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Prevalence of type 2 diabetes in psychiatric disorders: An umbrella review with meta-analysis of 245 observational studies from 32 systematic reviews

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Abstract

Aims/hypothesis Estimates of the global prevalence of type 2 diabetes vary between 6% and 9%. The prevalence of type 2 diabetes has also been investigated in psychiatric populations, but a critical appraisal of the existing evidence is lacking, and an overview is needed. This umbrella review summarizes existing systematic reviews of observational studies investigating the prevalence of type 2 diabetes in people with a psychiatric disorder.

Methods We searched PubMed, EMBASE, PsycINFO and Cochrane Database of Systematic Reviews from inception to January 17, 2021, and screened reference lists of included systematic reviews. Based on pre-specified criteria we included systematic reviews investigating prevalence of type 2 diabetes in adults (≥18-years) with a psychiatric disorder. Title and abstracts of 5,155 identified records and full text of 431 selected studies were screened by two independent reviewers, based on predefined eligibility criteria and an *a priori* developed extraction form, following the PRISMA and MOOSE guidelines. Risk of bias was assessed with the ROBIS instrument. Data extracted from primary studies were synthesized using random-effects meta-analyses.

Results A total of 32 systematic reviews with 245 unique primary studies were identified and met inclusion criteria. Of them, 12 had low risk of bias. They reported type 2 diabetes prevalence estimates ranging from 5% to 22% depending on the specific psychiatric disorder. We meta-analyzed data for ten categories of psychiatric disorders and found prevalence estimates of type 2 diabetes varying between 8% to 40%: 40% among people with sleep disorders, 21% in binge eating disorders, 16% in substance use disorders, 14% in anxiety disorders, 11% in bipolar disorders, 11% in psychosis, 10% in schizophrenia, 10% in a mixed group of psychiatric disorders, 9% in depression, and 8% in intellectual disabilities. All meta-analyses revealed high levels of heterogeneity.

Conclusions/interpretation Type 2 diabetes is a common comorbidity in people with a psychiatric disorder. Future research should investigate whether routine screening for type 2 diabetes and subsequent prevention initiatives for these people are warranted.

PROSPERO registration no: CRD42020159870

Tweet:

NEW REVIEW: Type 2 diabetes is a common comorbidity in individuals with psychiatric disorders. Prevalence estimates range between 8% and 40% depending on the psychiatric disorder

Research in Context

What is already known about this subject?

- The prevalence of type 2 diabetes has been investigated in different psychiatric populations, but an overview with meta-analysis is needed.
- In some papers, the prevalence of type 2 diabetes in people with a psychiatric disorder is reported higher compared to the general population.

What is the key question?

- What is the prevalence of type 2 diabetes in people with a psychiatric disorder?

What are the new findings?

- Meta-analyses of 245 primary studies from 32 systematic reviews show that diabetes prevalence is higher in individuals with sleep disorders (40%), binge eating disorders (21%), substance use disorders (16%), anxiety disorders (14%), bipolar disorders (11%), psychosis (11%), schizophrenia (10%), mixed group of psychiatric disorders (10%) than in the general population over 18 years of age (6% to 9%).

How might this impact on clinical practice in the foreseeable future?

- Type 2 diabetes is a common comorbidity in individuals with psychiatric disorders. Future research should evaluate whether diabetes screening is warranted and whether diabetes treatment targets are currently met in this group.

Introduction

Psychiatric disorders are common [1], can substantially impair quality of life [2], and are associated with elevated mortality rates [3, 4]. Excess mortality in individuals with a psychiatric disorder can be attributed to more frequent suicides and accidents, but also the high prevalence of comorbid somatic disorders in this population [5-8]. The prevalence of type 2 diabetes mellitus (T2DM), for example, has been reported to be higher in people with bipolar disorder [9], schizophrenia [10], or major depression [11], compared to the general population. The global prevalence of T2DM has increased from 1990 onwards, current estimates ranging between 6.3% and 9.3%, and the prevalence is expected to increase further within the next 20 years [12, 13]. During the last decades, a number of systematic reviews have investigated the prevalence of T2DM in people with different psychiatric disorders. However, no systematic overview and critical appraisal of this literature is currently available.

To address this limitation, this umbrella review sought to summarize and critically assess the existing evidence on the prevalence of T2DM in people with a psychiatric disorder. We focused on systematic reviews of observational studies to generate a narrative synthesis of the prevalence estimates. Our review included a risk of bias assessment and meta-analyses of prevalence estimates from the primary studies included in the systematic reviews.

Methods

Protocol, registration, and study design

We registered the protocol for this umbrella review at PROSPERO (registration no: CRD42020159870) and described it in an a priori published protocol [14]. We followed the Preferred Reporting Items for Systematics Reviews and Meta-Analyses (PRISMA) [15] and the Meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines [16] (ESM Table 1 and ESM Table 2). The umbrella review covers systematic reviews describing the prevalence of T2DM in people with a psychiatric disorder.

Search strategy and eligibility criteria

We searched four electronic databases (PubMed, EMBASE, PsycINFO, and Cochrane Database of Systematic Reviews) from their inception to 17th of January 2021. We used a structured search strategy with searches in four blocks: (I) psychiatric disorders, (II) diabetes, (III) prevalence, and (IV) systematic reviews. Search words and MeSH-terms within each block of the search were combined with an "OR". In the final search, the blocks (I-IV) were combined with an "AND". We included only systematic reviews in English, Dutch, German, or Scandinavian language, with no limitations in publication date. The complete block search is reported in ESM Table 3.

More specifically, we included systematic reviews of observational studies, investigating the prevalence of T2DM in people with a psychiatric disorder. We used a definition of psychiatric disorders as psychiatric diagnoses mentioned in the ICD or DSM classification systems or elevated levels of clusters of psychiatric symptoms (DSM III or DSM IV, axis I or axis II; DSM5 section II; ICD 10, F00-F99) [17-20]. We did not include reviews focusing on 1) a single psychiatric symptom or 2) distress not described as a condition in the ICD or DSM classification systems (e.g., work-related stress and sleep duration). We included systematic reviews where the psychiatric disorders were assessed by diagnosis, diagnostic interviews, hospital records, prescriptions of psychotropic medication, or self-reported, and where T2DM was assessed by diagnosis, medical records, prescription of glucose-lowering medication, or self-reports. Only systematic reviews focusing on adult samples (≥18 years) were included. If no information was available regarding type of diabetes, we expected that the majority of adults had T2DM and included the study. Studies with a design other than a systematic review were excluded. Similarly, reviews without an explicit literature search strategy were regarded as unsystematic and were thus excluded.

We removed duplicates in merged searches from different databases with the reference managing package EndNote X8 (Clarivate Analytics (US) LLC). Two independent reviewers (NL and SHS) selected studies to be read in full text by screening titles and abstracts using the software package Covidence (Melbourne,

Australia), and subsequently selected studies for final inclusion based on the full text of these studies, based on the predefined eligibility criteria. If at least one of the reviewers regarded a record as potentially eligible during the title/abstract screening, the record was included and evaluated at the full-text level. Any disagreements at the full-text level were resolved after consulting a third author (FR). Finally, the reference lists of the included systematic reviews were manually screened for other potentially eligible systematic reviews.

Data extraction

Two independent reviewers (NL and SHS) extracted the following information from the included systematic reviews, using an extraction form we developed before extraction of the information: name of first author, year of publication, country where the study was conducted, type of study (systematic review with or without meta-analysis), type of psychiatric disorder(s), assessment of psychiatric disorder(s) and assessment of T2DM, number of primary studies of the prevalence of T2DM, total number of study participants, and primary findings including information on the prevalence of T2DM, odds and relative risk ratios, when possible. The first author (NL) extracted the following information from all primary studies included in the systematic reviews: name of first author, year of publication, total number of study participants, number of study participants with T2DM and/or prevalence estimates. We divided the included systematic reviews into categories of psychiatric disorders and conducted a narrative data-synthesis for each of the identified categories of psychiatric disorders.

Statistical analysis

If more than one systematic review described the prevalence of T2DM for each of the identified categories of psychiatric disorders, we conducted separate meta-analyses to summarize the results of a large number of prevalence estimates quantitatively. This was a deviation from the original PROSPERO protocol although the amendment was described in our published protocol [14]. We conducted meta-analyses based on data

extracted from the primary studies that were included in the systematic reviews. We defined the numerator as number of people with a psychiatric disorder and T2DM, and the denominator as total number of people with a psychiatric disorder in the primary study. We included each primary study only once in the meta-analysis. If several primary studies were based on the same sample, we included the study with the largest sample size. If data regarding the numerator and denominator were not available in the primary study, we extracted data from the original systematic review when possible, as the authors of the systematic reviews in some cases had contacted the author of the primary study to obtain the relevant information. In cases where no data was available, we excluded the primary study from the meta-analyses.

We used a random effects model for all meta-analyses. In order to stabilize the variance, we used double arcsine transformations and the inverse variance method [21]. We calculated the I^2 metrics to evaluate between-study heterogeneity [22, 23]. In our published protocol [14], we planned to use Egger's test to examine publication bias [24]. However, concerns have been raised about the sensitivity of Egger's test to detect asymmetry, when the number of included studies is small [25]. Therefore, we decided to use two more recent methods, the Doi plot and the Luis Furuya-Kanamori index [LFK index], to identify publication bias. In the LFK index a value beyond ±1 is deemed consistent with publication bias and this index has shown to be more sensitive than Egger's test [25]. All meta-analyses were conducted in MetaXL, a software package for meta-analysis in Microsoft Excel [21, 26].

Risk of bias assessment

Two independent reviewers (NL and either SHS or LK) assessed the risk of bias for each of the included systematic reviews, using the Risk of Bias in Systematic Reviews (ROBIS) tool [27]. A third author (LK or SHS) resolved disagreements. We assessed the following four types of risk of bias: (I) study eligibility criteria, II) identification and selection of studies, (III) data collection and study appraisal, and (IV) synthesis and findings. Based on how we assessed potential risk of bias within the four types (I-IV), we assessed an overall risk of bias in the systematic review (high, low or unclear risk of bias).

Results

Study selection and characteristics

In total, we identified 32 systematic reviews including a total of 245 unique primary studies focusing on prevalence of T2DM in psychiatric disorders from 431 full-text screenings and 5,155 records found in the dataset searches (Figure 1). The included systematic reviews were focused on 11 categories of psychiatric disorders: 1) schizophrenia (*n* = 7) [10, 28-33], 2) bipolar disorders (*n* = 4) [9, 31, 34, 35], 3) depression (*n* = 3) [11, 31, 36], 4) substance use disorders (*n* = 3) [31, 37, 38], 5) anxiety disorders (*n* = 2) [31, 39], 6) eating disorders (*n* = 2) [40, 41], 7) intellectual disabilities (*n* = 2) [42, 43], 8) psychosis (*n* = 2) [44, 45], 9) sleep disorders (*n* = 2) [46, 47], 10) dementia (*n* = 1) [48], and 11) an "mixed" group that comprised different types of psychiatric disorders (*n* = 9) [31, 49-56].

We present the characteristics of the 32 systematic reviews in Table 1. Nineteen (59%) of the 32 systematic reviews originated from Europe, six (19%) from the USA, four (13%) from Australia, one (3%) from each of Chile, China, and Ethiopia. Different methods were used to identify psychiatric disorders and T2DM, including diagnostic criteria, prescription data, screening, admission status, medical records, diagnostic tests, surveys, questionnaires, interviews, and self-reports. In most of the systematic reviews (91%, 29/32), multiple types of assessments were used. A considerable proportion (41%, 13/32) did not report the type of assessment for psychiatric disorders or T2DM. Several systematic reviews were based on an overlapping set of primary studies. We report an overview of the 245 unique primary studies of the prevalence of T2DM in ESM Table 4.

Risk of bias assessment

We report an overview of the risk of bias assessment in Table 2 and ESM Fig 1. A total of 20 included systematic reviews had a high risk of bias [28-36, 41, 42, 45, 47-49, 51, 52, 54-56] while 12 reviews had a

low risk of bias [9-11, 37-40, 43, 44, 46, 50, 53]. We found high concerns regarding the identification and selection of studies in 19 reviews (59%) and concerns regarding the data collection and study appraisal in 18 reviews (56%).

Narrative synthesis

An overview of prevalence estimates for each category of psychiatric disorder is shown in Table 3. In the 32 systematic reviews, prevalence estimates for T2DM in the identified psychiatric disorders ranged between 1.3% and 66.0%. When only including systematic reviews with low risk of bias (n = 12), the prevalence estimates of T2DM ranged from 5.1% to 22.3%. In the systematic reviews with low risk of bias, the highest prevalence estimates of T2DM was reported in people with sleep disorders (22.3%) [46], psychosis (18.9%) [44], and substance use disorders (11.9-15.3%) [37, 38]. Forty-four percent (14/32) of the included systematic reviews made comparisons with control groups and reported increased risk of T2DM in people with psychiatric disorders. In one of the included systematic reviews investigating intellectual disabilities, three primary studies reported a tendency of decreased risk of T2DM [42].

Meta-analyses of the prevalence of T2DM

For ten of the 11 categories of psychiatric disorders, more than one systematic review reported the prevalence of people with T2DM. We therefore conducted new meta-analyses of T2DM prevalence estimates for each of these categories of psychiatric disorders. These ten meta-analyses included between six and 153 unique primary studies depending on the psychiatric disorder, and an overview of the estimated prevalence estimates for each of the categories is presented in Table 4. According to our meta-analyses, people with sleep disorders have the highest prevalence of T2DM (39.7%, 95% CI 34.9-44.7%), followed by those with binge eating disorders (20.7%, 95% CI 7.6-37.4%), substance use disorders (15.6%, 95% CI 10.3-21.7%), anxiety disorders (13.7%, 95% CI 7.7-20.9%), bipolar disorders (11.4%, 95% CI 7.8-15.6%) and

psychosis (11.1%, 95% CI 7.3-15.5%). We found the lowest prevalence of T2DM in people with intellectual disabilities (8.1%, 95% CI 6.5-9.8%). We report forest plots for all meta-analyses in ESM Fig 2.

In all meta-analyses, a high level of between-study heterogeneity was detected (I^2 0.89-0.99). We found substantial publication bias in the four meta-analyses focusing on schizophrenia, substance use disorders, binge eating disorders and mixed group of psychiatric disorders. We found only minor publication bias in the meta-analysis of T2DM prevalence in people with psychosis. We report Doi plots for all meta-analyses in ESM Fig 3.

Discussion

In this umbrella review, we systematically summarized and critically assessed the existing evidence on prevalence of T2DM in people with a psychiatric disorder.

We meta-analyzed data from primary studies for ten categories of psychiatric disorders revealing prevalence estimates between 8% and 40%. Our meta-analyses were based on primary studies from several systematic reviews and therefore were built on more data than previous meta-analyses. Overall, we found that the majority of the meta-analyses revealed prevalence estimates that were comparable with existing meta-analyses within each of the categories of psychiatric disorders [9-11, 38-40, 44, 46, 50, 53]. However, meta-analyzed data revealed notable high prevalence estimates for sleep disorders (40%) and binge eating disorders (20%). Sleep disorders, as defined in DSM5 constitute a subgroup of psychiatric disorders [19], and has high comorbidity with several other somatic diseases [57, 58]. In our umbrella review, the majority of the primary studies were conducted among people with additional somatic diseases such as chronic kidney diseases. It is likely that this physical comorbidity contributes to the high T2DM prevalence estimates in people with sleep disorders. A previous review suggested the association between sleep disorders and T2DM is bidirectional with sleep disorders being a risk factor for T2DM and T2DM, especially when combined with poor metabolic control, being a risk factor for sleep disorders [59]. For people with binge eating disorders, the T2DM prevalence estimates were based on data from four primary studies with limited

sample sizes. The results should be interpretated with caution, due to large confidence intervals. Additionally, there might be an effect of publication year, with more recent publications reporting higher prevalence of T2DM in people with binge eating disorders (see ESM Fig. 2).

