Comorbid depression and risk of lower extremity amputation in people with diabetes: systematic review and meta-analysis

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ABSTRACT

Objective To compare the risk of lower extremity amputation (LEA) in people with diabetes with and without comorbid depression.

Research design and methods A systematic review of the published literature was conducted. Six databases were searched including PubMed, CINAHL, Embase, Medline, the Cochrane Library and PsycARTICLES from inception to 22 June 2016, using a detailed search strategy and cross-checking of reference lists for potentially eligible studies published in English. No date restrictions were employed. All studies were reviewed independently for inclusion by two review authors. Data extraction was performed using a standardized data abstraction form, and study quality was assessed independently by two reviewers. A meta-analysis was performed reporting pooled hazard ratios (HRs) and 95% CIs in Review Manager software.

Results In total, seven studies were eligible for inclusion in the systematic review. Data on 767,997 patients from five studies were included in the meta-analysis. Pooled estimates across the studies were obtained using a random-effects model due to significant heterogeneity (I²=87%). People with diabetes and depression had an increased hazard of LEA (HR 1.76, 95% CI 1.19 to 2.60) compared to people with diabetes and no depression.

Conclusions Based on the available evidence, comorbid depression appears to increase the risk of LEA in people with diabetes. Limited data were available, however, with significant heterogeneity between studies. Further research is needed to inform intervention and clinical practice development in the management of diabetes.

INTRODUCTION

Depression and diabetes

The presence of diabetes doubles the odds of comorbid depression.1 In the USA, the 2006 Behavioral Risk Factor Surveillance System documented that depression was highly prevalent among people with diabetes and that the prevalence rate varied greatly by demographic characteristics and diabetes types.2 The Diabetes Attitudes, Wishes and Needs study (DAWN2) assessed psychosocial outcomes in people with diabetes across 17 countries and documented that the proportion with likely depression (WHO-5 Well-Being Index score ≤28) was 13.8% (country range 6.5%–24.1%).3

The etiology of the relationship between depression and diabetes is multifactorial.4 Risk factors for the development of depression among people with diabetes include gender, age, years since diagnosis, socioeconomic status, HbA1c control (HbA1c refers to glycated haemoglobin (A1c), which identifies average plasma glucose concentration), number of complications, insulin dose, number of injections, ketoacidosis admission and living alone.5

Depression, diabetes and lower extremity amputations

When diabetes and depression coexist, depression is negatively associated with adherence to diabetes management including self-care of diet, medication, exercise, blood glucose monitoring and medical appointment attendance.6 This increases the risk of complications in people with diabetes.
LEA is one complication of diabetes, is multifactorial and
negatively impacts on a patient’s quality of life. Diabetes is
associated with a significantly increased risk of LEA. LEA
rates vary between populations with estimates ranging from
46 to 960/10^5 people with diabetes. The International
Diabetes Federation (IDF) and the International Working
Group on the Diabetic Foot have prioritised reducing LEA
rates in people with diabetes.11

Little is documented on the role of comorbid depression
on LEA rates in people with diabetes. The relationship
between depression and foot complications in people with
diabetes is likely to be bi-directional. Previous research
has suggested that comorbid depression is associated with
risk factors for the development of diabetes-related compli-
cations. A retrospective cohort study showed a 33% higher
risk of major LEA in veterans with diabetes and comorbid
depression. Also, in a veteran population, a five-point
increase in mental health functioning score was associated
with a 5% decrease in risk of major LEAs (OR 0.95, 95%CI
0.94 to 0.96) after controlling for independent variables.14

Rationale for the current systematic review and meta-
analysist
LEA is a concrete and easily definable outcome that is
more common in people with diabetes. Significant
reductions in the incidence of LEA have been shown
with various interventions that target risk factors in
people with diabetes. The role of comorbid depression
as a risk factor for LEA in people with diabetes is
Uncertain. Given that there are a number of successful
treatments available for depression, it could be a modi-
ﬁable risk factor for the development of LEA in people
with diabetes. Thus, the aim of this systematic review was
to identify all of the published literature to date and to
provide an overall quantitative estimate of the relation-
ship using a meta-analysis.

