Diabetes increases the risk of breast cancer: a meta-analysis

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Abstract

The aim of this meta-analysis was to collate and analyse all primary observational studies investigating the risk of breast cancer (BC) associated with diabetes. In addition, we aimed to complete subgroup analyses by both type of diabetes and gender of study participants to further clarify the origin of any such association between the two. Studies were obtained from a database search of MEDLINE, EMBASE, PubMed, Current Contents Connect and Google Scholar with additional cross-checking of reference lists. Collated data were assessed for heterogeneity and a pooled odds ratio (OR) calculated. Forty-three studies were included in the meta-analysis with 40 studies investigating BC in women and six studies investigating BC in men. Overall, we found a significantly increased risk of BC associated with diabetes in women (OR 1.20, 95% confidence interval (CI) 1.13–1.29). After subgroup analysis by type of diabetes, the association was unchanged with type 2 diabetes (OR 1.22, 95% CI 1.07–1.40) and nullified with gestational diabetes (OR 1.06, 95% CI 0.79–1.40). There were insufficient studies to calculate a pooled OR of the risk of BC associated with type 1 diabetes. There was an increased risk of BC in males with diabetes mellitus; however, the results did not reach statistical significance (OR 1.29, 95% CI 0.99–1.67). In conclusion, diabetes increases the risk of BC in women. This association is confirmed in women with type 2 diabetes and supports the hypothesis that diabetes is an independent risk factor for BC.

Endocrine-Related Cancer (2012) 19 793–803

Introduction

The increased risk of breast cancer (BC) associated with lifestyle factors has been the subject of numerous observational studies. While there is significant evidence of an increased risk associated with obesity (Harvie et al. 2003), smoking (Khuder et al. 2001, Mucha et al. 2006) and alcohol intake (Key et al. 2006), the risk associated with specific types of diabetes mellitus is yet to be determined. In a meta-analysis published in 2007, Larsson et al. reported an increased risk of BC associated with non-specific diabetes mellitus; however, due to a lack of primary studies, there was no subgroup analysis by type of diabetes completed.

Liao et al. (2011) published another relevant study in 2011. This meta-analysis focused on studies published after 2000, investigating the association between diabetes and BC incidence with subgrouping by geographical location and menopausal status. Interestingly, this study reported an increased BC risk in Europe and America with no increased risk identified in Asia. Furthermore, this study reported a significant association between BC and diabetes mellitus in only the postmenopausal age group.

In regard to the primary studies, there is a degree of inconsistency in the literature, especially when considering specific types of diabetes. Gestational diabetes has been found to be protective in one study (Rollison et al. 2008) while other studies reported an increased risk (Perrin et al. 2008) or no association between the two (Troisi et al. 1998, Lawlor et al. 2004, Sella et al. 2011). This discrepancy is also present within studies investigating type 2 diabetes mellitus and studies investigating the aetiology of BC in males.

While the exact mechanism behind any association between diabetes mellitus and BC has not yet been identified, the main hypothesis at this stage has focused on the hyperinsulinaemia associated with type 2 diabetes mellitus. In addition, the increased risk observed in women with diabetes is likely to be linked to the increased level of insulin and other hormones associated with this condition. This hypothesis is supported by the results of the meta-analysis, which found a significantly increased risk of BC associated with diabetes in women (OR 1.20, 95% CI 1.13–1.29). After subgroup analysis by type of diabetes, the association was unchanged with type 2 diabetes (OR 1.22, 95% CI 1.07–1.40) and nullified with gestational diabetes (OR 1.06, 95% CI 0.79–1.40). There were insufficient studies to calculate a pooled OR of the risk of BC associated with type 1 diabetes. There was an increased risk of BC in males with diabetes mellitus; however, the results did not reach statistical significance (OR 1.29, 95% CI 0.99–1.67). In conclusion, diabetes increases the risk of BC in women. This association is confirmed in women with type 2 diabetes and supports the hypothesis that diabetes is an independent risk factor for BC.