In 44% of the included systematic reviews, comparisons with control groups were made, revealing an increased prevalence of T2DM in people with a psychiatric disorder. This increased prevalence of T2DM was detected for most of the investigated psychiatric disorders, suggesting a shared vulnerability in people with psychiatric disorders to develop T2DM. In line with these findings, our meta-analyzed T2DM prevalence estimates typically exceeded those for global prevalence estimates of T2DM [12, 13]. However, better understanding of these differences and explaining factors are still needed. The global prevalence estimates of 6.3% to 9.3% for T2DM is as in 2017 and 2019 respectively [12, 13] whereas the primary studies included in the meta-analyses were conducted between 1980 and 2020. The comparison of the global prevalence estimates with the findings from our meta-analyses suggest people across all the investigated psychiatric disorders more often have T2DM. However, more refined comparisons should be made between prevalence estimates in the future to better account differences in populations groups, study settings and the broad range of years as well as methods to ascertain T2DM.

In the general population, the prevalence of T2DM has increased considerably over the past decades [13, 60, 61], due to an increase in the population incidence of obesity and T2DM, a decrease in age-standardized mortality and a growing proportion of the aging population [62]. However, with the exception of people with binge eating disorder, the forest plots (ESM Fig 2.) show that when the primary studies are ranked according to publication year, there is no indication of increase in prevalence estimates of T2DM in people with a psychiatric disorder with publication year of the study over the past 2-3 decades. This might be explained by issues, such as changes in prescription patterns of psychotropic drugs over the past decades [63] and the high amount of undiagnosed T2DM in people with a psychiatric disorder [64]. These issues warrant further investigation.

Overall, this umbrella review highlights the importance to focus on prevalent T2DM across different psychiatric disorders as we see a general tendency of elevated T2DM prevalence rates in people with a

psychiatric disorder. Much of previous research has focused on schizophrenia and depression [10, 65, 66, 67], but our findings suggest that the prevalence of T2DM is high also in several other psychiatric disorders emphasizing the need for future studies that cover the full range of psychiatric disorders. Future collaborations should follow the example by the initiative of the European Depression in Diabetes (EDID) Research Consortium [68], combining researchers from different fields and countries to collaborate with a focus on a psychiatric disorder and diabetes.

Strengths and limitations

To the best of our knowledge, this is the most comprehensive summary on T2DM in psychiatric disorders to date providing an overview across different psychiatric disorders in one and same paper. We have summarized all existing systematic reviews in the field and included all primary studies to estimate the T2DM prevalence for each psychiatric disorder.

There are also several limitations that should be acknowledged. First, our umbrella review included studies published during an extended period of several decades, where the clinical context has changed considerably. Changes in treatment guidelines [69] and lifestyle factors such as physical activity [70], dietary habits [71], and smoking behaviors [72] will presumably have had an impact on prevalence estimates of T2DM in people with a psychiatric disorder. We have not explored possible effects of these developments in this umbrella review. Another limitation is that we have not included most recent observational studies, that are not included in a systematic review. However, primary studies up to 2020 have been included in the umbrella review and we therefore estimate this gap is modest. A third limitation is that the prevalence of T2DM was not available for some common psychiatric disorders such as attention deficit hyperactivity disorder and autism. Fourth, a majority of the included systematic reviews had high risk of bias regarding the identification and selection of studies and there were also concerns regarding data collection and study appraisal. In most cases, the systematic reviews were rated as having high risk of bias because no efforts were taken to minimize error during the conduction of the study. For example, there was no description of

two independent reviewers conducting the procedures. Lastly, we detected publication bias in several of the identified categories of psychiatric disorders. All conducted meta-analyses yielded wide confidence intervals and we found a high level of heterogeneity. This might be explained by different types of study populations due to different purposes of the included systematic reviews and primary studies. Some systematic reviews had no restrictions on the study population, whereas other reviews had a narrower focus on elderly populations or inpatients. Furthermore, different assessment methods of psychiatric disorders and T2DM were used. More homogenous prevalence estimates could be expected if all primary studies used the golden standards for diagnosis of T2DM [73].

Conclusions

In more than a decade, the importance of screening and adequate treatment of T2DM in people with psychiatric disorders has been highlighted [74]. By providing the most comprehensive review on this issue to date, this umbrella review confirms that T2DM is a common comorbidity in people with a psychiatric disorder particularly sleep disorders, binge eating disorders, substance use disorders, and anxiety disorders. Our review identified a need for future research to identify contributors to this comorbidity. Future research must determine whether underdiagnosis of T2DM in people with psychiatric disorders means that the present figures are lower-bound estimates. Reliable information about prevalence and a better understanding of biological and behavioral factors driving increased prevalence of T2DM in people with psychiatric disorders, will be crucial to developing cost-effective strategies for care of T2DM in people with psychiatric disorders.

Author Contributions:

All authors have contributed in a meaningful way. NL and FP had the original idea, and NL completed the searches. NL, SS and LK conducted the screening for relevant papers, extracted data and assessed risk of bias. NL conducted the analyses and made the first draft of the manuscript. All authors (NL, SS, FR, LK, ML, KHR, JEH, GSA, MK, and FP) have commented on the manuscript and likewise, all authors have read and approved the final manuscript. FP is the guarantor of this work.

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Role of the sponsor/funder:

The study sponsor/funder was not involved in the design of the study; the collection, analysis, and interpretation of data; writing the report; and did not impose any restrictions regarding publication of the report.

Potential Conflicts of Interests:

G.S.A. own shares in Novo Nordisk A/S. F.R. is associate editor with Diabetologia. The rest of the authors declared that they have no potential conflicts of interests.

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Table 1. Characteristic of 32 systematic reviews included in the umbrella review investigating prevalence of type 2 diabetes among people with psychiatric disorders

First author (year), country	Study design	Psychiatric disorder	Assessment of psychiatric disorder	Assessment of T2DM	No of primary studies (in MA)	No of participants (Characteristics of participants)	Prevalence estimates T2DM	Comparison of prevalence estimates with control group
Schizophrenia (*n* = 7)								
Oud (2009) The Netherlands	SR	Schizophrenia	Not reported	Not reported	2	21,114 including cases with schizophrenia and controls	9-14%	Not reported
Mitchell (2013a) United Kingdom	MA	Schizophrenia (divided into First episode and unmedicated)	Diagnosis (DSM, ICD); clinical expert judgement or miscellaneous criteria	Not reported	(First episode: 9 Un-medicated: 4)	15,693 cases with schizophrenia	First episode: 1.3% (95% CI, .5–2.4). Unmedicated: 2.1% (95% CI, .5–4.8)	Not reported
Mitchell (2013b) United Kingdom	MA	Schizophrenia and related disorders	Diagnosis (DSM, ICD); clinical expert judgement or miscellaneous criteria	Not reported	(14)	2,186 cases with schizophrenia or related disorders	10.9% (95% CI, 7.0–15.5)	Not reported
van den Brink (2013) The Netherlands*	SR	Schizophrenia	Assessment instruments; medical records *(Not distinguished between assessment of psychiatric disorder or diabetes assessment)*		2	5,499 cases with schizophrenia (People living in long-term care facilities)	15.8-31.5%	Not reported
Stubbs (2015) United Kingdom	MA	Schizophrenia	Diagnosis (DSM, ICD); diagnostic interviews; medical records	Recognized criteria (ADA, WHO), medical records; self-or physician report; medication use	(25)	145,718 cases with schizophrenia and 4,343,407 controls	9.5% (95% CI, 7.0-12.8%)	RR=1.82 (95% CI, 1.56-2.13) (*n* studies = 25)
Ayano (2019) Ethiopia	SR	Schizophrenia	Not reported	Glucose level (only reported in one study)	4	Not reported	9.8-15%	In one study reported 3 times higher than the general population
Ma (2020) Australia	MA	Schizophrenia and other psychotic disorders	Diagnosis (DSM5)	Medical records ; self-report ; prescription of medication ; measure of abnormal glucose states (impaired glucose regulation and abnormal reference range of glucose	4	1,685 (Inpatients from secure psychiatric hospitals or custodial centres)	12.4% (95% CI 10.8-14.0)	Not reported
Bipolar disorders (*n* = 4)								
Lala (2012) USA	SR	Bipolar disorder	Medical records		4	418 cases with psychiatric disorders	13-31.3%	Not reported

			(Not distinguished between assessment of psychiatric disorder or diabetes assessment)			(Focuses on elderly people above 50)		
van den Brink (2013) The Netherlands*	SR	Bipolar disorder	Assessment instruments; medical records *(Not distinguished between assessment of psychiatric disorder or diabetes assessment)*		1	5,299 cases with bipolar disorder (People living in long-term care facilities)	28.0%	Not reported
Vancampfort (2015a) Belgium	MA	Bipolar disorder	Diagnosis (DSM, ICD); diagnostic interviews	Screening (OGTT+ADA criteria); medication use; self-or physician report; medical records; medical claims	19(17)	18,060 cases with bipolar disorder 783,049 matched controls	9.4% (95% CI, 6.5-12.7%)	RR=1.98 (95% CI, 1.6-2.4) (n studies = 4, comparing to matched controls)
Charles (2016) USA	SR	Bipolar disorder	Admission status; medical records; medication use	Medical records; medication use	5	35,272 cases with bipolar disorder and around 35,500,000 controls	10.77% (*n* studies =1)	People with bipolar disorder have higher rates of diabetes ranging from OR = 1.6 to RR = 3.19 (95% CI 2.74-3.70) (*n* studies =5)
Depression (*n* = 3)								
van den Brink (2013) The Netherlands*	SR	Depression	Assessment instruments; medical records *(Not distinguished between assessment of psychiatric disorder or diabetes assessment)*		1	154,262 cases with depression (Individuals living in long-term care facilities)	30.3%	Not reported
Vancampfort (2015b) Belgium	MA	Major depressive disorder	Diagnosis (DSM, ICD); diagnostic interviews; surveys/rating scales	Screening (fasting glucose); self-report; medical records; medical claims	17(16)	158,834 cases with major depressive disorder and 2,098,063 controls	8.7% (95% CI, 7.3-10.2%)	RR = 1.49 (95% CI = 1.29–1.72; p < 0.001) (*n* studies = 10, comparing to the general controls).
Ross (2019) Australia	SR	Depression (including postpartum depression and major depression disorder)	Diagnosis (DSM, ICD); questionnaires; self-report	Not reported	8 *Note: of two references reported almost identical data – only the most recent is included*	33,114,038 including cases with depression and controls (Focuses on pregnancy)	Postpartum depression: 14.5% (*n* studies =1) Depression: 3.4-49% (*n* studies =6)	Postpartum depression: In one study women with postpartum depression had significant higher prevalence of DM compared to controls. Another study found no significant differences. Depression: In three studies, women with depression have significant higher prevalence of DM than control (reported in one study: OR=1.52 (95% CI, 1.47-1.589)).
Substance use disorders (*n* = 3)								
van den Brink (2013) The Netherlands*	SR	Substance use disorder	Assessment instruments; medical records *(Not distinguished between assessment of psychiatric disorder or diabetes assessment)*		1	4,849 cases with substance use disorder (Individuals living in long-term care facilities)	31.1%	Not reported

Vancampfort (2016c) Belgium	MA	Alcohol Use disorder	Diagnosis (DSM, ICD); test-score	Screening (fasting glucose, OGTT); self-or physician report	(7)	8,998 cases with alcohol use disorder	Unadjusted 11.9% (95% CI, 9.3-15.1%). When applying the trim and fill method adjusted for 2 studies:12.4% (95% CI, 11.8-13.9%)	No data available
Dam (2019) The Netherlands	SR	Korsakoff´s syndrome	Diagnosis (ICD); survey/rating scales; medical records *(Not distinguished between assessment of psychiatric disorder or diabetes assessment)*		6	1,102 cases with Korsakoff´s syndrome	15.6% (range 10-26%)	Not reported
Anxiety disorders (*n* = 2)								
van den Brink (2013) The Netherlands*	SR	Anxiety disorder	Assessment instruments; medical records *(Not distinguished between assessment of psychiatric disorder or diabetes assessment)*		1	22,513 cases with anxiety disorder (Individuals living in long-term care facilities)	24.9%	Not reported
Vancampfort (2016b) Belgium	MA	Posttraumatic stress disorder	Diagnosis (DSM, ICD); validated screening instruments	Screening (fasting glucose, OGTT); medication use; self-report	(9)	23,396 cases with posttraumatic stress disorders and 125,723 controls	Unadjusted 10.0% (95% CI, 8.1-12.0%), and remained the same after the trim and fill methods	RR=1.49 (95% CI, 1.17-1.89) (*n* studies = 5)
Eating disorders (*n* = 2)								
Nieto-Martinez (2017) USA	MA	Eating disorder (including binge eating disorder, bulimia nervosa, anorexia nervosa)	Diagnosis (DSM, ICD); clinical interviews; questionnaire; self-report	Clinical criteria; medication use; self-report	(4)	18,752 including cases with eating disorder and controls	Binge eating: 5.1% (*n* studies = 1)	Binge eating disorder: OR = 3.69 (95% CI 1.12-12.12) (*n* studies = 4) Bulimia nervosa: OR = 3.45 (95% CI 1.92-6.19) (*n* studies = 2) Anorexia nervosa: NS OR = .868 (95% CI .40-1.88) (*n* studies = 1)
Olguin (2017) Chile	SR	Binge eating disorder	Questionnaires/surveys; medical records *(Not distinguished between assessment of psychiatric disorder or diabetes assessment)*		3	5,227 including cases with binge eating disorder and controls	2-26%	Two studies found higher rates of diabetes and one study found comparable rates of diabetes in cases with binge eating disorder compared to control group.
Intellectual disabilities (*n* = 2)								
McVilly (2014) Australia	SR	Intellectual disabilities and developmental disabilities	Not reported	Interview; survey; physician report; medical records	13	Sample sizes ranged between, *n* = 4-27,116	8.7% (range 3.4-18.5%)	Not reported
MacRae (2015) United Kingdom	SR	Intellectual disabilities	Not reported	Screening (fasting glucose); questionnaire; diagnosis; medical records; physical;	22	49,011 cases with intellectual disabilities	8.3% (range .4-25%)	Eight studies found significant higher prevalence of diabetes in cases with intellectual disabilities compared to the general population.