RESEARCH DESIGN AND METHODS
Primary objective
The primary objective of this systematic review was to
synthesize the available published literature to date on
the relationship between depression among people with
diabetes and the risk of LEA.

The secondary objective was to quantify the ﬁndings
from each included study and to report an overall pooled
estimate of the relationship between depression and risk
of LEA in the form of a meta-analysis.

Primary outcome
The outcome of interest in this review was LEA in people
with diabetes and depression compared to people with
diabetes and no depression. This outcome was used in
the meta-analysis to estimate the pooled risk of LEA
among people with diabetes and depression.

Exposure
Depression defined by self-report, clinical diagnosis or a
combination of both.

Search strategy
The protocol for this systematic review and meta-analysis
was registered on PROSPERO, the international prospec-
tive register of systematic reviews (unique identiﬁcation
number: CRD42014013897), and is available in full on the
National Institute for Health Research website. This
systematic review and meta-analysis was conducted in
accordance with the preferred reporting items for system-
atic reviews and meta-analyses statement (PRISMA),
which is a detailed checklist of items speciﬁcally designed
for this purpose. The following databases were searched
from inception until 22 June 2016: PubMed, CINAHL,
EMBASE, Medline, the Cochrane Database of System-
atic Reviews and PsycARTICLES. The key search terms
used included ‘diabetes’, ‘amputation’ and ‘depres-
sion’ (online supplementary table 1). MeSH (Medical
Subject Heading) terms and truncation as appropriate
according to the principles of Boolean logic were used
(e.g., diabet* was used to include studies referring to
diabetes, diabetic, etc). There were no date restrictions
applied; however, only published studies in the English
language were considered for review. We supplemented
our electronic searches by cross-checking the reference
lists of all included studies.

Study selection
Titles, abstracts and full texts of potentially eligible
studies were assessed by two reviewers (SON and CMB)
for inclusion using a priori defined inclusion exclusion
criteria (online supplementary table 2). Where the
reviewers could not agree on study eligibility, consensus
was reached by asking a third reviewer (ZK). Regarding
multiple reports from the same dataset, only one report
was included in the systematic review and meta-analysis
based on the primary outcome of the study, sample size
and length of follow-up.

Eligibility criteria for inclusion in the meta-analysis included
► Data were from an original study (ie, no review
articles, editorials or commentaries).
► Randomized and non-randomized studies in which
depression was measured at baseline and LEA
was an outcome measure after a period of follow-up.
► Reporting of an adjusted relative risk (RR), OR, HR
or incidence rate ratio on the measured exposure of
depression and the outcome of LEA.
► Where only crude estimates (ie, potential
confounders were not taken into account in the
analysis) are presented in a study, these studies
will not be included in the meta-analysis, and their
results will be presented individually in a separate
table.

Data abstraction
Data on eligible studies were summarized systematically
by two reviewers (SON, CMB) using a standardised data
abstraction form and included author and year of publi-
cation, the country the study was conducted in and time
period, study design, data source, sample size, diagnosis of the exposure and outcome (table 1). Where data required for the review were missing, the authors were contacted.

Data synthesis and meta-analysis
Our principal analysis investigated the overall risk of LEA in people with diabetes and depression compared to people with diabetes and no depression. Pooled estimates across studies were obtained by means of a random-effects model where heterogeneity was considered substantial (ie, an $I^2$ value of greater than 50%) based on the Cochrane criteria. Studies were weighted according to an estimate of statistical size defined as the inverse of the variance (IV) of the HR. Where data were presented in a way that could not be included in a meta-analysis, results of the studies are presented individually in a table. Statistical analysis was performed using the Cochrane Collaboration’s Review Manager V.5.1 software.

A priori subgroup analyses
The review team decided on the following a priori defined subgroup analyses: by type of diabetes (type 1 vs type 2), by study design, by sample size ($<10000$ vs $\geq 10000$), by country in which the study was conducted and by study quality (risk of bias minimal, low, moderate or high).

