The global impact of non-communicable diseases on macro-economic productivity: a systematic review

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Abstract Non-communicable diseases (NCDs) have large economic impact at multiple levels. To systematically review the literature investigating the economic impact of NCDs [including coronary heart disease (CHD), stroke, type 2 diabetes mellitus (DM), cancer (lung, colon, cervical and breast), chronic obstructive pulmonary disease (COPD) and chronic kidney disease (CKD)] on macro-economic productivity. Systematic search, up to November 6th 2014, of medical databases (Medline, Embase and Google Scholar) without language restrictions. To identify additional publications, we searched the reference lists of retrieved studies and contacted authors in the field. Randomized controlled trials, cohort, case–control, cross-sectional, ecological studies and modelling studies carried out in adults (>18 years old) were included. Two independent reviewers performed all abstract and full text selection. Disagreements were resolved through consensus or consulting a third reviewer. Two independent reviewers extracted data using a pre-designed data collection form. Main outcome measure was the impact of the selected NCDs on productivity, measured in DALYs, productivity costs, and labor market participation, including unemployment, return to work and sick leave. From 4542 references, 126 studies met the inclusion criteria, many of which focused on the impact of more than one NCD on productivity. Breast cancer was the most common (n = 45), followed by stroke (n = 31), COPD (n = 24), colon cancer (n = 22), lung cancer (n = 16), CVD (n = 15), cervical cancer (n = 7) and CKD (n = 2). Four studies were from the WHO African Region, 52 from the European Region, 53 from the Region of the Americas and 16 from the Western Pacific Region, one from the Eastern Mediterranean Region and none from South East Asia. We found large regional differences in DALYs attributable to NCDs but especially for cervical and lung cancer. Productivity losses in the USA ranged from 88 million US dollars (USD) for COPD to 20.9 billion USD for colon cancer. CHD costs the Australian economy 13.2 billion USD per year. People with DM, COPD and survivors of breast and especially lung cancer are at a higher risk of reduced labor market participation. Overall NCDs generate a large impact on macro-economic productivity in most WHO regions irrespective of continent and income. The absolute global impact in terms of dollars and DALYs remains an

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elusive challenge due to the wide heterogeneity in the included studies as well as limited information from low-and middle-income countries.

**Keywords** Noncommunicable diseases · Productivity · Return to work absenteeism · Systematic review

**Introduction**

Non-communicable diseases (NCDs), such as coronary heart disease (CHD), stroke, chronic obstructive pulmonary disease (COPD), cancer, type 2 diabetes and chronic kidney disease (CKD) currently constitute the number one cause of morbidity and mortality worldwide, claiming 36 million lives each year (accounting for 63% of all adult deaths) [1]. Infectious disease prevention and control, economic growth, improvements in medical and scientific knowledge, and health and social systems development have all contributed to increased life expectancy, improved quality of life and increased likelihood of living to age 60 years and beyond. While these are notable achievements, together with lifestyle-related shifts, these epidemiological and socio-demographic changes also mean that the burden of NCDs will grow [2].

Productivity is a measure of the efficiency of a person, business or country in converting inputs into useful outputs. The productive age span of a person is from adulthood to retirement and ranges from 18 years to around 65 years of age depending on, amongst other things, profession and country. The measurement of productivity greatly relies on the output and the economic or social system context. The focus in this report is macro-economic productivity loss in the productive age range due to NCDs. Key macro-economic measures related to the labor market include: (un-) employment, (loss in) hours worked (including full or part-time work status change), presenteeism (defined as impaired performance while at work), absenteeism, disability adjusted life years (DALYs) and productivity costs/losses. Key macro-economic outcomes are reduction in the able workforce, NCD-related health and welfare expenditure and loss of income earned by the productive workforce. While both the burden of NCDs and the socio-economic contexts vary greatly, the impact of the former on macro-economic outcomes across the global regions remains unclear.

We aimed to systematically identify and summarize the literature investigating the impact of six NCDs (CHD, stroke, COPD cancer, type 2 diabetes and CKD) on macro-economic productivity and to determine directions for future research.

**Methods**

**Search strategy and inclusion criteria**

We systematically searched the electronic medical databases (Medline, Embase and Google Scholar) up to November 6th, 2014 (date of last search) to identify relevant articles evaluating the macro-economic consequences of the six selected NCDs, specifically the impact on economic productivity of working age citizens. The complete search strategy is available in “Appendix 1”. We defined the major NCDs of interest as CHD, stroke, chronic obstructive lung disease (COPD), type 2 diabetes mellitus (DM), cancer (lung, colon, breast and cervical) and chronic kidney disease (CKD). The step-wise inclusion and exclusion procedure is outlined in Fig. 1. Eligible study design included randomized controlled trials (RCTs), cohort, case–control, cross-sectional, systematic reviews, meta-analysis, ecological studies and modeling studies. We included studies that estimated the impact of at least one of the NCDs defined above on at least one of the following measures of macro-economic productivity: DALYs, economic costs related to reduced work productivity, presenteeism, absenteeism, (un) employment, (non-) return to work (RTW) after sickness absence and medical/sick leave. DALY is also considered as essentially it is an economic measure of human productive capacity for the affected individual and when taken together (e.g. all those in a company, society etc.) forms an economic measure also on the group level. Only studies involving adults (>18 years old) were included, without any restriction on language or date.

**Study selection**

Two independent reviewers screened the titles and abstracts of the initially identified studies to determine if they satisfied the selection criteria. Any disagreements were resolved through discussion and consensus, or by consultation with a third reviewer. In order to ensure that all retrieved full texts (of the selected abstracts) satisfied the inclusion criteria appropriately, they were further assessed by two independent reviewers. We further screened the reference lists of all retrieved studies to retrieve relevant articles. Systematic reviews were not included in the data extraction but a supplementary scan of their reference lists was performed to identify any additional studies.

**Data extraction**

A data collection form (DCF) was prepared to extract the relevant information from the included full texts, including
study design, World Health Organization (WHO) region, participants, NCD-related exposure and macro-economic outcome characteristics. When evaluating economic costs, US dollars (USD) was used as outcome measure. If a study reported costs in another currency, the corresponding exchange rate to USD as reported by the study itself was used. However, if an exchange rate was not provided, we calculated USD applying the conversion rate for the indicated study time-period.

Quality evaluation

To evaluate the quality of the included non-randomized studies, we applied the Newcastle–Ottawa Scale (NOS) [3]. The NOS scale assesses the quality of articles in three domains: selection, comparability and exposure. ‘Selection’ assesses four items and a maximum of one star can be awarded for each item. ‘Comparability’ awards a maximum of two stars to the one item within the category. Finally, ‘exposure’ includes four items for which one star can be awarded. A quality score is made for each study by summing the number of stars awarded, and thus the NOS scale can have maximum of nine stars. We used this scale to assess the quality of case–control and cohort studies. For cross-sectional and descriptive studies, we used an adapted version of NOS scale (“Appendix 2”).

Statistical methods

We aimed to pool the results using a random effects model. If pooled, results would be expressed as pooled relative risks with 95% confidence intervals. Pooling possibility was conditional on the level of heterogeneity between studies.

