 DOI: 10.1507/endocrj.EJ16-0340]

20 **Wang CS**, Chang TT, Yao WJ, Wang ST, Chou P. The impact of smoking on incident type 2 diabetes in a cohort with hepatitis B but not hepatitis C infection. *J Viral Hepat* 2017; **24**: 1114-1120 [PMID: 20819148 DOI: 10.1111/j.1365-2893.2010.01337.x]

21 **Harris ML**, Oldmeadow C, Hure A, Luu J, Loxton D, Attia J. Stress increases the risk of type 2 diabetes onset in women: A 12-year longitudinal study using causal modelling. *PLoS One* 2017; **12**: e0172126 [PMID: 28222165 DOI: 10.1371/journal.pone.0172126]

22 **Cho NH**, Chan JC, Jang HC, Lim S, Kim HL, Choi SH. Cigarette smoking is an independent risk factor for type 2 diabetes: a four-year community-based prospective study. *Clin Endocrinol (Oxf)* 2009; **71**: 679-685 [PMID: 19508609 DOI: 10.1111/j.1365-2265.2009.03586.x]

23 **Cho NH**, Jang HC, Park C and Kimm KC. Evaluation of smoking effects on glucose metabolism: Community based prospective study. Proceedings of the 65th Scientific Sessions of the American Diabetes Association; 2005 Jun 10-14; San Diego, California, USA. American Diabetes Association, 2005: 987

24 **Han SJ**, Kim HJ, Kim DJ, Lee KW, Cho NH. Incidence and predictors of type 2 diabetes among Koreans: A 12-year follow up of the Korean Genome and Epidemiology Study. *Diabetes Res Clin Pract* 2017; **123**: 173-180 [PMID: 28043048 DOI: 10.1016/j.diabres.2016.10.004]

25 **Yeh HC**, Duncan BB, Schmidt MI, Wang NY, Brancati FL. Smoking, smoking cessation, and risk for type 2 diabetes mellitus: a cohort study. *Ann Intern Med* 2010; **152**: 10-17 [PMID: 20048267 DOI: 10.7326/0003-4819-152-1-201001050-00005]

26 **Rebholz CM**, Yu B, Zheng Z, Chang P, Tin A, Köttgen A, Wagenknecht LE, Coresh J, Boerwinkle E,