Heterogeneity assessment
The degree of variability between studies attributable to between-study heterogeneity was assessed using the $\chi^2$ heterogeneity test and the $I^2$ statistic. In the $\chi^2$ test, a $p$ value lower than 0.05 indicates statistical heterogeneity.

<table>
<thead>
<tr>
<th>Study authors (year)</th>
<th>Country (time period)</th>
<th>Study design (data source)</th>
<th>Sample size</th>
<th>Depression diagnosis</th>
<th>Outcome diagnosis amputation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gendelman et al (2009)24</td>
<td>USA (2006–2008)</td>
<td>Cross-sectional (data from the CACTI study)</td>
<td>1004 participants (n=458 type 1 diabetics)</td>
<td>BDI-II scale (validated and/or self-reported use of antidepressant medication)</td>
<td>Self-reported in interview</td>
</tr>
<tr>
<td>Pearson et al (2014)26</td>
<td>Australia (February–August 2012)</td>
<td>Cross-sectional survey of patients attending podiatry clinic</td>
<td>60 patients with type 1 or 2 diabetes</td>
<td>PHQ-9 self-reported questionnaire (validated)</td>
<td>Medical record review</td>
</tr>
<tr>
<td>Salmi et al (2011)27</td>
<td>Sweden (2006), follow-up 2007–2009</td>
<td>National register-based cohort</td>
<td>229956 patients prescribed antidiabetic drugs</td>
<td>Not reported (abstract only) but most likely ICD codes</td>
<td>Not reported (abstract only) but most likely ICD codes</td>
</tr>
<tr>
<td>Williams et al (2011)13</td>
<td>USA (2000), follow-up until 2004</td>
<td>Prospective cohort (Diabetes Epidemiology Registry)</td>
<td>531973 veterans with diabetes (type unknown)</td>
<td>ICD-9 codes</td>
<td>ICD-9 codes</td>
</tr>
<tr>
<td>Winkley et al (2007)28</td>
<td>UK (2001–2003), follow-up 18 months</td>
<td>Prospective cohort</td>
<td>253 type 1 or 2 diabetic patients attending a podiatry clinic</td>
<td>SCAN 2.1 diagnostic interview</td>
<td>Recorded by trained podiatrist</td>
</tr>
</tbody>
</table>

BDI-II, Beck Depression Inventory—version two; CACTI, Coronary Artery Calcification in Type I Diabetes Study; CESD, Center for Epidemiologic Studies Depression Scale; CIDI, Composite International Diagnostic Interview; EPESE, Established Population for the Epidemiologic Study of the Elderly Survey; ICD, International Classification of Diseases; PEFS, Pathways Epidemiologic Follow-Up Study; PHQ-9, Patient Health Questionnaire version 9; SCAN, Schedules for Clinical Assessment in Neuropsychiatry.
**Results**

The initial electronic database searches yielded 384 studies with 74 duplicates to result in 310 studies eligible for screening. Of these, 279 were rejected based on the perceived amount of each bias present (selection, exposure, outcome, confounding, analytical and attrition) and rated as minimal, low, moderate, high or not reported. An overall likelihood of bias was then estimated. The bias assessment tool is available in online supplementary table 3.

**Quality assessment**

Quality assessment of the studies included in the review was conducted independently by two reviewers (SON, CMB) using the six types of bias tool described in detail in a previous study. Studies were assessed based on the perceived amount of each bias present (selection, exposure, outcome, confounding, analytical and attrition) and rated as minimal, low, moderate, high or not reported. An overall likelihood of bias was then estimated. The bias assessment tool is available in online supplementary table 3.

**Characteristics of studies included in the systematic review**

Characteristics of studies included in the systematic review are presented in table 1.