Results

General characteristics of the included studies

From 4542 references initially identified, a total of 126 unique studies met the inclusion criteria (Fig. 1; Table 1). All eligible studies were published between 1984 and 2014. Of the 126 studies identified, 52 were from the
| Source | Period of surveillance | Location | WHO region | Study design | Number in analysis | Gender | Ethnicity | Reported NCDs |
|--------|------------------------|----------|------------|--------------|--------------------|--------|-----------|--------------|
| Adepoju et al. [71] | 2007–2012 | USA | RA | Retrospective | 376 | Both | Hispanic, non-Hispanic black, non-Hispanic white | DM |
| Ahn et al. [31] | 1993–2002 | South Korea | WPR | Cross-sectional | 1594 | Female | NR | Breast cancer |
| Alavinia and Burdorf [69] | 2004 | 10 EU countries | ER | Cross-sectional | 11,462 | Both | NR | CVD, stroke, DM |
| Alexopoulos and Burdorf [54] | 1993–1995 | The Netherlands | ER | Prospective cohort | 326 | Male | NR | COPD |
| Anesetti-Rothermel and Sambamoorthi [10] | 2007 | USA | RA | Cross-sectional | 12,860 | Both | White, Latino, African American, other | COPD, CVD, stroke, DM |
| Angeleri et al. [80] | NR | Italy | ER | Prospective study | 180 | Both | NR | Stroke |
| Arrossi et al. [23] | 2002–2004 | Argentina | RA | Cross-sectional | 120 | Female | NR | Cervical cancer |
| Bains et al. [44] | 2008–2009 | UK | ER | Prospective cohort | 50 | Female | NR | Colon cancer |
| Balak et al. [34] | 2001–2007 | The Netherlands | ER | Retrospective cohort | 72 | Female | NR | Breast cancer |
| Bastida and Pagan [81] | 1994–1999 | USA | RA | Population based | 1021 | Both | Mexican Americans | DM |
| Black-Schaffer and Osberg [82] | 1984–1986 | USA | RA | Prospective study | 79 | Both | NR | Stroke |
| Bogousslavsky and Regli [83] | NR | Switzerland | ER | Prospective study | 41 | Both | NR | Stroke |
| Boles et al. [84] | 2001 | USA | RA | Cross-sectional | 2264 | Both | NR | DM |
| Bouknight et al. [37] | 2001–2002 | USA | RA | Prospective study | 416 | Female | White, black | Breast Cancer |
| Bradley and Bednarek [85] | 1999 | USA | RA | Cross-sectional | 184 | Both | Caucasian, African-American, Hispanic, other | Breast cancer, colon cancer, lung cancer |
| Bradley et al. [86] | 1992 | USA | RA | Retrospective study | 5974 | Female | Caucasian, African-American, Hispanic, other | Breast cancer |
| Bradley et al. [87] | 1992 | USA | RA | Cross-sectional | 5728 | Female | Caucasian, African-American, Hispanic, other | Breast cancer |
| Bradley et al. [88] | 2001–2002 | USA | RA | Prospective study | 817 | Female | Non-Hispanic White, Non-Hispanic African American, other | Breast cancer |
| Bradley et al. [89] | 2001–2002 | USA | RA | Prospective study | 239 | Female | Non-Hispanic White, Non-Hispanic African American, other | Breast cancer |
| Bradley and Dahman [33] | 2007–2011 | USA | RA | Cross-sectional | 828 | Both | Non-Hispanic white, non-Hispanic black, other | Breast cancer |
| Bradley et al. [40] | 2005 | USA | RA | Modelling study | NR | Both | NR | Colon cancer |
| Bradshaw et al. [66] | 2000–2000 | South Africa | AR | Modelling | NR | Both | NR | DM |
| Source                        | Period of surveillance | Location     | WHO region | Study design      | Number in analysis | Gender | Ethnicity                  | Reported NCDs                                                                 |
|-------------------------------|------------------------|--------------|------------|-------------------|--------------------|--------|---------------------------|----------------------------------------------------------------------------|
| Broekx et al. [90]            | 1997–2004              | Belgium      | ER         | Cost-of-Illness analysis | 20,439             | Female | NR                        | Breast cancer                                                               |
| Burton et al. [91]            | 2002                   | USA          | RA         | Survey            | 16,651             | Both   | NR                        | DM                                                                         |
| Carlsen et al. [45]           | 2001–2009              | Denmark      | ER         | Epidemiological   | 4343               | Both   | NR                        | Colon cancer                                                                |
| Carlsen et al. [29]           | 2001–2011              | Denmark      | ER         | Cross-sectional and prospective | 14,750             | Female | NR                        | Breast cancer                                                               |
| Catalá-López et al. [13]      | 2008                   | Spain        | ER         | Cross-sectional   | 37,563,454         | Both   | NR                        | Stroke                                                                     |
| Choi et al. [42]              | 2001–2003              | South Korea  | RA         | Survey            | 305                | Male   | NR                        | Colon cancer                                                                |
| Collins et al. [92]           | 2002                   | USA          | RA         | Survey            | 7797               | Both   | NR                        | DM                                                                         |
| Costilla et al. [22]          | 2006                   | New Zealand  | WPR        | Modelling         | NR                 | Both   | Maori and non-Maori     | Breast cancer, colon cancer, lung cancer, cervical cancer                  |
| Dacosta DiBonaventura et al.  | 2009                   | USA          | RA         | Cross-sectional   | 20,024             | Both   | Non-Hispanic White, Non-Hispanic Black/African-American, Hispanic, other | COPD                                                                        |
| Dall et al. [68]              | 2007–2007              | USA          | RA         | Modelling         | NR                 | NR     | NR                        | DM                                                                         |
| Darkow et al. [63]            | 2001–2004              | USA          | RA         | Case–control      | 4045               | Both   | NR                        | COPD                                                                        |
| De Backer et al. [93]         | 1994–1998              | Belgium      | ER         | Prospective cohort | 15,740             | Both   | NR                        | DM                                                                         |
| Eaker et al. [94]             | 1993–2003              | Sweden       | ER         | Cross-sectional   | 28,566             | Female | NR                        | Breast Cancer                                                               |
| Earle et al. [46]             | 2003–2005              | USA          | RA         | Prospective cohort | 2422               | Both   | Non-Hispanic white, African American, Hispanics, Asian, mixed race | Lung cancer, colon cancer                                                   |
| Ekwueme et al. [26]           | 1970–2008              | USA          | RA         | Retrospective cohort | 53,368             | Female | White and Black         | Breast cancer                                                               |
| Etyang et al. [6]             | 2007–2012              | Kenya        | AR         | Prospective surveillance | 18,712             | Both   | NR                        | CVD, Stroke, DM                                                            |
| Fantoni et al. [38]           | 2004–2005              | France       | ER         | Cross-sectional   | 379                | Female | NR                        | Breast cancer                                                               |
| Fernandez de Larrea-Baz et al.| 2000                   | Spain        | ER         | Ecological        | 40,376,294         | Both   | NR                        | Breast cancer, colon cancer, lung cancer                                     |
| Ferro and Crespo [96]         | 1985–1992              | Portugal     | ER         | Prospective cohort | 215                | Both   | NR                        | Stroke                                                                     |
| Fu et al. [97]                | 2004–2006              | USA          | RA         | Survey            | 46,617             | Both   | White, black, Asian, other | DM                                                                         |
| Gabriele and Renate [18]      | 2001–2004              | Germany      | ER         | Prospective cohort | 70                 | Both   | NR                        | Stroke                                                                     |
| Genova-Maleras et al. [4]     | 2008                   | Spain        | ER         | Modelling         | NR                 | Both   | NR                        | CVD, stroke, COPD, lung cancer, colon cancer, breast cancer, DM             |
| Source                      | Period of surveillance | Location       | WHO region | Study design                        | Number in analysis | Gender | Ethnicity                   | Reported NCDs |
|-----------------------------|------------------------|----------------|------------|-------------------------------------|--------------------|--------|-----------------------------|----------------|
| Gordon et al. [47]          | 2003–2004              | Australia      | WPR        | Prospective cohort                  | 975                | Both   | NR                          | Colon cancer  |
| Hackett et al. [19]         | 2008–2010              | Australia      | WPR        | Prospective cohort                  | 441                | Both   | NR                          | Stroke        |
| Halpern et al. [98]         | 2000                   | USA            | RA         | Economical evaluation               | 447                | Both   | NR                          | COPD           |
| Hansen et al. [99]          | NR                     | USA            | RA         | Cross-sectional                     | 203                | Female | White and non-white         | Breast cancer |
| Hauglann et al. [30]        | 1992–1996              | Norway         | ER         | National registry cohort            | 3096               | Female | Female                     | Breast cancer |
| Hauglann et al. [49]        | 1992–1996              | Norway         | ER         | Case–control                        | 1480               | Both   | NR                          | Colon cancer  |
| Helanterä et al. [65]       | 2007                   | Finland        | ER         | Cross-sectional                     | 2637               | Both   | NR                          | CKD            |
| Herquelot et al. [100]      | 1989–2007              | France         | ER         | Prospective cohort                  | 20,625             | Both   | NR                          | DM             |
| Holden et al. [52]          | 2004–2006              | Australia      | WPR        | Cross-sectional                     | 78,430             | Both   | NR                          | CVD, COPD, DM |
| Hoyer et al. [101]          | 2007–2008              | Sweden         | ER         | Prospective cohort                  | 651                | Female | NR                          | Breast cancer |
| Jansson et al. [59]         | 1999                   | Sweden         | ER         | Economic evaluation                 | 212                | Both   | NR                          | COPD           |
| Kabadi et al. [17]          | 2005–2006              | Tanzania       | AR         | Prospective surveillance study      | 16                 | Both   | NR                          | Stroke        |
| Kang et al. [16]            | 2008                   | South Korea    | WPR        | Economic Evaluation                 | 296                | Both   | NR                          | Stroke        |
| Kappelle et al. [102]       | 1977–1992              | USA            | RA         | Prospective study                   | 68,661             | Both   | Indigenous; non-indigenous | Stroke        |
| Katzenellenbogen et al. [14]| 1997–2002              | Western Australia | WPR | Modelling, ecological               | 2074               | Both   | NR                          | DM             |
| Kessler et al. [70]         | 1995–1996              | USA            | RA         | Survey                              | 5558               | Both   | White, black, other         | CVD, COPD, DM, CKD |
| Klarenbach et al. [64]      | 1988–1994              | USA            | RA         | Cross-sectional                     | 255                | Both   | NR                          | Stroke        |
| Kotila et al. [103]         | 1978–1980              | Finland        | ER         | Prospective                         | 826                | Both   | NR                          | COPD           |
| Kruse et al. [104]          | 1980–2003              | Denmark        | ER         | Cohort                              | 2212               | Both   | NR                          | CHD            |
| Lauzier et al. [35]         | 2003                   | Canada         | RA         | Prospective cohort                  | 962                | Female | NR                          | Breast cancer |
| Lavigne et al. [67]         | 1999–1999              | USA            | RA         | Cross-sectional                     | 472                | Both   | NR                          | DM             |
| Leigh et al. [105]          | 1996                   | USA            | RA         | Ecological study                    | 2,395,650          | Both   | NR                          | COPD           |
| Source                        | Period of surveillance | Location                  | WHO region | Study design                  | Number in analysis | Gender            | Ethnicity                                      | Reported NCDs                  |
|-------------------------------|------------------------|---------------------------|------------|-------------------------------|--------------------|------------------|-----------------------------------------------|-------------------------------|
| Leng [106]                    | 2004–2005              | Singapore                 | WPR        | Retrospective cohort          | 29                 | NR    | NR                                           | Stroke                        |
| Lenneman et al. [107]         | 2005–2009              | USA                       | RA         | Survey                        | 577,186            | Both  | White, black, Hispanic, Asian, other         | DM                            |
| Lindgren et al. [108]         | 1994                   | Sweden                    | ER         | Cross-sectional               | 393                | Both  | NR                                           | Stroke                        |
| Lokke et al. [62]             | 1998–2010              | Denmark                   | ER         | Case–control                  | 262,622            | Both  | NR                                           | COPD                          |
| Lokke et al. [61]             | 1998–2010              | Denmark                   | ER         | Case–control                  | 1,269,162          | Both  | NR                                           | COPD                          |
| Lopez-Bastida et al. [15]     | 2004                   | Canary Islands, Spain     | ER         | Cross-sectional               | 448                | Both  | NR                                           | Stroke                        |
| Mahmoudlou [39]               | 2008                   | Iran                      | EMR        | Cross-sectional               | 72,992,154         | Both  | NR                                           | Colon cancer                  |
| Maunsell et al. [32]          | 1999–2000              | Canada                    | RA         | Cross-sectional               | 57,307             | Female | (non)African American, (non) Hispanic        | Breast cancer                 |
| Mayfield et al. [109]         | 1987                   | USA                       | RA         | Survey                        | 35,000             | Both  | (non)African American, Hispanic              | DM                            |
| McBurney et al. [110]         | 1999–2000              | USA                       | RA         | Cross-sectional survey        | 89                 | Both  | Caucasian or minority/unknown               | CVD                           |
| Molina et al. [111]           | 2004–2005              | Spain                     | ER         | Cross-sectional               | 347                | Both  | NR                                           | Breast cancer, colorectal cancer, lung cancer |
| Molina Villaverde et al. [112]| NR                     | Spain                     | ER         | Cohort                        | 96                 | Both  | NR                                           | Breast Cancer                 |
| Moran et al. [5]              | 2000–2029              | China                     | WPR        | Ecological and modelling      | 1,270,000,000      | Both  | NR                                           | CVD                           |
| Nair et al. [113]             | 2000–2007              | USA                       | RA         | Economic evaluation           | 853,496            | Both  | NR                                           | COPD                          |
| Neau et al. [114]             | 1990–1994              | France                    | ER         | Retrospective                 | 67                 | Both  | NR                                           | Stroke                        |
| Niemi et al. [115]            | 1978–1980              | Finland                   | ER         | Retrospective case-series     | 46                 | Both  | NR                                           | Stroke                        |
| Nishimura and Zaher [58]      | 1990–2002              | Japan                     | WPR        | Modelling study               | 1,848,000          | Both  | NR                                           | COPD                          |
| Noeres et al. [28]            | 2002–2010              | Germany                   | ER         | Prospective cohort            | 874                | Female | NR                                           | Breast cancer                 |
| Nowak et al. [60]             | 2001                   | Germany                   | ER         | Cross-sectional               | 814                | Both  | NR                                           | COPD                          |
| O’Brien et al. [116]          | NR                     | USA                       | RA         | Cross-sectional               | 98                 | Both  | Caucasian and African American               | Stroke                        |
| Ohguri et al. [117]           | 2000–2005              | Japan                     | WPR        | Cross-sectional               | 43                 | Both  | NR                                           | Lung cancer, colon cancer     |
| Orbon et al. [56]             | 1998–2000              | The Netherlands           | ER         | Cross-sectional               | 2010               | Both  | NR                                           | COPD                          |
| Osler et al. [12]             | 2001–2009              | Denmark                   | ER         | Cohort                        | 21,926             | Both  | NR                                           | CVD                           |
| Park et al. [48]              | 2001–2006              | South Korea               | WPR        | Cross-sectional               | 2538               | Both  | NR                                           | Lung cancer, colon cancer, breast cancer, cervical cancer |
| Park et al. [118]             | 2001–2006              | South Korea               | WPR        | Prospective study             | 1602               | Both  | NR                                           | Lung cancer, colon cancer, breast cancer, cervical cancer |
| Source                        | Period of surveillance | Location          | WHO region | Study design          | Number in analysis | Gender | Ethnicity                                      | Reported NCDs                                      |
|------------------------------|------------------------|-------------------|------------|-----------------------|--------------------|--------|-----------------------------------------------|---------------------------------------------------|
| Peters et al. [119]          | NR                     | Nigeria           | AR         | Cross-sectional       | 110                | Both   | NR                                            | Stroke                                            |
| Peuckmann et al. [120]       | 1989–1999              | Denmark           | ER         | Cross-sectional       | 1316               | Female | NR                                            | Breast cancer                                     |
| Quinn et al. [20]            | 1998–2008              | UK                | ER         | Prospective Cohort    | 214                | Both   | NR                                            | Stroke                                            |
| Robinson et al. [121]        | 1985–1989              | UK                | ER         | Cross-sectional       | 2104               | Both   | Caucasian, West-Indian, Asian                | DM                                                |
| Roelen et al. [122]          | 2001–2005              | The Netherlands   | ER         | Ecological            | 259                | Female | NR                                            | Breast cancer                                     |
| Roelen et al. [50]           | 2004–2006              | The Netherlands   | ER         | Retrospective cohort  | 300,024            | Both   | NR                                            | Lung cancer, breast cancer                        |
| Saeki and Toyonaga [123]     | 2006–2007              | Japan             | WPR        | Prospective cohort    | 325                | Both   | NR                                            | Stroke                                            |
| Sasser et al. [8]            | 1998–2000              | USA               | RA         | Economic evaluation   | 38,012             | Female | NR                                            | Breast cancer, CVD                                |
| Satariano et al. [27]        | 1984–1985              | USA               | RA         | Cross-sectional       | 1011               | Female | White, black                                  | Breast cancer                                     |
|                             | 1987–1988              |                   |            |                       |                    |        |                                               |                                                   |
| Short et al. [124]           | 1997–1999              | USA               | RA         | Cross-sectional       | 1433               | Both   | White, non-white, undetermined               | Breast cancer                                     |
| Short et al. [111]           | 2002                   | USA               | RA         | Cross-sectional       | 6635               | Both   | NR                                            | CVD, stroke, COPD, DM                              |
| Sin et al. [125]             | 1988–1994              | USA               | RA         | Cross-sectional       | 12,436             | Both   | White, Black, other                           | COPD                                              |
| Sjovall et al. [36]          | 2004–2005              | Sweden            | ER         | Ecological study      | 14,984             | Both   | NR                                            | Breast cancer, colon cancer, lung cancer          |
| Spelten et al. [126]         | NR                     | The Netherlands   | ER         | Prospective cohort    | 235                | Female | NR                                            | Breast cancer                                     |
| Stewart et al. [127]         | NR                     | Canada            | RA         | Cross-sectional       | 378                | Female | NR                                            | Breast cancer                                     |
| Strassels et al. [128]       | 1987–1988              | USA               | RA         | Cross-sectional       | 238                | Both   | African American, White, other               | COPD                                              |
| Syse et al. [51]             | 1953–2001              | Norway            | ER         | Cross-sectional       | 1,116,300          | Both   | NR                                            | Breast cancer, lung cancer, colorectal cancer     |
| Taskila-Brandt et al. [24]   | 1987–1988              | Finland           | ER         | Cross-sectional       | 5098               | Both   | NR                                            | Cervical cancer, breast cancer, colon cancer lung cancer |
|                             | 1992–1993              |                   |            | population based      |                    |        |                                               |                                                   |
| Taskila et al. [129]         | 1997–2001              | Finland           | ER         | Cross-sectional       | 394                | Female | NR                                            | Breast cancer                                     |
| Teassell et al. [130]        | 1986–1996              | Canada            | RA         | Retrospective cohort  | 563                | Both   | NR                                            | Stroke                                            |
| Tevaarwerk et al. [43]       | 2006–2008              | USA and Peru      | RA         | Cross-sectional       | 530                | Both   | Non-Hispanic whites and whites               | Breast cancer, lung cancer, colon cancer          |
| Timperi et al. [131]         | 2006–2011              | USA               | RA         | Prospective cohort    | 2013               | Female | Whites, Blacks, Hispanic, Asian, other       | Breast cancer                                     |
| Torp et al. [25]             | 1999–2004              | Norway            | ER         | Prospective Registry  | 9646               | Both   | NR                                            | Cervical cancer, breast cancer, colon cancer lung cancer |
| Source                              | Period of surveillance | Location          | WHO region   | Study design                  | Number in analysis | Gender  | Ethnicity                             | Reported NCDs                                      |
|------------------------------------|------------------------|-------------------|--------------|-------------------------------|--------------------|---------|---------------------------------------|---------------------------------------------------|
| Traebert et al. [21]               | 2008                   | Brazil            | RA           | Modelling, ecological         | NR                 | Both    | NR                                    | Cervical cancer, breast cancer, colon cancer, lung cancer |
| van Boven et al. [57]              | 2009                   | The Netherlands   | ER           | Economic evaluation           | 45,137             | Both    | NR                                    | COPD                                              |
| Van der Wouden et al. [132]        | 1978–1980              | The Netherlands   | ER           | Cross-sectional              | 313                | Female  | NR                                    | Breast cancer                                     |
| Vestling et al. [133]              | NR                     | Sweden            | ER           | Retrospective study           | 120                | Both    | NR                                    | Stroke                                            |
| Wang et al. [134]                  | NR                     | USA               | RA           | Cross-sectional              | 199                | Both    | NR                                    | CVD, COPD, diabetes                                |
| Ward et al. [135]                  | 1993–1994              | USA               | RA           | Cross-sectional              | 2529               | Both    | Mixed ethnicities                     | COPD                                              |
| Wozniak et al. [136]               | NR                     | USA               | RA           | Retrospective study           | 203                | Both    | Whites, blacks and other              | Stroke                                            |
| Yaldo et al. [41]                  | 2006–2009              | USA               | RA           | Case–control                 | 330                | Both    | NR                                    | Colon Cancer                                      |
| Yabroff et al. [137]               | 2000                   | USA               | RA           | Cross-sectional              | 496                | Both    | Hispanic, non-Hispanic white, non-    | Breast cancer, colon cancer                        |
|                                    |                        |                   |              |                               |                    |         | Hispanic black, other                 |                                                   |
|                                    |                        |                   |              |                               |                    |         |                                        |                                                   |
| Zhao and Winget [7]                | 2003–2006              | USA               | RA           | Retrospective cohort          | 10,487             | Both    | NR                                    | CVD (CHD)                                         |
| Zheng et al. [9]                   | 2004                   | Australia         | WPR          | Economic evaluation           | NR                 | Both    | NR                                    | CVD (CHD)                                         |

AR African Region, COPD chronic obstructive pulmonary disease, CKD chronic kidney disease, CVD cardiovascular disease, DM diabetes mellitus, EMR Eastern Mediterranean Region, ER European Region, NCD no-communicable diseases, NR not reported, RA Region of the Americas, USA United States of America, WHO World Health Organization, WPR Western Pacific Region
WHO European Region, 53 from the Region of the Americas (of which all but two were from Canada or the United States of America [USA]), 16 from the Western Pacific Region, four were from the WHO African Region and one from the Eastern Mediterranean Region. We found no studies from South East Asia. The majority of the identified studies were observational in design, analyzed prospectively as well as cross-sectional. Two studies reported cross-sectional data from an RCT and six were modeling studies. National or hospital-based disease registries were often used to select patients, which were in some cases linked to national socio-economic databases to extract corresponding employment data. The control group, if used, was often a sample from the general population and sometimes sought within the same environment of the patients (e.g. same company). Many studies focused on the impact of more than one NCD on productivity. Most studies used one measure of productivity. Of all the published studies including cancers, cervical cancer was included in seven studies, breast cancer in 45, colon cancer in 24 and lung cancer in 16. Stroke was included in a total of 31 studies, COPD in 24, DM in 22 and CHD was included in 15 studies. Relevant data on CKD was included in only two of the studies and two of the studies mention NCDs in general.