Selvin E. Serum metabolomic profile of incident diabetes. *Diabetologia* 2018; **61**: 1046-1054 [PMID: 29556673 DOI: 10.1007/s00125-018-4573-7]
27 **Kim CH**, Park JY, Lee KU, Kim JH, Kim HK. Fatty liver is an independent risk factor for the development of Type 2 diabetes in Korean adults. *Diabet Med* 2008; **25**: 476-481 [PMID: 18346164 DOI: 10.1111/j.1464-5491.2008.02410.x]
28 **Koloverou E**, Panagiotakos DB, Pitsavos C, Chrysohoou C, Georgousopoulou EN, Tousoulis D and Stefanadis C. The long term effect of dietary habits and physical activity on type 2 diabetes incidence: 10-year follow up of the ATTICA study (2002-2012): Diet, physical activity and diabetes. *Hellenic J Atherosclerosis* 2018; **9**: 5-16
29 **Magliano DJ**, Barr EL, Zimmet PZ, Cameron AJ, Dunstan DW, Colagiuri S, Jolley D, Owen N, Phillips P, Tapp RJ, Welborn TA, Shaw JE. Glucose indices, health behaviors, and incidence of diabetes in Australia: the Australian Diabetes, Obesity and Lifestyle Study. *Diabetes Care* 2008; **31**: 267-272 [PMID: 17989310 DOI: 10.2337/dc07-0912]
30 **Keen H**, Jarrett RJ, McCartney P. The ten-year follow-up of the Bedford survey (1962-1972): glucose tolerance and diabetes. *Diabetologia* 1982; **22**: 73-78 [PMID: 7060852 DOI: 10.1007/bf00254832]
31 **Tenenbaum A**, Fisman EZ, Adler Y, Motro M, Boyko V, Behar S. Smoking and development of type 2 diabetes in patients with decreased functional capacity. *Int J Cardiol* 2005; **104**: 275-281 [PMID: 16186056 DOI: 10.1016/j.ijcard.2004.10.034]
32 **Cugati S**, Wang JJ, Rochtchina E, Mitchell P. Ten-year incidence of diabetes in older Australians: the Blue Mountains Eye Study. *Med J Aust* 2007; **186**: 131-135 [PMID: 17309402 DOI: 10.5694/j.1326-5377.2007.tb00836.x]
33 **Pollock BD**, Chen W, Harville EW, Shu T, Fonseca V, Mauvais-Jarvis F, Kelly TN, Bazzano LA. Differential sex effects of systolic blood pressure and low-density lipoprotein cholesterol on type 2 diabetes: Life course data from the Bogalusa Heart Study. *J Diabetes* 2018; **10**: 449-457 [PMID: 28239958 DOI: 10.1111/1753-0407.12543]
34 **Lyssenko V**, Almgren P, Anevski D, Perfekt R, Lahti K, Nissén M, Isomaa B, Forsen B, Homström N, Saloranta C, Taskinen MR, Groop L, Tuomi T; Botnia study group. Predictors of and longitudinal changes in insulin sensitivity and secretion preceding onset of type 2 diabetes. *Diabetes* 2005; **54**: 166-174 [PMID: 15616025 DOI: 10.2337/diabetes.54.1.166]
35 **Wannamethee SG**, Shaper AG, Perry IJ; British Regional Heart Study. Smoking as a modifiable risk factor for type 2 diabetes in middle-aged men. *Diabetes Care* 2001; **24**: 1590-1595 [PMID: 11522704 DOI: 10.2337/diacare.24.9.1590]
36 **Bonora E**, Kiechl S, Willeit J, Oberhollenzer F, Egger G, Meigs JB, Bonadonna RC, Muggeo M; Bruneck study. Population-based incidence rates and risk factors for type 2 diabetes in white individuals: the Bruneck study. *Diabetes* 2004; **53**: 1782-1789 [PMID: 15220202 DOI: 10.2337/diabetes.53.7.1782]
37 **Burke V**, Zhao Y, Lee AH, Hunter E, Spargo RM, Gracey M, Smith RM, Beilin LJ, Puddey IB. Predictors of type 2 diabetes and diabetes-related hospitalisation in an Australian Aboriginal cohort. *Diabetes Res Clin Pract* 2007; **78**: 360-368 [PMID: 17532084 DOI: 10.1016/j.diabres.2007.04.007]
38 **Coogan PF**, White LF, Yu J, Burnett RT, Marshall JD, Seto E, Brook RD, Palmer JR, Rosenberg L, Jerrett M. Long term exposure to NO2 and diabetes incidence in the Black Women's Health Study. *Environ Res* 2016; **148**: 360-366 [PMID: 27124624 DOI: 10.1016/j.envres.2016.04.021]
39 **Cassano PA**, Rosner B, Vokonas PS, Weiss ST. Obesity and body fat distribution in relation to the incidence of non-insulin-dependent diabetes mellitus. A prospective cohort study of men in the normative aging study. *Am J Epidemiol* 1992; **136**: 1474-1486 [PMID: 1288277 DOI: 10.1093/oxfordjournals.aje.a116468]
40 **Brateanu A**, Barwacz T, Kou L, Wang S, Misra-Hebert AD, Hu B, Deshpande A, Kobaivanova N, Rothberg MB. Determining the optimal screening interval for type 2 diabetes mellitus using a risk prediction model. *PLoS One* 2017; **12**: e0187695 [PMID: 29135987 DOI: 10.1371/journal.pone.0187695]
41 **de León AC**, Coello SD, González DA, Díaz BB, Rodríguez JC, Hernández AG, Aguirre-Jaime A, Pérez Mdel C. Impaired fasting glucose, ancestry and waist-to-height ratio: main predictors of incident diagnosed diabetes in the Canary Islands. *Diabet Med* 2012; **29**: 399-403 [PMID: 21883429 DOI: 10.1111/j.1464-5491.2011.03420.x]
42 **Qiu H**, Schooling CM, Sun S, Tsang H, Yang Y, Lee RS, Wong CM, Tian L. Long-term exposure to fine particulate matter air pollution and type 2 diabetes mellitus in elderly: A cohort study in Hong Kong. *Environ Int* 2018; **113**: 350-356 [PMID: 29357993 DOI: 10.1016/j.envint.2018.01.008]
43 **Lv J**, Yu C, Guo Y, Bian Z, Yang L, Chen Y, Hu X, Hou W, Chen J, Chen Z, Qi L, Li L; China Kadoorie Biobank Collaborative Group. Adherence to a healthy lifestyle and the risk of type 2 diabetes in Chinese adults. *Int J Epidemiol* 2017; **46**: 1410-1420 [PMID: 28582543 DOI: 10.1093/ije/dyx074]
44 **Le Boudec J**, Marques-Vidal P, Cornuz J, Clair C. Smoking cessation and the incidence of pre-diabetes and type 2 diabetes: a cohort study. *J Diabetes Complications* 2016; **30**: 43-48 [PMID: 26547408 DOI: 10.1016/j.jdiacomp.2015.10.005]
45 **Will JC**, Galuska DA, Ford ES, Mokdad A, Calle EE. Cigarette smoking and diabetes mellitus: evidence of a positive association from a large prospective cohort study. *Int J Epidemiol* 2001; **30**: 540-546 [PMID: 11416080 DOI: 10.1093/ije/30.3.540]
46 **Woo YC**, Lee CH, Fong CH, Xu A, Tso AW, Cheung BM, Lam KS. Serum fibroblast growth factor 21 is a superior biomarker to other adipokines in predicting incident diabetes. *Clin Endocrinol (Oxf)* 2017; **86**: 37-43 [PMID: 27611701 DOI: 10.1111/cen.13229]
47 **Anjana RM**, Shanthi Rani CS, Deepa M, Pradeepa R, Sudha V, Divya Nair H, Lakshmipriya N, Subhashini S, Binu VS, Unnikrishnan R, Mohan V. Incidence of Diabetes and Prediabetes and Predictors of Progression Among Asian Indians: 10-Year Follow-up of the Chennai Urban Rural Epidemiology Study (CURES). *Diabetes Care* 2015; **38**: 1441-1448 [PMID: 25906786 DOI: 10.2337/dc14-2814]
48 **Li X**, Wang J, Shen X, An Y, Gong Q, Li H, Zhang B, Shuai Y, Chen Y, Hu Y, Li G. Higher blood pressure predicts diabetes and enhances long-term risk of cardiovascular disease events in individuals with impaired glucose tolerance: Twenty-three-year follow-up of the Daqing diabetes prevention study. *J Diabetes* 2019; **11**: 593-598 [PMID: 30556339 DOI: 10.1111/1753-0407.12887]
49 **Dehghan A**, van Hoek M, Sijbrands EJ, Stijnen T, Hofman A, Witteman JC. Risk of type 2 diabetes attributable to C-reactive protein and other risk factors. *Diabetes Care* 2007; **30**: 2695-2699 [PMID: 17623828 DOI: 10.2337/dc07-0348]
50 **Balkau B**, Lange C, Fezeu L, Tichet J, de Lauzon-Guillain B, Czernichow S, Fumeron F, Froguel P, Vaxillaire M, Cauchi S, Ducimetière P, Eschwège E. Predicting diabetes: clinical, biological, and genetic approaches: data from the Epidemiological Study on the Insulin Resistance Syndrome (DESIR). *Diabetes*