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diabetes mellitus and consequentially the proliferative effects of insulin. However, it is difficult to isolate diabetes mellitus from potential confounders with other hypotheses focusing on risk factors known to be associated with both diabetes and BC. Obesity is one such example.

The aim of this study was to quantify the risk of BC associated with diabetes. Specifically, we aimed to complete a comprehensive literature search updating the findings of Larsson et al. while also subgrouping the identified studies to investigate the effect of certain types of diabetes on the incidence of BC.

Materials and methods

Study protocol

One reviewer (P J H), following the meta-analysis of Observational Studies in Epidemiology (MOOSE) guidelines (Stroup et al. 2000), completed a comprehensive database search. The databases, MEDLINE (from 1950), EMBASE (from 1949), PubMed (from 1946), Current Contents Connect (from 1998) and Google Scholar (from 1992), were searched using medical subject headings, text word and key word searches wherever possible. The search terms used were ‘diabetes’ and ‘breast carcinoma’ or ‘BC’ or ‘breast neoplasm’. The reference lists of relevant studies were manually checked for missing studies; however, we did not search for unpublished literature.

Study selection

Studies that met the following inclusion criteria were included in the meta-analysis: i) the risk point estimate was reported as an odds ratio (OR) or the OR could be calculated from the presented data; ii) the 95% confidence interval (CI) was reported or the CI could be calculated from the presented data; and iii) an internal control group was used to calculate the OR and the internal control group had been diagnosed with neither diabetes nor breast disease. Any study that did not meet the above criteria was excluded from the meta-analysis.

Data extraction

Data were extracted by a single reviewer (P J H) and entered into a standardised data spreadsheet (Table 1). For each article, data collected included publication date, study period, study type (cross section (CS), cohort (CO) or case–control (CC)), sample size, mean age, country (geographical and economic status), OR, CI and adjusted variables. Where applicable, adjusted ORs were recorded. However, where no OR was given, an unadjusted OR and CI were calculated by the reviewer (P J H). Where multiple ORs were given within the same study, i.e. from two different geographical locations, the data were entered as two separate ORs. Studies that did not define the specific type of diabetes were analysed as ‘non-specific diabetes’.

Statistical analysis

A random effects model was used to calculate a pooled OR for the effect of diabetes on the risk of developing BC. Heterogeneity was assessed using Cochran’s Q statistic with a P value of <0.10 indicating significant heterogeneity. The extent of heterogeneity was further quantified using the $I^2$ statistic with results of 25, 50 and 75% correlating with low, moderate and high levels of heterogeneity respectively. Egger’s regression model was used to calculate publication bias with the extent of bias documented using the ‘fail safe’ method whereby the number of studies required nullifying our results was calculated. A fail safe (n) with a P value <0.05 was considered significant. In addition to the Egger’s regression model, the Begg and Mazumdar rank correlation was used to assess the symmetrical nature of funnel plot to further assess publication bias. Data were analysed using Comprehensive Meta-analysis (version 2.0).

Results

The literature search identified 59 studies investigating the association between BC and diabetes, 16 studies were excluded from the meta-analysis for failing to meet the inclusion criteria (Fig. 1). Eleven studies were excluded for failing to include an internal control group (De Waard & Baanders Van Halewijn 1974, Ragozzino et al. 1982, Adami et al. 1991, Hjalgrim et al. 1997, Weiderpass et al. 1997, Wideroff et al. 1997, Kath et al. 2000, Zendehel et al. 2003, Swerdlow et al. 2005, Hemminki et al. 2010, Shu et al. 2010), three studies were excluded for investigating mortality rather than incidence (Coughlin et al. 2004, Siegelmann-Danieli et al. 2006, Tseng et al. 2009), one study was excluded for using benign breast disease as a comparator (Muck et al. 1975) and the final study was excluded for investigating the effect of glycaemic control on BC incidence (Stefansdottir et al. 2011). The remaining 43 studies were included in the meta-analysis.
Table 1 Summary of included studies

