The impact of coronary heart disease prevention on work productivity: a 10-year analysis

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Aims
To determine the impact of preventing new (incident) cases of coronary heart disease (CHD) on years of life and productivity, using the novel measure ‘productivity-adjusted life year’ (PALY), over the next 10 years.

Methods and results
A dynamic life table model was constructed for the total Australian working-age population (15–69 years) over 10 years (2020–2029), separated by CHD status. Productivity estimates were sourced from the literature. The PALY was ascribed a financial value in terms of gross domestic product (GDP) per equivalent full-time worker. The total number of years lived, PALYs, and economic burden (in terms of GDP per PALY) were estimated. The model simulation was repeated assuming incidence was reduced, and the differences represented the impact of CHD prevention. All outcomes were discounted by 5% per annum. Over 10 years, the total projected years lived and PALYs in the Australian working-age population (with and without CHD) were 132 million and 83 million, respectively, amounting to A$17.2 trillion in GDP. We predicted nearly 40 000 new (incident) CHD cases over the next 10 years. If all new cases of CHD could be prevented during this period, a total of 14 000 deaths could be averted, resulting in more than 8000 years of life saved and 104 000 PALYs gained, equivalent to a gain of over A$21.8 billion (US$14.8 billion) in GDP.

Conclusion
Prevention of CHD will prolong years of life lived and productive life years, resulting in substantial economic benefit. Policy makers and employers are encouraged to engage in preventive measures addressing CHD.

Keywords
Coronary heart disease • Productivity • Prevention • Health economics

Introduction
Coronary heart disease (CHD) is the most common type of cardiovascular disease (CVD), accounting for nearly half (47%) of all Australian CVD-related mortality¹ and a third of all deaths worldwide in people over 35 years of age.² Recent data suggest CHD is the leading cause of CVD-related hospitalisations and the highest disease burden in Australia.³ Importantly, 80% of CHD cases in Australia are preventable,⁴ suggesting the potential benefit of employing preventative strategies for CHD.

In addition to the health impacts, non-fatal CHD is associated with increased unplanned absence from work (absenteeism) and reduced output while at work (presenteeism).⁵⁻⁷ CHD is also linked to delayed resumption of work, early labour force dropout and unemployment.⁸⁻⁹ The collective impact of absenteeism, presenteeism, and early labour force dropout associated with CHD, however, is rarely considered in health economic evaluations and many studies assessing these parameters are outdated. Therefore, we sought to investigate the impact of preventing new (incident) CHD cases on the
health and productivity of working-age Australians over the next 10 years, estimated using years of life lived and productivity-adjusted life years (PALYs). PALYs are conceptually similar to quality-adjusted life years (QALYs); however, years of life are adjusted for productivity loss instead of quality of life impacts.

**Methods**

**Dynamic life table model**

A dynamic Markov model (Supplementary material online, Figure S1) was constructed to assess the impact of incident CHD on mortality, years of life lived and work productivity among the Australian cohort of working age (stratified by CHD status) over the next 10 years (from 2020 to 2029). Working age was defined as 15–69 years of age and was chosen to reflect the commonly accepted employment age in Australia. The model comprised three health states: ‘Alive without CHD’, ‘Alive with CHD’, and ‘Dead’. Subjects within the ‘Alive without CHD’ health state were at risk of developing CHD or dying, while those within the ‘Alive with CHD’ could remain alive or die. The dynamic nature of the model accounted for future migration, births and deaths, and allowed movement into and out of the working-age population over time. First, we estimated the total years of life lived, PALYs and associated economic costs over the next 10 years for the Australian population of working age, stratified by CHD status. Then, we re-simulated the Australian population of working-age hypothetically assuming we could prevent all new cases of CHD. The difference in years of life lived, PALYs and costs represented the potential gains from prevention of CHD. All outcomes were discounted by 5% annually after the first year.

**Data sources**

Full explanation of the methods and model inputs can be found in Supplementary material online, Table S1. National population, migration, mortality, and birth data were sourced from the Australian Bureau of Statistics (ABS) Population Projection data. CHD prevalence rates were obtained from the Australian Institute of Health and Welfare (AIHW) report based on self-reported long-term illnesses captured in the 2011–2013 Australian Health Survey (AHS). The AHS included approximately 25 000 households across Australia and a total of 31 837 persons in the final sample. CHD incidence rates were extrapolated from AIHW data of a proxy measure for acute coronary events (encompassing heart attacks and angioplasty) and hospitalisation and mortality data in 2012 (Supplementary material online, Table S2).