				self- or physician report; interviews; medication use				Three studies found less prevalence of diabetes in cases with intellectual disabilities compared to the general population.
Psychosis (*n* = 2)								
Chung (2020) USA	MA	Non-affective psychosis	Diagnosis (DSM, ICD)	Screening (Fasting glycose); medication use; medical records	(10)	3,790 cases with non-affective psychosis. (Around 20 % of the cases have a family history of DM.)	18.9%	Not reported
Foley (2011) Australia	SR	Psychosis	Not reported	Not reported	1	Not reported	5%	10-fold higher prevalence of diabetes in cases with psychosis compared to controls (5% vs .5%, *n* studies = 1)
Sleep disorders (*n* = 2)								
Guo (2016) China	MA	Obstructive sleep apnea	Not reported	Not reported	(8)	1,063 cases with obstructive sleep apnea	22.3%	Not reported
Puthenpura (2020) USA	SR	Sleep apnea	Apnea–hypopnea index criteria or Diagnosis (ICD-9)	Not reported	7	186,686 (Patients with a chronic kidney disease)	17.0-66.0%	Not reported
Dementia (*n* = 1)								
Smith (2014) United Kingdom	SR	Dementia	Diagnosis (DSM); diagnostic tests; assessment instruments	Not reported	2	193 with dementia	15 %	Not reported
Mixed group of psychiatric disorders (n = 9)								
Osborn (2008) United Kingdom	MA	Severe mental illness (including schizophrenia, schizoaffective disorder, and bipolar disorder)	Diagnosis	Screening (for random glucose, fasting glucose or impaired glucose tolerance); Diagnosis; medical records; self-report	26(9)	9,612 cases with severe mental illness and 3,449,677 controls	12.13%	RR = 1.70 (1.21-2.37) (*n* studies = 9)
Barnard (2013) United Kingdom	SR	Antidepressant medication *(as a proxy for undefined psychiatric disorders)*	Medication use	Screening (glucose level); self-report; medication use	1	461 cases with depression and 25,315 controls	2.8%	OR = 1.43 [95% CI .73–2.80], *p* = 0.293)
van den Brink (2013) The Netherlands*	SR	Severe mental illness (not specified)	Assessment instruments; medical records *(Not distinguished between assessment of psychiatric disorder or diabetes assessment)*		1	13,730 cases with severe mental illness (Individuals living in long-term care facilities)	29.90%	Not reported
Janssen (2015) USA	SR	Severe mental illness (including schizophrenia. bipolar disorder,	Not reported	Screening (fasting glucose); medical records	6	Not reported	16.1% (median 12.5% range 6.9-34%)	Not reported

		major depression and PTSD)						
Young (2015) United Kingdom	SR	Antipsychotic medication use *(as a proxy for undefined psychiatric disorders)*	Medication use	WHO definition	12	Not reported	2-28%	Not reported
Vancampfort (2016a) Belgium	MA	Severe mental illness (including; schizophrenia, bipolar disorder and major depressive disorder)	Diagnosis (DSM, ICD)	Screening (blood testing); self-report; medical records	(118)	438,245 cases with severe mental illness and 5,622,664 matched controls	Unadjusted 10.2% (95% CI, 9.1-11.4%) When applying the trim and fill method adjusted for 13 studies: 11.3% (95% CI, 10.0-12.6%)	For multi-episode severe mental illness: RR=1.85 (95% CI, 1.45-2.37) (*n* studies = 38). For first-episode patients: NS RR=4.64 (95% CI, 0.73-29.3) (*n* studies = 3)
Roberts (2017) United Kingdom	MA	Psychiatric inpatients (including schizophrenia, schizoaffective disorder, mood disorder, substance use disorder, or not specified)	Diagnostic criteria (DSM, ICD); Admission status; medication use	Diagnosis; screening (fasting glucose, blood glucose); medication use	(13)	3,122 cases with mental disorder (Inpatients from psychiatric setting)	9 % (95% CI: 6-13)	Not reported
Rigal (2018) France	SR	Mental disorders (including schizophrenia, schizoaffective disorder, bipolar, other psychiatric disorder or depressive symptoms)	Diagnosis (DSM or unspecified); questionnaire	Screening (Glycemia> 1.26 g/dL (2 different dosages)); medication use	(4)	963 with mental disorder and 1,681 controls	5.5-13% (*n* studies =3)	RR = 4.8-fold higher in individuals with mental disorders compared to controls. (*n* studies = 4)
Onyeka (2019) Norway	MA	Severe mental illness (including schizophrenia, bipolar disorder and other psychotic conditions) with or without substance use disorder.	Diagnosis (DSM, ICD)	Not reported	(3)	Not reported	For severe mental illness with substance use disorder 7.5% (95% CI, 1.1-37.6) For severe mental illness without substance use disorder 7.5% (95% CI 1.3-33.9)	Not reported

ADA, American Diabetes Association; DSM, Diagnostic and Statistical Manual of Mental Disorders; ICD, International Statistical Classification of Diseases and Related Health Problems; MA, meta-analysis; NS, not significant; OGTT, oral glucose tolerance test; OR, odds ratio; RR, relative risk; SR, systematic review; T2DM, Type 2 diabetes; WHO, World Health Organization; *, The paper include several exposures and is therefore represented in several categories

Table 2. Presentation of ROBIS assessment of the 32 systematic reviews included in the umbrella review

	Phase 2				Phase 3
Systematic review	1. study eligibility criteria	2. Identification and selection of studies	3. Data collection and study appraisal	4. Synthesis and findings	Risk of bias in the review
Osborn (2008)	High	Low	High	High	High
Oud (2009)	High	High	High	Low	High
Foley (2011)	Low	High	High	High	High
Lala (2012)	High	High	High	High	High
Barnard (2013)	Low	Low	High	High	High
Mitchell (2013a)	Low	High	High	High	High
Mitchell (2013b)	Low	High	High	Low	High
van den Brink (2013)	Low	High	Low	High	High
McVilly (2014)	Low	High	Low	Low	Low
Smith (2014)	High	High	High	High	High
Janssen (2015)	Low	High	High	Low	High
MacRae (2015)	High	High	Low	Low	High
Stubbs (2015)	Low	Low	Low	Low	Low
Vancampfort (2015a)	Low	Low	Low	Low	Low
Vancampfort (2015b)	Low	Low	Low	Low	Low
Young (2015)	High	High	High	High	High
Charles (2016)	Low	High	High	High	High
Guo (2016)	Low	High	Low	Low	Low
Vancampfort (2016a)	Low	Low	High	Low	High
Vancampfort (2016b)	Low	Low	Low	Low	Low
Vancampfort (2016c)	Low	Low	Low	Low	Low
Nieto-Martinez (2017)	Low	Low	Low	Low	Low
Olguin (2017)	Low	High	High	High	High
Roberts (2017)	Low	High	Low	Low	Low
Rigal (2018)	Low	High	High	Low	High
Dam (2019)	High	Low	Low	Low	Low
Onyeka (2019)	High	Low	Low	Low	Low
Ross (2019)	Low	High	High	High	High
Ayano (2019)	High	High	High	High	High
Chung (2020)	Low	Low	Low	Low	Low
Ma (2020)	Low	High	High	Low	High
Puthenpura (2020)	Low	Low	High	Low	High

Low = Low risk of bias; High = High risk of bias

Table 3. Overview of prevalence estimates of T2DM for 11 categories of psychiatric disorders identified in 32 systematic reviews included within the umbrella review

Psychiatric disorder	No of SR (MA) included, n	Prevalence estimates of T2DM in all SR, %	No of SR with low risk of bias, n	Prevalence estimates of T2DM in SR with low risk of bias, %	No of SR comparing with controls, n	Comparison of prevalence estimates with control group
Schizophrenia	7 (4)	1.3% - 31.5%	1	9.5%	1	1.8 – 3 times increased risk
Bipolar disorder	4 (1)	9.4% - 31.3%	1	9.4%	2	1.6 - 3.19 increased risk
Depression	3 (1)	3.4% - 49%	1	8.7%	2	1.43 – 1.52 increased risk
Substance use disorder	3 (1)	11.9% - 31.1%	2	11.9%-15.6%	0	-
Anxiety disorder	2 (1)	10.0% - 24.9%	1	10.0%	1	1.49 increased risk
Eating disorder	2 (1)	BED: 2% - 26%	1	BED: 5.1%	2	BED and BN: Increased risk (not specified)
Intellectual disability	2	8.3%-8.7%	1	8.7%	1	7 primary studies reported increased risk, 3 primary studies reported decreased risk
Psychosis	2 (1)	5% - 18.9%	1	18.9%	1	1 primary study reported 10 times increased risk
Sleep disorder	2 (1)	22.3%-66.0%	1	22.3%	0	-
Dementia	1	15%	0	-	0	-
Mixed group of psychiatric disorders	9 (5)	2%-31.5%	2	7.5% to 9%	3	1.43 - 4.8 increased risk

BED, Binge Eating Disorder; BN, Bulimia Nervosa; SR, systematic review; T2DM, type 2 diabetes mellitus

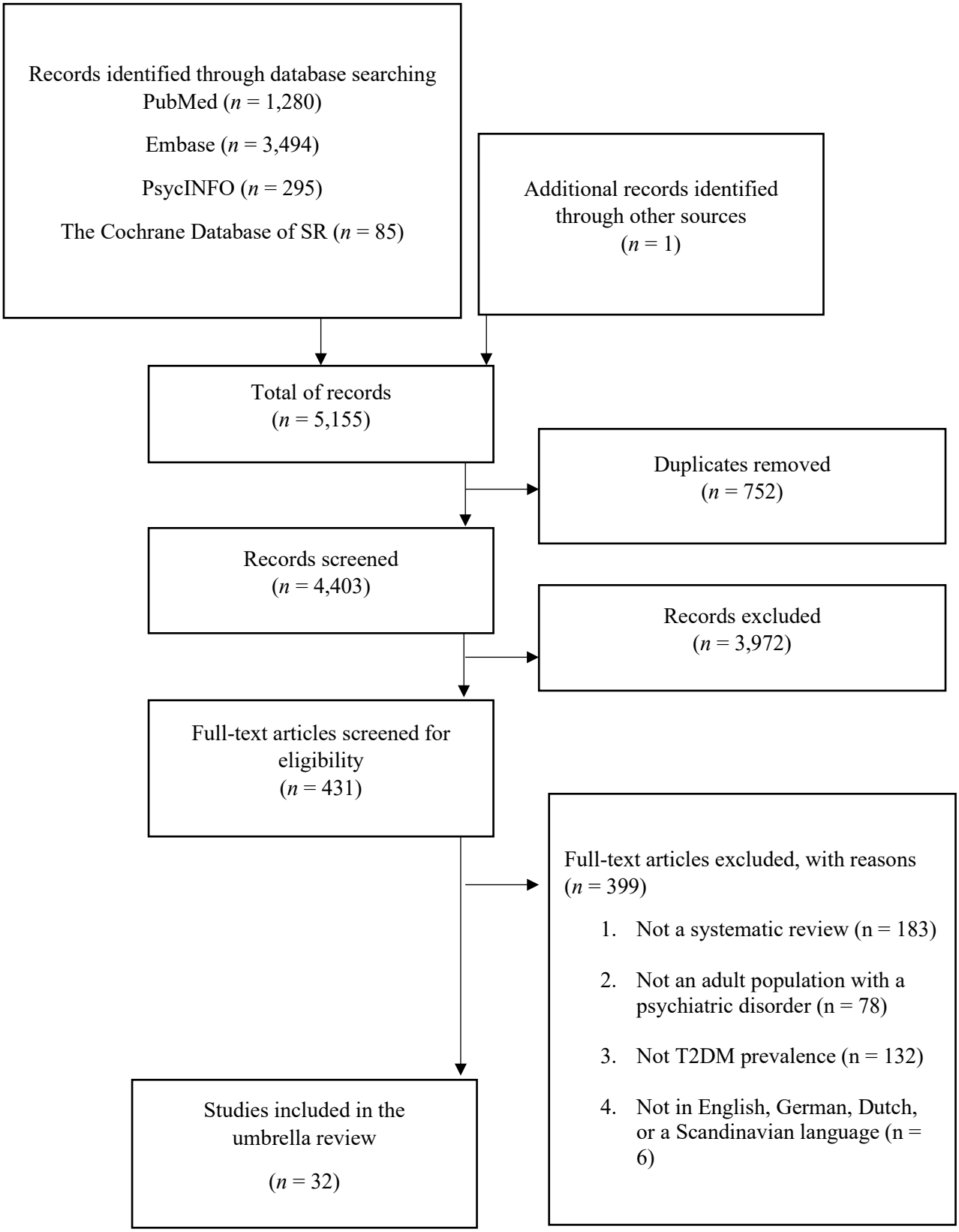
Table 4. Prevalence estimates of type 2 diabetes in psychiatric disorders from random-effects meta-analyses of 245 primary studies from 32 systematic reviews.

Psychiatric disorder	No of systematic reviews, n	No of primary studies, n	No of included primary studies, n	No of participants, n	Prevalence of T2DM (95% confidence intervals) %	I^2, %	Publication bias (LFK index of asymmetry)
Schizophrenia	7*	35	32	149,295	10.05% (8.07-13.13)	>.99	4.49 (major)
Bipolar disorder	4	26	23	23,493	11.44% (7.84-15.60)	.99	.22 (no)
Depression	3	24	21	12,568,442	9.08% (6.41-12.15)	>.99	.58 (no)
Substance use disorder	3	14	14	9,926	15.58% (10.33-21.66)	.98	-4.42 (major)
Anxiety disorder	2	10	10	45,899	13.66% (7.71-20.92)	>99	-.99 (no)
Binge eating disorder	2	6	6	969	20.65% (7.64-37.43)	.97	-2.13 (major)
Intellectual disability	2	23	20	42,378	8.07% (6.49-9.81)	.96	.71 (no)
Psychosis	2	11	11	4,744	11.06% (7.25-15.54)	.95	1.70 (minor)
Sleep disorder	2	15	15	186,274	39.73% (34.90-44.66)	.89	-.85 (no)
Mixed group of psychiatric disorders	7	153	138	13,524,005	9.95% (9.28-10.73)	>99	2.69 (major)

LFK index, Luis Furuya-Kanamori index; T2DM, Type 2 diabetes.

* In two of the seven systematic reviews describing people with schizophrenia, primary studies were not reported and therefore only primary studies from five systematic review were included in the meta-analysis

Figure 1. Study flowchart



Electronic Supplementary Materials (ESM)

Contains:

ESM Table 1

ESM Table 2

ESM Table 3

ESM Table 4

ESM Figure 1

ESM Figure 2

ESM Figure 3

Note: In the ESM Figures, decimals are denoted with commas instead of full stops due to settings in the applied software program.

ESM Table 1. PRISMA 2009 Checklist and MOOSE guidelines

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	3-4
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	5
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	5
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	5
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	6-7
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	6
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	6 + Appendix 3
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	6-7
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	7
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	7-8
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	8-9
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	7-9

Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	8-9
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	8-9
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	N/A
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	9, + Figure 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	9-10, + Table 1+ Table 3
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	10, + Table 2 + Appendix 5
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	9-11, + Table 1
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	10-11, + Table 4, + Appendix 6
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	10, Table 4, + Appendix 7
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	N/A
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	11-12
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	13
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	14
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	15

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(6): e1000097. doi:10.1371/journal.pmed1000097

ESM Table 2. MOOSE Checklist for Meta-analyses of Observational Studies

Item No	Recommendation	Reported on Page No
Reporting of background should include		
1	Problem definition	5
2	Hypothesis statement	5
3	Description of study outcome(s)	5
4	Type of exposure or intervention used	5
5	Type of study designs used	5
6	Study population	5
Reporting of search strategy should include		
7	Qualifications of searchers (eg, librarians and investigators)	N/A
8	Search strategy, including time period included in the synthesis and key words	6-7, Appendix 3
9	Effort to include all available studies, including contact with authors	N/A
10	Databases and registries searched	6
11	Search software used, name and version, including special features used (eg, explosion)	6-7
12	Use of hand searching (eg, reference lists of obtained articles)	7
13	List of citations located and those excluded, including justification	6-7 Figure 1
14	Method of addressing articles published in languages other than English	N/A
15	Method of handling abstracts and unpublished studies	N/A
16	Description of any contact with authors	N/A
Reporting of methods should include		
17	Description of relevance or appropriateness of studies assembled for assessing the hypothesis to be tested	6-7
18	Rationale for the selection and coding of data (eg, sound clinical principles or convenience)	6-7
19	Documentation of how data were classified and coded (eg, multiple raters, blinding and interrater reliability)	7-8
20	Assessment of confounding (eg, comparability of cases and controls in studies where appropriate)	N/A
21	Assessment of study quality, including blinding of quality assessors, stratification or regression on possible predictors of study results	9
22	Assessment of heterogeneity	8-9
23	Description of statistical methods (eg, complete description of fixed or random effects models, justification of whether the chosen models account for predictors of study results, dose-response models, or cumulative meta-analysis) in sufficient detail to be replicated	8-9
24	Provision of appropriate tables and graphics	8-9
Reporting of results should include		
25	Graphic summarizing individual study estimates and overall estimate	Table 3, Table 4, Appendix 6, Appendix 7
26	Table giving descriptive information for each study included	Table 1
27	Results of sensitivity testing (eg, subgroup analysis)	N/A

28	Indication of statistical uncertainty of findings	10-12, Table 4, Appendix 6, Appendix 7
Reporting of discussion should include		
29	Quantitative assessment of bias (eg, publication bias)	10-11
30	Justification for exclusion (eg, exclusion of non-English language citations)	N/A
31	Assessment of quality of included studies	10
Reporting of conclusions should include		
32	Consideration of alternative explanations for observed results	11-12
33	Generalization of the conclusions (ie, appropriate for the data presented and within the domain of the literature review)	14
34	Guidelines for future research	12-14
35	Disclosure of funding source	15

From: Stroup DF, Berlin JA, Morton SC, et al, for the Meta-analysis Of Observational Studies in Epidemiology (MOOSE) Group. Meta-analysis of Observational Studies in Epidemiology. A Proposal for Reporting. *JAMA*. 2000;283(15):2008-2012. doi: 10.1001/jama.283.15.2008.