<table>
<thead>
<tr>
<th>Reference</th>
<th>Design</th>
<th>Cases</th>
<th>Controls</th>
<th>Type of diabetes</th>
<th>Summary of findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attner et al. (2012)</td>
<td>CC</td>
<td>19756</td>
<td>147324</td>
<td>Non-specific</td>
<td>Increased risk of BC in patients with DM</td>
</tr>
<tr>
<td>Baron et al. (2001)</td>
<td>CC</td>
<td>5564</td>
<td>5841</td>
<td>Non-specific</td>
<td>Increased risk of BC associated with late-onset DM, decreased risk of BC associated with early-onset DM</td>
</tr>
<tr>
<td>Beji &amp; Reis (2007)</td>
<td>CC</td>
<td>405</td>
<td>1050</td>
<td>Non-specific</td>
<td>Increased risk of BC in patients with DM</td>
</tr>
<tr>
<td>Bowker et al. (2011)</td>
<td>CO</td>
<td>84506</td>
<td>84506</td>
<td>T2DM</td>
<td>No association between BC and DM</td>
</tr>
<tr>
<td>Brinton et al. (2010)</td>
<td>CO</td>
<td>111</td>
<td>4501578</td>
<td>Non-specific</td>
<td>Increased risk of BC in patients with DM</td>
</tr>
<tr>
<td>Carstensen et al. (2012)</td>
<td>CO</td>
<td>23846</td>
<td>3481378</td>
<td>Non-specific</td>
<td>No association between BC and DM</td>
</tr>
<tr>
<td>Chlebowksi et al. (2012)</td>
<td>CO</td>
<td>3401</td>
<td>64618</td>
<td>Non-specific</td>
<td>No association between BC and DM</td>
</tr>
<tr>
<td>Chodick et al. (2010)</td>
<td>CO</td>
<td>16721</td>
<td>83874</td>
<td>Non-specific</td>
<td>No association between BC and DM</td>
</tr>
<tr>
<td>Cleveland et al. (2012)</td>
<td>CC</td>
<td>1447</td>
<td>1453</td>
<td>Non-specific</td>
<td>No significant association between BC and DM</td>
</tr>
<tr>
<td>Ewertz et al. (2001)</td>
<td>CC</td>
<td>156</td>
<td>468</td>
<td>Non-specific</td>
<td>Increased risk of BC in patients with DM</td>
</tr>
<tr>
<td>Franceschi et al. (1990)</td>
<td>CO</td>
<td>2663</td>
<td>2344</td>
<td>Non-specific</td>
<td>No association between BC and DM</td>
</tr>
<tr>
<td>Garmendia et al. (2007)</td>
<td>CC</td>
<td>170</td>
<td>170</td>
<td>Non-specific</td>
<td>No association between diabetes and BC</td>
</tr>
<tr>
<td>Goodman et al. (1997)</td>
<td>CO</td>
<td>161</td>
<td>22039</td>
<td>Non-specific</td>
<td>Increased risk of BC in patients with diabetes</td>
</tr>
<tr>
<td>Hsieh et al. (2012)</td>
<td>CO</td>
<td>61777</td>
<td>677378</td>
<td>T2DM</td>
<td>Increased risk of BC associated with T2DM</td>
</tr>
<tr>
<td>Inoue et al. (2006)</td>
<td>CO</td>
<td>4668</td>
<td>93103</td>
<td>Non-specific</td>
<td>No association between BC and DM</td>
</tr>
<tr>
<td>Jee et al. (2005)</td>
<td>CO</td>
<td>21056</td>
<td>270157</td>
<td>Non-specific</td>
<td>Increased risk of BC in patients with DM</td>
</tr>
<tr>
<td>Jordan et al. (2009)</td>
<td>CC</td>
<td>43</td>
<td>860</td>
<td>T2DM</td>
<td>Increased risk of BC in patients with DM</td>
</tr>
<tr>
<td>Khachatryan et al. (2011)</td>
<td>CO</td>
<td>150</td>
<td>152</td>
<td>T2DM</td>
<td>Increased risk of BC associated with T2DM</td>
</tr>
<tr>
<td>Khan et al. (2006)</td>
<td>CO</td>
<td>1554</td>
<td>31949</td>
<td>Non-specific</td>
<td>No association between BC and DM</td>
</tr>
<tr>
<td>Lambe et al. (2011)</td>
<td>CO</td>
<td>5615</td>
<td>218279</td>
<td>Non-specific</td>
<td>Increased risk of BC in postmenopausal women with DM</td>
</tr>
<tr>
<td>La Vecchia et al. (1994)</td>
<td>CO</td>
<td>9991</td>
<td>7834</td>
<td>Non-specific</td>
<td>No association between BC and DM</td>
</tr>
<tr>
<td>Lawlor et al. (2004)</td>
<td>CS</td>