Care 2008; **31**: 2056-2061 [PMID: 18689695 DOI: 10.2337/dc08-0368]
51 **van Waateringe RP**, Fokkens BT, Slagter SN, van der Klauw MM, van Vliet-Ostaptchouk JV, Graaff R, Paterson AD, Smit AJ, Lutgers HL, Wolffenbuttel BHR. Skin autofluorescence predicts incident type 2 diabetes, cardiovascular disease and mortality in the general population. *Diabetologia* 2019; **62**: 269-280 [PMID: 30460578 DOI: 10.1007/s00125-018-4769-x]
52 **Hansen AB**, Ravnskjær L, Loft S, Andersen KK, Bräuner EV, Baastrup R, Yao C, Ketzel M, Becker T, Brandt J, Hertel O, Andersen ZJ. Long-term exposure to fine particulate matter and incidence of diabetes in the Danish Nurse Cohort. *Environ Int* 2016; **91**: 243-250 [PMID: 26989812 DOI: 10.1016/j.envint.2016.02.036]
53 **Han X**, Wang J, Li Y, Hu H, Li X, Yuan J, Yao P, Miao X, Wei S, Wang Y, Liang Y, Zhang X, Guo H, Pan A, Yang H, Wu T, He M. Development of a new scoring system to predict 5-year incident diabetes risk in middle-aged and older Chinese. *Acta Diabetol* 2018; **55**: 13-19 [PMID: 28918462 DOI: 10.1007/s00592-017-1047-1]
54 **Poulsen K**, Andersen LL. Linking data on work, health and lifestyle to explain socio-occupational inequality in Danish register-based incidence of diabetes. *Scand J Public Health* 2016; **44**: 361-368 [PMID: 26862125 DOI: 10.1177/1403494816629533]
55 **InterAct Consortium**. Spijkerman AM, van der A DL, Nilsson PM, Ardanaz E, Gavrila D, Agudo A, Arriola L, Balkau B, Beulens JW, Boeing H, de Lauzon-Guillain B, Fagherazzi G, Feskens EJ, Franks PW, Grioni S, Huerta JM, Kaaks R, Key TJ, Overvad K, Palli D, Panico S, Redondo ML, Rolandsson O, Roswall N, Sacerdote C, Sánchez MJ, Schulze MB, Slimani N, Teucher B, Tjonneland A, Tumino R, van der Schouw YT, Langenberg C, Sharp SJ, Forouhi NG, Riboli E, Wareham NJ. Smoking and long-term risk of type 2 diabetes: the EPIC-InterAct study in European populations. *Diabetes Care* 2014; **37**: 3164-3171 [PMID: 25336749 DOI: 10.2337/dc14-1020]
56 **Steele CJ**, Schöttker B, Marshall AH, Kouvonen A, O'Doherty MG, Mons U, Saum KU, Boffetta P, Trichopoulou A, Brenner H, Kee F. Education achievement and type 2 diabetes-what mediates the relationship in older adults? Data from the ESTHER study: a population-based cohort study. *BMJ Open* 2017; **7**: e013569 [PMID: 28420660 DOI: 10.1136/bmjopen-2016-013569]
57 **Fagerberg B**, Kellis D, Bergström G, Behre CJ. Adiponectin in relation to insulin sensitivity and insulin secretion in the development of type 2 diabetes: a prospective study in 64-year-old women. *J Intern Med* 2011; **269**: 636-643 [PMID: 21198995 DOI: 10.1111/j.1365-2796.2010.02336.x]
58 **Njølstad I**, Arnesen E, Lund-Larsen PG. Sex differences in risk factors for clinical diabetes mellitus in a general population: a 12-year follow-up of the Finnmark Study. *Am J Epidemiol* 1998; **147**: 49-58 [PMID: 9440398 DOI: 10.1093/oxfordjournals.aje.a009366]
59 **Holmboe SA**, Jensen TK, Linneberg A, Scheike T, Thuesen BH, Skakkebaek NE, Juul A, Andersson AM. Low Testosterone: A Risk Marker Rather Than a Risk Factor for Type 2 Diabetes. *J Clin Endocrinol Metab* 2016; **101**: 3180-3190 [PMID: 27285294 DOI: 10.1210/jc.2016-1778]
60 **Paprott R**, Mühlenbruch K, Mensink GB, Thiele S, Schulze MB, Scheidt-Nave C, Heidemann C. Validation of the German Diabetes Risk Score among the general adult population: findings from the German Health Interview and Examination Surveys. *BMJ Open Diabetes Res Care* 2016; **4**: e000280 [PMID: 27933187 DOI: 10.1136/bmjdrc-2016-000280]
61 **Icks A**, Albers B, Haastert B, Pechlivanis S, Bokhof B, Slomiany U, Erbel R, Jöckel KH, Kruse J, Nowotny B, Herder C, Giani G, Moebus S; Heinz Nixdorf Recall Study Investigative Group; German BMBF Competence Network for Diabetes Mellitus. Diabetes incidence does not differ between subjects with and without high depressive symptoms--5-year follow-up results of the Heinz Nixdorf Recall Study. *Diabet Med* 2013; **30**: 65-69 [PMID: 22672118 DOI: 10.1111/j.1464-5491.2012.03724.x]
62 **Weinmayr G**, Hennig F, Fuks K, Nonnemacher M, Jakobs H, Möhlenkamp S, Erbel R, Jöckel KH, Hoffmann B, Moebus S; Heinz Nixdorf Recall Investigator Group. Long-term exposure to fine particulate matter and incidence of type 2 diabetes mellitus in a cohort study: effects of total and traffic-specific air pollution. *Environ Health* 2015; **14**: 53 [PMID: 26087770 DOI: 10.1186/s12940-015-0031-x]
63 **Zhang L**, Wang B, Wang C, Li L, Ren Y, Zhang H, Yang X, Zhao Y, Han C, Zhou J, Luo X, Hu D. High pulse pressure is related to risk of type 2 diabetes mellitus in Chinese middle-aged females. *Int J Cardiol* 2016; **220**: 467-471 [PMID: 27390971 DOI: 10.1016/j.ijcard.2016.06.233]
64 **Hayashino Y**, Fukuhara S, Okamura T, Yamato H, Tanaka H, Tanaka T, Kadowaki T, Ueshima H; HIPOP-OHP Research Group. A prospective study of passive smoking and risk of diabetes in a cohort of workers: the High-Risk and Population Strategy for Occupational Health Promotion (HIPOP-OHP) study. *Diabetes Care* 2008; **31**: 732-734 [PMID: 18235051 DOI: 10.2337/dc07-1905]
65 **Hippisley-Cox J**, Coupland C, Robson J, Sheikh A, Brindle P. Predicting risk of type 2 diabetes in England and Wales: prospective derivation and validation of QDScore. *BMJ* 2009; **338**: b880 [PMID: 19297312 DOI: 10.1136/bmj.b880]
66 **Hippisley-Cox J**, Coupland C. Development and validation of QDiabetes-2018 risk prediction algorithm to estimate future risk of type 2 diabetes: cohort study. *BMJ* 2017; **359**: j5019 [PMID: 29158232 DOI: 10.1136/bmj.j5019]
67 **Doi Y**, Ninomiya T, Hata J, Hirakawa Y, Mukai N, Iwase M, Kiyohara Y. Two risk score models for predicting incident Type 2 diabetes in Japan. *Diabet Med* 2012; **29**: 107-114 [PMID: 21718358 DOI: 10.1111/j.1464-5491.2011.03376.x]
68 **Rimm EB**, Chan J, Stampfer MJ, Colditz GA, Willett WC. Prospective study of cigarette smoking, alcohol use, and the risk of diabetes in men. *BMJ* 1995; **310**: 555-559 [PMID: 7888928 DOI: 10.1136/bmj.310.6979.555]
69 **Rasouli B**, Grill V, Midthjell K, Ahlbom A, Andersson T, Carlsson S. Smoking is associated with reduced risk of autoimmune diabetes in adults contrasting with increased risk in overweight men with type 2 diabetes: a 22-year follow-up of the HUNT study. *Diabetes Care* 2013; **36**: 604-610 [PMID: 23172971 DOI: 10.2337/dc12-0913]
70 **Vazquez LA**, Calvo-Bonacho E, Reviriego J, García-Margallo T, Caveda E, Goday A. Incidence of Diabetes in the Working Population in Spain: Results from the ICARIA Cohort. *Diabetes Ther* 2019; **10**: 57-69 [PMID: 30430366 DOI: 10.1007/s13300-018-0529-7]
71 **Sadeghi M**, Talaei M, Parvaresh Rizi E, Dianatkhah M, Oveisgharan S, Sarrafzadegan N. Determinants of incident prediabetes and type 2 diabetes in a 7-year cohort in a developing country: The Isfahan Cohort Study. *J Diabetes* 2015; **7**: 633-641 [PMID: 25350916 DOI: 10.1111/1753-0407.12236]
72 **Wiernik E**, Nabi H, Thomas F, Pannier B, Hanon O, Simon T, Simon JM, Danchin N, Limosin F, Czernichow S, Lemogne C. Association between current perceived stress and incident diabetes is dependent on occupational status: Evidence from the IPC cohort study. *Diabetes Metab* 2016; **42**: 328-335