Measures of productivity

Measures of productivity impact in the available studies included DALYs, absenteeism, presenteeism, labor market (non-) participation, RTW, change in hours worked and medical/sickness leave. Most studies focused on the direct impact on the patient but a minority also examined the impact on caregivers/spouses. Outcomes were quantified using risks, proportions, odds, dollars, years and days. In some studies, time-to-event data was analyzed using Cox proportional-hazards regression. Adjusting for education, age and employment status was most frequently applied, although the measurement of education and employment was not consistently defined, measured or validated. A small minority of studies reported differences in impact according to ethnicity. Pooling of outcomes was not possible due to substantial heterogeneity across and within NCD groups ($I^2 > 70\%$).

Impact of cardiovascular disease on productivity

Of all DALYs on a population level in Spain (Table 2a), 4.2 % were attributable to CHD [4] with an estimated age-standardized rate of 4.7 per 1000 persons per year. In China, DALYs attributable to CHD were estimated to be 8,042,000 for the year 2000 and predicted to more than double in 2030, rising up to 16,356,000 [5]. In the same study, the estimated DALY in 2000 was 16.1 per 1000 persons and predicted to be 20.4 in 2030 (estimate not accounted for age). A study from Kenya estimated the DALY to be 68 per 100,000 person-years of observation [6]. CHD-related productivity loss in the USA was estimated to be 8539 USD per person per year (PP/PY), at 10175 USD PP/PY [7] for absenteeism and 2698 USD PP/PY for indirect work-related loss [8]. Total absenteeism-related costs in Australia were estimated at 5.69 billion USD, mortality-related costs at 23 million USD and costs related to lower employment at 7.5 billion USD [9]. An estimated 4.7 working days PP/PY were lost in the USA owing to CHD [10]. Also in the USA, the odds of experiencing limited amount of paid work due to illness were significantly higher for those with CHD compared to the control group, with an odds ratio (OR) of 2.91 for women (95 % CI 2.34–3.61) and 2.34 for men (95 % CI 1.84–2.98) [11]. In Denmark workforce participation increased with increasing time from 37 % after 30 days to 65 % after 5 years of diagnosis [12]. In a study conducted in 10 European Union (EU) countries, no difference was found for the risk of non-participation in the labor force between those with and without self-reported CHD with an OR of 0.96 (95 % CI 0.66–1.40).

Impact of stroke on productivity

Stroke accounted for 3.5 % of all DALYs reported in Spain (Table 2b) with a rate of 3.8 per 1000 people [4]. Another study from Spain reports a total count of DALYs of 418,052 with a higher number of male than for female (220,005 vs. 198,046) [13]. A study from Kenya reports a rate of 166 DALYs per 100,000 person-years observed [6]. In Western Australia, the average annual stroke-attributable DALY count is an estimated 26,315 for men and 30,918 for women [14]. In Spain, costs after diagnosis increased over time for caregivers but declined for patients (14,732 USD in caregivers compared to 2696 USD among patients after 1 year and 15,621 USD to 1362 USD after 2 years) [15]. Modeled productivity losses in South Korea were higher for a severe stroke among men (537,724 USD) than women (171,157 USD) [16]. A prospective surveillance study from Tanzania report a mean costs of productivity loss to be 213 USD [17]. Inconclusive evidence of the impact of stroke on RTW was reported. Estimates ranged from 26.7 to 75 % in studies reporting RTW in stroke patients after 1 year of the event [18, 19]. In Nigeria, 55 % returned to work at a mean of 19.5 months after stroke. A report from the United Kingdom (UK) found that 47 % were unemployed 1 year after stroke [20]. Increased odds to report limited ability for paid work were found among men (3.86) and women (2.26) after stroke [11].
Table 2 Results of the included studies investigating the impact of CVD on productivity

| Study                        | Type of outcome      | Outcome specified as                                      | Assessment type | Point estimate | SD for mean   | 95% CI        | Quality score |
|------------------------------|----------------------|-----------------------------------------------------------|-----------------|----------------|---------------|---------------|---------------|
| Alavinia and Burdorf [69]    | Unemployment         | Non-participation in the labor force                     | OR              | NR             | 0.66–1.40     |               | 4             |
| Anesetti-Rothermel and Sambamoorthi [10] | Sick leave         | Work days in last year lost due to illness                | Mean            | 4.700          | 7.89 (SE)     | NR            | 6             |
| Etyang et al. [6]            | DALYs                | Rate per 100,000 person year of observation               | Rate            | 68             | NR            | NR            | 5             |
| Genova-Maleras et al. [4]    | DALYs                | Rate per 1000 age standardised                            | Rate            | 4.7            | NR            | NR            | NA            |
|                               | Percentage of all causes of mortality                     | Percent         | 4.2            | NR             | NR            |               |               |
| Holden et al. [52]           | Productivity Loss   | Absenteeism (no. days or part days missed from work in last 4 weeks) | IRR             | 1.17           | NR            | 1.03–1.32     | 3             |
|                              |                      | Presenteeism (self-rated score of overall performance over last 4 weeks) | IRR             | 1.65           | NR            | 1.22–2.21     |               |
| Klarenbach et al. [64]       | Unemployment         | Non-participation in labor force                         | OR              | 1.27           | NR            | 0.45–3.53     | 6             |
| Kruse et al. [104]           | Labor market participation | Labor market withdrawal a year after the disease debut (controls 7 %) | Percent         | 21             | NR            | NR            | 6             |
|                              |                      | Risk of labor market withdrawal                          | HR              | 1.32           | NR            | 1.11–1.57     |               |
| McBumey et al. [110]         | Return to work       | Return to work at a mean of 7.5 months                    | Percent         | 76.4           | NR            | NR            | 4             |
|                              | Presenteeism         | Perceived work performance                               | Mean            | 3.6            | NR            | 0.52          |               |
| Moran et al. [5]             | DALYs                | Observed period 2000                                     | Count           | 80,420,00      | NR            | NR            | NA            |
|                              |                      | Observed period 2000                                     | Rate            | 16.1           | NR            | NR            |               |
|                              |                      | Predicted 2010                                            | Count           | 107,300,00     | NR            | NR            |               |
|                              |                      | Predicted 2010                                            | Rate            | 16.5           | NR            | NR            |               |
|                              |                      | Predicted 2020                                            | Count           | 134,220,00     | NR            | NR            |               |
|                              |                      | Predicted 2020                                            | Rate            | 18.2           | NR            | NR            |               |
|                              |                      | Predicted 2030                                            | Count           | 16356000       | NR            | NR            |               |
|                              |                      | Predicted 2030                                            | Rate            | 20.4           | NR            | NR            |               |
| Osler et al. [12]            | Labor market participation | Workforce participation 30 days after diagnosis (among patients who were part of the workforce at time of diagnosis) | Percent         | 37.2           | NR            | NR            | 5             |
|                              |                      | Workforce participation 1 year after diagnosis (among patients who were part of the workforce at time of diagnosis) | Percent         | 40.1           | NR            | NR            |               |
|                              |                      | Workforce participation 2 years after diagnosis (among patients who were part of the workforce at time of diagnosis) | Percent         | 45.0           | NR            | NR            |               |
|                              |                      | Workforce participation 5 years after diagnosis (among patients who were part of the workforce at time of diagnosis) | Percent         | 65.2           | NR            | NR            |               |
| Study                        | Type of outcome       | Outcome specified as                                                                 | Assessment type | Point estimate | SD for mean | 95 % CI | Quality score |
|------------------------------|-----------------------|-------------------------------------------------------------------------------------|-----------------|---------------|------------|---------|---------------|
| Sasser et al. [8]            | Productivity loss costs | Attributable annual indirect work-loss costs per patient                            | USD             | 2698          | NR         | NR      | 8             |
| Short et al. [124]           | Unemployment          | Limited amount of paid work possible due to illness female                           | OR              | 2.91          | NR         | 2.34–3.61| 5             |
|                              |                       | Limited amount of paid work possible due to illness male                            | OR              | 2.34          | NR         | 1.84–2.98|               |
| Wang et al. [134]            | Absenteeism           | Annual excess in days                                                               | Mean            | 8.8           | 7.0 (SE)  | NR      | 4             |
|                              | Presenteeism          | Annual excess in days                                                               | Mean            | 8.9           | 11.8 (SE) | NR      |               |
| Zhao and Winget [7]          | Productivity loss costs | Short term 1 year productivity costs/per person                                      | USD             | 8539          | NR         | NR      | 6             |
| Zheng et al. [9]             | Productivity loss costs | Absenteeism related total                                                           | USD             | 568,500,000   | NR         | NR      | NA            |
|                              | Mortality related     | Mortality related                                                                   | USD             | 235,650,00    | NR         | NR      |               |
|                              | Due to lower employment|                                                                                   | USD             | 750,000,000   | NR         | NR      |               |
| b                            | Alavinia and Burdorf  | Non participation in the labour force                                               | OR              | 1.110         | NR         | 0.530–2.320| 4             |
| Anesetti-Rothermel and Sambamoorthi [10] | Non participation in the labour force |                                                                                   | OR              | 1.110         | NR         | 0.530–2.320| 4             |
| Angeleri et al. [80]         | Return to work        | Return to work 12–196 months (mean 37.5) in hemiplegic patients                    | Percent         | 20.64         | NR         | NR      | 6             |
| Black-Schaffer and Osberg [82] | Return to work        | Return to work at 6–25 months post-rehabilitation                                   | Percent         | 49            | NR         | NR      | 3             |
| Bogousslavsky and Regli [83] | Return to work        | Return to work 6–96 months (mean 46)                                               | Percent         | 43            | NR         | NR      | 3             |
| Catalá-López et al. [13]    | DALYs                 | Total                                                                               | Count           | 418,052       | NR         | NR      | 4             |
|                              |                       | Male                                                                                | Count           | 220,005       | NR         | NR      |               |
|                              |                       | Female                                                                              | Count           | 198,046       | NR         | NR      |               |
| Etyang et al. [6]            | DALYs                 | Rate per 100,000 person year of observation                                         | Rate            | 166           | NR         | NR      | 5             |
| Ferro and Crespo [96]        | Unemployment          | Inactive at end of follow-up (mean 33.4 months, range 1–228 months)               | Percent         | 27            | NR         | NR      | 4             |
### Table 2 continued