<td>147</td>
<td>3690</td>
<td>Non-specific, gestational, T2DM</td>
<td>No significant association between DM and BC</td>
</tr>
<tr>
<td>Li et al. (2011)</td>
<td>CS</td>
<td>48418</td>
<td>349365</td>
<td>Non-specific</td>
<td>Increased risk of BC associated with DM</td>
</tr>
<tr>
<td>Lipscombe et al. (2006)</td>
<td>CO</td>
<td>73796</td>
<td>391714</td>
<td>Non-specific</td>
<td>Increased risk of BC associated with DM</td>
</tr>
<tr>
<td>Michels et al. (2003)</td>
<td>CO</td>
<td>6220</td>
<td>116488</td>
<td>T2DM</td>
<td>Increased risk of BC associated with T2DM</td>
</tr>
<tr>
<td>Mink et al. (2002)</td>
<td>CO</td>
<td>26</td>
<td>7894</td>
<td>Non-specific</td>
<td>No association between BC and DM</td>
</tr>
<tr>
<td>Moseson et al. (1993)</td>
<td>CO</td>
<td>354</td>
<td>747</td>
<td>Non-specific</td>
<td>No significant association between BC and DM</td>
</tr>
<tr>
<td>Perrin et al. (2008)</td>
<td>CO</td>
<td>410</td>
<td>37516</td>
<td>Gestational</td>
<td>Increased risk of BC associated with gestational diabetes</td>
</tr>
<tr>
<td>Resta et al. (2004)</td>
<td>CO</td>
<td>1663</td>
<td>4702</td>
<td>T2DM</td>
<td>Increased risk of BC associated with T2DM</td>
</tr>
<tr>
<td>Ronco et al. (2012)</td>
<td>CC</td>
<td>367</td>
<td>545</td>
<td>Non-specific</td>
<td>Increased risk of BC associated with DM</td>
</tr>
<tr>
<td>Rollison et al. (2008)</td>
<td>CO</td>
<td>2324</td>
<td>2523</td>
<td>Non-specific, gestational, T2DM</td>
<td>Gestational diabetes reduces risk of BC, no association between T2DM and non-specific DM</td>
</tr>
<tr>
<td>Rosato et al. (2011)</td>
<td>CO</td>
<td>3869</td>
<td>4082</td>
<td>Non-specific</td>
<td>Increased risk of BC associated with DM</td>
</tr>
<tr>
<td>Sanderson et al. (2010)</td>
<td>CC</td>
<td>190</td>
<td>979</td>
<td>T2DM</td>
<td>No association between DM and BC</td>
</tr>
<tr>
<td>Sella et al. (2011)</td>
<td>CO</td>
<td>11624</td>
<td>174051</td>
<td>Gestational</td>
<td>No association between gestational diabetes and BC</td>
</tr>
<tr>
<td>Sellers et al. (2007)</td>
<td>CO</td>
<td>403</td>
<td>5727</td>
<td>T2DM</td>
<td>No significant risk of BC associated with DM</td>
</tr>
<tr>
<td>Sinagra et al. (2002)</td>
<td>CS</td>
<td>50</td>
<td>25</td>
<td>Non-specific</td>
<td>Increased risk of BC associated with DM</td>
</tr>
<tr>
<td>Steenland et al. (1995)</td>
<td>CC</td>
<td>12500</td>
<td>11804</td>
<td>Non-specific</td>
<td>No significant increased risk of BC associated with DM</td>
</tr>
<tr>
<td>Talimini et al. (1997)</td>
<td>CC</td>
<td>2769</td>
<td>2588</td>
<td>Non-specific</td>
<td>Increased risk of BC in postmenopausal women with DM</td>
</tr>
<tr>
<td>Thomas et al. (1992)</td>
<td>CC</td>
<td>227</td>
<td>300</td>
<td>Non-specific</td>
<td>No significant increase in risk of BC in males with DM</td>
</tr>
<tr>
<td>Troisi et al. (1998)</td>
<td>CC</td>
<td>1239</td>
<td>1166</td>
<td>Gestational</td>
<td>No association between gestational diabetes and BC</td>
</tr>
<tr>
<td>Weiss et al. (1999)</td>
<td>CC</td>
<td>2173</td>
<td>1990</td>
<td>Gestational</td>
<td>No significant increase in risk of BC associated with BC</td>
</tr>
<tr>
<td>Wu et al. (2007)</td>
<td>CC</td>
<td>1248</td>
<td>1148</td>
<td>T2DM</td>
<td>Increased risk of BC associated with T2DM</td>
</tr>
<tr>
<td>Yu et al. (2012)</td>
<td>CC</td>
<td>103</td>
<td>309</td>
<td>Non-specific</td>
<td>No significant increased risk of BC associated with DM</td>
</tr>
</tbody>
</table>