[PMID: 26952644 DOI: 10.1016/j.diabet.2016.01.004]
73 **Foy CG**, Bell RA, Farmer DF, Goff DC, Wagenknecht LE. Smoking and incidence of diabetes among U.S. adults: findings from the Insulin Resistance Atherosclerosis Study. *Diabetes Care* 2005; **28**: 2501-2507 [PMID: 16186287 DOI: 10.2337/diacare.28.10.2501]
74 **Cullen MW**, Ebbert JO, Vierkant RA, Wang AH, Cerhan JR. No interaction of body mass index and smoking on diabetes mellitus risk in elderly women. *Prev Med* 2009; **48**: 74-78 [PMID: 19000710 DOI: 10.1016/j.ypmed.2008.10.008]
75 **Eshak ES**, Iso H, Maruyama K, Muraki I, Tamakoshi A. Associations between dietary intakes of iron, copper and zinc with risk of type 2 diabetes mellitus: A large population-based prospective cohort study. *Clin Nutr* 2018; **37**: 667-674 [PMID: 28285974 DOI: 10.1016/j.clnu.2017.02.010]
76 **Akter S**, Okazaki H, Kuwahara K, Miyamoto T, Murakami T, Shimizu C, Shimizu M, Tomita K, Nagahama S, Eguchi M, Kochi T, Imai T, Nishihara A, Sasaki N, Nakagawa T, Yamamoto S, Honda T, Uehara A, Yamamoto M, Hori A, Sakamoto N, Nishiura C, Totsuzaki T, Kato N, Fukasawa K, Pham NM, Kurotani K, Nanri A, Kabe I, Mizoue T, Sone T, Dohi S; Japan Epidemiology Collaboration on Occupational Health Study Group. Smoking, Smoking Cessation, and the Risk of Type 2 Diabetes among Japanese Adults: Japan Epidemiology Collaboration on Occupational Health Study. *PLoS One* 2015; **10**: e0132166 [PMID: 26200457 DOI: 10.1371/journal.pone.0132166]
77 **Hu H**, Nakagawa T, Yamamoto S, Honda T, Okazaki H, Uehara A, Yamamoto M, Miyamoto T, Kochi T, Eguchi M, Murakami T, Shimizu M, Tomita K, Nagahama S, Imai T, Nishihara A, Sasaki N, Ogasawara T, Hori A, Nanri A, Akter S, Kuwahara K, Kashino I, Kabe I, Mizoue T, Sone T, Dohi S; Japan Epidemiology Collaboration on Occupational Health Study Group. Development and validation of risk models to predict the 7-year risk of type 2 diabetes: The Japan Epidemiology Collaboration on Occupational Health Study. *J Diabetes Investig* 2018; **9**: 1052-1059 [PMID: 29380553 DOI: 10.1111/jdi.12809]
78 **White WB**, Cain LR, Benjamin EJ, DeFilippis AP, Blaha MJ, Wang W, Okhomina V, Keith RJ, Al Rifai M, Kianoush S, Winniford MD, Robertson RM, Bhatnagar A, Correa A, Hall ME. High-Intensity Cigarette Smoking Is Associated With Incident Diabetes Mellitus In Black Adults: The Jackson Heart Study. *J Am Heart Assoc* 2018; **7** [PMID: 29330255 DOI: 10.1161/JAHA.117.007413]
79 **Waki K**, Noda M, Sasaki S, Matsumura Y, Takahashi Y, Isogawa A, Ohashi Y, Kadowaki T, Tsugane S; JPHC Study Group. Alcohol consumption and other risk factors for self-reported diabetes among middle-aged Japanese: a population-based prospective study in the JPHC study cohort I. *Diabet Med* 2005; **22**: 323-331 [PMID: 15717882 DOI: 10.1111/j.1464-5491.2004.01403.x]
80 **Oba S**, Noda M, Waki K, Nanri A, Kato M, Takahashi Y, Poudel-Tandukar K, Matsushita Y, Inoue M, Mizoue T, Tsugane S; Japan Public Health Center-Based Prospective Study Group. Smoking cessation increases short-term risk of type 2 diabetes irrespective of weight gain: the Japan Public Health Center-Based Prospective Study. *PLoS One* 2012; **7**: e17061 [PMID: 22879858 DOI: 10.1371/journal.pone.0017061]
81 **Lee JY**, Ryu S, Sung KC. Association of baseline level of physical activity and its temporal changes with incident hypertension and diabetes mellitus. *Eur J Prev Cardiol* 2018; **25**: 1065-1073 [PMID: 29719968 DOI: 10.1177/2047487318774419]
82 **Kawahara T**, Imawatari R, Kawahara C, Inazu T, Suzuki G. Incidence of type 2 diabetes in pre-diabetic Japanese individuals categorized by HbA1c levels: a historical cohort study. *PLoS One* 2015; **10**: e0122698 [PMID: 25853519 DOI: 10.1371/journal.pone.0122698]
83 **Kawakami N**, Takatsuka N, Shimizu H, Ishibashi H. Effects of smoking on the incidence of non-insulin-dependent diabetes mellitus. Replication and extension in a Japanese cohort of male employees. *Am J Epidemiol* 1997; **145**: 103-109 [PMID: 9006306 DOI: 10.1093/oxfordjournals.aje.a009080]
84 **Hur NW**, Kim HC, Nam CM, Jee SH, Lee HC, Suh I. Smoking cessation and risk of type 2 diabetes mellitus: Korea Medical Insurance Corporation Study. *Eur J Cardiovasc Prev Rehabil* 2007; **14**: 244-249 [PMID: 17446803 DOI: 10.1097/01.hjr.0000239474.41379.79]
85 **Song BM**, Kim HC, Lee JY, Lee JM, Kim DJ, Lee YH, Suh I. Performance of HbA1c for the prediction of diabetes in a rural community in Korea. *Diabet Med* 2015; **32**: 1602-1610 [PMID: 25962707 DOI: 10.1111/dme.12794]
86 **Lee SW**, Kim HC, Lee JM, Yun YM, Lee JY, Suh I. Association between changes in systolic blood pressure and incident diabetes in a community-based cohort study in Korea. *Hypertens Res* 2017; **40**: 710-716 [PMID: 28250411 DOI: 10.1038/hr.2017.21]
87 **Herder C**, Kannenberg JM, Carstensen-Kirberg M, Huth C, Meisinger C, Koenig W, Peters A, Rathmann W, Roden M, Thorand B. Serum levels of interleukin-22, cardiometabolic risk factors and incident type 2 diabetes: KORA F4/FF4 study. *Cardiovasc Diabetol* 2017; **16**: 17 [PMID: 28143481 DOI: 10.1186/s12933-017-0498-6]
88 **Rathmann W**, Strassburger K, Heier M, Holle R, Thorand B, Giani G, Meisinger C. Incidence of Type 2 diabetes in the elderly German population and the effect of clinical and lifestyle risk factors: KORA S4/F4 cohort study. *Diabet Med* 2009; **26**: 1212-1219 [PMID: 20002472 DOI: 10.1111/j.1464-5491.2009.02863.x]
89 **Nichols GA**, Hillier TA, Brown JB. Normal fasting plasma glucose and risk of type 2 diabetes diagnosis. *Am J Med* 2008; **121**: 519-524 [PMID: 18501234 DOI: 10.1016/j.amjmed.2008.02.026]
90 **Mani H**, Levy MJ, Davies MJ, Morris DH, Gray LJ, Bankart J, Blackledge H, Khunti K, Howlett TA. Diabetes and cardiovascular events in women with polycystic ovary syndrome: a 20-year retrospective cohort study. *Clin Endocrinol (Oxf)* 2013; **78**: 926-934 [PMID: 23046078 DOI: 10.1111/cen.12068]
91 **Salminen M**, Vahlberg T, Räihä I, Niskanen L, Kivelä SL, Irjala K. Sex hormones and the risk of type 2 diabetes mellitus: A 9-year follow up among elderly men in Finland. *Geriatr Gerontol Int* 2015; **15**: 559-564 [PMID: 24891075 DOI: 10.1111/ggi.12312]
92 **Lindberg S**, Jensen JS, Bjerre M, Pedersen SH, Frystyk J, Flyvbjerg A, Galatius S, Jeppesen J, Mogelvang R. Adiponectin, type 2 diabetes and cardiovascular risk. *Eur J Prev Cardiol* 2015; **22**: 276-283 [PMID: 24265290 DOI: 10.1177/2047487313514894]
93 **Sherratt FC**, Field JK, Marcus MW. Association between smoking and health outcomes in an economically deprived population: the Liverpool Lung Project. *J Epidemiol Community Health* 2017; **71**: 806-810 [PMID: 28416569 DOI: 10.1136/jech-2016-208730]
94 **Gyawali P**, Martin SA, Heilbronn LK, Vincent AD, Taylor AW, Adams RJT, O'Loughlin PD, Wittert GA. The role of sex hormone-binding globulin (SHBG), testosterone, and other sex steroids, on the development of type 2 diabetes in a cohort of community-dwelling middle-aged to elderly men. *Acta Diabetol* 2018; **55**: 861-872 [PMID: 29845345 DOI: 10.1007/s00592-018-1163-6]