Mortality rates for those with and without CHD were estimated by adjusting the projected Australian all-cause mortality rates by the increased risk of mortality associated with CHD based on a report by Majed et al. [15] [hazard ratio (HR) 1.58, 95% confidence interval (CI) 1.18–2.12].

Age- and sex-specific net overall migration (NOM) estimates were calculated using projected ABS overseas departure and arrival data. It was assumed that NOM estimates were apportioned into ‘CHD’ and ‘no CHD’ categories as per Australian CHD prevalence rates in 2013. Australian labour force participation rates for the latest available year (2019) were obtained from the ABS. Age- and sex-specific labour force participation in those with and without CHD was calculated by applying the HR of labour force dropout in those with CHD to the national labour force participation rate (Supplementary material online, Table S1). The HR employed was from a study by Kruse et al. [17] (HR 1.32, 95% CI 1.11–1.57). The estimated labour force participation rates for those with and without CHD were adjusted to the reported mean number of hours worked for the total population (based on 2016 employment data from the ABS) to account for part-time/full-time employment and obtain the proportion of equivalent full-time (EFT) workers with and without CHD.

Productivity indices account for the proportional loss in productivity attributable to absenteeism and presenteeism. The indices range from 0 (completely unproductive) to 1 (completely productive). Productivity indices were determined based on the average number of working days in a year (240 assuming full time workers have 4 weeks annual leave and therefore work 48 weeks per year and 5 days per week), and absenteeism and presenteeism data. For those with CHD, the productivity estimates were derived from Goetzel et al. [23] The study estimated losses in productivity attributed to acute myocardial infarction, angina pectoris and aneurysm of heart and coronary vessels. It was estimated that there were 6.7 (range 1.2–17.8) missed days of work and 16.3 (range 0–32.4) days of unproductive time at work per person per year in those with CHD (Supplementary material online, Table S1). Estimates from the general population were employed for those without CHD in our model, adapted from a study by Stewart et al. [25] which reported missed days per person per year due to absenteeism and presenteeism of 3.2 (95% CI 3.1–3.4) and 7.9 (95% CI 7.7–8.2), respectively (Supplementary material online, Table S1). The estimated productivity indices for those with and with CHD were 0.954 and 0.904, respectively.

To estimate the number of PALYs, the years of life lived for each year was multiplied by the productivity indices and the proportion of EFT workers for those with and without CHD. Thus, the PALY collectively accounts for productivity loss due to absenteeism and presenteeism (based on the productivity index), labour force dropout (based on EFT data), and premature mortality (based on hazard risk of all-cause mortality data and the resulting years of life lost). This is also analogous to multiplication of years of life lived by utilities to generate QALYs. The model simulation was repeated assuming incidence was reduced, and the differences in the estimated number of PALYs between simulations, reflected the impact of CHD prevention. For example, assuming there was a prevention strategy that could prevent 10% of incident cases, the extrapolated AIHW incidence rates of CHD were multiplied by 0.9. Thereafter, any reduction in CHD incidence would be reflected in terms of years of life saved and PALYs gained due to changes in the movement of those in the ‘no CHD’ cohort into the ‘CHD’ cohort.

The cost of lost productivity due to CHD was estimated by ascribing a cost to each PALY. Data on Australian gross domestic product (GDP) per hour worked (from 1975 to 2018) were drawn from the ABS and used to determine the projected economic value of a PALY (details in Supplementary material online, Table S1). The value of a PALY ranged from $197 259 in 2020 to $217 983 in 2029 (discounted). All costs are reported in 2020 Australian dollars (A$) and converted into US dollars (US$) based on the latest available (2019) purchasing power parity rate of 1.472.