Non-specific diabetes mellitus

Troisi et al. 1998, Weiss et al. 1999, Baron et al. 2001, Mink et al. 2002, Lawlor et al. 2004, Khan et al. 2006, Garmendia et al. 2007, Sellers et al. 2007, Perrin et al. 2008, Sanderson et al. 2010, Lambe et al. 2011, Li et al. 2011, Carstensen et al. 2012, Cleveland et al. 2012, Yu et al. 2012) while six studies favoured a decreased risk (Moseson et al. 1993, Inoue et al. 2006, Rollison et al. 2008, La Vecchia et al. 1994, Sella et al. 2011, Chlebowski et al. 2012). Three studies found no association between the two (Franceschi et al. 1990, Chodick et al. 2010, Bowker et al. 2011). Quantitative analysis revealed a significant pooled risk point estimate of 1.20 (95% CI 1.13–1.29) (Fig. 2). Heterogeneity was high ($I^2 = 73.41$, $P < 0.001$) and there was evidence of publication bias ($n = 932$, Egger’s $P = 0.01$). However, the funnel plot was found to be symmetrical using the Begg and Mazumdar rank correlation ($P = 0.07$; Fig. 3).

Figure 1 Results of the literature search.

Subgroup analysis by study design identified a slightly increased risk of BC in CC studies when compared with CO studies evident in risk point estimates of 1.29 (95% CI 1.12–1.49) and 1.12 (95% CI 1.05–1.20) respectively. The pooled analysis for cross-sectional studies was not significant despite an increased risk point estimate (OR 1.33, 95% CI 0.81–2.17).

To investigate the effect of confounders on BC incidence, a subgroup analysis was undertaken investigating only studies that adjusted for known risk factors of BC. Twenty-one studies adjusted for age and BMI with the pooled risk point estimate identifying a statistically significant increase in BC risk (OR 1.12, 95% CI 1.04–1.21) with no evidence of heterogeneity ($I^2 = 30.78$, $P = 0.09$). In a bid to further demonstrate causality, studies that adjusted for family history in addition to age and BMI were collated with
the results continuing to favour an increased risk of BC in patients with diabetes mellitus (OR 1.11, 95% CI 1.01–1.22, $I^2 = 25.02$, $P = 0.23$).