95 **Manson JE**, Ajani UA, Liu S, Nathan DM, Hennekens CH. A prospective study of cigarette smoking and the incidence of diabetes mellitus among US male physicians. *Am J Med* 2000; **109**: 538-542 [PMID: 11063954 DOI: 10.1016/s0002-9343(00)00568-4]

96 **Setiawan VW**, Stram DO, Porcel J, Chari ST, Maskarinec G, Le Marchand L, Wilkens LR, Haiman CA, Pandol SJ, Monroe KR. Pancreatic Cancer Following Incident Diabetes in African Americans and Latinos: The Multiethnic Cohort. *J Natl Cancer Inst* 2019; **111**: 27-33 [PMID: 29917105 DOI: 10.1093/jnci/djy090]

97 **Steinbrecher A**, Morimoto Y, Heak S, Ollberding NJ, Geller KS, Grandinetti A, Kolonel LN, Maskarinec G. The preventable proportion of type 2 diabetes by ethnicity: the multiethnic cohort. *Ann Epidemiol* 2011; **21**: 526-535 [PMID: 21497517 DOI: 10.1016/j.annepidem.2011.03.009]

98 **Keith RJ**, Al Rifai M, Carruba C, De Jarnett N, McEvoy JW, Bhatnagar A, Blaha MJ, Defilippis AP. Tobacco Use, Insulin Resistance, and Risk of Type 2 Diabetes: Results from the Multi-Ethnic Study of Atherosclerosis. *PLoS One* 2016; **11**: e0157592 [PMID: 27322410 DOI: 10.1371/journal.pone.0157592]

99 **Joseph JJ**, Echouffo-Tcheugui JB, Carnethon MR, Bertoni AG, Shay CM, Ahmed HM, Blumenthal RS, Cushman M, Golden SH. The association of ideal cardiovascular health with incident type 2 diabetes mellitus: the Multi-Ethnic Study of Atherosclerosis. *Diabetologia* 2016; **59**: 1893-1903 [PMID: 27272340 DOI: 10.1007/s00125-016-4003-7]

100 **Lao XQ**, Guo C, Chang LY, Bo Y, Zhang Z, Chuang YC, Jiang WK, Lin C, Tam T, Lau AKH, Lin CY, Chan TC. Long-term exposure to ambient fine particulate matter ($PM_{2.5}$) and incident type 2 diabetes: a longitudinal cohort study. *Diabetologia* 2019; **62**: 759-769 [PMID: 30706081 DOI: 10.1007/s00125-019-4825-1]

101 **Meisinger C**, Döring A, Thorand B, Löwel H. Association of cigarette smoking and tar and nicotine intake with development of type 2 diabetes mellitus in men and women from the general population: the MONICA/KORA Augsburg Cohort Study. *Diabetologia* 2006; **49**: 1770-1776 [PMID: 16710672 DOI: 10.1007/s00125-006-0298-0]

102 **Eliasson M**, Asplund K, Nasic S, Rodu B. Influence of smoking and snus on the prevalence and incidence of type 2 diabetes amongst men: the northern Sweden MONICA study. *J Intern Med* 2004; **256**: 101-110 [PMID: 15257722 DOI: 10.1111/j.1365-2796.2004.01344.x]

103 **Morimoto A**, Ohno Y, Tatsumi Y, Nishigaki Y, Maejima F, Mizuno S, Watanabe S. Risk of smoking and body mass index for incidence of diabetes mellitus in a rural Japanese population. *Prev Med* 2012; **54**: 341-344 [PMID: 22414741 DOI: 10.1016/j.ypmed.2012.02.016]

104 **Morimoto A**, Ohno Y, Tatsumi Y, Nishigaki Y, Maejima F, Mizuno S, Watanabe S. Impact of smoking cessation on incidence of diabetes mellitus among overweight or normal-weight Japanese men. *Diabetes Res Clin Pract* 2012; **96**: 407-413 [PMID: 22494491 DOI: 10.1016/j.diabres.2012.03.007]

105 **Mozaffarian D**, Kamineni A, Carnethon M, Djoussé L, Mukamal KJ, Siscovick D. Lifestyle risk factors and new-onset diabetes mellitus in older adults: the cardiovascular health study. *Arch Intern Med* 2009; **169**: 798-807 [PMID: 19398692 DOI: 10.1001/archinternmed.2009.21]

106 **Vasiliu O**, Cameron L, Gardiner J, Deguire P, Karmaus W. Polybrominated biphenyls, polychlorinated biphenyls, body weight, and incidence of adult-onset diabetes mellitus. *Epidemiology* 2006; **17**: 352-359 [PMID: 16755267 DOI: 10.1097/01.ede.0000220553.84350.c5]