**Sensitivity and scenario analyses**

To determine the effect of uncertainty related to key input data on the model outputs, sensitivity analyses were undertaken. Key input parameters assessed included the risk of mortality associated with CHD, early retirement (labour force dropout) due to CHD, and absenteeism and presenteeism estimates. We also measured the economic impact of these four key CHD-related factors on productivity separately (Supplementary material online, Table S3). To further test our model assumptions, we compared the base case to the following scenarios: (i) reducing the incidence of CHD using a sliding scale (in 10% decrements) to assess more realistic and achievable targets, including a 10% and 20% reduction in CHD incidence, (ii) narrowing the age bracket to 30–69 years, (iii) extending the time horizon to 20 years (projection until the year 2039), (iv) assuming no temporal trend in GDP and therefore...
maintaining the economic value of a PALY across the model time horizon (using the latest available data, 2018), (v) using the proportion of EFT for the general Australian population rather than the estimated condition-specific EFT (Supplementary material online, Table S3), (vi) reducing the discount rate to 3% (World Health Organisation standard),19 and (vii) 0% (assuming undiscounted).

Results
Projected incidence of coronary heart disease
In 2020, the estimated number of people with and without CHD in the Australian population of working age is 309,323 and 17,781,953, respectively (see Supplementary material online, Tables S4 and S5 for sex-specific results). Over the next 10 years, the number of working-age Australians with CHD is predicted to increase by 11% (or 39,990 new CHD cases) (Table 1). This means that 1.73% of all working-age Australians will live with CHD by the year 2029, assuming the current trend in CHD incidence remains stable. Among those with CHD, nearly 56% are males (Supplementary material online, Tables S4 and S5). If all new cases of CHD could be prevented over the next 10 years, a total of 14,202 premature deaths could be averted (Table 2). This consists of 11,068 deaths averted among males and 3,134 among females (Supplementary material online, Tables S6 and S7).

Projected years of life lived
The total number of years of life lived for the Australian population of working age (2020–2029) with and without CHD is 2,926,152 and 130,674,551, respectively. If all future cases of CHD could entirely be prevented over the next 10 years, a total of 822 years of life could be saved (6,408 years of life saved among males and 1,820 among females), equivalent to 0.004 years of life saved per person with CHD (Table 2).

Projected number and cost of productivity-adjusted life years
The total number of PALYs were 1,145,915 and 82,033,268 in those with and without CHD, respectively, accruing over A$17 trillion (US$11.5 trillion) in GDP over 10 years (2020–2029) (Table 1). Prevention of all new cases of CHD over this time period could result in 104,206 PALYs gained, comprising of 72,934 PALYs gained among males and 31,272 PALYs for females (Supplementary material online, Tables S6 and S7). This amounts to a potential saving of A$21.8 billion (US$14.8) or over A$6,500 (US$4,400) per person with CHD (Table 2). Please refer to Supplementary material online, Tables S8 and S9 for undiscounted values.

Sensitivity and scenario analyses
Figure 1 shows the contribution of the four major factors (premature mortality, labour force dropout, absenteeism, and presenteeism) on productivity loss attributable to CHD. Labour force dropout (A$34.5 billion or 69.4%) contributed the most to the estimated productivity loss, followed by presenteeism (A$10.4 billion or 21.0%), absenteeism (A$4.3 billion or 8.7%), and premature mortality (A$0.4 billion or 0.9%). Males contributed 61% to the total productivity losses due to CHD. The proportion of productivity (PALYs) lost to CHD-related labour force dropout, absenteeism and presenteeism were all higher in males than females (Figure 1).

The model was sensitive to several key inputs, mainly surrounding uncertainty in presenteeism and absenteeism estimates (Table 3 and Supplementary material online, Figure S2). Compared to the base case, altering CHD-specific presenteeism using the upper and lower limit estimate, reduced and increased the total number of estimated PALYs by 0.20%, respectively. Employing the upper bound estimate of CHD absenteeism reduced the number of PALYs by 0.12%, while the lower bound estimate increased PALYs by 0.09%.