## Male BC

Seven studies were identified investigating the association between BC and diabetes mellitus in men (Lenfant-PejoVic et al. 1990, Thomas et al. 1992, Ewertz et al. 2001, Brinton et al. 2010, Chodick et al. 2010, Li et al. 2011, Carstensen et al. 2012). Five studies were homogenous in their finding of an increased risk point estimate; however, only two studies reached statistical significance (Ewertz et al. 2001, Brinton et al. 2010). The remaining two studies, despite not reaching statistical significance, favoured a protective effect associated with diabetes mellitus. The pooled OR favoured an increased risk of BC in males with diabetes mellitus (OR 1.29, 95% CI 0.99–1.67) (Fig. 4). There was no evidence of heterogeneity ($I^2 = 32.83$, $P = 0.18$).

### Type 2 diabetes mellitus


<table>
<thead>
<tr>
<th>Study name</th>
<th>Odds ratio</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>$P$ value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attner et al. (2012)</td>
<td>1.37</td>
<td>1.10</td>
<td>1.71</td>
<td>0.01</td>
</tr>
<tr>
<td>Baron et al. (2001)</td>
<td>1.10</td>
<td>0.93</td>
<td>1.30</td>
<td>0.26</td>
</tr>
<tr>
<td>Beji &amp; Reis (2007)</td>
<td>3.31</td>
<td>2.36</td>
<td>4.64</td>
<td>0.00</td>
</tr>
<tr>
<td>Bowker et al. (2011)</td>
<td>1.00</td>
<td>0.91</td>
<td>1.10</td>
<td>1.00</td>
</tr>
<tr>
<td>Carstensen et al. (2012)</td>
<td>1.05</td>
<td>1.02</td>
<td>1.08</td>
<td>0.00</td>
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<tr>
<td>Chlebowski et al. (2012)</td>
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<td>0.85</td>
<td>1.15</td>
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<tr>
<td>Cleveland et al. (2012)</td>
<td>1.27</td>
<td>0.95</td>
<td>1.69</td>
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<tr>
<td>Chodick et al. (2010)</td>
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<td>1.19</td>
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<tr>
<td>Franceschi et al. (1990)</td>
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<td>0.77</td>
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<td>1.00</td>
</tr>
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<td>Garmendia et al. (2007)</td>
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<td>0.73</td>
<td>3.52</td>
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</tr>
<tr>
<td>Goodman et al. (1997)</td>
<td>2.06</td>
<td>1.27</td>
<td>3.34</td>
<td>0.00</td>
</tr>
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<td>Hsieh et al. (2012)</td>
<td>1.11</td>
<td>1.02</td>
<td>1.21</td>
<td>0.02</td>
</tr>
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<td>Inoue et al. (2006)</td>
<td>0.83</td>
<td>0.44</td>
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<td>0.57</td>
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<tr>
<td>Jee et al. (2005)</td>
<td>1.51</td>
<td>1.26</td>
<td>1.80</td>
<td>0.00</td>
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<tr>
<td>Jordan et al. (2009)</td>
<td>8.40</td>
<td>1.71</td>
<td>41.25</td>
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<tr>
<td>Khachatryan et al. (2011)</td>
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<td>1.34</td>
<td>22.82</td>
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<tr>
<td>Khan et al. (2006)</td>
<td>1.55</td>
<td>0.62</td>
<td>3.86</td>
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<td>Lambe et al. (2011)</td>
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<td>3.14</td>
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<td>LaVecchia et al. (1994)</td>
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<td>0.64</td>
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<td>0.05</td>
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<td>Lawler et al. (2004)</td>
<td>1.42</td>
<td>0.80</td>
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<td>Li et al. (2011)</td>
<td>1.10</td>
<td>0.93</td>
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<td>0.28</td>
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<td>Lipomen et al. (2006)</td>
<td>1.08</td>
<td>1.01</td>
<td>1.16</td>
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<td>Michaels et al. (2003)</td>
<td>1.17</td>
<td>1.01</td>
<td>1.35</td>
<td>0.03</td>
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</table>

**Figure 2** Diabetes and breast cancer incidence in women.
statistical significance (Michels et al. 2003, Resta et al. 2004, Wu et al. 2007, Jordan et al. 2009, Khachatryan et al. 2011, Hsieh et al. 2012). The final two studies did not find any association between the two (Sanderson et al. 2010, Bowker et al. 2011). The pooled OR and 95% CI supported an increased risk of BC associated with type 2 diabetes mellitus (OR 1.22, 95% CI 1.07–1.40) (Fig. 5).