107 **Ide R**, Hoshuyama T, Wilson D, Takahashi K, Higashi T. Periodontal disease and incident diabetes: a seven-year study. *J Dent Res* 2011; **90**: 41-46 [PMID: 21041549 DOI: 10.1177/0022034510381902]

108 **Kaneto C**, Toyokawa S, Miyoshi Y, Suyama Y, Kobayashi Y. Long-term weight change in adulthood and incident diabetes mellitus: MY Health Up Study. *Diabetes Res Clin Pract* 2013; **102**: 138-146 [PMID: 24139847 DOI: 10.1016/j.diabres.2013.08.011]

109 **Mitsuhashi K**, Hashimoto Y, Hamaguchi M, Obora A, Kojima T, Fukuda T, Fukui M. Impact of fatty liver disease and metabolic syndrome on incident type 2 diabetes; a population based cohort study. *Endocr J* 2017; **64**: 1105-1114 [PMID: 28867686 DOI: 10.1507/endocrj.EJ17-0245]

110 **Hashimoto Y**, Hamaguchi M, Nakanishi N, Ohbora A, Kojima T, Fukui M. Urinary pH is a predictor of diabetes in men; a population based large scale cohort study. *Diabetes Res Clin Pract* 2017; **130**: 9-14 [PMID: 28551482 DOI: 10.1016/j.diabres.2017.04.023]

111 **Nagaya T**, Yoshida H, Takahashi H, Kawai M. Heavy smoking raises risk for type 2 diabetes mellitus in obese men; but, light smoking reduces the risk in lean men: a follow-up study in Japan. *Ann Epidemiol* 2008; **18**: 113-118 [PMID: 18083537 DOI: 10.1016/j.annepidem.2007.07.107]

112 **Nakanishi N**, Nakamura K, Matsuo Y, Suzuki K, Tatara K. Cigarette smoking and risk for impaired fasting glucose and type 2 diabetes in middle-aged Japanese men. *Ann Intern Med* 2000; **133**: 183-191 [PMID: 10906832 DOI: 10.7326/0003-4819-133-3-200008010-00009]

113 **Montgomery SM**, Ekbom A. Smoking during pregnancy and diabetes mellitus in a British longitudinal birth cohort. *BMJ* 2002; **324**: 26-27 [PMID: 11777801 DOI: 10.1136/bmj.324.7328.26]

114 **Ford ES**, Mannino DM; National Health and Nutrition Examination Survey Epidemiologic Follow-up Study. Prospective association between lung function and the incidence of diabetes: findings from the National Health and Nutrition Examination Survey Epidemiologic Follow-up Study. *Diabetes Care* 2004; **27**: 2966-2970 [PMID: 15562215 DOI: 10.2337/diacare.27.12.2966]

115 **Jee SH**, Foong AW, Hur NW, Samet JM. Smoking and risk for diabetes incidence and mortality in Korean men and women. *Diabetes Care* 2010; **33**: 2567-2572 [PMID: 20823342 DOI: 10.2337/dc10-0261]

116 **Ha KH**, Lee YH, Song SO, Lee JW, Kim DW, Cho KH, Kim DJ. Development and Validation of the Korean Diabetes Risk Score: A 10-Year National Cohort Study. *Diabetes Metab J* 2018; **42**: 402-414 [PMID: 30113144 DOI: 10.4093/dmj.2018.0014]

117 **Kim ES**, Jeong JS, Han K, Kim MK, Lee SH, Park YM, Baek KH, Moon SD, Han JH, Song KH, Kwon HS. Impact of weight changes on the incidence of diabetes mellitus: a Korean nationwide cohort study. *Sci Rep* 2018; **8**: 3735 [PMID: 29487293 DOI: 10.1038/s41598-018-21550-3]

118 **Zhang L**, Curhan GC, Hu FB, Rimm EB, Forman JP. Association between passive and active smoking and incident type 2 diabetes in women. *Diabetes Care* 2011; **34**: 892-897 [PMID: 21355099 DOI: 10.2337/dc10-2087]

119 **Reis JP**, Loria CM, Sorlie PD, Park Y, Hollenbeck A, Schatzkin A. Lifestyle factors and risk for new-onset diabetes: a population-based cohort study. *Ann Intern Med* 2011; **155**: 292-299 [PMID: 21893622 DOI: 10.7326/0003-4819-155-5-201109060-00006]

120 **Kulick ER**, Moon YP, Cheung K, Willey JZ, Sacco RL, Elkind MS. Racial-ethnic disparities in the association between risk factors and diabetes: The Northern Manhattan Study. *Prev Med* 2016; **83**: 31-36 [PMID: 26658025 DOI: 10.1016/j.ypmed.2015.11.023]

121 **Novak M**, Björck L, Giang KW, Heden-Ståhl C, Wilhelmsen L, Rosengren A. Perceived stress and

incidence of Type 2 diabetes: a 35-year follow-up study of middle-aged Swedish men. *Diabet Med* 2013; **30**: e8-16 [PMID: 23075206 DOI: 10.1111/dme.12037]

122 **Castro MR**, Simon G, Cha SS, Yawn BP, Melton LJ, Caraballo PJ. Statin Use, Diabetes Incidence and Overall Mortality in Normoglycemic and Impaired Fasting Glucose Patients. *J Gen Intern Med* 2016; **31**: 502-508 [PMID: 26850412 DOI: 10.1007/s11606-015-3583-0]

123 **Onat A**, Ozhan H, Esen AM, Albayrak S, Karabulut A, Can G, Hergenç G. Prospective epidemiologic evidence of a "protective" effect of smoking on metabolic syndrome and diabetes among Turkish women--without associated overall health benefit. *Atherosclerosis* 2007; **193**: 380-388 [PMID: 16926017 DOI: 10.1016/j.atherosclerosis.2006.07.002]

124 **Katsuta S**. [Cigarette smoking and lifestyle-related diseases in Japan. A longitudinal study of health check-up data from urban areas]. *Nihon Koshu Eisei Zasshi* 2012; **59**: 447-456 [PMID: 22991769 DOI: 10.11236/jph.59.7_447]

125 **Holme I**, Tonstad S, Sogaard AJ, Larsen PG, Haheim LL. Leisure time physical activity in middle age predicts the metabolic syndrome in old age: results of a 28-year follow-up of men in the Oslo study. *BMC Public Health* 2007; **7**: 154 [PMID: 17625024 DOI: 10.1186/1471-2458-7-154]

126 **Östenson CG**, Hilding A, Grill V, Efendic S. High consumption of smokeless tobacco ("snus") predicts increased risk of type 2 diabetes in a 10-year prospective study of middle-aged Swedish men. *Scand J Public Health* 2012; **40**: 730-737 [PMID: 23117209 DOI: 10.1177/1403494812459814]