Table 1. The estimated number of people with and without CHD, years of life lived, PALYs and broader economic cost for the Australian population of working age (15-69 years) over 10 years (2020-2029)

<table>
<thead>
<tr>
<th>Year</th>
<th>Projected population With CHD</th>
<th>Total years of life lived With CHD</th>
<th>Total PALYs With CHD</th>
<th>Total costs (A$) With CHD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Projected population Without CHD</td>
<td>Total years of life lived Without CHD</td>
<td>Total PALYs Without CHD</td>
<td>Total costs (A$) Without CHD</td>
</tr>
<tr>
<td>2020</td>
<td>309,627</td>
<td>17,782,347</td>
<td>264,602</td>
<td>15,257,160</td>
</tr>
<tr>
<td>2021</td>
<td>315,752</td>
<td>18,028,583</td>
<td>257,251</td>
<td>14,730,870</td>
</tr>
<tr>
<td>2023</td>
<td>327,160</td>
<td>18,533,080</td>
<td>242,104</td>
<td>13,736,661</td>
</tr>
<tr>
<td>2024</td>
<td>332,463</td>
<td>18,777,426</td>
<td>234,391</td>
<td>13,257,940</td>
</tr>
<tr>
<td>2025</td>
<td>337,262</td>
<td>19,017,355</td>
<td>226,648</td>
<td>12,790,498</td>
</tr>
<tr>
<td>2026</td>
<td>341,152</td>
<td>19,244,195</td>
<td>218,865</td>
<td>12,331,868</td>
</tr>
<tr>
<td>2027</td>
<td>344,786</td>
<td>19,464,993</td>
<td>210,553</td>
<td>11,882,042</td>
</tr>
<tr>
<td>2028</td>
<td>347,841</td>
<td>19,684,621</td>
<td>202,482</td>
<td>11,444,984</td>
</tr>
<tr>
<td>2029</td>
<td>350,531</td>
<td>19,898,280</td>
<td>194,440</td>
<td>11,020,620</td>
</tr>
</tbody>
</table>

| TOTAL | 3,328,301 | 188,714,678 | 2,300,868 | 130,678,494 | 1,148,222 | 82,033,370 | $237,627,198,371 | $16,975,609,752,707 |

Costs are in terms of GDP. Costs in the ‘CHD’ cohort include prevalent and incident cases of CHD.

Years of life lived, PALYs and costs were subject to an annual discount rate of 5% applied beyond the first year, and therefore represent discounted values.

A$, Australian dollar; CHD, coronary heart disease; PALY, productivity-adjusted life year.
### Table 2  The impact of preventing new cases of CHD in terms of deaths averted, years of life saved, PALYs saved, and costs saved over 10 years

<table>
<thead>
<tr>
<th>CHD incidence (%)</th>
<th>Total deaths averted</th>
<th>Years of life saved</th>
<th>PALYs saved</th>
<th>Costs saved (A$ billion)</th>
<th>Costs saved per person with CHD (A$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>1405</td>
<td>815</td>
<td>10 292</td>
<td>$2.2</td>
<td>$648</td>
</tr>
<tr>
<td>80</td>
<td>2813</td>
<td>1631</td>
<td>20 612</td>
<td>$4.3</td>
<td>$1298</td>
</tr>
<tr>
<td>70</td>
<td>4225</td>
<td>2449</td>
<td>30 960</td>
<td>$6.5</td>
<td>$1950</td>
</tr>
<tr>
<td>60</td>
<td>5640</td>
<td>3269</td>
<td>41 338</td>
<td>$8.6</td>
<td>$2603</td>
</tr>
<tr>
<td>50</td>
<td>7058</td>
<td>4091</td>
<td>51 743</td>
<td>$10.8</td>
<td>$3259</td>
</tr>
<tr>
<td>40</td>
<td>8480</td>
<td>4915</td>
<td>62 178</td>
<td>$13.0</td>
<td>$3916</td>
</tr>
<tr>
<td>30</td>
<td>9906</td>
<td>5740</td>
<td>72 641</td>
<td>$15.2</td>
<td>$4575</td>
</tr>
<tr>
<td>20</td>
<td>11 334</td>
<td>6568</td>
<td>83 134</td>
<td>$17.4</td>
<td>$5236</td>
</tr>
<tr>
<td>10</td>
<td>12 766</td>
<td>7397</td>
<td>93 655</td>
<td>$19.6</td>
<td>$5899</td>
</tr>
<tr>
<td>0</td>
<td>14 202</td>
<td>8228</td>
<td>104 206</td>
<td>$21.8</td>
<td>$6563</td>
</tr>
</tbody>
</table>

Costs are in terms of GDP. Years of life lived, PALYs, and costs were subject to an annual discount rate of 5% applied beyond the first year, and therefore represent discounted values.