| Study                      | Type of outcome | Outcome specified as                                                                 | Assessment type | Point estimate | SD for mean | 95 % CI | Quality score |
|----------------------------|-----------------|---------------------------------------------------------------------------------------|-----------------|---------------|------------|---------|---------------|
| Gabriele and Renate [18]   | Return to Work  | Return to work after 1 year of those employed                                          | Percent         | 26.7          | NR         | NR      | 4             |
| Genova-Maleras et al. [4]  | DALYs           | Rate per 1000 age standardised                                                        | Rate            | 3.8           | NR         | NR      | NA            |
|                            |                  | Percentage of all causes of mortality                                                  | Percent         | 3.5           | NR         | NR      |               |
| Hackett et al. [19]        | Return to Work  | Return to work 1 year after event                                                      | Percent         | 75            | NR         | NR      | 2             |
| Kabadi et al. [17]         | Return to Work  | Average months off work in 6 month follow up period                                    | Mean            | 6             | NR         | NR      | 4             |
| Kang et al. [16]           | Productivity loss costs | Male, total modelled costs per severe stroke per year                               | USD             | 213           | NR         | NR      |               |
|                            |                 | Female, total modelled costs per severe stroke per year                               | USD             | 171,157       | NR         | NR      |               |
| Kappelle et al. [102]      | Unemployment    | Unemployment at 0.02–16 years after event (mean 6 years)                              | Percent         | 58            | NR         | NR      | 5             |
| Katzenellenbogen et al. [14]| DALYs           | Male                                                                                  | Count           | 26,315        | NR         | NR      | NA            |
|                            |                 | Female                                                                                | Count           | 30,918        | NR         | NR      |               |
|                            |                 | Male, rate per 10,000 people, age standardized—indigenous                             | Rate            | 2027          | NR         | 1909–2145 |               |
|                            |                 | Female, rate per 10,000 people, age standardized—indigenous                           | Rate            | 1598          | NR         | 1499–1697 |               |
|                            |                 | Male, rate per 10,000 people, age standardized—non-indigenous                         | Rate            | 640           | NR         | 633–648  |               |
|                            |                 | Female, Rate per 10,000 people, age standardized—non-indigenous                      | Rate            | 573           | NR         | 567–580  |               |
| Klarenbach et al. [64]     | Unemployment    | Non-participation in labour force                                                     | OR              | 2.21          | NR         | 0.7–7   | 6             |
| Kotila et al. [103]        | Return to Work  | Return to work after 12 months                                                        | Percent         | 59            | NR         | NR      | 4             |
| Leng [106]                 | Return to Work  | Return to work in 1 year                                                              | Percent         | 55.0          | NR         | NR      | NA            |
| Lindgren et al. [108]      | Productivity loss costs | Indirect costs during one ear                                                  | USD             | 17,844        | NR         | 12,275–23,864 | 4         |
| Lopez-Bastida et al. [15]  | Productivity loss costs | Indirect per person, 1 year after stroke                                           | USD             | 2696          | 6462       | NR      | 5             |
|                            |                 | Indirect per person, 2 year after stroke                                             | USD             | 1393          | 4754       | NR      |               |
|                            |                 | Indirect per person, 3 year after stroke                                             | USD             | 1362          | 4931       | NR      |               |
|                            |                 | Caregivers cost per person per year, 1 year after stroke                             | USD             | 14,732        | 14,616     | NR      |               |
|                            |                 | Caregivers cost per person per year, 2 year after stroke                             | USD             | 15,621        | 14,693     | NR      |               |
|                            |                 | Caregivers cost per person per year, 3 year after stroke                             | USD             | 13,759        | 15,470     | NR      |               |
| Study                  | Type of outcome | Outcome specified as                                      | Assessment type | Point estimate | SD for mean | 95 % CI     | Quality score |
|------------------------|-----------------|-----------------------------------------------------------|-----------------|----------------|-------------|-------------|---------------|
| Neau et al. [114]      | Return to work  | Return to work in same position as prior to stroke        | Percent         | 54             | NR          | NR          | 3             |
|                        |                 | Return to work after 0–40 month (mean 7.8)                | Percent         | 73             | NR          | NR          | 6             |
| Niemi et al. [115]     | Return to work  | Return to work after 4 years                              | Percent         | 54             | NR          | NR          | 1             |
| O’Brien et al. [116]   | Return to work  | Return after 6–18 months                                  | Percent         | 56.0           | NR          | NR          | 6             |
| Peters et al. [119]    | Return to work  | Return to work after 3–104 months (mean 19.5)             | Percent         | 55             | NR          | NR          | 3             |
| Quinn et al. [20]      | Return to Work  | unemployment at 1 year follow up                          | Percent         | 47             | NR          | NR          | 3             |
| Roelen et al. [122]    | Return to Work  | Return to work after 3–104 months (mean 19.5)             | Percent         | 55.0           | NR          | NR          | 6             |
| Saeki and Toyonaga     | Return to Work  | Return to work at 18 months                               | Percent         | 55.0           | NR          | NR          | 6             |
| Short et al. [124]     | Unemployment    | Limited amount of paid work possible due to illness female| OR              | 2.26           | NR          | 1.56–2.26   | 5             |
|                        |                 | Limited amount of paid work possible due to illness male  | OR              | 3.86           | NR          | 2.55–3.60   |               |
| Teasell et al. [130]   | Return to work  | Return to work at 3 months                                | Percent         | 20             | NR          | NR          | 3             |
|                        |                 | Return to work full-time at 3 months                      | Percent         | 6              | NR          | NR          |               |
| Vestling et al. [133]  | Return to work  | Return to work mean of 2.7 years                          | Percent         | 41             | NR          | NR          | 3             |
|                        |                 | Time to return to work in months                          | Mean            | 11.9           | 9           | NR          |               |
|                        |                 | Return to work with reduced work hours                    | Percent         | 21             | NR          | NR          |               |
| Wozniak et al. [136]   | Return to work  | Return to work after 1 year                               | Percent         | 53             | NR          | NR          | 6             |
|                        |                 | Return to work after 2 year                               | Percent         | 44             | NR          | NR          |               |
| Arrossi et al. [23]    | Return to work  | Reduced in hours worked (patients)                        | Percent         | 45             | NR          | NR          | 4             |
|                        |                 | Change of work (pat.)                                     | Percent         | 5              | NR          | NR          |               |
|                        |                 | Starting paid work (pat.)                                 | Percent         | 14             | NR          | NR          |               |
|                        |                 | Increased in hours worked (pat.)                          | Percent         | 11             | NR          | NR          |               |
|                        |                 | Odds of work interruption (pat.)                          | OR              | 4              | NR          | NR          |               |
|                        |                 | Odds of reduction in hours worked (pat.)                  | OR              | 1              | NR          | NR          |               |
|                        |                 | Odds of starting paid work (pat.)                         | OR              | 2              | NR          | NR          |               |
|                        |                 | Odds of increase in hours worked (pat.)                   | OR              | 1              | NR          | NR          |               |
|                        |                 | Work interruption (caregivers)                            | Percent         | 3              | NR          | NR          |               |
|                        |                 | Reduction in hours worked (caregivers)                    | Percent         | 61             | NR          | NR          |               |
|                        |                 | Change of work (caregivers)                               | Percent         | 2              | NR          | NR          |               |
|                        |                 | Starting paid work (caregivers)                           | Percent         | 5              | NR          | NR          |               |
|                        |                 | Increased in hours worked (caregivers)                    | Percent         | 24             | NR          | NR          |               |
|                        |                 | Work interruption (patients)                              | Percent         | 28             | NR          | NR          |               |
| Study                        | Type of outcome | Outcome specified as                                                                 | Assessment type | Point estimate | SD for mean | 95 % CI     | Quality score |
|-----------------------------|-----------------|---------------------------------------------------------------------------------------|-----------------|----------------|-------------|-------------|---------------|
| Costilla et al. [22]        | DALYs           | Female                                                                               | Count           | 1016           | NR          | NR          | NA            |
|                             |                 | Percentage of all cancers, female                                                     | Percent         | 1.6            | NR          | NR          |               |
|                             |                 | Rate per 10,000 people (age standardized)                                             | Rate            | 84             | NR          | NR          |               |
| Park et al. [48]            | Labour market participation | Time until job loss between patients and controls (age standardized) | HR              | 1.32           | NR          | 0.95–1.82   | 7             |
| Park et al. [118]           | Labour market participation | Time until re-employment between patients and controls (age standardized) | HR              | 0.67           | NR          | 0.46–0.97   | 5             |
| Taskila-Brandt et al. [24]  | Labour market participation | Employment status cancer survivors 2–3 years post-diagnosis compared to general population (58 vs. 75 %) | RR              | 0.77           | NR          | 0.67–0.90   | 6             |
| Traebert et al. [21]        | Labour market participation | Employment in 5 years from diagnosis                                                  | OR              | 0.92           | NR          | 0.63–1.34   | 9             |
| Traebert et al. [21]        | DALY             | Rate per 10,000 people (age standardized)                                             | Rate            | 118.7          | NR          | NR          | NA            |
| d                           | Labour market drop-out | Not working current for cancer survivors versus the general population (adjusted)    | OR              | 1.680          | 1.350       | 2.100       | 3             |
| Ahn et al. [31]             |                 | OR of not working for cancer survivors of currently not working compared with their employment status at the time of diagnosis | OR              | 1.630          | 1.510       | 1.760       |               |
|                            | Unemployment    | Unemployment Adjusted OR for not working at the time of diagnosis versus the general population | OR              | 1.210          | 0.960       | 1.530       |               |
| Balak et al. [34]           | Sick leave       | Months to fully return to work                                                        | Mean            | 11.4           | NR          | NR          | 3             |
|                            |                 | Months to return to partial work                                                       | Mean            | 9.5            | NR          | NR          |               |
| Bouknight et al. [37]       | Return to work   | Return to work in 12 months after diagnosis                                           | Percent         | 82             | NR          | NR          | 5             |
| Bradley and Bednarek [85]   | Unemployment     | Unemployed 5–7 years after diagnosis for cancer survivors                             | Percent         | 54.8           | NR          | NR          | 5             |
| Bradley et al. [86]         | Labor market participation | Probability of working of breast cancer patients compared to controls at mean of 7 years | Percent        | −7             | 4           | NR          | 8             |
| Bradley et al. [87]         | Labor market participation | Probability of working of breast cancer patients compared to controls at mean of 7.15 years | Percent        | −10            | 4           | NR          | 5             |
| Study | Type of outcome | Outcome specified as | Assessment type | Point estimate | SD for mean | 95 % CI | Quality score |
|-------|----------------|----------------------|----------------|----------------|------------|---------|--------------|
| Bradley et al. [89] | Employment | Probability of being employed for patients compared to controls at 6 months | Percent | −25 | NR | NR | 7 |
| | | Reduced weekly hours of work for patients compared to controls after 6 months | Percent | −18 | NR | NR | |
| Bradley et al. [40] | Absenteeism | Days absent from work evaluated at 6 months after diagnosis | Mean | 44.5 | 55.2 | NR | 7 |
| Bradley and Dahman [33] | Labor market participation | Probability of stopping work at 2 months post diagnosis (husbands of female patients) | OR | 2.642 | NR | 0.848–8.225 | 5 |
| | Labor market participation | Probability of stopping work at 9 months post diagnosis (husbands of female patients) | OR | 0.843 | NR | 0.342–2.198 | |
| | Productivity | Odds of decrease in weekly hours at 2 months post diagnosis (husbands of female patients) | OR | 1.449 | | 0.957–2.192 | |
| | Productivity | Odds of decrease in weekly hours at 9 months post diagnosis (husbands of female patients) | OR | 1.057 | | 0.69–1.62 | |
| | Productivity | Change in weekly hours at 2 months post diagnosis (husbands of female patients) (hours) | Count | −0.007 | | (0.885) SE | NR |
| | Productivity | Change in weekly hours at 9 months post diagnosis (husbands of female patients) (hours) | Count | 1.814 | | (1.261) SE | NR |
| Broekx et al. [90] | Productivity | Indirect costs work per patient per year (attributable) | USD | 5248 | NR | NR | 3 |
| | | Indirect costs housekeeping per patient per year (attributable) | USD | 2034 | NR | NR | |
| | | Indirect costs mortality per patient per year (attributable) | USD | 14,203 | NR | NR | |
| | | Sick leave days per year | USD | 47.2 | NR | NR | |
| | | Total indirect costs per patient per year (attributable) | USD | 21,485 | NR | NR | |
| Carlsen et al. [45] | Unemployment | % of working women 2 years after treatment | Percent | 72 | NR | NR | 5 |
| Costilla et al. [22] | DALYs | DALYs % of all cancers | Percent | 27.2 | NR | NR | NA |
| | | Rate per 10,000 people (age standardized) | Rate | 1065 | NR | NR | |
| | | DALYs | Count | 17,840 | NR | NR | |
| Eaker et al. [94] | Sick leave | Percentage difference of sickness absence comparing patients 5 years after diagnosis with women without breast cancer | Percent | 10.100 | NR | NR | 7 |
| | | Percentage difference of sickness absence comparing patients 3 years after diagnosis with women without breast cancer | Percent | 11.100 | NR | NR | |
| Study                           | Type of outcome | Outcome specified as                                                                 | Assessment type | Point estimate | SD for mean | 95% CI | Quality score |
|--------------------------------|----------------|---------------------------------------------------------------------------------------|-----------------|----------------|-------------|--------|--------------|
| Ekwueme et al. [26]            | Productivity loss | Mortality-related total lifetime productivity loss (whites)                           | USD             | 3,920,400,000  | NR          | NR     | 4            |
|                                |                | Mortality-related total lifetime productivity loss (blacks)                           | USD             | 1,323,000,000  | NR          | NR     |              |
|                                |                | Mortality-related total lifetime productivity loss per death (all)                    | USD             | 1,100,000      | NR          | NR     |              |
|                                |                | Mortality-related total lifetime productivity loss per death (whites)                 | USD             | 1,090,000      | NR          | NR     |              |
|                                |                | Mortality-related total lifetime productivity loss per death (blacks)                 | USD             | 1,110,000      | NR          | NR     |              |
| Fantoni et al. [38]            | Return to work | Return to work 12 months after starting treatment                                      | Percent         | 54.3           | NR          | NR     | 5            |
|                                |                | Return to work after 3 years after starting treatment                                 | Percent         | 82.1           | NR          | NR     |              |
|                                |                | Duration of sick leave 36 months after starting treatment in months                   | Mean            | 1.8            | NR          | 9.2–12.1|              |
| Fernandez de Larrea-Baz N et al. [95] | DALYs | Rate per 10,000 people, age standardized, male                                         | Rate            | 2              | NR          | NR     | 4            |
|                                |                | Rate per 10,000 people, age standardized, total                                      | Count           | 77,382         | NR          | NR     |              |
| Genova-Maleras et al. [4]      | DALYs          | Rate per 1,000 people, age standardized                                               | Rate            | 1.6            | NR          | NR     | NA           |
|                                |                | Percentage of all causes of mortality                                                | Percent         | 1.4            | NR          | NR     |              |
| Hansen et al. [99]             | Presenteeism   | Average score difference on work limitation scale between cases and non-cancer controls | Mean            | 2.9            | NR          | NR     | 5            |
| Hauglann et al. [30]           | Unemployment   | Unemployment at 9 years in females                                                    | Percent         | 18             | NR          | NR     | 9            |
| Hoyer et al. [101]             | Unemployment   | Unemployment at follow up                                                            | Percent         | 26             | NR          | NR     | 4            |
| Lauzier et al. [35]            | Sick leave     | Percent taking sick leave for 1 week or more                                         | Percent         | 90.7           | NR          | NR     | 6            |
|                                |                | Weeks of absence due to breast cancer                                                | Count           | 32.3           | NR          | NR     |              |
| Maunsell et al. [32]           | Unemployment   | Unemployment among disease free survivors                                            | Risk ratio      | 1.35           | NR          | 1.08–1.7| 7            |
|                                | Unemployment   | Unemployment among survivors with new breast cancer event                             | Risk ratio      | 2.24           | NR          | 1.57–3.18|              |
|                                | Unemployment   | Unemployment among all survivors (3 years after diagnosis)                           | Risk ratio      | 1.46           | NR          | 1.18–1.81|              |
|                                | Productivity loss | Survivors reporting part-time working compared to controls (3 years after diagnosis) | Percent         | 4              | NR          | NR     |              |
|                                | Productivity loss | Change in working hours among survivors—change over time compared to controls (3 years after diagnosis) | Mean            | −2.6           | NR          | NR     |              |
| Study                        | Type of outcome | Outcome specified as                                                                 | Assessment type | Point estimate | SD for mean | 95 % CI          | Quality score |
|------------------------------|-----------------|--------------------------------------------------------------------------------------|-----------------|----------------|-------------|-----------------|---------------|
| Molina et al. [111]          | Return to work   | Return to work at mean time since diagnosis (32.5 months)                           | Percent         | 56             | NR          | NR              | 5             |
| Molina Villaverde et al. [112]| Return to work   | Return to work by end of treatment                                                  | Percent         | 56             | NR          | NR              | NA            |
| Noeres et al. [28]           | Unemployment     | 6 years after diagnosis                                                              | Percent         | 43.2           | NR          | NR              | 5             |
|                              |                 | 1 year after diagnosis                                                               | Percent         | 49.8           | NR          | NR              |               |
| Park et al. [48]             | Labour market participation | Time until job loss (months)                                                      | Mean            | 36             | NR          | NR              | 7             |
|                              |                 | Time until 25% of patients were re-employment (months)                               | Mean            | 30             | NR          | NR              |               |
| Park et al. [118]            | Labour market participation | Cox proportional analysis comparing time until job loss between patients and controls | HR              | 1.83           | NR          | 1.60–2.10       | 5             |
|                              |                 | Cox proportional analysis comparing time until re-employment between patients and controls | HR              | 0.61           | NR          | 0.46–0.82       |               |
| Peuckmann et al. [120]       | Labor market participation | Age-standardized prevalence of employment at 5–15 years post primary surgery          | Percent         | 49             | NR          | NR              | 4             |
|                              |                 | Age-standardized risk ratio (SRR) of employment at 5–15 years post primary surgery  | SRR             | 1.02           | NR          | 0.95–1.10       |               |
|                              |                 | Age-standardized prevalence of sick leave at 5–15 years post primary surgery          | Percent         | 12             | NR          | NR              |               |
|                              |                 | Age-standardized risk ratio (SRR) of sick leave at 5–15 years post primary surgery  | SRR             | 1.28           | NR          | 0.88–1.85       |               |
| Roelen et al. [50]           | Return to work   | Time to return to full-time work (days)                                              | Count           | 349.0          | NR          | 329–369         | 6             |
| Roelen et al. [112]          | Return to work   | Time to return to part-time work (days)                                              | Count           | 271.0          | NR          | 246–296         |               |
| Roelen et al. [112]          | Return to work   | Return to work at 2 years                                                             | Percent         | 89.4           | NR          | NR              | 4             |
|                              | Sick leave       | Days of absence due to breast cancer                                                 | Count           | 349            | NR          | NR              |               |
| Sasser et al. [8]            | Productivity loss costs | Attributable annual indirect work-loss costs per female patient                   | USD             | 5944.0         | NR          | NR              | 8             |
| Satiriano et al. [27]        | Return to work   | 3 months after diagnosis (white women)                                               | Percent         | 74.2           | NR          | NR              | 3             |
|                              | Return to work   | 3 months after diagnosis (black women)                                               | Percent         | 59.6           | NR          | NR              |               |
|                              | Sick leave       | 3 months after diagnosis (white women)                                               | Percent         | 25.8           | NR          | NR              |               |
|                              | Sick leave       | 3 months after diagnosis (black women)                                               | Percent         | 40.4           | NR          | NR              |               |
| Short et al. [124]           | Unemployment     | The chances of quitting work/unemployment 1–5 years after diagnosis                 | OR              | 0.44           | NR          | 0.20–0.95       | 5             |
| Sjowall et al. [36]          | Sick leave       | Days sick leave taken before return to work                                          | Count           | 90             | NR          | NR              | 5             |
Table 2 continued