127 **Park CH**, Ga H, Leem JH, Kwak SM, Kim HC, Choi JH. [The effect of smoking status upon occurrence of impaired fasting glucose or type 2 diabetes in Korean men]. *J Prev Med Public Health* 2008; **41**: 249-254 [PMID: 18664731 DOI: 10.3961/jpmph.2008.41.4.249]

128 **Patja K**, Jousilahti P, Hu G, Valle T, Qiao Q, Tuomilehto J. Effects of smoking, obesity and physical activity on the risk of type 2 diabetes in middle-aged Finnish men and women. *J Intern Med* 2005; **258**: 356-362 [PMID: 16164575 DOI: 10.1111/j.1365-2796.2005.01545.x]

129 **Song X**, Qiu M, Zhang X, Wang H, Tong W, Ju L, Gu L, Sun S, Zhang H, Wang W, Tian J. Gender-related affecting factors of prediabetes on its 10-year outcome. *BMJ Open Diabetes Res Care* 2016; **4**: e000169 [PMID: 27239315 DOI: 10.1136/bmjdrc-2015-000169]

130 **Luo W**, Guo Z, Wu M, Hao C, Zhou Z, Yao X. Interaction of smoking and obesity on type 2 diabetes risk in a Chinese cohort. *Physiol Behav* 2015; **139**: 240-243 [PMID: 25449404 DOI: 10.1016/j.physbeh.2014.11.038]

131 **Gil-Montalbán E**, Martín-Ríos MD, Ortiz-Marrón H, Zorrilla-Torras B, Martínez-Cortés M, Esteban-Vasallo MD, López-de-Andrés A. Incidence of type 2 diabetes and associated factors in the adult population of the Community of Madrid. PREDIMERC cohort. *Rev Clin Esp* 2015; **215**: 495-502 [PMID: 26409707 DOI: 10.1016/j.rce.2015.07.011]

132 **Suthahar N**, Meijers WC, Brouwers FP, Heerspink HJL, Gansevoort RT, van der Harst P, Bakker SJL, de Boer RA. Heart failure and inflammation-related biomarkers as predictors of new-onset diabetes in the general population. *Int J Cardiol* 2018; **250**: 188-194 [PMID: 29074040 DOI: 10.1016/j.ijcard.2017.10.035]

133 **Joseph JJ**, Bennett A, Echouffo Tcheugui JB, Effoe VS, Odei JB, Hidalgo B, Dulin A, Safford MM, Cummings DM, Cushman M, Carson AP. Ideal cardiovascular health, glycaemic status and incident type 2 diabetes mellitus: the REasons for Geographic and Racial Differences in Stroke (REGARDS) study. *Diabetologia* 2019; **62**: 426-437 [PMID: 30643923 DOI: 10.1007/s00125-018-4792-y]

134 **Roediger MA**, Marucci MFN, Gobbo LA, Dourado DAQS, Santos JLF, Duarte YAO, Lebrão ML. Reported diabetes mellitus: incidence and determinants in cohort of community dwelling elderly people in São Paulo City, Brazil: SABE study, health, wellness and aging. *Cien Saude Colet* 2018; **23**: 3913-3922 [PMID: 30427461 DOI: 10.1590/1413-812320182311.13062016]

135 **Sairenchi T**, Iso H, Nishimura A, Hosoda T, Irie F, Saito Y, Murakami A, Fukutomi H. Cigarette smoking and risk of type 2 diabetes mellitus among middle-aged and elderly Japanese men and women. *Am J Epidemiol* 2004; **160**: 158-162 [PMID: 15234937 DOI: 10.1093/aje/kwh183]

136 **Jeon CY**, Haan MN, Cheng C, Clayton ER, Mayeda ER, Miller JW, Aiello AE. Helicobacter pylori infection is associated with an increased rate of diabetes. *Diabetes Care* 2012; **35**: 520-525 [PMID: 22279028 DOI: 10.2337/dc11-1043]

137 **Yu TY**, Jee JH, Bae JC, Hong WJ, Jin SM, Kim JH, Lee MK. Delayed heart rate recovery after exercise as a risk factor of incident type 2 diabetes mellitus after adjusting for glycometabolic parameters in men. *Int J Cardiol* 2016; **221**: 17-22 [PMID: 27400291 DOI: 10.1016/j.ijcard.2016.06.149]

138 **Eze IC**, Foraster M, Schaffner E, Vienneau D, Héritier H, Rudzik F, Thiesse L, Pieren R, Imboden M, von Eckardstein A, Schindler C, Brink M, Cajochen C, Wunderli JM, Röösli M, Probst-Hensch N. Long-term exposure to transportation noise and air pollution in relation to incident diabetes in the SAPALDIA study. *Int J Epidemiol* 2017; **46**: 1115-1125 [PMID: 28338949 DOI: 10.1093/ije/dyx020]

139 **Sawada SS**, Lee IM, Muto T, Matuszaki K, Blair SN. Cardiorespiratory fitness and the incidence of type 2 diabetes: prospective study of Japanese men. *Diabetes Care* 2003; **26**: 2918-2922 [PMID: 14514602 DOI: 10.2337/diacare.26.10.2918]

140 **Ding D**, Chong S, Jalaludin B, Comino E, Bauman AE. Risk factors of incident type 2-diabetes mellitus over a 3-year follow-up: Results from a large Australian sample. *Diabetes Res Clin Pract* 2015; **108**: 306-315 [PMID: 25737033 DOI: 10.1016/j.diabres.2015.02.002]

141 **Zhao J**, Zhu Y, Hyun N, Zeng D, Uppal K, Tran VT, Yu T, Jones D, He J, Lee ET, Howard BV. Novel metabolic markers for the risk of diabetes development in American Indians. *Diabetes Care* 2015; **38**: 220-227 [PMID: 25468946 DOI: 10.2337/dc14-2033]

142 **Kebede TG**, Pink C, Rathmann W, Kowall B, Völzke H, Petersmann A, Meisel P, Dietrich T, Kocher T, Holtfreter B. Does periodontitis affect diabetes incidence and haemoglobin A1c change? An 11-year follow-up study. *Diabetes Metab* 2018; **44**: 243-249 [PMID: 29249612 DOI: 10.1016/j.diabet.2017.11.003]

143 **Shi L**, Shu XO, Li H, Cai H, Liu Q, Zheng W, Xiang YB, Villegas R. Physical activity, smoking, and alcohol consumption in association with incidence of type 2 diabetes among middle-aged and elderly Chinese men. *PLoS One* 2013; **8**: e77919 [PMID: 24223743 DOI: 10.1371/journal.pone.0077919]

144 **Kouvonen AM**, Väänänen A, Woods SA, Heponiemi T, Koskinen A, Toppinen-Tanner S. Sense of coherence and diabetes: a prospective occupational cohort study. *BMC Public Health* 2008; **8**: 46 [PMID: 18254945 DOI: 10.1186/1471-2458-8-46]