All of the studies were conducted in the 21st century (one in 2003, one in 2007, one in 2009, one in 2010, two in 2011, and one in 2014). Four were conducted in the USA, one in Australia, one in Sweden and one in the UK. Five of the studies were prospective cohorts and two had a cross-sectional study design. The sample size ranged from 60 people to 531 973 people. One study included people with type 1 diabetes only, two studies included people with type 2 diabetes only, two studies included people with both type 1 and type 2 diabetes, and two studies did not report the type of diabetes. The exposure depression was diagnosed using a validated tool or measure in all seven studies. One study24 used the Beck Depression Inventory—version two tool, one study25 used the Schedules for Clinical Assessment in Neuropsychiatry tool, two studies26 used the Patient Health Questionnaire—version 9 tool and two studies27 used the ICD (International Classification of Diseases) codes. The outcome of LEA was self-reported in two studies, and medical records were examined in two studies. ICD codes from large database registries were used in two studies and one study used a trained podiatrist to diagnose the outcome.

**Meta-analysis**

Of the seven studies included in the systematic review, five provided sufficient data to be included in a meta-analysis. Data on 767 997 patients were included in the meta-analysis using the generic inverse variance method and reporting the log (HR) and SE for each study. In the fixed-effect model, an overall pooled estimate HR of 1.21 (95% CI 1.11 to 1.31) was found, implying a 21% increased hazard of LEA in people with diabetes and depression. Due to the evidence of substantial heterogeneity, the fixed-effect model was deemed more appropriate. The pooled HR of risk of LEA due to depression was 1.76 (95% CI 1.19 to 2.60) (figure 2).

Significant heterogeneity remained, however (I²=87%, p=0.005).

**Subgroup analyses**

It was not possible to conduct a subgroup analysis based on type of diabetes as these data were not reported in the studies. In addition, we did not conduct a subgroup analysis by study design as all five studies were prospective cohorts. A subgroup analysis by sample size was conducted (figure 3). The overall pooled estimate for studies with a sample size <10000 was 1.35 (95% CI 0.98 to 2.45, I²=44%, p=0.17) compared with studies with a sample size ≥10000 for which the pooled estimate was 2.16 (95% CI 0.57 to 8.23, I²=96%, p=0.00001). Neither was statistically significant, however. A subgroup analysis according to where the studies were conducted was also performed (figure 4). Studies that were conducted in the USA had a pooled HR of 1.28 (95% CI 0.99 to 1.66, I²=72%, p=0.03) compared with studies conducted in Europe, which had a pooled HR of 2.51 (95% CI 0.81 to 7.80, I²=0.00). A subgroup analysis according to study quality was also conducted (figure 5). Studies with a minimal risk of bias had a pooled HR of 1.34 (95% CI 1.11 to 1.62, I²=0%, p=0.94). Studies with a low risk of bias had a pooled HR of 1.95 (95% CI 0.51 to 7.40, I²=79%, p=0.03). One study had a moderate risk of bias and a HR of 4.39 (95% CI 2.58 to 7.47). We conducted a sensitivity analysis where two studies included the outcome LEA as a combined outcome with other microvascular complications (figure 6). This yielded a pooled HR of 1.86 (95% CI 0.78 to 4.48, I²=92%, p=0.00001).

**Studies not eligible for inclusion in the meta-analysis**

Two studies24 25 were not eligible for inclusion in the meta-analysis as they did not provide adjusted estimates.
The main findings and conclusions of these studies are presented in table 2. Both were small studies (one with 458 participants with diabetes, the second with 54 participants with diabetes), which only provided crude estimates.

**Quality assessment**

Two studies were assessed as having a minimal risk of bias, two were deemed to have a low risk of bias and three had a moderate risk of bias. No study was classified as having a high risk of bias (table 3).
Clinical care/Education/Nutrition/Psychosocial research

Figure 2 Random-effects model of the risk of lower extremity amputation in people with diabetes associated with depression compared with no depression from five published studies (IV=Inverse Variance).