ESM Table 3. Search strategy

PubMed		
No.	Description or domain:	Search term
1	Search terms for psychiatric disorders (title/abstract)	psychiatric OR psychological* OR mental OR disorder* OR dysfunction* OR "developmental delay" OR psychogenetic OR stuttering OR autis* OR Asperger OR ADHD OR ADD OR pica OR encopresis OR enuresis OR "selective mutism" OR "acquired aphasia with epilepsy" OR "Rett´s syndrome" OR "disturbance of activity and attention" OR "elective mutism" OR cluttering OR delirium OR dementia OR Alzheimer OR amnesia OR "amnesic syndrome" OR hallucinosis OR "postencephalitic syndrome" OR "postconcussional syndrome" OR dependence OR abuse OR intoxication OR withdrawal OR "harmful use" OR schizophrenia OR psychosis OR psychoses OR psychotic OR catatonia OR depress* OR manic OR mania OR hypomania OR bipolar OR cyclothymi* OR dysthymi* OR agoraphobia OR phobi* OR "panic attack*" OR PTSD OR anxiety OR "predominantly obsessional thoughts or ruminations" OR OCD OR obsessions OR compulsions OR "predominantly compulsive acts" OR "acute stress reaction" OR "reaction* to severe stress" OR dissociate* OR hypochondriasis OR neurasthenia OR depersonalization OR "premature ejaculation" OR dyspareunia OR vaginismus OR paraphilia OR exhibitionism OR fetishism OR pedophilia OR "sexual masochism" OR "sexual sadism" OR voyeurism OR "sexual desire" OR "sexual aversion" OR "failure of genital response" OR "excessive sexual drive" OR transsexualism OR transvestism OR paedophilia OR sadomasochism OR "egodystonic sexual orientation" OR "inhibited female orgasm" OR "inhibited male orgasm" OR frotteurism OR anorexia OR bulimia OR overeating OR dyssomnia OR insomnia OR hypersomnia OR narcolepsy OR parasomnia OR hypoventilation OR "sleep apnea" OR "sleep walking" OR "sleep terror" OR "restless legs syndrome" OR "abuse of non-dependence-producing substances" OR "behavioural syndrome" OR dysphoria OR kleptomania OR pyromania OR "pathological gambling" OR trichotillomania OR excoriation OR retardation OR personality
2	MeSH terms for psychiatric disorders	"Mental Disorders"[Mesh]
3	Search terms for prevalence (title/abstract)	prevalence OR incidence OR epidemiology OR epidemiological OR "risk factor*" OR cross-sectional OR "cross sectional"
4	MeSH terms for prevalence	"Prevalence"[Mesh] OR "Epidemiology"[Mesh] OR "Incidence"[Mesh] OR "Epidemiologic Studies"[Mesh]
5	Search terms for diabetes (title/abstract)	diabetes
6	MeSH terms for diabetes	"Diabetes Mellitus"[Mesh]
7	Search terms for systematic review (title/abstract)	"systematic review*" OR "comprehensive review*" OR "systematic overview*" OR "comprehensive overview*" OR meta-analys* OR metaanalys*
8	MeSH terms for systematic review	"Review Literature as Topic"[Mesh] OR "Meta-Analysis as Topic"[Mesh]
9	Domain for psychiatric disorders	1 OR 2
10	Domain for prevalence	3 OR 4
11	Domain for diabetes	5 OR 6
12	Domain for systematic reviews	7 OR 8
13	Total search string	9 AND 10 AND 11 AND 12

The Cochrane Database of Systematic Reviews		
No.	Description or domain:	Search term

1	Search terms for psychiatric disorders (title/abstract)	psychiatric OR psychological* OR mental OR disorder* OR dysfunction* OR "developmental delay" OR psychogenetic OR stuttering OR autis* OR Asperger OR ADHD OR ADD OR pica OR encopresis OR enuresis OR "selective mutism" OR "acquired aphasia with epilepsy" OR "Rett´s syndrome" OR "disturbance of activity and attention" OR "elective mutism" OR cluttering OR delirium OR dementia OR Alzheimer OR amnesia OR "amnesic syndrome" OR hallucinosis OR "postencephalitic syndrome" OR "postconcussional syndrome" OR dependence OR abuse OR intoxication OR withdrawal OR "harmful use" OR schizophrenia OR psychosis OR psychoses OR psychotic OR catatonia OR depress* OR manic OR mania OR hypomania OR bipolar OR cyclothymi* OR dysthymi* OR agoraphobia OR phobi* OR "panic attack*" OR PTSD OR anxiety OR "predominantly obsessional thoughts or ruminations" OR OCD OR obsessions OR compulsions OR "predominantly compulsive acts" OR "acute stress reaction" OR "reaction* to severe stress" OR dissociate* OR hypochondriasis OR neurasthenia OR depersonalization OR "premature ejaculation" OR dyspareunia OR vaginismus OR paraphilia OR exhibitionism OR fetishism OR pedophilia OR "sexual masochism" OR "sexual sadism" OR voyeurism OR "sexual desire" OR "sexual aversion" OR "failure of genital response" OR "excessive sexual drive" OR transsexualism OR transvestism OR paedophilia OR sadomasochism OR "egodystonic sexual orientation" OR "inhibited female orgasm" OR "inhibited male orgasm" OR frotteurism OR anorexia OR bulimia OR overeating OR dyssomnia OR insomnia OR hypersomnia OR narcolepsy OR parasomnia OR hypoventilation OR "sleep apnea" OR "sleep walking" OR "sleep terror" OR "restless legs syndrome" OR "abuse of non-dependence-producing substances" OR "behavioural syndrome" OR dysphoria OR kleptomania OR pyromania OR "pathological gambling" OR trichotillomania OR excoriation OR retardation OR personality
2	MeSH terms for psychiatric disorders	MeSH descriptor: [Mental Disorders] explode all trees
3	Search terms for prevalence (title/abstract)	prevalence OR incidence OR epidemiology OR epidemiological OR risk factor* OR cross-sectional OR cross sectional
4	MeSH terms for prevalence	MeSH descriptor: [Prevalence] explode all trees OR MeSH descriptor: [Cross-sectional Studies] explode all trees
5	Search terms for diabetes (title/abstract)	diabetes
6	MeSH terms for diabetes	MeSH descriptor: [Diabetes Mellitus] explode all trees
7	Search terms for systematic review (title/abstract)	systematic review* OR comprehensive review* OR systematic overview* OR comprehensive overview* OR meta-analys* OR metaanalys*
8	MeSH terms for systematic review	MeSH descriptor: [Review Literature as Topic] explode all trees OR MeSH descriptor: [Meta-Analysis as Topic] explode all trees
9	Domain for psychiatric disorders	1 OR 2
10	Domain for prevalence	3 OR 4
11	Domain for diabetes	5 OR 6
12	Domain for systematic reviews/meta-analysis	7 OR 8
13	Total search string	9 AND 10 AND 11 AND 12

PsycINFO		
No.	Description or domain:	Search term
1	Search terms for psychiatric disorders	psychiatric OR psychological* OR mental OR disorder* OR dysfunction* OR developmental delay OR psychogenetic OR stuttering OR autis* OR Asperger OR ADHD OR pica OR encopresis OR enuresis OR selective mutism OR

	mp. (mp=title, abstract, heading eord, table of contents,key consepts, original title, tests & measures, mesh)	acquired aphasia with epilepsy OR Retts syndrome OR disturbance of activity and attention OR elective mutism OR cluttering OR delirium OR dementia OR Alzheimer OR amnesia OR amnesic syndrome OR hallucinosis OR postencephalitic syndrome OR postconcussional syndrome OR dependence OR abuse OR intoxication OR withdrawal OR schizophrenia OR psychosis OR psychoses OR psychotic OR catatonia OR depress* OR manic OR mania OR hypomania OR bipolar OR cyclothymi* OR dysthymi* OR agoraphobia OR phobi* OR panic attack* OR PTSD OR anxiety OR predominantly obsessional thoughts or ruminations OR OCD OR obsessions OR compulsions OR predominantly compulsive acts OR acute stress reaction OR reaction* to severe stress OR dissociate* OR hypochondriasis OR neurasthenia OR depersonalization OR premature ejaculation OR dyspareunia OR vaginismus OR paraphilia OR exhibitionism OR fetishism OR pedophilia OR sexual masochism OR sexual sadism OR voyeurism OR sexual desire OR sexual aversion OR failure of genital response OR excessive sexual drive OR transsexualism OR transvestism OR paedophilia OR sadomasochism OR egodystonic sexual orientation OR inhibited female orgasm OR inhibited male orgasm OR frotteurism OR anorexia OR bulimia OR overeating OR dyssomnia OR insomnia OR hypersomnia OR narcolepsy OR parasomnia OR hypoventilation OR sleep apnea OR sleep walking OR sleep terror OR restless legs syndrome OR abuse of non-dependence-producing substances OR behavioural syndrome OR dysphoria OR kleptomania OR pyromania OR pathological gambling OR trichotillomania OR excoriation OR retardation OR personality
2	Subject headings for psychiatric disorders	exp Mental Disorders/
3	Search terms for prevalence mp. (mp=title, abstract, heading eord, table of contents,key consepts, original title, tests & measures, mesh)	prevalence OR incidence OR epidemiology OR epidemiological OR risk factor* OR cross-sectional OR cross sectional
4	Subject headings for prevalence	exp Epidemiology/ OR exp Risk factor/
5	Search terms for diabetes mp. (mp=title, abstract, heading eord, table of contents,key consepts, original title, tests & measures, mesh)	diabetes
6	Subject headings for diabetes	exp diabetes mellitus/
7	Search terms for systematic review mp. (mp=title, abstract, heading eord, table of contents,key consepts, original title, tests & measures, mesh)	systematic review* OR comprehensive review* OR systematic overview* OR comprehensive overview* OR meta-analys* OR metaanalys*
8	Subject headings for systematic review	exp "literature review"/ OR exp meta analysis/
9	Domain for psychiatric disorders	1 OR 2
10	Domain for prevalence	3 OR 4
11	Domain for diabetes	5 OR 6

12	Domain for systematic reviews/meta-analysis	7 OR 8
13	Total search string	9 AND 10 AND 11 AND 12

EMBASE		
No.	Description or domain:	Search term
1	Search terms for psychiatric disorders mp. (mp. = title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word)	psychiatric OR psychological* OR mental OR disorder* OR dysfunction* OR developmental delay OR psychogenetic OR stuttering OR autis* OR Asperger OR ADHD OR pica OR encopresis OR enuresis OR selective mutism OR acquired aphasia with epilepsy OR Retts syndrome OR disturbance of activity and attention OR elective mutism OR cluttering OR delirium OR dementia OR Alzheimer OR amnesia OR amnesic syndrome OR hallucinosis OR postencephalitic syndrome OR postconcussional syndrome OR dependence OR abuse OR intoxication OR withdrawal OR schizophrenia OR psychosis OR psychoses OR psychotic OR catatonia OR depress* OR manic OR mania OR hypomania OR bipolar OR cyclothymi* OR dysthymi* OR agoraphobia OR phobi* OR panic attack* OR PTSD OR anxiety OR predominantly obsessional thoughts or ruminations OR OCD OR obsessions OR compulsions OR predominantly compulsive acts OR acute stress reaction OR reaction* to severe stress OR dissociate* OR hypochondriasis OR neurasthenia OR depersonalization OR premature ejaculation OR dyspareunia OR vaginismus OR paraphilia OR exhibitionism OR fetishism OR pedophilia OR sexual masochism OR sexual sadism OR voyeurism OR sexual desire OR sexual aversion OR failure of genital response OR excessive sexual drive OR transsexualism OR transvestism OR paedophilia OR sadomasochism OR egodystonic sexual orientation OR inhibited female orgasm OR inhibited male orgasm OR frotteurism OR anorexia OR bulimia OR overeating OR dyssomnia OR insomnia OR hypersomnia OR narcolepsy OR parasomnia OR hypoventilation OR sleep apnea OR sleep walking OR sleep terror OR restless legs syndrome OR abuse of non-dependence-producing substances OR behavioural syndrome OR dysphoria OR kleptomania OR pyromania OR pathological gambling OR trichotillomania OR excoriation OR retardation OR personality
2	Subject headings for psychiatric disorders	exp mental disease/
3	Search terms for prevalence mp. (mp. = title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word)	prevalence OR incidence OR epidemiology OR epidemiological OR risk factor* OR cross-sectional OR cross sectional
4	Subject headings for prevalence	exp Prevalence/ OR exp Epidemiology/ OR exp Incidence/ OR cross-sectional studies/
5	Search terms for diabetes mp. (mp. = title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating	diabetes

	subheading word, candidate term word)	
6	Subject headings for diabetes	exp diabetes mellitus/
7	Search terms for systematic review mp. (mp. = title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword, floating subheading word, candidate term word)	systematic review* OR comprehensive review* OR systematic overview* OR comprehensive overview* OR meta-analys* OR metaanalys*
8	Subject headings for systematic review	exp "systematic review"/ OR exp meta analysis/
9	Domain for psychiatric disorders	1 OR 2
10	Domain for prevalence	3 OR 4
11	Domain for diabetes	5 OR 6
12	Domain for systematic reviews/meta-analysis	7 OR 8
13	Total search string	9 AND 10 AND 11 AND 12

ESM Table 4. Overview of 245 unique primary studies in 32 systematic reviews included in the umbrella review focusing on prevalence of T2DM diabetes in people with a psychiatric disorder

Included systematic reviews / Primary studes	Osborn (2008)	Oud (2009)	Foley (2011)	Lala (2012)	Barnard (2013)	Mitchell (2013a) *	Mitchell (2013b) *	van den Brink (2013)	McVilly (2014)	Smith (2014) *	Janssen (2015)	MacRae (2015)	Stubbs (2015)	Vancampfort (2015a)	Vancampfort (2015b)	Young (2015)	Charles (2016)	Guo (2016)	Vancampfort (2016a)	Vancampfort (2016b)	Vancampfort (2016c)	Nieto-Martinez (2017)	Olguin (2017)	Rigal (2017)	Roberts (2017)	Ayano (2019)	Dam (2019)	Onyeka (2029)	Ross (2019)	Chung (2020)	Ma (2020)	Puthenpura (2020)	No data for MA
Liliker 1980	x													x					x														
Tabata 1987																			x														x
Finney 1989	x																																x
Gierz 1993	x																																
Mukherjee 1996	x							x								x			x														
Steinert 1996	x																																
Casadebaig 1997	x																																
Valk 1997									x			x																					
Makikyro 1998	x												x						x														
Cassindy 1999	x													x					x														
Dickey 2000																												x					
Dixon 2000	x	x											x						x														
Schepers 2000																											x						
Johnson 2001																						x	x										
Levine 2001											x														x								
Bulik 2002																						x											
Butler 2002												x																					
Dickerson 2002	x												x						x														
McElroy 2002														x					x														
Weisberg 2002																				x													
Regenold 2002	x			x										x					x														

Sernyak 2002																			x														
Cohen 2003	x																																
Gupta 2003																			x														
Kerr 2003												x																					
Ryan 2003	x																		x														
Subramaniam 2003	x																		x														
Arranz 2004	x																																x
Curkendall 2004	x												x						x														
David 2004																				x	x												
Egede 2004															x				x														
Enger 2004	x												x						x														
Fernandez 2004																x																	
Goldacre 2004												x																					x
Havercamp 2004												x																					
Hobye 2004												x																					
Jones 2004		x																															
Kessing 2004	x																																x
Kilbourne 2004	x													x					x														
Lamberti 2004	x																		x											x			
Macfarlane 2004																x									x						x		
Singh 2004																													x				x
Sokal 2004	x												x						x														
Chafetz 2005	x																		x														
Cohen 2005																			x														
Goff 2005											x		x						x					x									
Hung 2005	x												x						x							x				x			
Lamberti 2005																														x			
Saari 2005	x																																x
Sajatovic 2005				x																													
Susce 2005	x																		x														