| Study                          | Type of outcome | Outcome specified as                                                                 | Assessment type | Point estimate | SD for mean | 95 % CI       | Quality score |
|-------------------------------|-----------------|--------------------------------------------------------------------------------------|-----------------|----------------|-------------|---------------|---------------|
| Spelten et al. [126]          | Return to work  | Time to return to work after diagnosis analyzed using Cox PH                         | HR              | 0.45           | NR          | 0.24–0.86   | 4             |
| Stewart et al. [127]          | Unemployment    | Unemployment assessed at least at 2 years after diagnosis, mean of 9 years           | Percent         | 41             | NR          | NR           | 3             |
| Syse et al. [51]              | Labor market participation | Employment probability in the year 2001 of cancer survivors compared to general population | OR              | 0.74           | NR          | 0.65–0.84   | 6             |
| Taskila-Brandt et al. [24]    | Labor market participation | Employment status of cancer survivors 2–3 years post-diagnosis compared to general population (61 vs. 65 %) | RR              | 0.95           | NR          | 0.92–0.98   | 6             |
| Taskila et al. [129]          | Work ability    | Current work ability assessed between 0 and 10 by questionnaire (reference group 8.37) | Mean            | 8.23           | NR          | NR           | 8             |
| Tevaarwerk et al. [43]        | Unemployment    | Unemployment                                                                         | Percent         | 19.4           | NR          | NR           | 6             |
| Timperi et al. [131]          | Unemployment    | 6 months post diagnosis                                                                | Percent         | 52.0           | NR          | NR           | 4             |
| Torp et al. [25]              | Labor market participation | Employment 5 years from diagnosis                                                    | OR              | 0.74           | NR          | 0.63–0.87   | 9             |
| Traebert et al. [21]          | DALYs           | Percentage of all cancers, female                                                      | Percent         | 21.9           | NR          | NR           | NA            |
|                               |                 | Rate per 10,000 people, age standardized, male                                         | Rate            | 3.2            | NR          | NR           |               |
|                               |                 | Percentage of all cancers, male                                                        | Percent         | 0.3            | NR          | NR           |               |
|                               |                 | Total                                                                                 | Count           | 6032.3         | NR          | NR           |               |
|                               |                 | Rate per 10,000 people, age standardized, female                                       | Rate            | 195            | NR          | NR           |               |
| Van der Wouden et al. [132]   | Labor market participation | Changes in employment status at least 5 years cancer free                              | Percent         | −7            | NR          | NR           | 3             |
|                               |                 | Maintained employment status after diagnosis                                          | Percent         | 16             | NR          | NR           |               |
| Yabroff et al. [137]          | Labor market participation | Job in past 12 months, compared to control group (45.9 % with a p value <0.001 for difference) | Percent         | 36.9           | NR          | 31.0–42.8   | 6             |
|                               |                 | Sick leave                                                                            | Mean            | 21.0           | NR          | 28.4–58.3   |               |
|                               |                 | Presenteeism                                                                           | Percent         | 22.5           | NR          | 17.4–27.6   |               |
| Bradley et al. [40]           | Productivity loss | Annual productivity losses total 2020 modelled (millions)                             | USD             | 21,780         | NR          | NR           | NA            |
|                               |                 | Annual productivity losses total 2005 (millions)                                       | USD             | 20,920         | NR          | NR           |               |
| Study                                      | Type of outcome | Outcome specified as                                                                 | Assessment type | Point estimate | SD for mean | 95 % CI | Quality score |
|-------------------------------------------|-----------------|--------------------------------------------------------------------------------------|-----------------|----------------|-------------|---------|--------------|
| Bradley and Bednarek [85]                 | Unemployment    | Unemployed 5–7 years after diagnosis cancer survivors                                | Percent         | 54.8           | NR          | NR      | 5            |
|                                           |                 | Unemployed 5–7 years after diagnosis spouse of cancer survivors                     | Percent         | 53             | NR          | NR      |              |
| Carlsen et al. [29]                      | Return to Work  | Return to work after 1 year after diagnosis                                          | Percent         | 69             | NR          | NR      | 8            |
| Choi et al. [42]                         | Unemployment    | Lost job at 24 months in males                                                       | Percent         | 46             | NR          | NR      | 7            |
| Costilla et al. [22]                     | DALYs           | % of all cancers (Female)                                                             | Percent         | 12.9           | NR          | NR      |              |
|                                           |                 | Rate per 10,000 people (age standardised, Female)                                    | Rate            | 333            | NR          | NR      |              |
|                                           |                 | Male                                                                                  | Count           | 8316           | NR          | NR      |              |
|                                           |                 | % of all cancers (Male)                                                                | Percent         | 13.5           | NR          | NR      |              |
|                                           |                 | Rate per 10,000 people (age standardised, Male)                                      | Rate            | 414            | NR          | NR      |              |
| Earle et al. [46]                        | Unemployment    | Unemployment at 15 months                                                            | Percent         | 65             | NR          | NR      | 4            |
| Fernandez de Larrea-Baz N et al. [95]    | DALYs           | Rate per 10,000 people, age standardized, female                                     | Rate            | 212            | NR          | NR      |              |
|                                           |                 | Rate per 10,000 people, age standardized, male                                      | Rate            | 284            | NR          | NR      |              |
|                                           |                 | Rate per 10,000 people, age standardized, total                                      | Count           | 99,833         | NR          | NR      |              |
| Genova-Maleras et al. [4]                | DALYs           | Percentage of all causes of mortality                                                | Percent         | 2.1            | NR          | NR      |              |
| Gordon et al. [47]                       | Return to work  | Working 1 year after diagnosis (%)                                                  | Percent         | 85             | NR          | NR      | 5            |
| Hauglann et al. [49]                     | Return to work  | % of employed that were on sick-leave at some point after 1 year of diagnosis        | Percent         | 65             | NR          | NR      | 9            |
|                                           |                 | Sickness absence for CRC localized, the OR is for 3 years after diagnosis            | Odds Ratio      | 2.61           | 1.36        | 4.95    |              |
|                                           |                 | Sickness absence for CRC regional, the OR is for 3 years after diagnosis             | Odds Ratio      | 1.09           | 0.56        | 2.11    |              |
|                                           |                 | Sickness absence for CRC distant, the OR is for 3 years after diagnosis              | Odds Ratio      | 2.30           | 0.57        | 0.927   |              |
| Mahmoudlou [39]                          | DALYs           | Total burden of colorectal cancer according to DALY in Iran in 2008                   | Count           | 52,534         | NR          | NR      | 8            |
|                                           |                 | DALYs for men in 2008                                                                 | Count           | 29,928         | NR          | NR      |              |
|                                           |                 | DALYs for women in 2008                                                               | Count           | 22,606         | NR          | NR      |              |
| Molina et al. [111]                      | Return to work  | Return to work at mean time since diagnosis(32.5 months)                              | Percent         | 55             | NR          | NR      | 5            |
| Ohguri et al. [117]                      | Sick leave      | Attendance rate after return to work of employees with disease compared to controls (p value 0.67) | Percent         | 86             | NR          | NR      | 4            |
| Study | Type of outcome | Outcome specified as | Assessment type | Point estimate | SD for mean | 95% CI | Quality score |
|-------|----------------|----------------------|-----------------|----------------|------------|--------|--------------|
| Park et al. [48] | Return to work | Time until re-employment (patients after job loss) Cox PH analysis | HR | 0.96 | NR | 0.7–1.32 | 7 |
| Park et al. [118] | Unemployment | Cox PH analysis time until job loss | HR | 1.04 | NR | 0.91–1.2 | 5 |
| Park et al. [118] | Labour market participation | Cox PH analysis comparing time until job loss between patients and controls | HR | 1.69 | NR | 1.50–1.90 | 5 |
| Park et al. [118] | Labour market participation | Cox PH analysis comparing time until re-employment between patients and controls | HR | 0.57 | NR | 0.43–0.75 | 5 |
| Sjovall et al. [36] | Sick leave | Days sick leave | Count | 115 | NR | NR | 5 |
| Syse et al. [51] | Employment | Employment probability in year 2001 of cancer survivors compared to general population–men Cox PH analysis | OR | 0.67 | NR | 0.58–0.78 | 6 |
| Syse et al. [51] | Employment | Employment probability in year 2001 of cancer survivors compared to general population–women Cox PH analysis | OR | 0.74 | NR | 0.65–0.84 | 6 |
| Taskila-Brandt et al. [24] | Labor market participation | Employment status of cancer survivors 2–3 years post-diagnosis compared to general population (53 vs. 59 %) | RR | 0.90 | NR | 0.81–0.99 | 6 |
| Tevaarwerk et al. [43] | Unemployment | Unemployment | Percent | 24.1 | NR | NR | 6 |
| Torp et al. [25] | Labour market participation | Employment in 5 years from diagnosis (females) OR | OR | 0.84 | NR | 0.53–1.35 | 9 |
| Torp et al. [25] | Labour market participation | Employment in 5 years from diagnosis (male) OR | OR | 0.7 | NR | 0.43–1.15 | 9 |
| Traebert et al. [21] | DALYs | Rate per 10,000 people, age standardized, female OR | Rate | 82.6 | NR | NR | NA |
| Traebert et al. [21] | DALYs | Percentage of all cancers, female | Percent | 9.3 | NR | NR | NA |
| Traebert et al. [21] | DALYs | Rate per 10,000 people, age standardized, male OR | Rate | 73.1 | NR | NR | NA |
| Traebert et al. [21] | DALYs | Percentage of all cancers, male | Percent | 7.5 | NR | NR | NA |
| Traebert et al. [21] | DALYs | Total | Count | 4867.2 | NR | NR | NA |
| Yabroff et al. [137] | Labor market participation | Job in past 12 months, compared to control group (45.9 % with a p value <0.001 for difference) Percent | Percent | 22.4 | NR | 15.6–29.3 | 6 |
| Yabroff et al. [137] | Sick leave | Days lost from wok due to health problems in past 12 months compared to control group (5.7 % with a p value <0.001 for difference) Mean | Mean | 10.0 | NR | 3.4–16.7 | 6 |
| Yabroff et al. [137] | Presenteeism | Limited in work due to health issues compared to control group (17.6 % with a p value of <0.001 for difference) Percent | Percent | 32.4 | NR | 24.2–40.6 | 6 |
| Yaldo et al. [41] | Absenteeism | Mean higher absenteeism costs after 1 year of diagnosis compared to controls USD | USD | 4245 | NR | NR | 7 |
Table 2 continued