**Type 1 diabetes mellitus**

The literature search identified three studies investigating the effect of type 1 diabetes mellitus on BC incidence. However, all three studies failed to meet the inclusion criteria with two studies failing to include an internal control group (Zendehel et al. 2003, Shu et al. 2010) while one study assumed a diagnosis of type 1 diabetes mellitus in all patients aged under 35 years without confirmation (Baron et al. 2001). Interestingly, the studies were homogenous in their finding of a protective risk point estimate despite none of the studies reaching statistical significance. Quantitative analysis was not undertaken on account of the studies failing to meet the inclusion criteria.

**Gestational diabetes**

Six studies were identified investigating the effect of gestational diabetes on BC incidence (Troisi et al. 1998, Lawlor et al. 2004, Perrin et al. 2008, Rollison et al. 2008, Sella et al. 2011). There was a degree of heterogeneity within the results with only one study reaching statistical significance (Rollison et al. 2008). This study found gestational diabetes to reduce the risk of BC. The remaining four studies did not reach statistical significance with three studies finding an

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**Figure 3** Funnel plot assessing publication bias.

**Figure 4** Diabetes and breast cancer incidence in men.

<table>
<thead>
<tr>
<th>Study name</th>
<th>Odds ratio</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>P value</th>
</tr>
</thead>
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<td>Brinton et al. (2010)</td>
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<td>Carstensen et al. (2012)</td>
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<td>Li et al. (2011)</td>
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<td>0.47</td>
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<tr>
<td>Thomas et al. (1992)</td>
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<td>1.29</td>
<td>0.99</td>
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</tbody>
</table>

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increased risk point estimate (Troisi et al. 1998, Lawlor et al. 2004, Perrin et al. 2008) and one study reporting a negative risk point estimate (Sella et al. 2011). The pooled OR did not find any association between gestational diabetes and BC (OR 1.06, 95% CI 0.79–1.40) while significant heterogeneity was present ($I^2 = 68.81$, $P = 0.01$).

**Discussion**

Our study identified a 20% increased risk of BC in people with diabetes mellitus. This association was unchanged when considering only people with confirmed type 2 diabetes mellitus while there was no evidence of an increased risk associated with type 1 diabetes mellitus. These findings are consistent with the hyperinsulinaemia hypothesis as a potential mechanism linking diabetes mellitus to BC.

While type 1 diabetes mellitus is predominantly associated with insulin deficiency, type 2 diabetes is more readily known for its hyperinsulinaemic state. This is particularly seen in the early stages of the disease where the pancreas is still able to compensate for the hyperglycaemia. This increase in insulin is hypothesised to increase proliferation in two ways; activation of the insulin receptor substrate to increase mitosis at a cellular level (Chan & Lee 2008) and causing an imbalance in sex steroids via a decrease in sex hormone binding globulin (Nestler 2000). However, we cannot exclude an indirect relationship with potential confounders triggering a rise in plasma oestrogen. For example, obesity has also been shown to trigger a reduction in sex hormone binding globulin and consequentially an increase in the bioavailability of oestrogen. In addition, adipose tissue is known to generate an increase in plasma oestrogen via the aromatase enzyme, thus providing an alternate mechanism linking diabetes to BC (Ballard-Barbash et al. 1990, Carmichael & Bates 2004).