Taylor 2005										x							
Carney 2006							x				x						
Citrome 2006											x						
Cohen 2006											x			x			
Correll 2006									x		x						
De Hert 2006											x						
Lambert 2006					x												
Lehmann 2006		x															
McDermott 2006				x		x											
Osborn 2006	x						x				x		x				
Reader 2006			x														
Shah 2006				x		x											
Wang 2006														x			
Almeida 2007									x		x						
Attux 2007											x						
Birkenaes 2007								x			x						
Bobes 2007											x						
Fairoz 2007											x						
Guerdjikova 2007												x					
Henderson 2007											x						
Kilbourne 2007											x						
Lasich 2007											x						
Mackin 2007										x			x				
McDermott 2007				x		x											
Moreno 2007											x						x
O´Brien 2007														x			
Reist 2007										x							x
Robson 2007															x		x
Straetsman 2007						x											
Voruganti 2007											x					x	

Yurtserver 2007																	x	
Cheon 2008															x			
Daumit 2008					x													
Fiedorowicz 2008								x				x						
Gildenger 2008		x																
Le Noury 2008										x								
Saddichha 2008												x						x
Suvisaari 2008												x						x
van Winkel 2008								x				x						
Yildiz 2008																	x	
Banta 2009										x								
Bell 2009					x							x						
Bernardo 2009												x						
Chien 2009							x					x						
Fullerton 2009			x															
Go 2009														x				
Jin 2009													x					
Kim 2009								x				x						
Patten 2009									x			x						
Rezai 2009												x						
Sohler 2009				x		x												
Tsai 2009								x				x						
Verma 2009	x						x					x						
Winter 2009				x														
Basil 2010																x		
Benute 2010																x		
Blank 2010									x			x						
Bresee 2010							x					x						
Chen 2010												x						
Chien 2010								x			x	x						

Ferreira 2010											x															
Gale 2010							x				x															
Holt 2010																		x							x
Jerrell 2010								x																		
Koponen 2010																x									x
Lemke 2010	x																									
Lozano 2010										x																
Okomura 2010						x			x			x														
Padmavati 2010											x														x
Ramos Rios 2010											x															
Rimmer 2010					x																					
Shirman 2010		x			x																					
Spitzer 2010												x														
Tang 2010																								x	
Tyler 2010		x			x																					
Achbrenner 2011	x																									
Argo 2011				x							x															
Bresee 2011						x					x															
Chen 2011		x			x																x					
Falissard 2011								x																		
Fiedorowicz 2011							x				x															
Hatt 2011							x				x															
Haveman 2011		x			x																					
Haw 2011																	x									
Hert 2011																		x							x
Ju 2011													x													
Kimijima 2011																	x									
Kursumi 2011																						x				
Lin 2011																				x						
Lunsky 2011					x																					

Mai 2011					x																				
Masuda 2011																								x	
Mookhoek 2011											x						x								
Nuevo 2011					x						x														
Phutane 2011					x						x														
Pietrzak 2011												x													
Reichard 2011	x			x																					
Substrahini 2011					x						x														
Webb 2011															x										
Wong 2011	x			x																					
Zhang 2011					x						x											x			
Atlantis 2012							x				x														x
Bensenor 2012											x														
Beumer 2012											x														
Chien 2012							x				x														
Hsieh 2012						x			x																
Kelbrick 2012																	x								
Kirkpatrick 2012					x						x														
Kodesh 2012									x																x
Li 2012							x				x														
Magalhaes 2012						x					x														
Morden 2012					x						x														
Morin 2012				x																					
Na 2012											x														
Said 2012											x														
Schoef 2012					x						x														
Svedal 2012									x																x
Tsan 2012								x																	
Vasudev 2012																	x								
Wijnia 2012																			x						

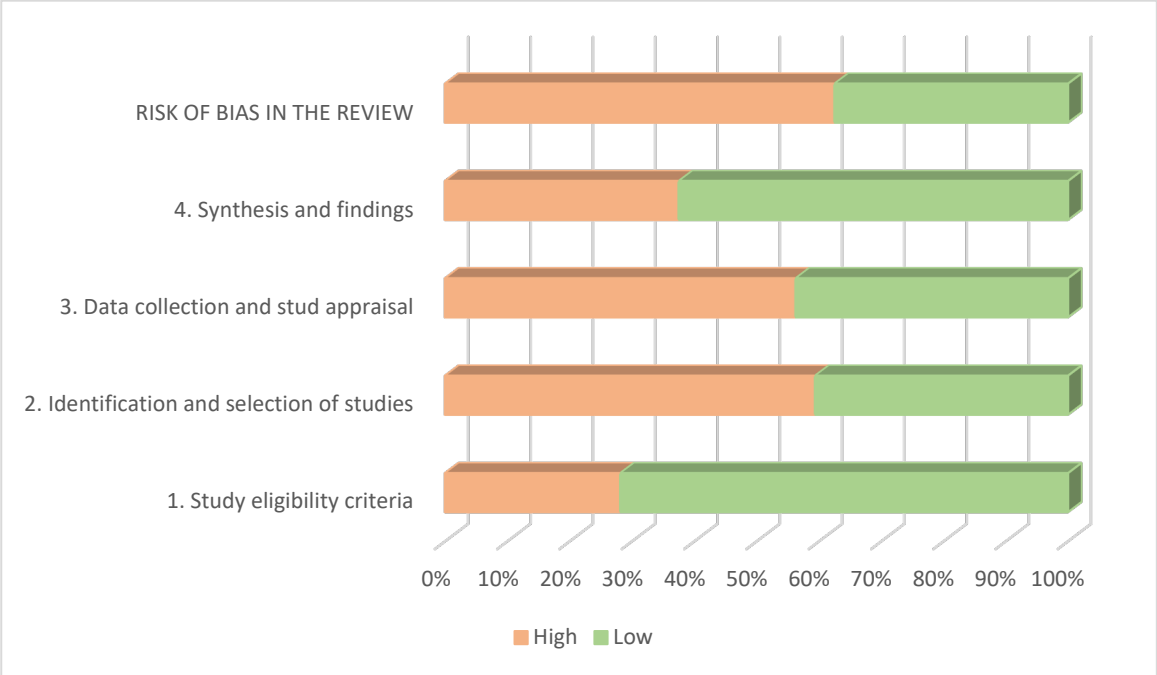
Wilson 2012																			x						
Winter 2012	x			x																					
Almital 2013							x				x														
Chandini 2013													x												
Chung 2013											x														
Crump 2013									x																x
Fleishhacher 2013											x														
Glaus 2013													x												
Gordon 2013											x														
Hendrie 2013											x														
Kelbrick 2013																	x								
Ko 2013											x														
Lukashek 2013												x													
Medeiros-Ferreira 2013											x														
Munhoz 2013							x				x														x
Semiz 2013											x														
Sivalingam 2013																								x	
Steylen 2013											x														
Sweileh 2013											x														
Vancampfort 2013											x														
Windle 2013							x				x														
Winter 2013				x																					
Agyemang 2014							x				x														
Chen 2014											x														x
Correl 2014											x														
Depp 2014						x					x														
Foley 2014					x	x					x										x				
Gerridzen 2014																			x						
Gladugau 2014											x														
Gottlieb 2014										x															

Keller 2014							x												
Kelly 2014							x												
Konz 2014							x												
Lloberes 2014						x													
Long 2014																			x
McMillan 2014						x													
Miller-Archie 2014								x											
Pach 2014									x										
Pedrosa 2014						x													
Räisänen 2014																	x		
Schoepf 2014	x	x	x				x												
Smith 2014			x				x												
Vaccarino 2014								x											
Wu 2014							x												
Wändell 2014							x												
Calkin 2015		x					x												
Hong 2015									x										
Huang 2015						x													
Kan 2015													x						
Kim 2015							x												
Mat 2015																			x
Mei-Dan 2015																	x		
Mitchell 2015										x									
Muxfeldt 2015						x													
Parra 2015						x													
Perugi 2015		x					x												
Odlaug 2015									x										
Osborn 2015							x												
Raevouori 2015										x									
Razzano 2015							x												

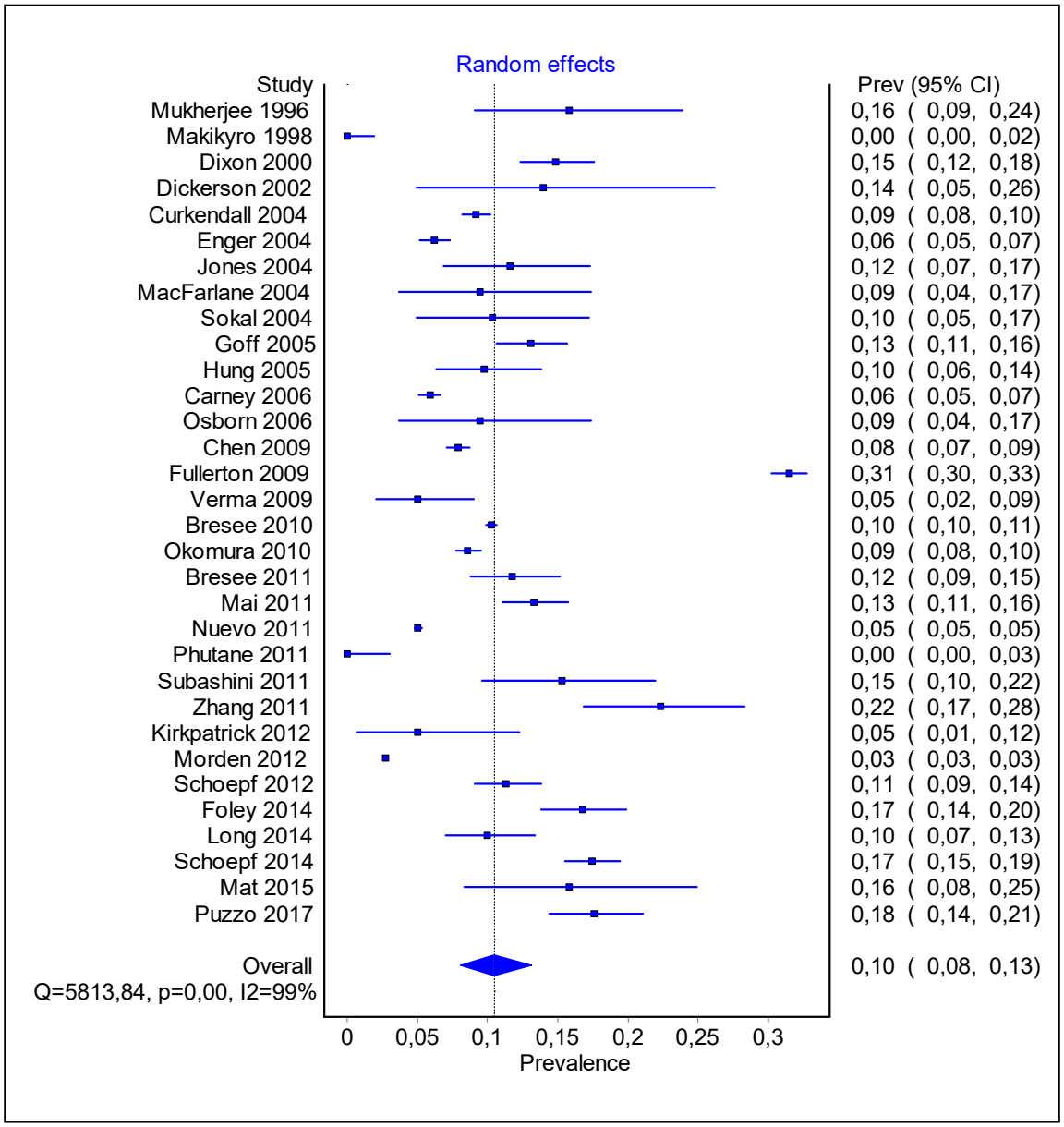
Roberts 2015			x						
Sicras Mainar 2015		x							
Strassnig 2015		x							
Sylvia 2015	x	x							
Wade 2015		x							
Wani 2015		x							x
Miller 2016						x			
Tuohy 2016								x	
Xu 2016								x	
Icick 2017					x				
Puzzy 2017							x		
Gerridzen 2018				x					
Kerns 2018								x	
Jhamp 2020								x	

* Three of the systematic reviews did not report the references of their primary studies

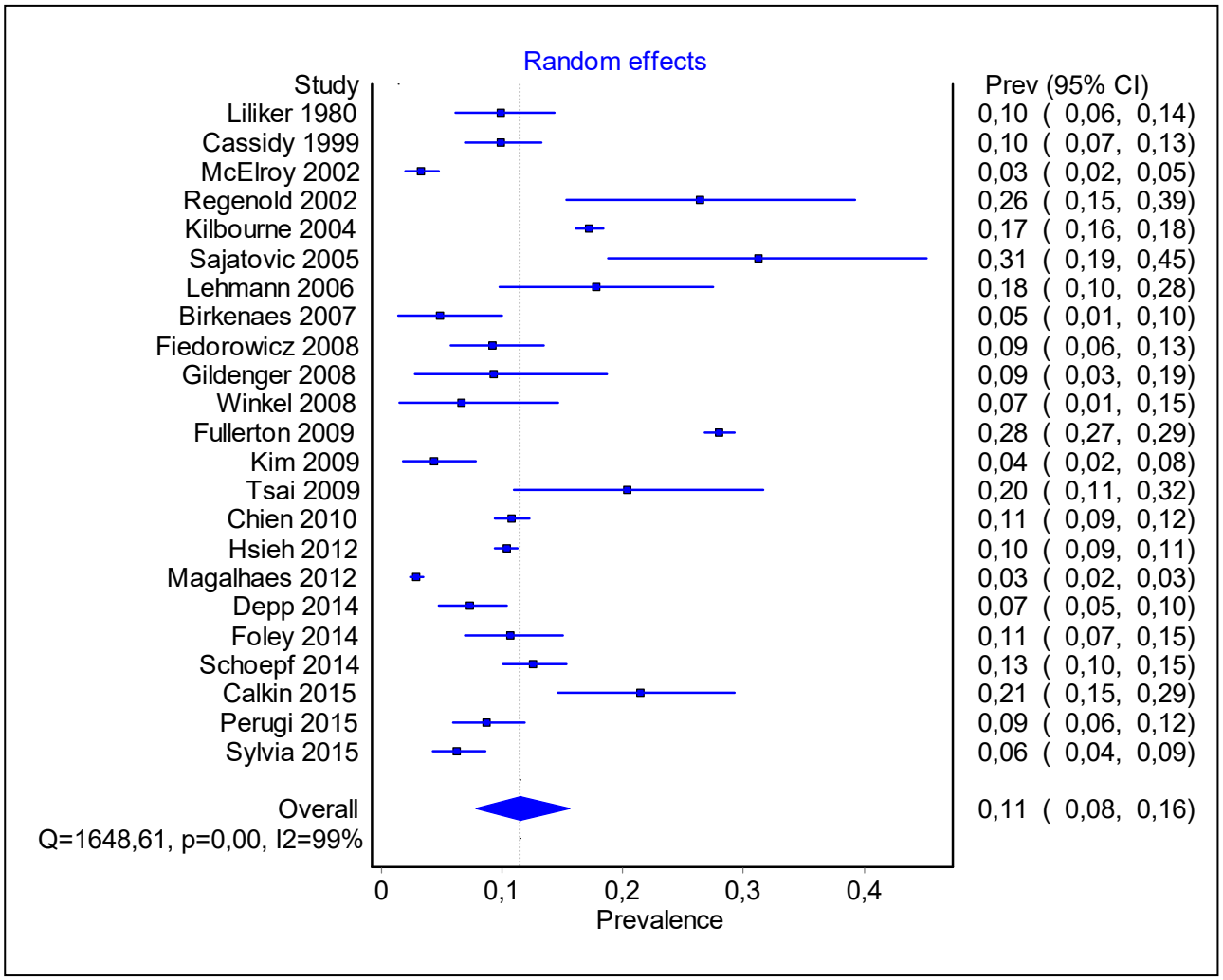
ESM Fig. 1. Graphical presentation of the ROBIS assessments of 32 systematic reviews included in the umbrella review