| Study                              | Type of outcome | Outcome specified as                                                                 | Assessment type | Point estimate | SD for mean | 95 % CI     | Quality score |
|------------------------------------|-----------------|--------------------------------------------------------------------------------------|-----------------|----------------|-------------|-------------|---------------|
| Bradley and Bednarek [85]          | Unemployment    | Unemployed 5–7 years after diagnosis cancer survivor                                 | Percent         | 62.2           | NR          | NR          | 5             |
|                                    |                 | Unemployed 5–7 years after diagnosis spouse of cancer survivor                        |                 |                |             |             |               |
| Costilla et al. [22]               | DALYs           | Female                                                                                 | Count           | 9334           | NR          | NR          | NA            |
|                                    |                 | % of all cancers (female)                                                                | Percent         | 14.3           | NR          | NR          |               |
|                                    |                 | Rate per 10,000 people (age standardised, female)                                      | Rate            | 849            | NR          | NR          |               |
|                                    |                 | Male                                                                                   | Count           | 9806           | NR          | NR          |               |
|                                    |                 | % of all cancers (male)                                                                  | Percent         | 15.9           | NR          | NR          |               |
|                                    |                 | Rate per 10,000 people (age standardised, male)                                        | Rate            | 775            | NR          | NR          |               |
| Earle et al. [46]                  | Unemployment    | Unemployment at 15 months                                                               | Percent         | 79             | NR          | NR          | 4             |
| Fernandez de Larrea-Baz N et al. [95] | DALYs           | Rate per 10,000 people (age standardised, female)                                      | Rate            | 98             | NR          | NR          | 4             |
|                                    |                 | Rate per 10,000 people (age standardised, male)                                        | Rate            | 736            | NR          | NR          |               |
| Genova-Maleras et al. [4]          | DALYs           | Percentage of all causes of mortality                                                 | Percent         | 3.4            | NR          | NR          | NA            |
| Molina et al. [111]                | Return to work  | Return to work at mean time since diagnosis(32.5 months)                              | Percent         | 15             | NR          | NR          | 5             |
| Ohguri et al. [117]                | Sick leave      | Attendance rate after return to work of employees with disease compared to controls (p value 0.59) | Percent         | 75             | NR          | NR          | 4             |
| Park et al. [48]                   | Labour market participation | Time until job loss                                                                           | Cox PH         | 1.31          | NR          | 1.12–1.53  | 7             |
| Park et al. [118]                  | Labour market participation | Time until re-employment (patients after job loss)                                         | Cox PH         | 0.79          | NR          | 0.55–1.16  |               |
| Roelen et al. [122]                | Return to work  | Cox proportional analysis comparing time until job loss between patients and controls | HR              | 2.22          | NR          | 1.93–2.65  | 5             |
|                                    |                 | Cox proportional analysis comparing time until re-employment between patients and controls | HR              | 0.45          | NR          | 0.32–0.64  |               |
| Syse et al. [51]                   | Employment      | Employment probability in year 2001 of cancer survivors compared to general population--men | OR              | 0.37          | NR          | 0.31–0.45  | 6             |
|                                    |                 | Employment probability in year 2001 of cancer survivors compared to general population--women | OR              | 0.58          | NR          | 0.48–0.71  |               |
| Sjovall et al. [36]                | Sick leave      | Days                                                                                   | Count           | 275            | NR          | NR          | 5             |
| Study                        | Type of outcome       | Outcome specified as                                                                                                                                                                                                 | Assessment type | Point estimate | SD for mean | 95 % CI     | Quality score |
|------------------------------|-----------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|----------------|-------------|-------------|---------------|
| Taskila-Brandt et al. [24]   | Labor market participation | Employment status of cancer survivors 2–3 years post-diagnosis compared to general population (19 vs. 43 %)                                                                                                          | RR              | 0.45           | NR          | 0.34–0.59   | 6             |
| Tevaarwerk et al. [43]       | Unemployment          | Unemployment                                                                                                                                                                                                          | Percent         | 33             | NR          | NA          | 6             |
| Torp et al. [25]             | Unemployment          | Employment in 5 years from diagnosis (male)                                                                                                                                                                           | OR              | 0.39           | NR          | 0.18–0.83   | 9             |
|                             |                       | Employment in 5 years from diagnosis (female)                                                                                                                                                                             | OR              | 0.39           | NR          | 0.19–0.81   |               |
| Traebert et al. [21]         | DALYs                 | Rate per 10,000 people, age standardized, female                                                                                                                                                                        | Rate            | 87.6           | NR          | NR          | NA            |
|                             |                       | Percentage of all cancers, female                                                                                                                                                                                        | Percent         | 9.8            | NR          | NR          |               |
|                             |                       | Rate per 10,000 people, age standardized, male                                                                                                                                                                          | Rate            | 239.9          | NR          | NR          |               |
|                             |                       | Percentage of all cancers, male                                                                                                                                                                                          | Percent         | 24.5           | NR          | NR          |               |
|                             |                       | Total                                                                                                                                                                                                                 | Count           | 10,832.2       | NR          | NR          |               |
| Alexopoulos and Burdorf [54] | Sick leave            | Days of sick leave during 2 year follow up attributable to COPD                                                                                                                                                         | Mean            | 8.53           | NR          | NR          | 2             |
| Anesetti-Rothermel and Sambamoorthi [10] | Sick Leave           | Work days in last year lost due to illness                                                                                                                                                                              | Mean            | 8.600          | 0.76 (SE)   | NR          | 6             |
| Dacosta DiBonaventura et al. [53] | Productivity loss     | Percentage reporting absenteeism (difference between cases of COPD and controls)                                                                                                                                        | Percent         | 4.190          | NR          | NR          | 7             |
|                             |                       | Absenteeism hours (over last 7 days) (difference between COPD cases and controls)                                                                                                                                       | Mean            | 1.250          | NR          | NR          |               |
|                             |                       | Percentage reporting presenteeism (difference between cases of COPD and controls)                                                                                                                                       | Percent         | 16.550         | NR          | NR          |               |
|                             |                       | Estimated number of hours of presenteeism in last 7 days (difference between COPD cases and controls)                                                                                                                 | Mean            | 4.780          | NR          | NR          |               |
|                             |                       | Percentage of those reporting work impairment (difference between cases of COPD and controls)                                                                                                                             | Percent         | 17.280         | NR          | NR          |               |
|                             |                       | Percentage reporting absenteeism (difference between cases of COPD and controls)                                                                                                                                       | Percent         | 2.330          | NR          | NR          |               |
|                             |                       | Absenteeism hours (over last 7 days) (difference between cases of COPD and controls)                                                                                                                                     | Mean            | 0.330          | NR          | NR          |               |
|                             |                       | Percentage reporting presenteeism (difference between cases of COPD and controls)                                                                                                                                       | Percent         | 10.230         | NR          | NR          |               |
|                             |                       | Estimated number of hours of presenteeism in last 7 days (difference between cases of COPD and controls)                                                                                                                  | Mean            | 2.070          | NR          | NR          |               |
|                             |                       | Percentage of those reporting work impairment (difference between cases of COPD and controls)                                                                                                                             | Percent         | 11.530         | NR          | NR          |               |
| Study                        | Type of outcome | Outcome specified as                              | Assessment type | Point estimate | SD for mean | 95 % CI          | Quality score |
|------------------------------|-----------------|--------------------------------------------------|-----------------|----------------|-------------|-----------------|---------------|
| Darkow et al. [63]           | Productivity loss | Indirect per person per year                      | USD             | 9815           | NR          | 8384–11246      | 6             |
| Genova-Maleras et al. [4]    | DALYs           | Rate per 1000 age standardised                    | Rate            | 2.6            | NR          | NR              | 2             |
|                              |                 | Percentage of all causes of mortality            | Percent         | 2.3            | NR          | NR              |               |
| Halpern et al. [98]          | Productivity loss | Costs due to work loss up from 45 years up to    | USD             | 100.55         | NR          | NR              | 6             |
|                              |                 | age of retirement per patient per day             | Mean            | 18.7           | NR          | NR              |               |
|                              |                 | Days lost per patient of working age per year     | Mean            | 1.7            | NR          | NR              |               |
|                              |                 | Days lost per caregiver of working age per year   | Percent         | 34             | NR          | NR              |               |
| Holden et al. [52]           | Productivity loss | Absenteeism (no. of full/part days missed from  | IRR             | 1.57           | NR          | 1.33–1.86       | 3             |
|                              |                 | work in last 4 weeks)                             | IRR             | 1.22           | NR          | 1.04–1.43       |               |
|                              |                 | Presenteeism (self-rated score of overall         |                |                |             |                 |               |
|                              |                 | performance in last 4 weeks)                      |                |                |             |                 |               |
| Jansson et al. [59]          | Productivity loss | Indirect per person per year                      | USD             | 749            | NR          | NR              | 6             |
| Kremer et al. [55]           | Unemployment    | Percentage of who stopped work (among people     | Percent         | 39             | NR          | NR              | 5             |
|                              |                 | in work) because of the onset of COPD             |                |                |             |                 |               |
| Leigh et al. [105]           | Productivity loss | Total indirect costs in 1996 in billions of      | USD             | 21,400         | NR          | NR              | 3             |
| Lokke et al. [62]            | Unemployment    | % receiving income from employment                | Percent         | 16.7           | NR          | NR              | 7             |
|                              |                 | Indirect costs per patient before the diagnosis   | USD             | 4266           | NR          | NR              |               |
|                              |                 | indirect costs per patient after diagnosis        | USD             | 2816           | NR          | NR              |               |
| Lokke et al. [61]            | Productivity loss | Indirect costs per patient before the diagnosis   | USD             | 5912           | NR          | NR              | 9             |
|                              |                 | indirect costs per patient after diagnosis        | USD             | 3819           | NR          | NR              |               |
| Unemployment                 |                 | % of spouses receiving income from employment     | Percent         | 36.9           | NR          | NR              |               |
| Nair et al. [113]            | Productivity loss | Short term 1 year productivity costs/per person  | USD             | 527            | NR          | NR              | 9             |
|                              |                 | Absenteeism 1 year productivity costs/per person | USD             | 55             | NR          | NR              |               |
|                              |                 | Total costs                                       | USD             |                | NR          | NR              |               |
| Nishimura and Zaher [58]     | Productivity loss | Modelling total annual costs per year in        | USD             | 1471           | NR          | NR              | 2             |
|                              |                 | country (millions)                                | USD             | 262            | NR          | NR              |               |
|                              |                 | Days modelled per person                          | Count           | 8.1            | NR          | NR              |               |
| Study | Type of outcome | Outcome specified as | Assessment type | Point estimate | SD for mean | 95 % CI | Quality score |
|-------|----------------|---------------------|-----------------|----------------|-------------|---------|--------------|
| Nowak et al. [60] | Productivity loss | early retirement (per patient/year) (all COPD stages) | USD | 566 | NR | NR | 3 |
| | | early retirement (per patient/year) (light COPD) | USD | 489 | NR | NR |
| | | early retirement (per patient/year) (medium COPD) | USD | 567 | NR | NR |
| | | early retirement (per patient/year) (severe COPD) | USD | 1064 | NR | NR |
| | | disability (per patient/year) (all COPD stages) | USD | 398 | NR | NR |
| | | disability (per patient/year) (light COPD) | USD | 459 | NR | NR |
| | | disability (per patient/year) (medium COPD) | USD | 249 | NR | NR |
| | | disability (per patient/year) (severe COPD) | USD | 340 | NR | NR |
| Orbon et al. [56] | Unemployment | Unemployment | Percent | 53.8 | NR | NR | 4 |
| Sin et al. [125] | Employment | Adjusted probability of being in work force for those with self-reported COPD compared to those without self-reported COPD | Percent | −3.9 | NR | −1.3 to −6.4 | 4 |
| Short et al. [124] | Productivity loss | Total loss productivity cost in 1994 in billions | USD | 9.9 | NR | NR |
| | Unemployment | Limited amount of paid work possible due to illness (female) | OR | 2.63 | NR | 2.03–3.42 | 5 |
| | | Limited amount of paid work possible due to illness (male) | OR | 4.89 | NR | 3.46–6.9 |
| Strassels et al. [128] | Productivity loss | Number of lost work days COPD related | Mean | 1.0 | NR | <0.1–2.0 | 5 |
| | | Number of restricted activity days COPD related | Mean | 15.9 | NR | 10.3–21.5 |
| van Boven et al. [57] | Productivity loss | Costs total per patient a year (2009) | USD | 938 | NR | NR | 6 |
| | | Costs in total (2009) | USD | 88,340,000 | NR | NR |
| | Absenteeism | Days total per patient (2009) | Count | 10.7 | NR | NR |
| | | Days total (2009) | Count | 482,966 | NR | NR |
| Wang et al. [134] | Absenteeism | Annual excess in days | Mean | 19.4 | 8.9 (SE) | NR | 4 |
| | | Annual excess in Days | Mean | 27.5 | 15.6 (SE) | NR |
| | | Absenteeism & Presenteeism combined | Mean | 42.9 | 17.0 (SE) | NR |
| Ward et al. [135] | Unemployment | Inability to work attributable to COPD | Percent | 10.6 | NR | NR | 6 |
| | Productivity loss | Number work loss days per year | Mean | 1.4 | NR | NR |
| Study                  | Type of outcome | Outcome specified as                                                          | Assessment type | Point estimate | SD for mean | 95 % CI | Quality score |
|-----------------------|----------------|--------------------------------------------------------------------------------|-----------------|----------------|-------------|---------|---------------|
| h                     | Unemployment   | Unemployed in 2007 for patients with dialysis or after kidney transplant      | Percent         | 35             | NR          | NR      | 6             |
| Klarenbach et al. [64]| Unemployment   | Non-participation in labour force                                             | OR              | 7.94           | NR          | 1.6–39.43 | 6             |
| i                     | Absenteeism    | Absenteeism Days total                                                        | Count           | 11,664         | NR          | NR      | 9             |
|                       | Absenteeism    | Absenteeism Costs total                                                       | USD             | 85,314         | NR          | NR      |               |
|                       | Absenteeism    | Proportion of total productivity losses attributable to absenteeism            | Percent         | 4              | NR          | NR      |               |
|                       | Presenteeism   | Presenteeism days total                                                       | Count           | 7864           | NR          | NR      |               |
|                       | Presenteeism   | Presenteeism Costs total                                                       | USD             | 866,744        | NR          | NR      |               |
|                       | Presenteeism   | Proportion of total productivity losses attributable to presenteeism           | Percent         | 3              | NR          | NR      |               |
|                       | Productivity loss | Costs of premature mortality costs as a product of YLL and income | USD             | 953,373        | NR          | NR      |               |
|                       | Productivity loss | Proportion of total productivity losses attributable premature mortality | Percent         | 49             | NR          | NR      |               |
|                       | Productivity loss | Total productivity related loss                                                | Count           | 20,064         | NR          | NR      |               |
|                       | Productivity loss | Total productivity related costs loss                                          | USD             | 1,962,314      | NR          | NR      |               |
| Alavinia and Burdorf [69] | Unemployment | Non participation in the labor force                                          | OR              | 1.380          | NR          | 0.990–1.930 | 4             |
| Anesetti-Rothermel and Sambamoorthi [10] | Sick leave   | Work days in last year lost due to illness                                    | Mean            | 7.250          | 1.18 (SE)   | NR      | 6             |
| Bastida and Pagan [81] | Productivity loss | Unemployment due to diabetes in females                                       | Maximum likelihood | -0.073 | 0.198 | NR | NA |
|                       | Productivity loss | Unemployment due to diabetes in males                                         | Maximum likelihood | -1.047 | 0.447 | NR |               |
| Study              | Type of outcome | Outcome specified as                                      | Assessment type | Point estimate | SD for mean | 95 % CI     | Quality score |
|------------------|-----------------|----------------------------------------------------------|-----------------|----------------|-------------|-------------|--------------|
| Boles et al. [84] | Productivity loss | Lost earnings per diabetic person/week                  | USD             | 67             | NR          | NR          | 4            |
|                  | Absenteeism     | Absenteeism                                              | OR              | 2.285          | NR          | 1.167–4.474 |              |
|                  | Absenteeism     | Absenteeism                                              | Least squares regression coefficient | 3.254          | 7.286       | NR          |              |
| Presenteeism     | Presenteeism    | Presence of diabetes                                     | OR              | 1.271          | NR          | 0.724–2.230 |              |
|                  | Presenteeism    | Presenteeism                                              | Least squares regression coefficient | 4.308          | 4.369       | NR          |              |
| Bradshaw et al. [66] | DALYs          | Total                                                    | Count           | 162,877        | NR          | NR          | 3            |
|                  | Male            | Count                                                    | 102,454         | NR             | NR          | 1.14–1.73   | 5            |
|                  | Female          | Count                                                    | 101,690         | NR             | NR          | 0.95–1.42   |              |
| Burton et al. [91] | Presenteeism    | Time management (work the required no. of hours; start work on time) | OR              | 1.401          | NR          | 1.14–1.73   | 5            |
|                  | Physical work activities (e.g. repeat the same hand motions; use work equipment) | OR | 1.415 | NR | 1.15–1.75 |              |
|                  | Mental/interpersonal activities (concentration; teamwork) | OR | 1.233 | NR | 1.02–1.50 |              |
|                  | Overall output (complete required amount of work; worked to capability) | OR | 1.158 | NR | 0.95–1.42 |              |
| Collins et al. [92] | Productivity loss | Impairment score (WIS)                                    | Count           | 17.8           | NR          | 15.9, 19.6  | 7            |
|                  | Absent hours per patient/month | Count | 1.3 | NR | 0.6, 1.9 |              |
|                  | Work Impairment | Linear regression coefficient | 17.8 | NR | 15.9, 19.6 |              |
|                  | Absence         | Logistic regression coefficient | 1.2 (not significant) | NR | NR |              |
| Dall et al. [68]  | Productivity loss | Absenteeism                                              | USD             | 2470           | NR          | NR          | 1            |
|                  | Presenteeism    | USD                                                      | 18,715          | NR             | NR          |              |
|                  | Inability to work due to diabetes | USD | 7276 | NR | NR |              |
| Study                      | Type of outcome | Outcome specified as                                                                 | Assessment type | Point estimate | SD for mean | 95 % CI | Quality score |
|----------------------------|-----------------|--------------------------------------------------------------------------------------|-----------------|----------------|------------|---------|---------------|
| De Backer et al. [93]      | Sick leave      | Univariate analysis of high 1 year incidence rate of sick leave in diabetes compared to controls (25.3 %) in men (p value <0.001) | Percent         | 36.9           | NR         | NR      | 8             |
|                            |                 | Univariate analysis of long absences (defined as more than 7 days) in diabetes compared to controls (19.3 %) in men. (p value 0.002) | Percent         | 25.3           | NR         | NR      |               |
|                            |                 | Univariate analysis for repetitive absences in diabetes compared to controls (14.5 %) in men (p value <0.001) | Percent         | 21.2           | NR         | NR      |               |
|                            |                 | Adjusted analysis of high 1 year incidence rate of sick leave in diabetes compared to controls in men | OR              | 1.51           | NR         | 1.22–1.88 |               |
|                            |                 | Adjusted analysis of long absences in diabetes compared to controls in men             | OR              | 1.11           | NR         | 0.87–1.41 |               |
|                            |                 | Adjusted analysis for repetitive absences in diabetes compared to controls in men     | OR              | 1.54           | NR         | 1.20–1.98 |               |
|                            |                 | Univariate analysis of high 1 year incidence rate of sick leave in diabetes compared to controls (25.1 %) in women (p value <0.04) | Percent         | 33.9           | NR         | NR      |               |
|                            |                 | Univariate analysis of long absences (defined as more than 7 days) in diabetes compared to controls (25.2 %) in women. (p value 0.04) | Percent         | 33.9           | NR         | NR      |               |
|                            |                 | Univariate analysis for repetitive absences in diabetes compared to controls (24.0 %) in women (p value 0.002) | Percent         | 36.7           | NR         | NR      |               |
|                            |                 | Adjusted analysis of high 1 year incidence rate of sick leave in diabetes compared to controls in women | OR              | 1.38           | NR         | 0.89–2.14 |               |
|                            |                 | Adjusted analysis of long absences in diabetes compared to controls in women          | OR              | 1.45           | NR         | 0.94–2.23 |               |
|                            |                 | Adjusted analysis for repetitive absences in diabetes compared to controls in men     | OR              | 1.71           | NR         | 1.12–2.62 |               |
| Etyang et al. [6]          | DALYs           | Rate per 100,000 PY of observation                                                   | Rate            | 364            | NR         | NR      | 5             |
| Fu et al. [97]             | Productivity loss| Work loss days due to diabetes/year                                                  | Count           | 6.7            | NR         | NR      | 8             |
| Genova-Maleras et al. [4]  | DALYs           | Bed days due to diabetes/year                                                        | Count           | 13             | NR         | NR      |               |
|                            |                 | Rate per 1000 age standardised                                                       | Rate            | 2.2            | NR         | NR      | 2             |
|                            |                 | Percentage of all causes of mortality                                               | Percent         | 1.9            | NR         | NR      |               |
| Study                  | Type of outcome          | Outcome specified as                                      | Assessment type                        | Point estimate | SD for mean | 95 % CI | Quality score |
|-----------------------|--------------------------|----------------------------------------------------------|----------------------------------------|----------------|-------------|----------|---------------|
| Herquelot et al. [100]| Presenteeism             | Work disability due to diabetes                           | Incidence rate per 1000 person-years   | 7.9            | NR          | NR       | 7             |
|                       |                          | Work disability due to diabetes                           | HR                                     | 1.7            | NR          | 1.0–2.9  |               |
|                       |                          | Absenteeism, number of full/part days missed from work in last 4 weeks | IRR                                     | 1.17           | NR          | 1.09–1.26| 3             |
|                       |                          | Presenteeism, self-rated score of overall performance over last 4 weeks | IRR                                     | 0.89           | NR          | 0.83–0.96|               |
| Holden et al. [52]    | Productivity loss        | Absenteeism, number of full/part days missed from work in last 4 weeks | IRR                                     | 1.17           | NR          | 1.09–1.26| 3             |
| Lenneman et al. [107] | Productivity loss        | Productivity impairment                                    | Unstandardized linear regression coefficient | 1.816          | NR          |          |               |
| Klarenbach et al. [64]| Unemployment             | Non-participation in labour force                          | OR                                     | 2.17           | NR          | 1.2–3.93| 6             |
| Kessler et al. [70]   | Productivity loss        | Impairment days                                           | Count                                  | 3.6            | 0.8         | NR       | 2             |
|                       |                          | Any work impairment                                        | OR                                     | 1.1            | NR          | 0.6–1.9  |               |
|                       |                          | Impairment days                                           | Unstandardized linear regression coefficient | −0.3           | 0.5         | NR       |               |
| Lavigne et al. [67]   | Productivity loss        | Work while feeling unwell                                  | Percent                                | 0.54           | NR          | NR       | 4             |
|                       |                          | Variance explained work efficiency losses                 | Percent                                | 13             | NR          | NR       |               |
|                       |                          | Hours of work lost due to diabetes, per month per person   | Tobit regression coefficients          | −1             | NR          | −13.92 to −12.18 | |
|                       |                          | Hours of absence from work due to diabetes, per month per person | Tobit regression coefficients         | 1              | NR          | −1.09 to −3.45 | |
|                       |                          | Hours of total productivity time lost per month per person due to diabetes | Tobit regression coefficients         | 8              | NR          | 1.42–15.03 |               |
|                       |                          | Cost of productivity time lost due to diabetes             | Tobit regression coefficients          | 94             | NR          | −456.8 to −645.2 | |
| Study                  | Type of outcome | Outcome specified as                                      | Assessment type          | Point estimate | SD for mean | 95 % CI | Quality score |
|-----------------------|-----------------|----------------------------------------------------------|--------------------------|----------------|-------------|---------|---------------|
| Mayfield et al. [109] | Productivity    | Work disability due to diabetes                          | Probit model estimates   | 1.46           | 0.228       | NR      | 8             |
|                       |                 | Work disability due to diabetes                          | Percent                  | 25.6           | NR          | NR      |               |
|                       |                 | Work loss days due to diabetes                           | Linear regression        | 0.67           | 0.318       | NR      |               |
|                       |                 | Work loss days due to diabetes per year                  | Count                    | 5.65           | NR          | NR      |               |
|                       |                 | Lost earnings per diabetic person/year                   | USD                      | 3099           | NR          | NR      |               |
| Robinson et al. [121] | Unemployment    | Rate of unemployed in those economically active for males (controls 7.8 %) | Percent                  | 21.9           | NR          | NR      | 7             |
|                       |                 | Rate of unemployed in those economically active for females (controls 5.1 %) | Percent                  | 11.5           | NR          | NR      |               |
|                       |                 | Rate of unemployed in those economically active for females (controls 7.0 % with a \( p \) value of <0.001 for difference) | Percent                  | 18             | NR          | NR      |               |
| Short et al. [11]     | Unemployment    | Limited amount of paid work possible due to illness Female | OR                       | 1.54           | NR          | 1.23–1.92| 5             |
|                       |                 | Limited amount of paid work possible due to illness Male | OR                       | 2.02           | NR          | 1.57–2.6|               |
| Wang et al. [134]     | Absenteeism     | Annual excess in days                                     | Mean                     | 6.4            | 6.0 (SE)    | NR      | 4             |
|                       | Presenteeism    | Annual excess in days                                     | Mean                     | 7.3            | 10.3 (SE)   | NR      |               |
|                       | Absenteeism and | Annual excess in days                                     | Mean                     | 16.0           | 11.0 (SE)   | NR      |               |
|                       | Presenteeism combined |                                   |                          |                |             |         |               |
| Torp et al. [25]      | Unemployment    | Unemployment at follow up                                | Percent                  | 25.6           | NR          | NR      | 9             |
| Earle et al. [46]     | Unemployment    | Unemployment at 15 months                                 | Percent                  | 69             | NR          | NR      | 4             |