145 **Strandberg TE**, Salomaa V. Factors related to the development of diabetes during a 20-year follow-up. A prospective study in a homogeneous group of middle-aged men. *Nutr Metab Cardiovasc Dis* 2000; **10**: 239-246 [PMID: 11213532]

146 **Singh-Manoux A**, Fayosse A, Sabia S, Tabak A, Shipley M, Dugravot A, Kivimäki M. Clinical, socioeconomic, and behavioural factors at age 50 years and risk of cardiometabolic multimorbidity and mortality: A cohort study. *PLoS Med* 2018; **15**: e1002571 [PMID: 29782486 DOI: 10.1371/journal.pmed.1002571]

147 **Stringhini S**, Tabak AG, Akbaraly TN, Sabia S, Shipley MJ, Marmot MG, Brunner EJ, Batty GD, Bovet P, Kivimäki M. Contribution of modifiable risk factors to social inequalities in type 2 diabetes: prospective Whitehall II cohort study. *BMJ* 2012; **345**: e5452 [PMID: 22915665 DOI: 10.1136/bmj.e5452]

148 **Sugimori H**, Miyakawa M, Yoshida K, Izuno T, Takahashi E, Tanaka C, Nakamura K, Hinohara S. Health risk assessment for diabetes mellitus based on longitudinal analysis of MHTS database. *J Med Syst* 1998; **22**: 27-32 [PMID: 9554107 DOI: 10.1023/a:1022650305109]

149 **Waris L**, Mihardja LK, Pratomo H, Lampe M, Soewondo P, Djuwita R and Ronoatmodjo S. Understanding pre-diabetic life style as a determinant factor of type-2 diabetes mellitus in south Sulawesi province, Indonesia. *Indian J Public Health Res Dev* 2018; **9**: 86-92 [DOI: 10.5958/0976-5506.2018.00188.2]

150 **Karvonen-Gutierrez CA**, Peng Q, Peterson M, Duchowny K, Nan B, Harlow S. Low grip strength predicts incident diabetes among mid-life women: the Michigan Study of Women's Health Across the Nation. *Age Ageing* 2018; **47**: 685-691 [PMID: 29726885 DOI: 10.1093/ageing/afy067]

151 **Papier K**, Jordan S, D'Este C, Bain C, Peungson J, Banwell C, Yiengprugsawan V, Seubsman SA, Sleigh A. Incidence and risk factors for type 2 diabetes mellitus in transitional Thailand: results from the Thai cohort study. *BMJ Open* 2016; **6**: e014102 [PMID: 27974373 DOI: 10.1136/bmjopen-2016-014102]

152 **Teratani T**, Morimoto H, Sakata K, Oishi M, Tanaka K, Nakada S, Nogawa K, Suwazono Y. Dose-response relationship between tobacco or alcohol consumption and the development of diabetes mellitus in Japanese male workers. *Drug Alcohol Depend* 2012; **125**: 276-282 [PMID: 22445622 DOI: 10.1016/j.drugalcdep.2012.03.002]

153 **Tsai AC**, Lee SH. Determinants of new-onset diabetes in older adults—Results of a national cohort study. *Clin Nutr* 2015; **34**: 937-942 [PMID: 25453397 DOI: 10.1016/j.clnu.2014.09.021]

154 **Heianza Y**, Arase Y, Hsieh SD, Saito K, Tsuji H, Kodama S, Tanaka S, Ohashi Y, Shimano H, Yamada N, Hara S, Sone H. Development of a new scoring system for predicting the 5 year incidence of type 2 diabetes in Japan: the Toranomon Hospital Health Management Center Study 6 (TOPICS 6). *Diabetologia* 2012; **55**: 3213-3223 [PMID: 22955996 DOI: 10.1007/s00125-012-2712-0]

155 **Joseph J**, Svartberg J, Njølstad I, Schirmer H. Incidence of and risk factors for type-2 diabetes in a general population: the Tromsø Study. *Scand J Public Health* 2010; **38**: 768-775 [PMID: 20696770 DOI: 10.1177/1403494810380299]

156 **Uchimoto S**, Tsumura K, Hayashi T, Suematsu C, Endo G, Fujii S, Okada K. Impact of cigarette smoking on the incidence of Type 2 diabetes mellitus in middle-aged Japanese men: the Osaka Health Survey. *Diabet Med* 1999; **16**: 951-955 [PMID: 10588526 DOI: 10.1046/j.1464-5491.1999.00173.x]

157 **Phillips LS**, Ho YL, Rhee MK, Vassy JL, Gagnon DR, Wilson PWF. Levels of random plasma glucose predict the diagnosis of diabetes. Proceedings of the 70th Scientific Sessions (2010); 2010 Jun 25-29; Orlando, Florida, USA. Diabetes 2017; 66: A422

158 **Long GH**, Johansson I, Rolandsson O, Wennberg P, Fhärm E, Weinehall L, Griffin SJ, Simmons RK, Norberg M. Healthy behaviours and 10-year incidence of diabetes: a population cohort study. *Prev Med* 2015; **71**: 121-127 [PMID: 25532678 DOI: 10.1016/j.ypmed.2014.12.013]

159 **Luo J**, Rossouw J, Tong E, Giovino GA, Lee CC, Chen C, Ockene JK, Qi L, Margolis KL. Smoking and diabetes: does the increased risk ever go away? *Am J Epidemiol* 2013; **178**: 937-945 [PMID: 23817918 DOI: 10.1093/aje/kwt071]

160 **Pitkänen N**, Juonala M, Rönnemaa T, Sabin MA, Hutri-Kähönen N, Kähönen M, Lehtimäki T, Viikari JS, Raitakari OT. Role of Conventional Childhood Risk Factors Versus Genetic Risk in the Development of Type 2 Diabetes and Impaired Fasting Glucose in Adulthood: The Cardiovascular Risk in Young Finns Study. *Diabetes Care* 2016; **39**: 1393-1399 [PMID: 27298332 DOI: 10.2337/dc16-0167]

161 **Feskens EJ**, Kromhout D. Cardiovascular risk factors and the 25-year incidence of diabetes mellitus in middle-aged men. The Zutphen Study. *Am J Epidemiol* 1989; **130**: 1101-1108 [PMID: 2589303 DOI: 10.1093/oxfordjournals.aje.a115437]

162 **National Institute of Diabetes and Digestive and Kidney Diseases (NIDDK)**. Risk factors for type 2 diabetes. 2016 Nov [Cited February 2020]. In: Diabetes Overview [Internet]. Available from: https://www.niddk.nih.gov/health-information/diabetes/overview/risk-factors-type-2-diabetes

163 **Taylor R**. Life without diabetes-The definitive guide to understanding and reversing type 2 diabetes. Vol London: Short Books, 2020: 319

Published By Baishideng Publishing Group Inc
7041 Koll Center Parkway, Suite 160, Pleasanton, CA 94566, USA
Telephone: +1-925-3991568
E-mail: bpgoffice@wjgnet.com
Help Desk: https://www.f6publishing.com/helpdesk
https://www.wjgnet.com