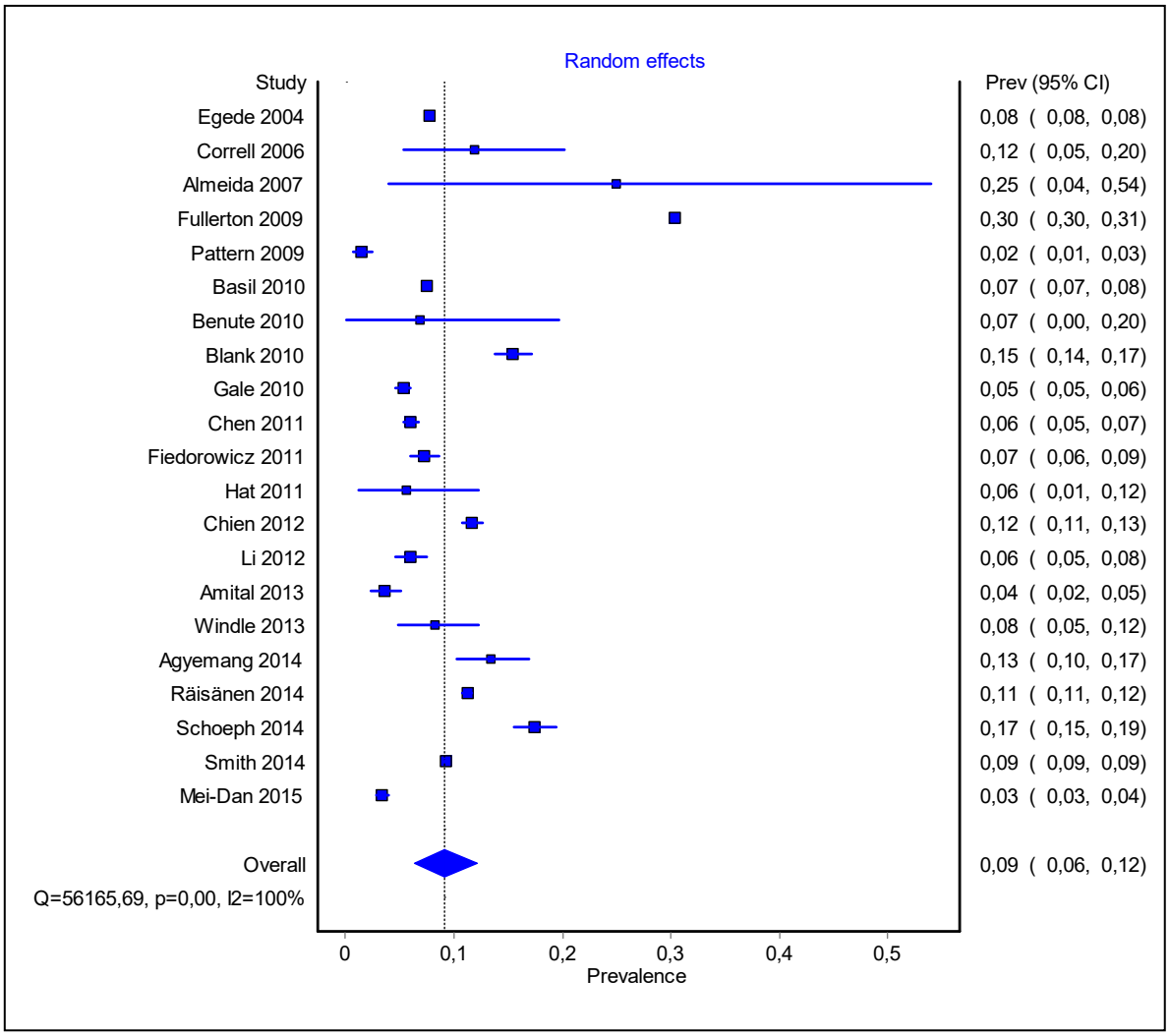
ESM Fig. 2. Forest plots illustrating random effects models of prevalence estimates of T2DM in 10 categories of psychiatric disorders



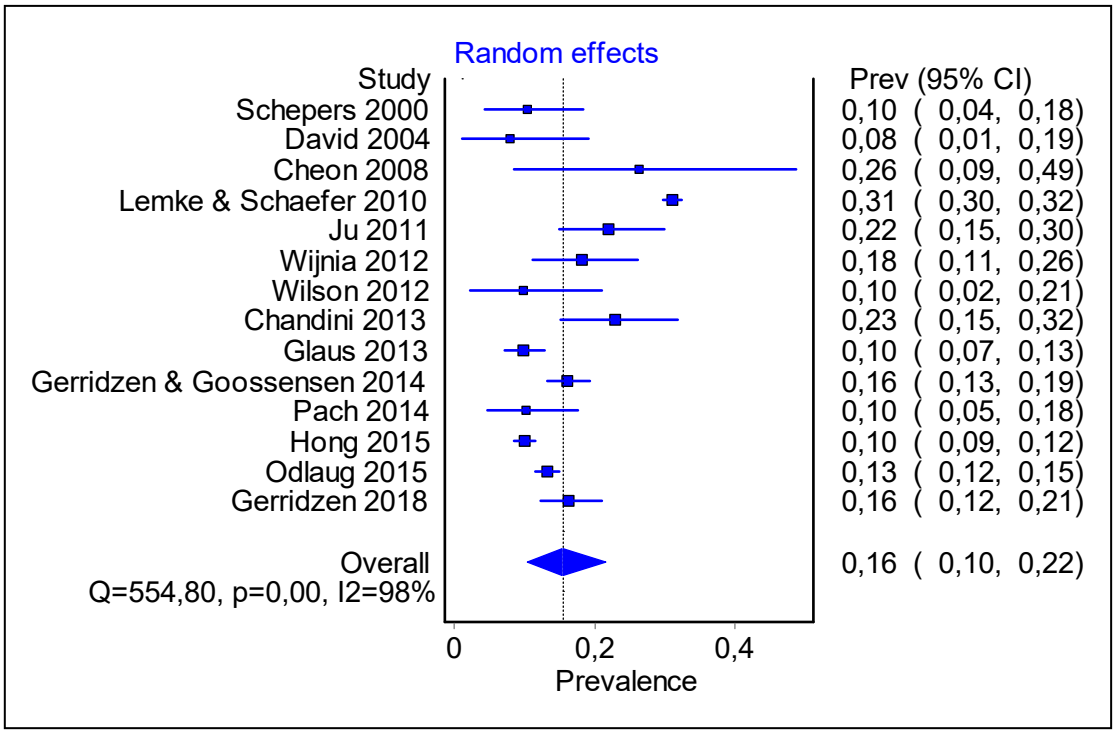
ESM Fig 2a. Forest plot for prevalence of T2DM among people with schizophrenia



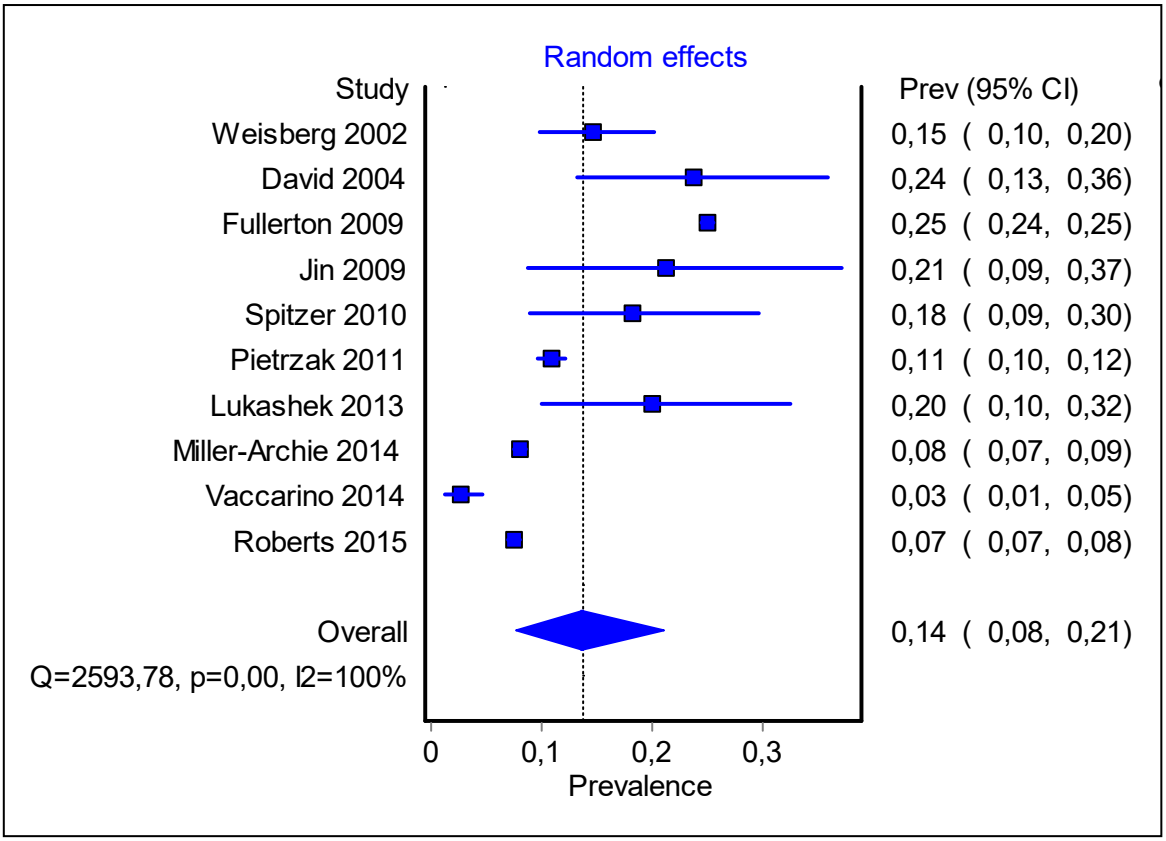
ESM Fig 2b. Forest plot for prevalence of T2DM among people with bipolar disorder



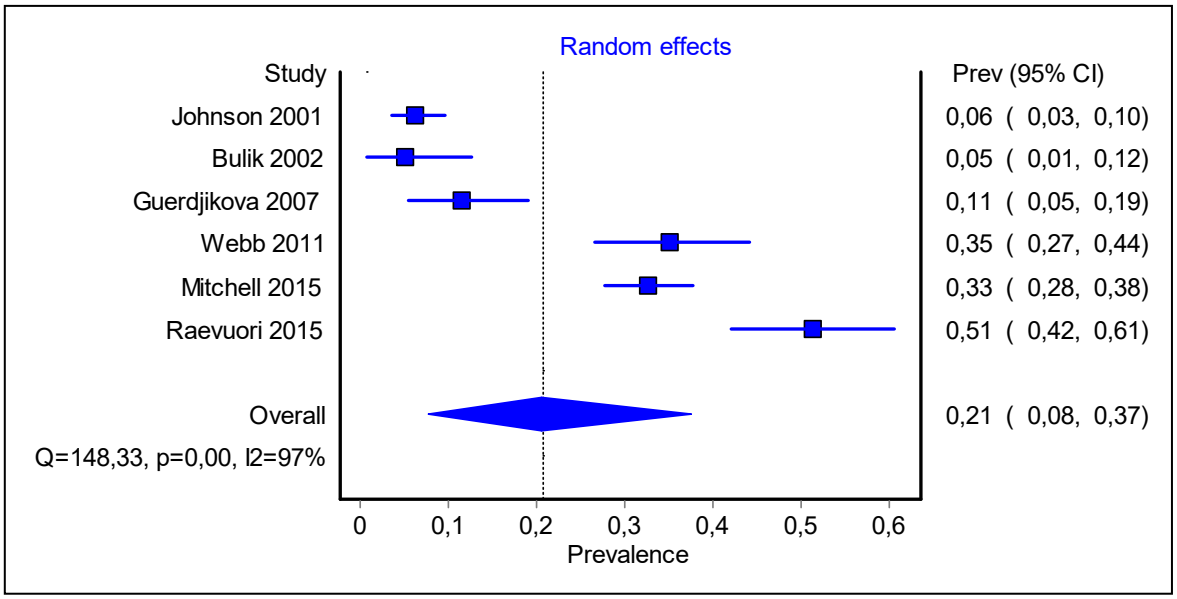
ESM Fig 2c. Forest plot for prevalence of T2DM among people with depression



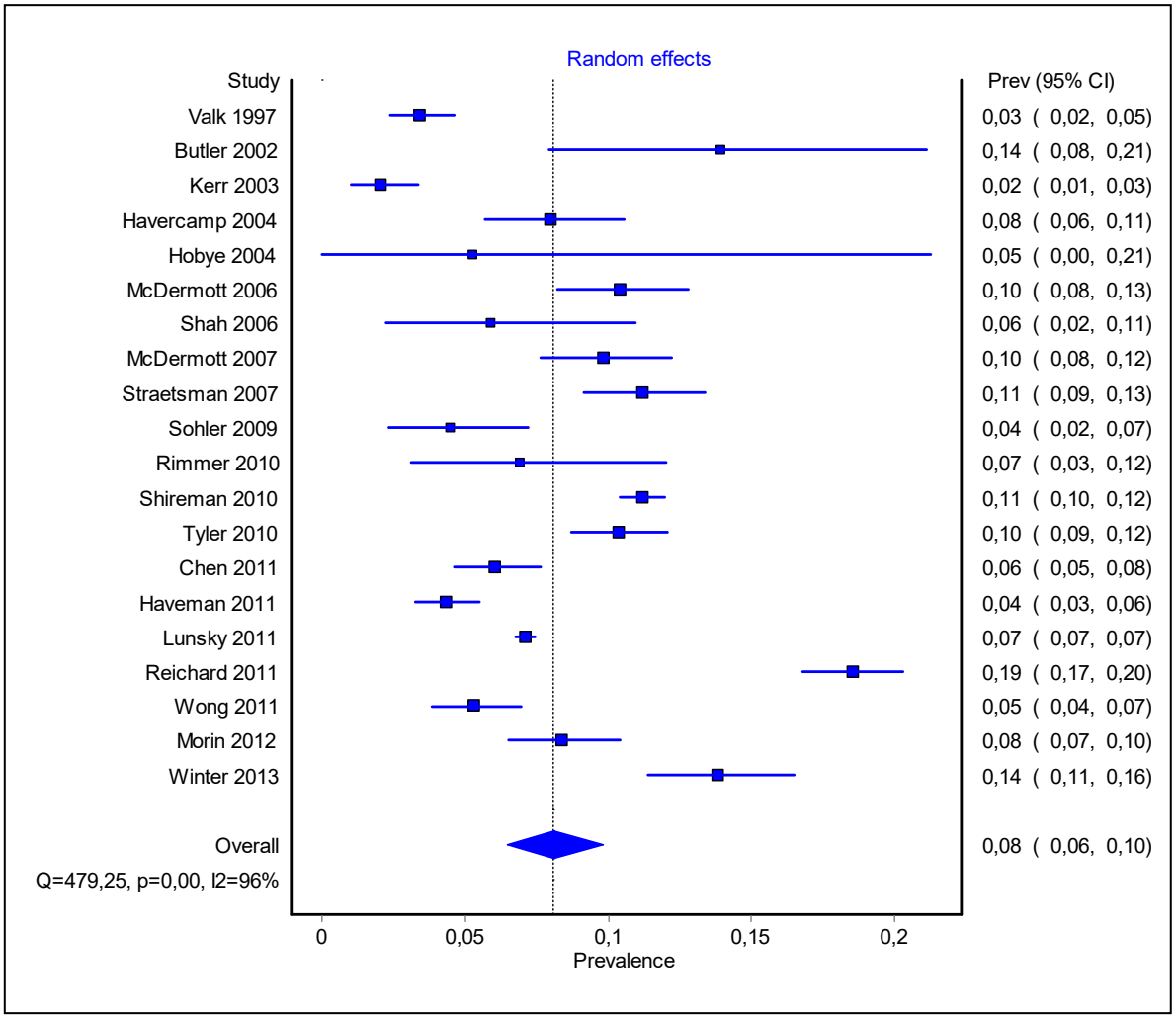
ESM Fig 2d. Forest plot for prevalence of T2DM among people with substance use disorder