*Cox PH* Cox proportional hazard regression, *DALY's* disability adjusted life years, *IRR* incidence risk ratio, *NCD* no-communicable diseases, *NA* not applicable, *NR* not reported, *OR* odds ratio, *RR* relative risk, *SD* standard deviation, *USD* United States of America dollars
Impact of cervical cancer on productivity

There are strong regional differences in the percentage of DALYs attributable to cervical cancer (Table 2c) among women, from 1.6 % (absolute DALYs, 1061 per year) in New Zealand to 13.4 % (2516 per year) in Brazil [21, 22]. Cervical cancer patients in Argentina reported negative outcomes after 1 year; 45 % of patients reported reduced labor market participation, 28 % experienced work interruption and 5 % changed work [23]. Compared to the general population, the relative risk (RR) for cervical cancer survivors in labor force participation was 0.77 (95 % CI 0.67–0.90), 2–3 years after diagnosis in Finland [24]. In Norway however, no differences were found 5 years from diagnosis with an OR of 0.92 (0.63–1.34) [25].

Impact of breast cancer on productivity

Of all the DALYs attributable to cancers among women, 27.3 % (17,840 per year) in New Zealand (Table 2d) and 13.4 % (6280 per year) in Brazil are attributable to breast cancer [21, 22]. Total mortality-related lifetime productivity loss costs in the USA were estimated to be 5.5 billion USD [26]. This was differentially distributed between the two ethnic groups reported, with 71 % (or 3.9 billion USD) of the costs attributable to white women and 24 % (or 1.3 billion) attributable to black women. Differential RTW and sick absence rates are also observed comparing black and white women in the USA; the percentage of white women returning to work three months after diagnosis was 74.2 % compared to 59.6 % of black women; the proportion reporting sick leave was 25.8 % of white women compared to 40.4 % of black women [27]. 1 year after primary surgery in Germany, nearly three times as many cancer survivors had left their job as compared to women in the control group. [28] Various studies suggest higher unemployment among breast cancer survivors, reported by around half after 1 year, 72 % after 2 years [29], 43 % after 6 years and 18 % after 9 years [27, 28, 30–32]. In contrast, in a study assessing unemployment among the spouses of breast cancer patients, no differences were found [33]. Differences between countries in average time to RTW were also found, from 11.4 months in the Netherlands [34] and 7.4 months in Canada [35] to only 3 months in Sweden [36]. Percentage of RTW after 1 year ranged from 54.3 % in a cross-sectional study from France to 82 % in a prospective study from the USA [37, 38].

Impact of cancer on productivity

In New Zealand, of all the DALYs attributable to cancers, 12.9 % (8431 per year) among women and 13.5 % (8316 per year) among men are attributable to colon cancer (Table 2e) [22]. In Brazil, these proportions are 9.3 % among women and 7.5 % among men [21]. In Spain, 2.1 % of DALY’s overall are attributable to colon cancer [4]. In Iran the total burden of colorectal cancer in 2008 was 52,534 DALYs and higher for men than for women [39]. In the USA, annual productivity losses were calculated to be 20.9 billion USD [40], while costs due to absenteeism after 1 year of diagnosis was 4245 USD per patient compared to the general population [41]. Although the DALY and dollar costs of colon cancer are undoubtedly large, the evidence for micro-level labor market indicators including risk and proportions of RTW, sickness absence and employment following diagnosis and treatment is however inconclusive [25, 42–49]. In New Zealand, of all cancer-attributable DALYs, 14.4 % (9334 per year) among women and 15.9 % (9806 per year) among men are attributable to lung cancer (Table 2f) [22]. In Brazil, lung cancer results in an estimated 10,832 DALYs per year, 9.8 % of all cancer-related DALYs among women and 24.5 % among men [21]. In Spain, 3.4 % of all DALYs are attributable to lung cancer [4]. Most of the first year of disease (275 days) is spent in sickness absence in Sweden [36] and between 33 and 79 % of lung cancer patients in the USA were unemployed 15 months after diagnosis [43, 46]. Average time to re-enter the labor market was 484 days for full-time work and 377 for part-time work in the Netherlands [50]. The odds of re-entry into the labor market were significantly lower for lung cancer than the general population [24, 25, 51].

Impact of COPD on productivity

COPD patients have a higher chance of working fewer hours, of absenteeism and of poorer work performance (presenteeism) (Table 2g). [11, 52, 53]. A COPD patient loses around 8.5 workdays per year due to disease [10, 54]. Between 39 and 50 % of people stopped working due to the onset of COPD in the Netherlands [55, 56]. COPD-related productivity losses cost the US economy around 88 million USD or around 482,966 working days per year [57]. Modeled annual costs of COPD, estimated at 1.47 billion USD [58], are higher in Japan than the USA. The productivity loss costs PP/PY were somewhat comparable between Germany, Sweden and the Netherlands (566, 749 and938 USD respectively) [57, 59, 60]; but differed fourfold to estimated costs in Denmark (2816–3819 USD) [61, 62] and more than tenfold to what was estimated (9815 USD) in the USA [63]. In the USA, 8.5 work days are lost PP/PY on average [10], while COPD patients take an estimated 8.6 days of sickness absence in the Netherlands during a 2 year follow-up period [54]. Also in the Netherlands, 39 % of COPD patients left the labor force due to disease onset [55].
Impact of chronic kidney disease on productivity

Only two studies (Table 2 h) examined the impact of CKD on productivity. One found that renal dysfunction was independently associated with labor force non-participation, with an odds ratio of 7.94 (95% confidence interval, 1.60–39.43) [64]. The second study, evaluating labor market participation in CKD patients specifically after dialysis or transplantation, found that 35% of these CKD patients were unemployed [65].

Impact of diabetes mellitus on productivity

In Spain, nearly 2% of all mortality-related DALYs are attributable to DM [4]. In South Africa, 162,877 DALYs annually are attributable to DM (Table 2i) [4, 66]. A study from Kenya reports a rate of 364 DALYs per 100,000 observed person-years [6]. An estimated 7.2 days are lost P/PPY due to DM in the USA [10] and DM patients have an increased risk of absenteeism, presenteeism and inability to work [4, 10, 11, 52, 64, 67–69]. Productivity days lost per year due to diabetes ranged from 3.6 to 7.3 [10, 70]. In the USA, proportion of productivity loss was large due to premature mortality (49%) and presenteeism (44%) compared to absenteeism (4%) and total productivity related costs were estimated to be 1,962,314 USD [71]. The odds of non-participation of the labor force for diabetes patients compared to the general population were slightly higher with borderline significance in the EU, an OR of 1.38 (95% CI 0.99–1.93) [69].