DISCUSSION

Overall, in this pooled analysis, people with diabetes and depression had a 76% increased risk of LEA compared with people with diabetes without depression; this result was statistically significant. There was, however, a high level of heterogeneity between studies ($I^2=87\%$). To investigate this further, we conducted various subgroup analyses. Sample size did not explain our findings (with large and small studies both showing increased but insignificant findings) or the heterogeneity. Geographical variation in LEA rates has been previously documented.29 30 Potential reasons why results might differ between continents would include different population characteristics and healthcare systems.31 In this review, the region in which the studies were conducted (USA vs Europe) also yielded increased but insignificant results, and heterogeneity remained. The subgroup analysis by study quality showed that the studies with the least bias (minimal bias) produced a 34% increased risk of LEA in people with diabetes and depression, which was statistically significant.

While the outcome of interest was LEA, two of the included studies (Black et al and Lin et al) grouped the outcome of LEA with other microvascular outcomes. It was decided to include these studies due to the dearth of research in this area and to perform a sensitivity analysis removing studies that included LEA as a combined outcome under ‘microvascular complications’. This analysis produced an increased but insignificant result.

It must be acknowledged that only five studies were eligible for inclusion in the meta-analysis, and this limits the robustness of the subgroup analyses performed. Thus, while there is an overall increased risk of LEA in people with depression and diabetes, further research is needed including population-based registry data and more methodologically robust methods of recording depression, diabetes and LEA (ie, ICD codes or medical diagnoses).

Figure 3 Subgroup analysis: random-effects model of the risk of lower extremity amputation in people with diabetes associated with depression compared with no depression according to sample size (<10,000, >10,000) (IV=Inverse Variance).
Figure 4  Subgroup analysis: random-effects model of the risk of lower extremity amputation in people with diabetes associated with depression compared with no depression according to region (USA vs Europe) [IV=Inverse Variance].

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>log[Hazard Ratio]</th>
<th>SE</th>
<th>Weight</th>
<th>Hazard Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SE</td>
<td>Weight</td>
<td>IV, Random, 95% CI</td>
</tr>
<tr>
<td>3.1 United States of America</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Black 2003</td>
<td>1.5063</td>
<td>0.6347</td>
<td>7.4%</td>
<td>4.51 [1.30, 15.65]</td>
</tr>
<tr>
<td>Lin 2010</td>
<td>0.2927</td>
<td>0.1007</td>
<td>27.9%</td>
<td>1.34 [1.10, 1.63]</td>
</tr>
<tr>
<td>Williams 2011</td>
<td>0.1133</td>
<td>0.0477</td>
<td>29.5%</td>
<td>1.12 [1.02, 1.23]</td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td></td>
<td></td>
<td></td>
<td>64.9%</td>
</tr>
</tbody>
</table>

Heterogeneity: $\text{Tau}^2 = 0.03, \text{Chi}^2 = 7.16, \text{df} = 2 (P = 0.03); I^2 = 72%$
Test for overall effect: $Z = 1.86 (P = 0.06)$

3.1.2 Europe

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>log[Hazard Ratio]</th>
<th>SE</th>
<th>Weight</th>
<th>Hazard Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SE</td>
<td>Weight</td>
<td>IV, Random, 95% CI</td>
</tr>
<tr>
<td>Salmi 2011</td>
<td>1.4793</td>
<td>0.2712</td>
<td>19.3%</td>
<td>4.39 [2.56, 7.47]</td>
</tr>
<tr>
<td>Winkleby 2007</td>
<td>0.3221</td>
<td>0.3463</td>
<td>15.6%</td>
<td>1.38 [0.70, 2.72]</td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td></td>
<td></td>
<td></td>
<td>35.1%</td>
</tr>
</tbody>
</table>

Heterogeneity: $\text{Tau}^2 = 0.57, \text{Chi}^2 = 6.92, \text{df} = 1 (P = 0.009); I^2 = 86%$
Test for overall effect: $Z = 1.50 (P = 0.11)$

Total (95% CI)

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>log[Hazard Ratio]</th>
<th>SE</th>
<th>Weight</th>
<th>Hazard Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SE</td>
<td>Weight</td>
<td>IV, Random, 95% CI</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Heterogeneity: $\text{Tau}^2 = 0.13, \text{Chi}^2 = 30.67, \text{df} = 4 (P < 0.00001); I^2 = 87%$
Test for overall effect: $Z = 5.05 (P = 0.0002)$
Test for subgroup differences: $\text{Chi}^2 = 17.04, \text{df} = 2 (P = 0.0002), I^2 = 88.3%$

Figure 5  Subgroup analysis: random-effects model of the risk of lower extremity amputation in people with diabetes associated with depression compared with no depression according to study quality (minimal vs low vs moderate risk of bias) [IV=Inverse Variance].