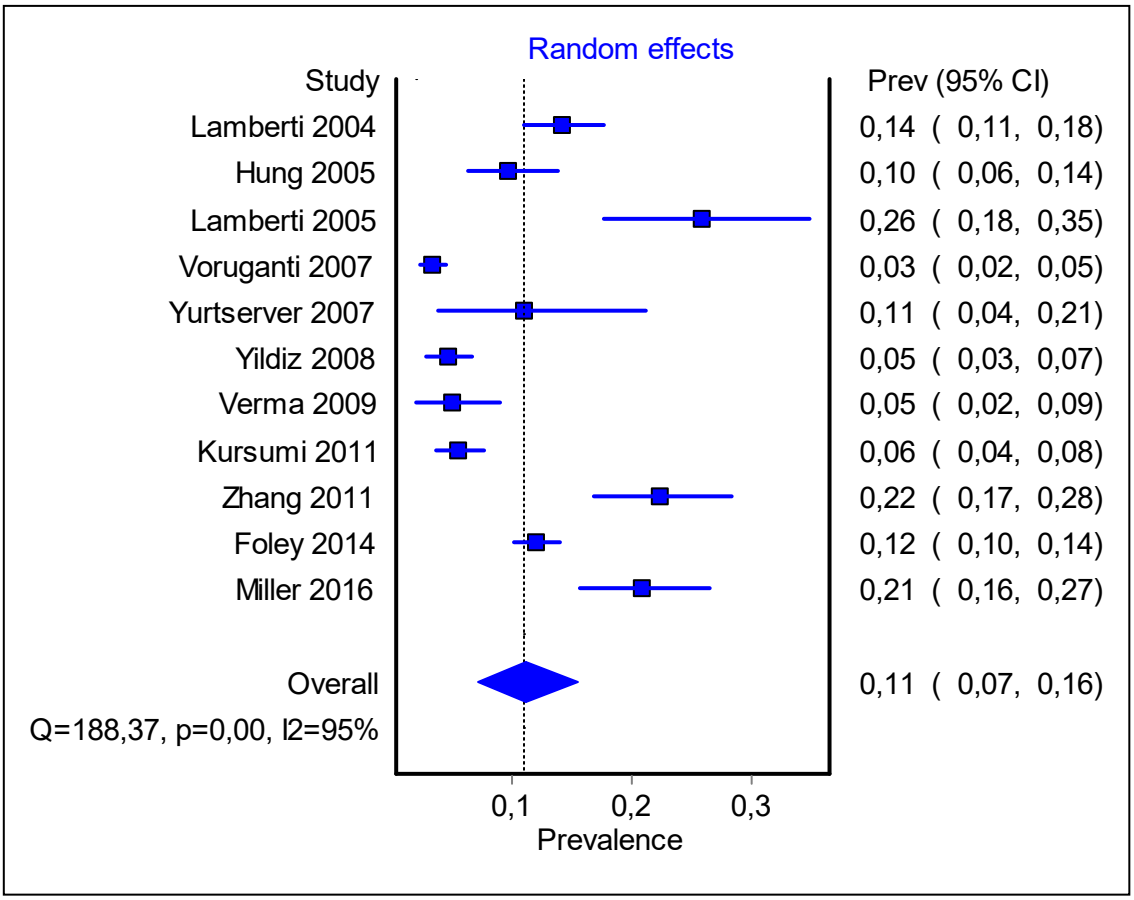
ESM Fig 2e. Forest plot for prevalence of T2DM among people with anxiety disorder



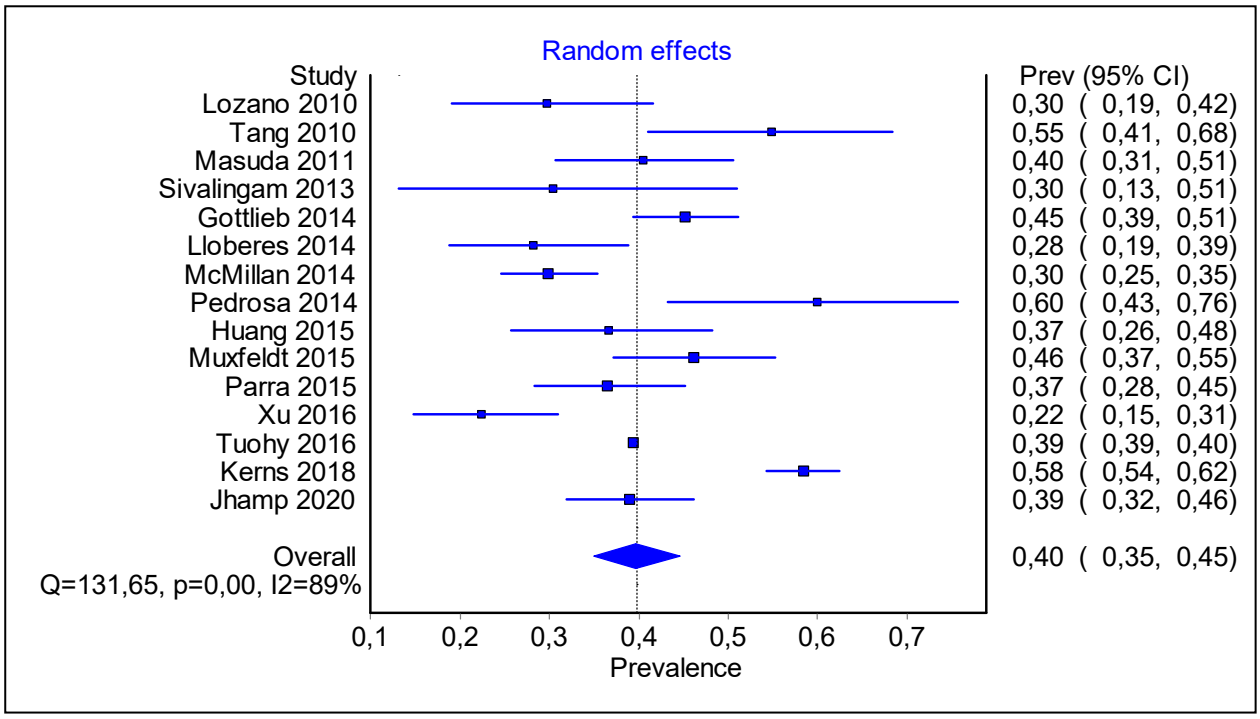
ESM Fig 2f. Forest plot for prevalence of T2DM among people with binge eating disorder



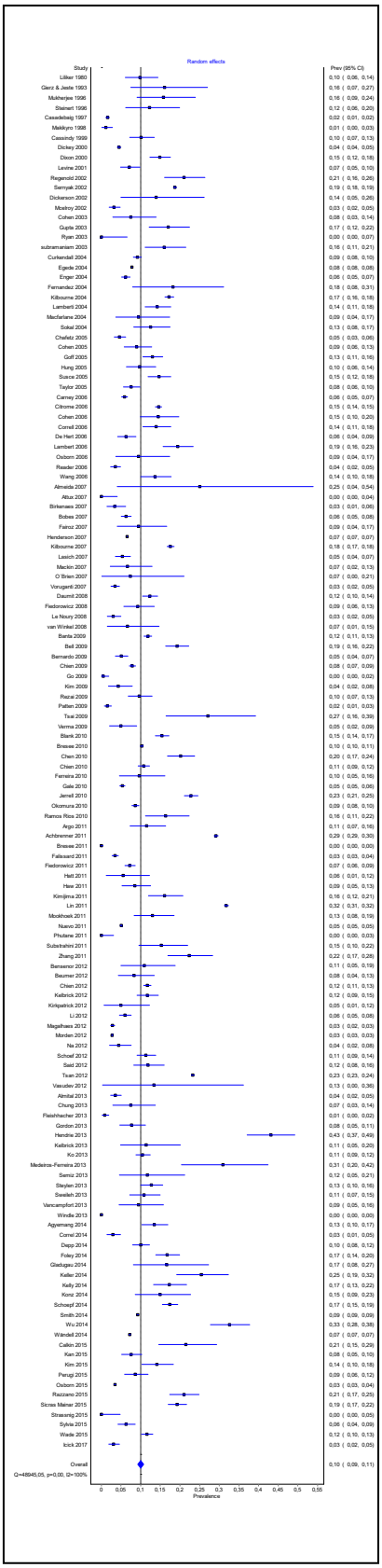
ESM Fig 2g. Forest plot for prevalence of T2DM among people with intellectual disability



ESM Fig 2h. Forest plot for prevalence of T2DM among people with psychosis

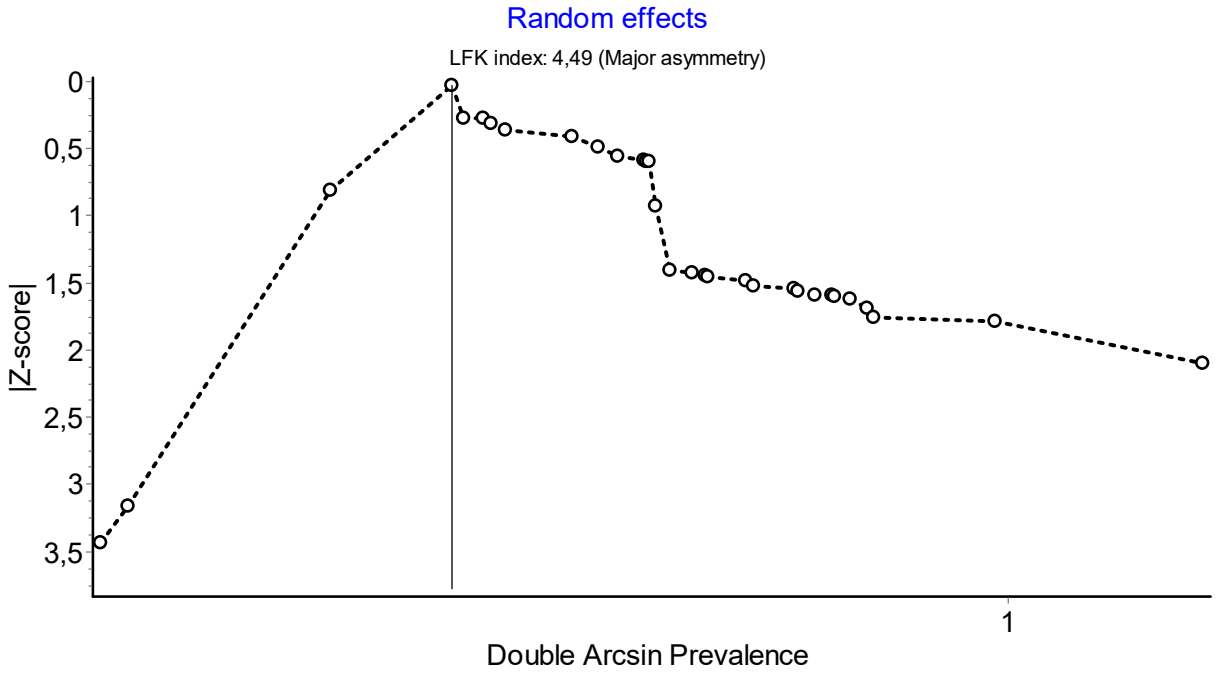


ESM Fig 2i. Forest plot for prevalence of T2DM among people with sleep disorder

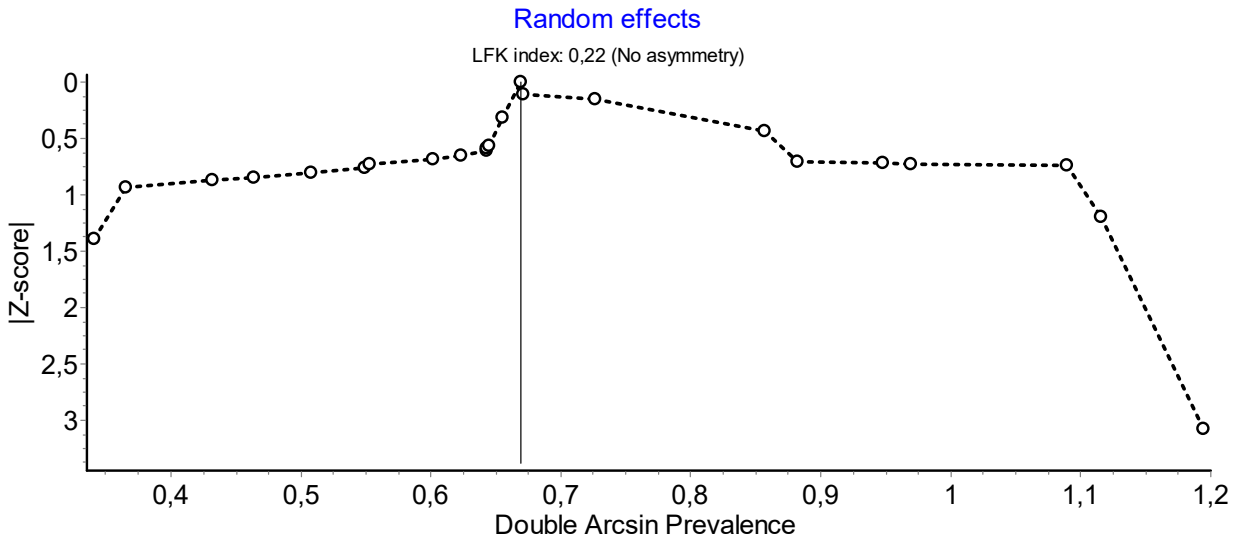


ESM Fig 2j. Forest plot for prevalence of T2DM among people in the group of mixed psychiatric disorders

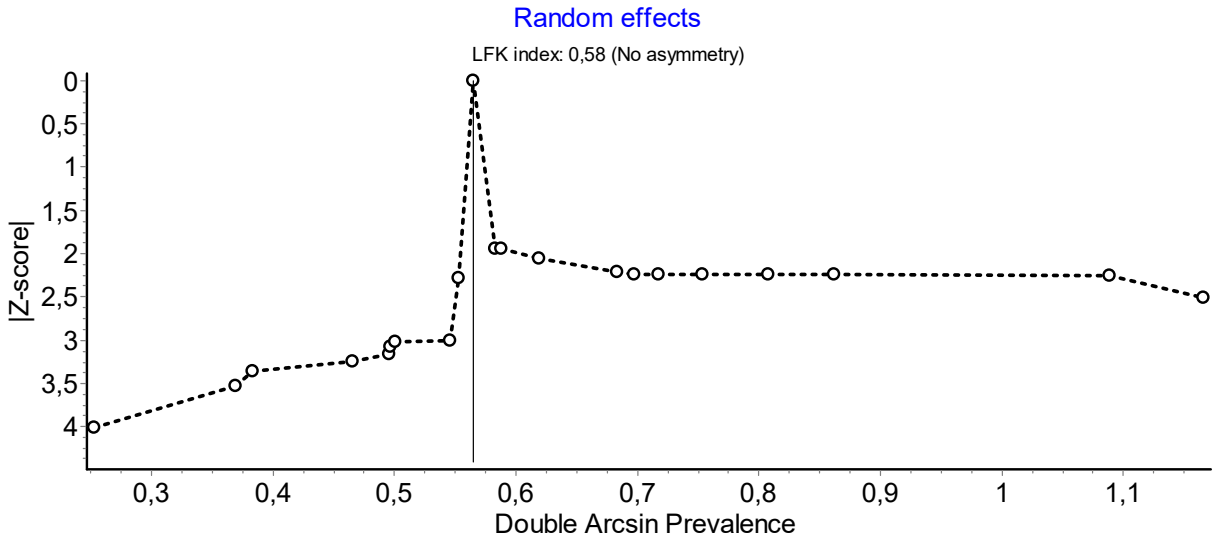
ESM Fig. 3. Doi-plots for 10 meta-analyses investigating the prevalence of T2DM in people with a psychiatric disorder.