Discussion

This systematic review identified 126 studies investigating the impact of NCDs on productivity. Most studies (96%) were from the Western world (North America, Europe or Asia Pacific), with limited evidence available from Brazil, South Africa, Kenya, Tanzania, Iran, Japan, South Korea and Argentina. Macro-economic productivity losses were measured in percentage and absolute numbers of DALYs and annual productivity loss costs (in USD). Studies also estimated productivity losses using labor market indicators including unemployment, RTW, absenteeism, presenteeism, sickness absence and loss in working hours. There is a clear scarcity in literature concerning the effect of CKD on productivity, with only two studies both reporting a substantial impact on productivity [64, 65].

Diversity in the macro-economic measures and outcomes

There were considerable global differences in the NCD-attributable DALY burden, especially the differential impact of each NCD comparing high-income countries (HIC) and low- and middle-income countries (LMIC). Lung and colon cancer account for nearly 30% of all cancer-attributable DALYs in men in New Zealand whereas in Brazil, lung cancer alone accounts for nearly 25%. Among women in HIC, breast cancer seems to impose a large productivity burden whereas cervical cancer impacts more dramatically in LMIC [4, 21, 22]. Although DALYs are a reliable measure and capture both years of life lost and years spent in ill-health, we found inconsistent application in the identified studies; some estimated proportions within specific disease groups or of the overall DALY burden in a country; others estimated absolute DALY numbers.

Diversity in the macro-economic impact of the cardiopulmonary diseases

Absolute costs (measured in USD) were estimated for COPD, CHD, and stroke events [7, 9, 15, 57, 58, 71]. These studies mainly came from HIC, although two studies, one from Kenya and one from Tanzania, were also retrieved. In Australia, absenteeism and lower employment due to CHD cost 13.2 billion USD annually, as well as an additional 23 million USD in mortality-related costs [9]. Evidence suggests that COPD costs around 88 million USD or nearly 500,000 working days per year in the US compared to 1.47 billion (modeled) in Japan. While annual COPD-related productivity costs were comparable in Germany, Sweden and the Netherlands (between 566 and 938 USD), costs differed fourfold (2816–3819 USD) in Denmark, tenfold (9815 USD) in the USA [57, 59–63]. In the USA, nearly half of the annual 1.96 m USD productivity losses due to DM are attributable to mortality, with 44% attributable to presenteeism and just 4% to absenteeism. In South Korea, modeled productivity losses for a stroke were 68% higher among men compared to women [16]. Around half of all stroke survivors in unemployed after 1 year [20]. In Tanzania, productivity losses after 6 months following stroke were 213 USD on average although these losses were most acutely experienced by those in higher skill roles [17]. Interestingly, indirect productivity losses were higher among caregivers than stroke patients themselves and costs increased for caregivers but declined for patients after 1 and 2 years following a stroke in Spain. COPD patients experience reduced working hours, unemployment, absenteeism and presenteeism [10, 11, 52–56]. DM patients also have an increased risk of reduced labor market participation [10, 11, 52, 64]. By contrast, other than for presenteeism [10] the evidence for the risk of reduced labor market participation due to CVD is inconclusive. In Kenya, 68/100,000 person year observed are attributable to CVD compared to 166/100,000 for stroke and 364/100,000 for...
DM [6]. Although evidence is limited, the higher productivity impact associated with diseases with a large morbidity was perhaps to be expected; chronic diseases such as COPD and DM affect people during their productive years and cannot really be ‘cured’, only managed. The extent to which employers or societies support and enable NCD populations to remain members of the productive workforce will also differentially distribute the impact. The extent to which secondary or tertiary prevention is possible will also affect productivity estimates, specifically so for labor market indicators such as RTW, change in work status or unemployment.

Diversity in the macroeconomic impact of cancer

Lung cancer survival is associated with reduced labor market participation through sickness absence, extended RTW [36, 50] and unemployment [25, 43, 46]. Total mortality-related lifetime productivity loss due to breast cancer were an estimated 5.5 billion USD in the USA [26] and annual productivity losses due to colon cancer costs the US economy 20.9 billion USD [40]. We found inconclusive evidence of risk of reduced labor market participation (RTW, sickness absence and unemployment) following colon cancer diagnosis and treatment [25, 42–46, 48]. The evidence for breast cancer-related labor market drop-out shows higher unemployment among survivors 1, 2, 6 and 9 years after diagnosis [29–32]. Evidence from the USA also suggests ethnicity-patterned differences in sick leave and unemployment [27]. Along with possible socio-economic differences associated with these outcomes [72], pathophysiological differences may also play a role. African-American women have lower incidence of breast cancer but higher mortality and are also diagnosed in later stages and with more aggressive types of tumors [73]. However, we are cautious in over interpretation of this finding as few studies included ethnicity. Geographic differences in average months to RTW were observed from 11.4 in the Netherlands [34] to 7.4 in Canada [35] to just three months in Sweden [36].

Although evidence is limited, the higher productivity impact associated with diseases with a large morbidity was perhaps to be expected; chronic diseases such as COPD and DM affect people during their productive years and cannot really be ‘cured’, only managed. It is surprising that half of all productivity losses in the USA attributable to DM are due to mortality rather than absenteeism and presenteeism. The extent to which employers or societies support and enable NCD populations to remain members of the productive workforce will also differentially distribute the impact both within societies but also comparing more affluent to less affluent countries. The extent to which secondary or tertiary prevention is possible will also affect productivity estimates, specifically so for labor market indicators such as RTW, change in work status or unemployment.

Comparison with the previous work

Findings of this systematic review generally concur with and further extend the previous reviews. This study is a comprehensive systematic review tackling work-related burden of six major NCDs using a global perspective and without language limitation. Two reviewers included and assessed the studies and references of the included studies were tracked for any missing evidence. These approaches ensured that we included most of the relevant articles in our review. Similar to previous reviews, we found that, due to a great amount of variation in the studies included, comparability and pooling the studies were not possible. Most of the previous reviews were performed non-systematically and previous systematic reviews have included studies only in English. Previous studies were mainly focused on the impact of cancers [74–78] on work-related outcomes (mainly RTW) and often included a mix of cancers without specifying the type of cancer. Van Muijen and colleagues [78] reviewed only cohort studies of cancer-related work outcomes and were focused on English language. Steiner and colleagues [76] reviewed English publications published up until 2003, Breton and colleagues were focused only on diabetes and Krisch and colleagues focused on COPD in Germany [79].

Strengths and limitations of the current work

In this systematic review we evaluated the literature concerning the impact on productivity of six top NCDs. These six were selected based on their dominance in the global burden of disease and together make a huge contribution to mortality and morbidity worldwide. Several important issues are out of scope for this work but do merit future research. First, we did not look into the underlying mechanisms of what forces people with NCDs in and out of the labor force, specifically in terms of co-morbidities (certain NCDs cluster in the same populations) and financial/social means available at an individual and collective level. How these mechanisms interact will also be different according to the level of economic and social development. For example, children in LMIC are more likely to be forced into the labor market due to the onset of NCDs in parents compared to children in HIC and the productive output of this child cannot replace the loss due to drop out by the parents. These related topics should be addressed separately to better understand how to modify and target these outcomes more specifically. Second, we observed wide heterogeneity in all domains within the studies.
selected, including study design, methods and sources used to measure productivity, adjustment for confounders and analyses. Third, no identified studies quantified the differential productivity impact by national economic development and labor market structure across countries. How these inter-country macro-economic differences might mitigate or magnify productivity losses associated with NCDs is worth further exploration. Fourth, we identified a crucial gap of relevant information from LMICs—limiting the relevance of our review most acutely in these settings. This lack of evidence could reflect differences in disease burden, in research capacity, in welfare systems and in epidemiological surveillance. The burden of NCDs is growing rapidly in LMIC; countries that often lack capacity in these key areas of support, prevention and knowledge generation. Further evaluation, therefore, of the macro-economic impact in the LMIC countries is urgently needed. Also, many NCDs affect people cumulatively over time; people may suffer DM, may experience absenteeism/presenteeism as a result, may reduce work as DM worsens and may finally drop out of the workforce due a stroke or CHD, which is related to the DM. Given NCDs are shifting more and more into chronic conditions, as our understanding of treatment and natural history improve, it would be of great interest to investigate the effects over the life course rather than using short time horizons such as a year. This is no mean feat, but could be crucial for developing a better understanding of the economic impact of NCDs on a regional, national and international level. Also out of scope for this review but of interest for future work are the productivity-related impact of behavioural risk factors that contribute to the development of NCDs.

Conclusions

In summary, available studies indicate that the six main NCDs generate a large impact on macro-economic productivity in the WHO regions. However, this evidence is heterogeneous, of varying quality and not evenly geographically distributed. Data from LMI countries in economic and epidemiological transition are virtually absent. Further work to reliably quantify the absolute global impact of NCDs on macro-economic productivity and DALYs is urgently required.

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Conflict of interest With regard to potential conflicts of interest, there is nothing to disclose. Drs. Chaker, van der Lee, Falla and Franco had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis.

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Appendix 1: Search strategy up to 6th of November 2014

(‘non communicable disease’/de OR ‘ischemic heart disease’/exp OR ‘cerebrovascular accident’/exp OR ‘chronic obstructive lung disease’/de OR ‘lung cancer’/exp OR ‘colon cancer’/exp OR ‘breast cancer’/exp OR ‘chronic kidney disease’/de OR ‘non insulin dependent diabetes mellitus’/de OR ‘uterine cervix cancer’/exp OR (‘non communicable’ OR noncommunicable OR ((heart OR cardiac OR cardial OR cardiopath* OR cardiomyopath* OR coronar* OR myocard*) NEAR/3 (ischem* OR ischaem* OR anoxia OR hypoxia)) OR (coronary NEAR/3 (insufficien* OR occlus* OR disease* OR acute OR atherosclero* OR arteriosclero* OR sclero* OR cardio* OR constrict* OR vasocostrict* OR obstruct* OR stenosis* OR thrombo*))) OR angina* OR ((heart OR myocard* OR cardiac OR cardial) NEAR/3 infarct*)) OR ((cerebrovascul* OR brain OR ‘cerebral vascular’ OR ‘cerebro vascular’) NEAR/3 (accident* OR lesion* OR attack OR ischem* OR ischaem* OR insult* OR insufficien* OR arrest* OR apoplex*)) OR eca OR stroke OR chronic (chronic AND (obstruct* NEAR/3 NEAR/3 (lung* OR pulmonary* OR airway* OR bronch* OR respirat*))) OR ((lung* OR pulmonary* OR colon* OR colorect* OR breast* OR mamma*) OR NEAR/3 (neoplas* OR cancer* OR carcino* OR adenocarcino* OR metasta* OR sarcom*)) OR chronic NEAR/3 (kidney* OR nephropathy* OR renal)) OR ((‘adult onset’ OR ‘type 2’ OR ‘type ii’ OR ‘non-insulin dependent’ OR ‘noninsulin dependent’ OR ‘insulin independent’) NEAR/3 diabet*) OR ((cervix OR cervical) NEAR/3 (cancer* OR neoplas* OR tumor* OR carcino* OR malign*)):(ab,ti) AND (adult/exp) AND (‘randomized controlled trial’/exp OR ‘cohort analysis’/de OR ‘case control study’/exp OR ‘cross-sectional study’/de OR ‘systematic review’/de OR ‘meta analysis’/de OR ecology/exp OR ‘ecosystem health’/exp OR ‘ecosystem
monitoring’/exp OR model/exp OR ((random* NEAR/3 (trial* OR control*)) OR rct* OR cohort* OR ‘case control’ OR ‘cross-sectional’ OR (systematic* NEAR/3 review*) OR metaanaly* OR (meta NEXT/1 analy*) OR ecolog* OR ecosystem* OR model*):ab,ti) NOT ([animals]/lim NOT [humans]/lim NOT ([Conference Abstract]/lim OR [Conference Paper]/lim OR [Letter]/lim OR [Note]/lim OR [Conference Review]/lim OR [Editorial]/lim OR [Erratum]/lim).
AND (productivity/de OR absenteeism/de OR ‘job performance’/de OR ‘return to work’/de OR ‘work capacity’/de OR ‘working time’/de OR ‘medical leave’/de OR workload/de OR retirement/de OR employment/exp OR unemployment/de OR (productivit* OR unproductivit* OR absenteeis* OR presenteeis* OR ((job OR work* OR profession* OR occupation* OR labour) NEAR/3 (perform* OR efficien* OR return* OR back OR capacit* OR abilit* OR disabilit* OR unah* OR limit* OR impair* OR loss OR losing OR restrict* OR reduct* OR input*)) OR (work* NEXT/1 (time OR week* OR day* OR load*)) OR workweek* OR workday* OR ((medical OR sick) NEXT/1 leave) OR workload* OR ‘time off work’ OR retire* OR employment* OR employed* OR unemploy* OR daly OR (‘disability adjusted’ NEXT/2 year*)):ab,ti).

Appendix 2: Newcastle–ottawa quality assessment scale

Cross-sectional and descriptive studies

Note: A study can be awarded a maximum of one star for each numbered item within the Selection and Exposure categories. A maximum of two stars can be given for Comparability.

Selection

(1) Is definition of NCDs adequate?
   (a) Yes, according to a clear and widely used definition*
   (b) Yes, e.g. record linkage or based on self-reports
   (c) No description

(2) Representativeness of the cases
   (a) Consecutive or obviously representative series of cases*
   (b) Excluded cases are random*
   (c) No description of the excluded cases or potential for selection biases or not stated

(3) Comparison with a reference group

(a) The results are compared with a reference from community or with the status of the cases prior to the disease*
(b) The results are compared with the results from other patients
(c) No description/no comparison available

(4) Definition of reference
   (a) Individuals with no NCD or sample from general population or the same individuals before NCD suffering*
   (b) Non community comparator is described
   (c) No description of source

Comparability

(1) Comparability of the results on the basis of the design or analysis
   (a) The results are described in age and sex sub groups (sex is not applicable for female diseases)*
   (b) The results are additionally adjusted for/ described in different socioeconomic factors or disease related confounders*

Exposure (costs, productivity, households)

(1) Ascertainment of exposure
   (a) Secure record (e.g. surgical records, hospital records, and administrative records, national...)*
   (b) Structured interview where blind to case/control status*
   (c) Interview not blinded to case/control status
   (d) Written self-report or medical record only
   (e) No description

(2) Same method of ascertainment for NCDs and comparators
   (a) Yes*
   (b) No
   (c) No comparator group exist

(3) Non-response rate
   (a) All participants included or same rate for both groups or respondents and non-respondents have the same characteristics*
   (b) Non respondents described
   (c) Rate different and no designation
   (d) Response rate not described
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