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>log[Hazard Ratio]</th>
<th>SE</th>
<th>Weight</th>
<th>Hazard Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SE</td>
<td>Weight</td>
<td>IV, Random, 95% CI</td>
</tr>
<tr>
<td>4.1 Minimal risk of bias</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lin 2010</td>
<td>0.2927</td>
<td>0.1007</td>
<td>27.9%</td>
<td>1.34 [1.10, 1.63]</td>
</tr>
<tr>
<td>Winkleby 2007</td>
<td>0.3221</td>
<td>0.3463</td>
<td>15.6%</td>
<td>1.38 [0.70, 2.72]</td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td></td>
<td></td>
<td></td>
<td>43.7%</td>
</tr>
</tbody>
</table>

Heterogeneity: $\text{Tau}^2 = 0.00, \text{Chi}^2 = 0.01, \text{df} = 1 (P = 0.94); I^2 = 0%$
Test for overall effect: $Z = 3.05 (P = 0.002)$

4.1.2 Low risk of bias

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>log[Hazard Ratio]</th>
<th>SE</th>
<th>Weight</th>
<th>Hazard Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SE</td>
<td>Weight</td>
<td>IV, Random, 95% CI</td>
</tr>
<tr>
<td>Black 2003</td>
<td>1.5063</td>
<td>0.6347</td>
<td>7.4%</td>
<td>4.51 [1.30, 15.65]</td>
</tr>
<tr>
<td>Williams 2011</td>
<td>0.1133</td>
<td>0.0477</td>
<td>29.5%</td>
<td>1.12 [1.02, 1.23]</td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td></td>
<td></td>
<td></td>
<td>37.0%</td>
</tr>
</tbody>
</table>

Heterogeneity: $\text{Tau}^2 = 0.77, \text{Chi}^2 = 4.79, \text{df} = 1 (P = 0.03); I^2 = 79%$
Test for overall effect: $Z = 0.98 (P = 0.33)$

4.1.3 Moderate risk of bias

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>log[Hazard Ratio]</th>
<th>SE</th>
<th>Weight</th>
<th>Hazard Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SE</td>
<td>Weight</td>
<td>IV, Random, 95% CI</td>
</tr>
<tr>
<td>Salmi 2011 (1)</td>
<td>1.4793</td>
<td>0.2712</td>
<td>19.3%</td>
<td>4.39 [2.58, 7.47]</td>
</tr>
<tr>
<td>Subtotal (95% CI)</td>
<td></td>
<td></td>
<td></td>
<td>19.3%</td>
</tr>
</tbody>
</table>

Heterogeneity: Not applicable
Test for overall effect: $Z = 5.45 (P < 0.00001)$

Total (95% CI)

<table>
<thead>
<tr>
<th>Study or Subgroup</th>
<th>log[Hazard Ratio]</th>
<th>SE</th>
<th>Weight</th>
<th>Hazard Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>SE</td>
<td>Weight</td>
<td>IV, Random, 95% CI</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>100.0%</td>
</tr>
</tbody>
</table>

Heterogeneity: $\text{Tau}^2 = 0.13, \text{Chi}^2 = 30.67, \text{df} = 4 (P < 0.00001); I^2 = 87%$
Test for overall effect: $Z = 2.83 (P = 0.005)$
Test for subgroup differences: $\text{Chi}^2 = 17.04, \text{df} = 2 (P = 0.0002), I^2 = 88.3%$

(1) Studies were assessed for quality based on the risk of bias. Bias was classified as minimal, low moderate or high.
Sensitivity analysis: random-effects model of the risk of lower extremity amputation (LEA) in people with diabetes associated with depression compared with no depression where two studies were excluded (LEA was included in these studies as a combined outcome ‘vascular complications’) (IV=Inverse Variance).