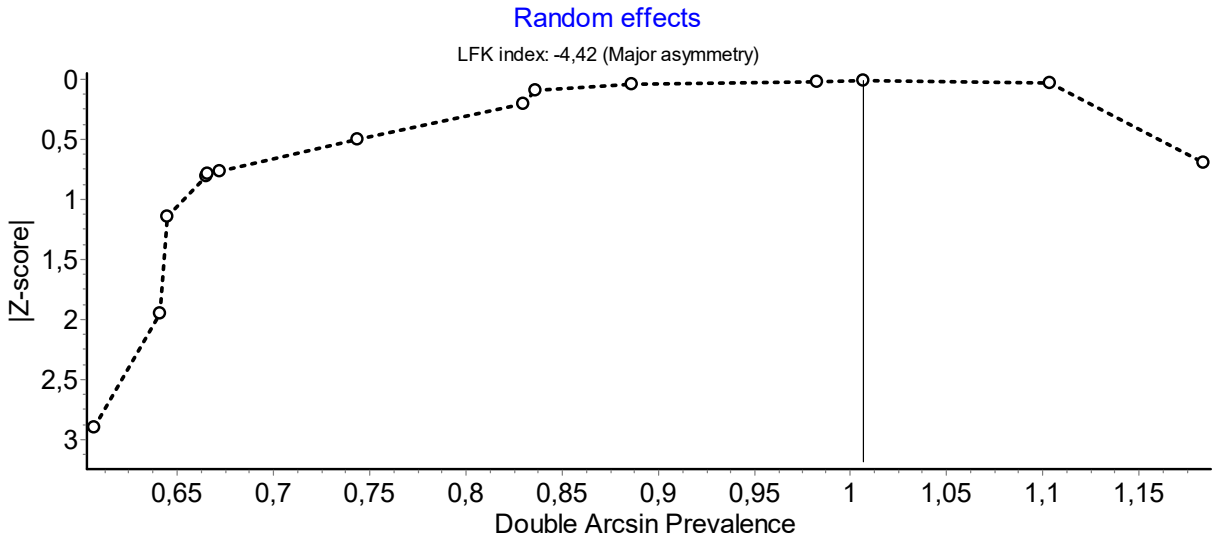
ESM Fig. 3a. Doi plot for prevalence of T2DM among people with schizophrenia



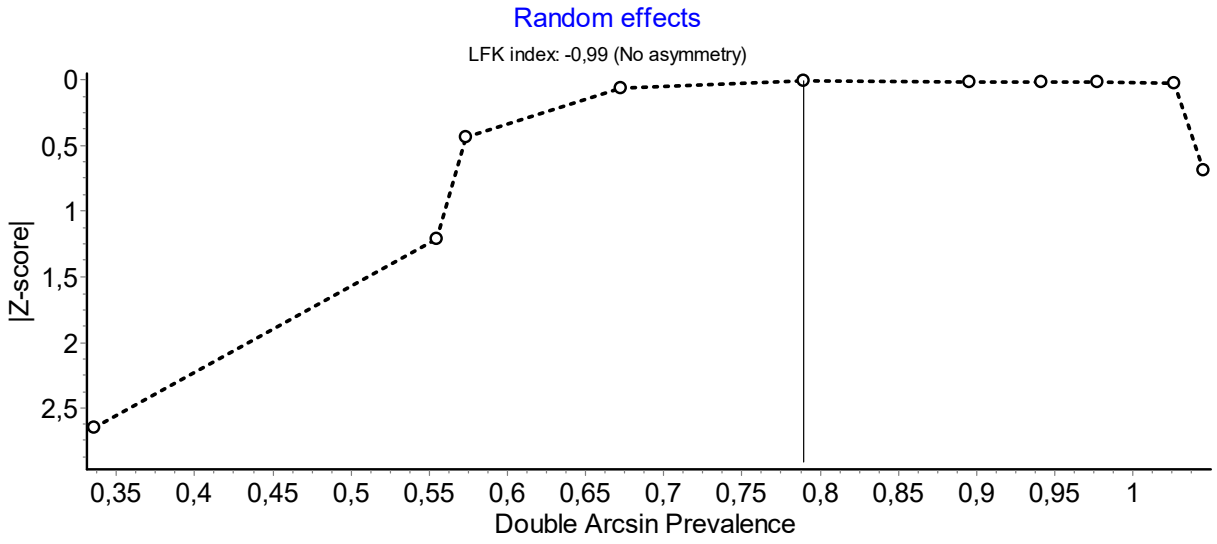
ESM Fig. 3b. Doi plot for prevalence of T2DM among people with bipolar disorder



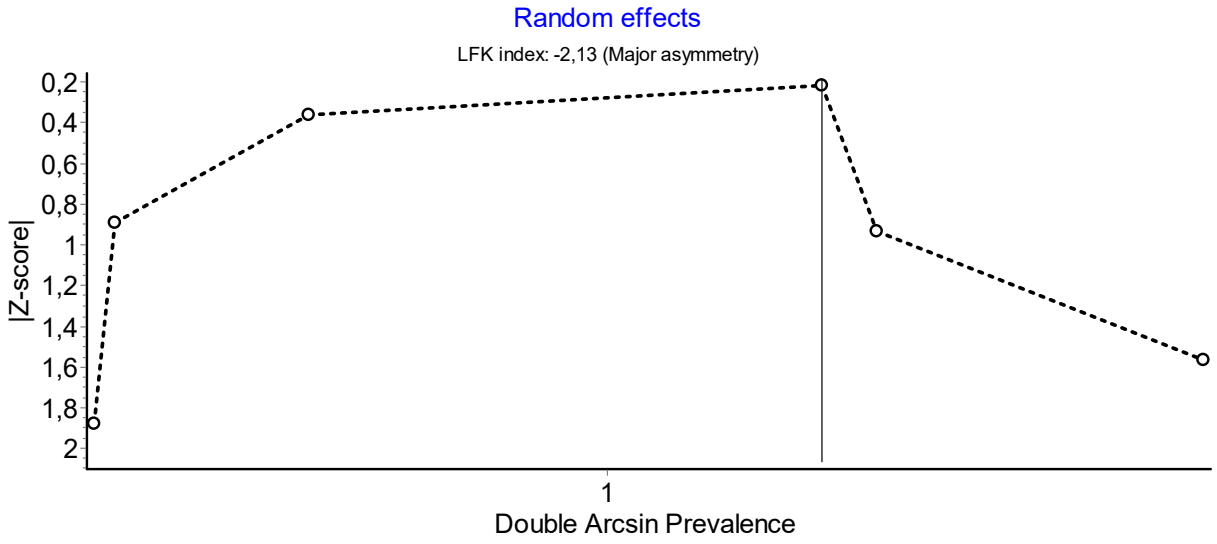
ESM Fig. 3c. Doi plot for prevalence of T2DM among people with depression



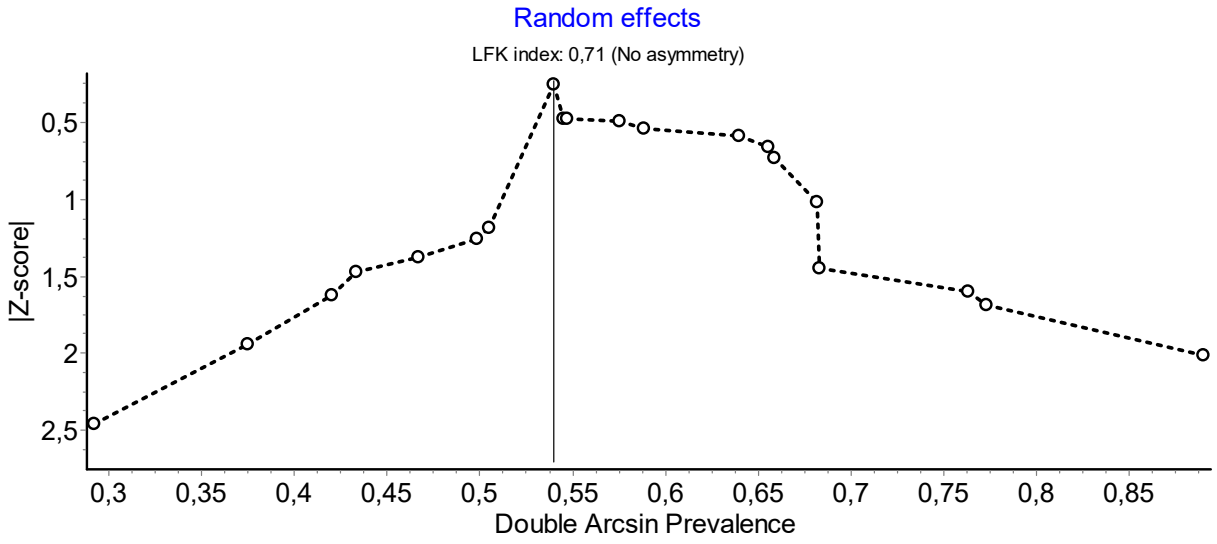
ESM Fig. 3d. Doi plot for prevalence of T2DM among people with substance use disorder



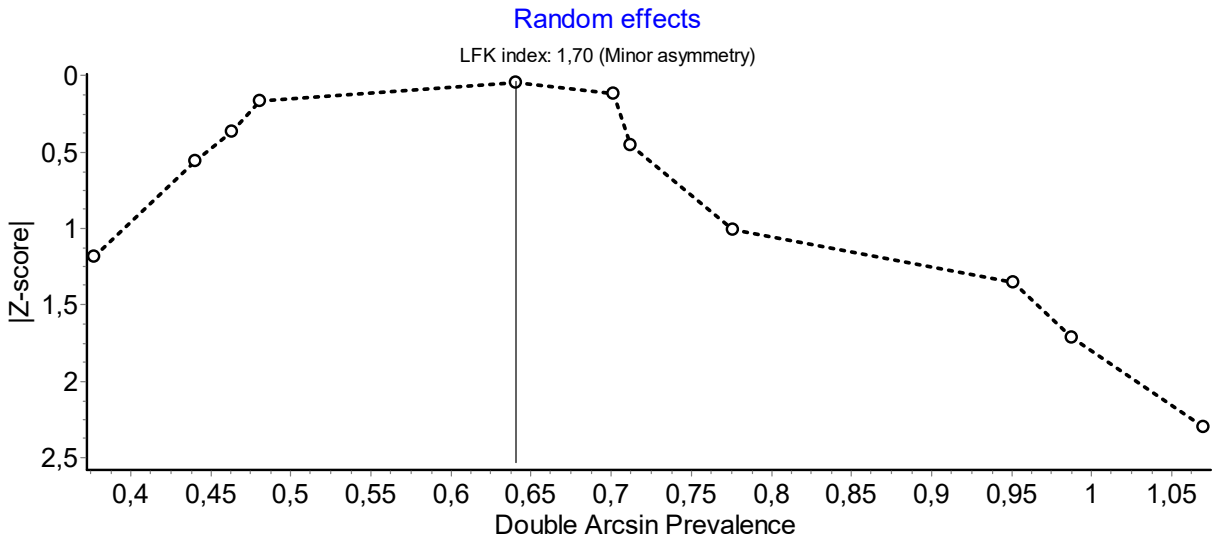
ESM Fig. 3e. Doi plot for prevalence of T2DM among people with anxiety disorder



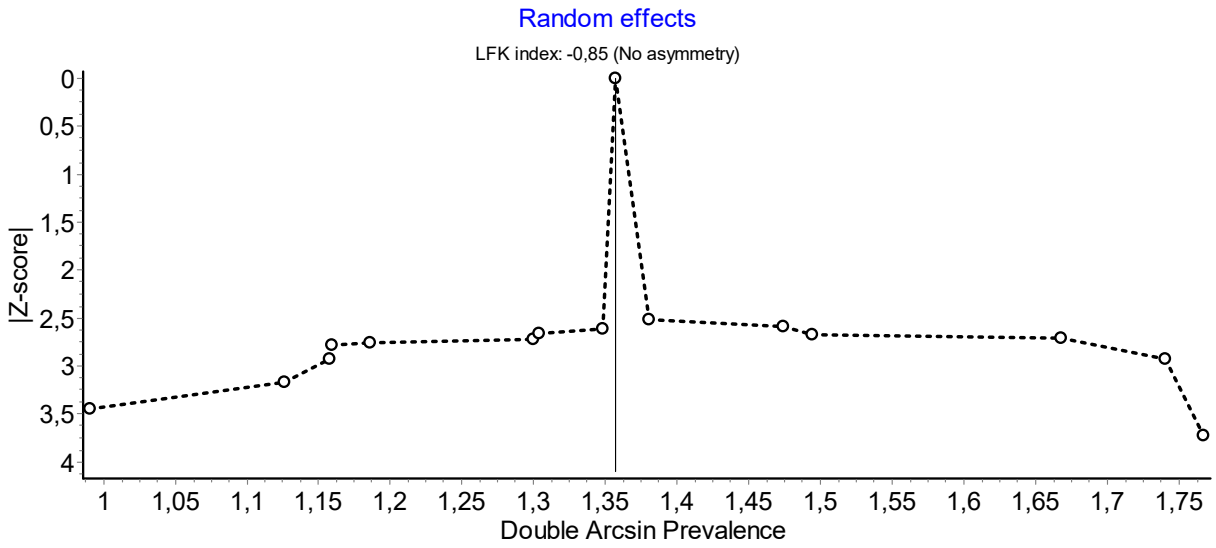
ESM Fig. 3f. Doi plot for prevalence of T2DM among people with binge eating disorder



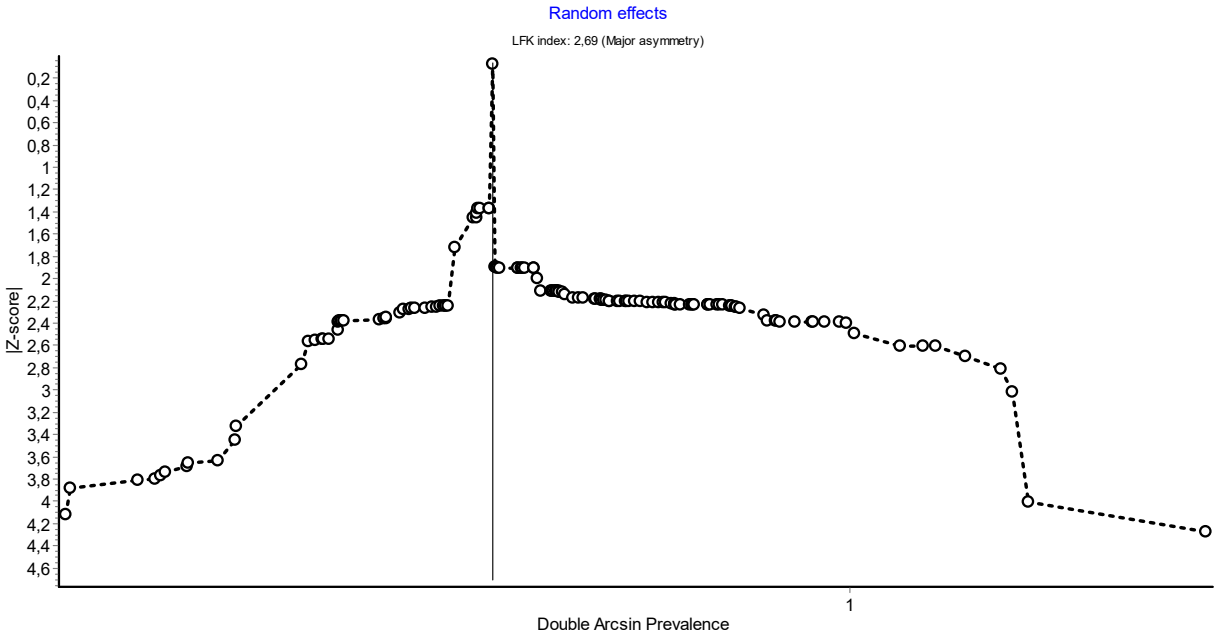
ESM Fig. 3g. Doi plot for prevalence of T2DM among people with intellectual disability



ESM Fig. 3h. Doi plot for prevalence of T2DM among people with psychosis



ESM Fig. 3i. Doi plot for prevalence of T2DM among people with sleep disorder



ESM Fig. 3j. Doi plot for prevalence of T2DM among people in the group of mixed psychiatric disorders