Another hypothesis centres on an iatrogenic link between BC and diabetes mellitus. Insulin use has long been suspected of increasing the risk of BC and more recently the debate has focused on the use of insulin glargine. Jonasson et al. (2009) in a study published in 2009 found an increased risk of BC associated with glargine use. These results, however, have not been replicated in other observational studies (Colhoun & Group 2009, Currie et al. 2009, Home & Lagarenne 2009). Additionally, while there has been a degree of heterogeneity in the results of broader studies investigating insulin use in general (rather than specifically glargine use), a recent Danish study did not find an association between the risk of BC in people using insulin and people using other antiglycaemic agents (Carstensen et al. 2012).

Metformin use, on the other hand, has actually been shown to reduce the risk of BC (Bodmer et al. 2010). Hypothesised mechanisms explaining this protective effect include metformin’s ability to reduce the hyperinsulinaemia associated with type 2 diabetes and in vitro evidence of direct anticarcinogenic properties (Martin-Castillo et al. 2010, Belda-Iniesta et al. 2011). While a number of observational studies have confirmed this protective effect, a recent study specifically identified a 25% reduction in BC incidence associated with metformin use (Chlebowski et al. 2012). New evidence has also indicated that metformin use may improve prognosis (Jiralerspong et al. 2009).

**Figure 5** Type 2 diabetes and breast cancer incidence.

<table>
<thead>
<tr>
<th>Study name</th>
<th>Odds ratio</th>
<th>Lower limit</th>
<th>Upper limit</th>
<th>$P$ value</th>
</tr>
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<td>Khachatryan et al. (2011)</td>
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<td>Michaels et al. (2003)</td>
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<td>1.24</td>
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<td>0.85</td>
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<td>Seller et al. (2007)</td>
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<td></td>
<td>1.22</td>
<td>1.07</td>
<td>1.40</td>
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</table>
The vast majority of the included studies comprised broad, large-scale observational studies, which took neither current nor past therapeutic regimes into account. For this reason, we were unable to exclude antiglycaemic therapy as a potential confounder. This constraint, in the context of new evidence potentially linking antiglycaemic agents to BC incidence, is a major limitation in our study. We recommend that all future primary studies take both past and present therapy into account when considering aspects of study design. In addition, the effect of diabetes mellitus on different types of BC has not been thoroughly assessed and it may be worthwhile for future studies to also take this into account.

A further weakness in this study lay in our inability to differentiate between the different types of diabetes investigated. Thirty-four studies were included in this analysis; however, only 13 of these studies specifically stated the type of diabetes investigated. While the vast majority of the studies had a mean age above 50 years, and thus a diagnosis of type 2 diabetes was most likely, we were unable to include the studies in our subgroup analysis. For this reason, the power of the subgroup analysis in type 2 diabetes mellitus was reduced. Furthermore, with only three studies investigating the association between type 1 diabetes mellitus and all three studies failing to meet the inclusion criteria, we were unable to quantitatively analyse the results. For future research, we recommend further longitudinal studies of high quality be undertaken in this area.

Strengths of this study include a broad literature review, the use of precise inclusion criteria and comprehensive subgrouping to identify the differences between types of diabetes. We used five databases as well as reference list checking to identify relevant studies with double the number of studies identified compared with previous reviews (Larsson et al. 2007, Liao et al. 2011). The increased number of studies allowed subgroup analysis by type of diabetes for the first time.

In conclusion, in patients with diabetes mellitus, we have found a 20% increase in the incidence of BC in women and 29% increase in men. This association was unchanged when the analysis was restricted to studies with a confirmed diagnosis of type 2 diabetes mellitus. These findings are consistent with the hyperinsulinaemia theory in the aetiology of BC.

Funding
This research did not receive any specific grant from any funding agency in the public, commercial or not-for-profit sector.

Author contribution statement
All authors contributed to the conception, design and interpretation of the data; the preparation of the manuscript; and the final editing and approval of the manuscript.

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Received in final form 5 September 2012
Accepted 3 October 2012
Made available online as an Accepted Preprint 3 October 2012