Table 2

<table>
<thead>
<tr>
<th>Study</th>
<th>Results</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gendelman et al</td>
<td>6/458 diabetic participants in the study had amputations. No results were provided for diabetics who were depressed and not depressed in terms of the outcome.</td>
<td>The study authors concluded that ‘Type 1 diabetic participants reporting the prevalence of at least one diabetic complication scored higher on the BDI-II depression scale than participants without complications’.</td>
</tr>
<tr>
<td>Pearson et al</td>
<td>2/26 diabetic patients with no depression had an amputation compared with 3/28 diabetic patients with depression.</td>
<td>Data were missing for six participants (three had died, three were lost to follow-up). ‘There was no significant difference between the two groups in terms of outcome’.</td>
</tr>
</tbody>
</table>

BSI-II, Beck Depression Inventory—version two.
the I2 value does not depend on the number of studies total variation across studies is due to heterogeneity and any heterogeneity in the meta-analysis, the percentage of BMJ Open Diab Res Care: e000366. doi:10.1136/bmjdr-2016-000366 2017; 5

There was a great degree of heterogeneity in the current

Heterogeneity
There was a great degree of heterogeneity in the current meta-analysis and would be deemed ‘high’ according to the Cochrane criteria for I2 (>75%). The authors tried to control for this heterogeneity by using the random-effects model. Under the random-effects model, we allow that the true effect could vary from study to study. For example, the effect size might be a little higher if the subjects are older, or more educated, or healthier; or if the study used a slightly more intensive or longer variant of the intervention; or if the effect was measured more reliably. In addition, we quantified heterogeneity by using the I2 statistic that focuses attention on the effect of any heterogeneity in the meta-analysis, the percentage of total variation across studies is due to heterogeneity and most importantly in the case of the current meta-analysis, the I2 value does not depend on the number of studies in the meta-analysis. Ideally, to further explore reasons for heterogeneity, authors would conduct a priori defined subgroup and sensitivity analyses as well as meta-regression using different covariates. These are largely dependent on the number of studies in the meta-analysis, however, and were not feasible for the current meta-analysis.

Recommendations for future research
Differing definitions and assessment tools for diagnosing depression were used in the studies included in this systematic review. The reported prevalence of depression differs between self-report versus clinical interview diagnosis. The use of a standard assessment tool for depression would improve comparability of results from different settings. Further research is required to explore whether the level of severity of depression is predictive of complications. Potential confounders needing consideration in future research include age, gender, education, marital status/living alone, socioeconomic status, type of diabetes, duration of diabetes, insulin use, diabetes treatment/control, self-reported health status, risk behaviours, quality of life, foot care behavior, mood, smoking status, alcohol problems, macrovascular complications, microvascular complications, foot-specific complications, severity of complications, other medical or mental health conditions, and healthcare utilisation.

CONCLUSIONS
In conclusion, there appears to be an unfavorable effect of comorbid depression in people with diabetes on the risk of LEA. Given the significant heterogeneity present between studies and the need for studies of a more robust methodological quality, the current findings need to be interpreted with caution. To detect the true effect, future longitudinal studies need to include large sample sizes with a breakdown by type of diabetes, assess confounders at baseline and follow-up and adjust for confounders in the statistical analysis. Further research is needed to explore the role of comorbid depression as a risk factor for LEA, to document the effect size and, thus, to inform intervention and clinical practice development. Considering the availability of various treatments for depression, efforts to detect the true effect of comorbid depression on the risk of LEA and indeed other complications in people with diabetes are worthwhile.

The six different types of bias were classified as ‘minimal’, ‘low’, ‘moderate’, ‘high’ or ‘not reported’ based on criteria outlined previously in O’Neill et al.

The literature review confirmed clinical practices vary per individual practitioner, per location and per patient. The evidence of under-diagnosing depression in patients with diabetes needs to be considered as a potential bias. Such bias would cause over-reporting of LEAs in patients with no comorbidity and under-reporting of LEAs in patients with comorbid depression.

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