A$, Australian dollar; CHD, coronary heart disease; PALY, productivity-adjusted life year.

*Including CHD and non-CHD-related deaths.

### Figure 1  Impact of coronary heart disease on work productivity.

Economic burden of productivity loss (in terms of lost GDP) in the Australian working population attributable to increased risk of mortality, early labour force dropout, absenteeism and presenteeism due to CHD over the next 10 years (2020–2029). A$, Australian dollar; CHD, coronary heart disease; GDP, gross domestic product.
Preventing 10% of new CHD cases over the next 10 years could avert 1405 premature deaths, and save 815 years of life and 10 292 PALYs (A$2.2 billion in GDP) (Table 2). A 20% reduction in incident cases of CHD resulted in 20 612 PALYs or A$4.3 billion of GDP gained (Table 2).

As the incidence of CHD is low in those below 30 years of age (Supplementary material online, Table S2), we assessed outcomes in the cohort aged 30–69 years (Table 3 and Supplementary material online, Tables S10 and S11). The number of individuals with CHD over 10 years were reduced by 0.6% compared to the base case (Supplementary material online, Table S10). The number of deaths prevented and years of live saved were almost identical when compared to simulations in the base case population (15–69 years old), while the number of PALYs saved were lowered by 0.5% (Supplementary material online, Table S11).

Extending the time horizon to 20 years (2020–2039) resulted in 57 327 390 additional PALYs (69% more than the total PALYs in the base case) or A$13.2 trillion (Table 3). Assuming the World Health Organisation discounting rate of 3%, there was an addition of 12 500 249 PALYs (11% increase). When no discount rate was applied

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### Table 3  Scenario analyses to assess the impact of key model parameters on the estimated number of PALYs saved, and associated economic costs, when preventing new cases of CHD in the Australian working-age population

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Details</th>
<th>% PALYs lost/saved compared to the base case</th>
<th>Total GDP lost/gained (A$ billion)</th>
<th>GDP lost/gained per person with CHD (A$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age limit (30–69 years)*</td>
<td>Projected CHD incidence (2020–2029)</td>
<td>-23.3%</td>
<td>-$4009</td>
<td>-$1 207 337</td>
</tr>
<tr>
<td>Time horizon (20 years)</td>
<td>Projected CHD incidence (2020–2039)</td>
<td>+68.9%</td>
<td>+$13 181</td>
<td>+$3 969 565</td>
</tr>
<tr>
<td></td>
<td>2020–2039 with CHD incidence reduced by 10%</td>
<td>+68.9%</td>
<td>+13 186</td>
<td>$3 971 071</td>
</tr>
<tr>
<td></td>
<td>2020–2039 with CHD incidence reduced by 50%</td>
<td>+69.1%</td>
<td>+$13 206</td>
<td>+$3 977 155</td>
</tr>
<tr>
<td></td>
<td>2020–2039 with CHD incidence reduced by 100% (no new cases of CHD)</td>
<td>+69.2%</td>
<td>+$13 232</td>
<td>+$3 984 898</td>
</tr>
<tr>
<td>Proportion of EFT</td>
<td>Abolishing CHD-specific risk of labour force dropout to estimate proportion of EFT (i.e. non-disease-specific)</td>
<td>-10.1%</td>
<td>-$1736</td>
<td>-$522 892</td>
</tr>
<tr>
<td>Discount rate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3%</td>
<td>+11.0%</td>
<td>+$1920</td>
<td>+$578 349</td>
</tr>
<tr>
<td></td>
<td>0%</td>
<td>+43.3%</td>
<td>+$7397</td>
<td>+$2 287 795</td>
</tr>
<tr>
<td>GDP</td>
<td>No growth in GDP over time (2017 values)</td>
<td>N/A</td>
<td>-$1188</td>
<td>-$357 694</td>
</tr>
<tr>
<td>Absenteeism inputs*b</td>
<td>Lower limit</td>
<td>+0.09%</td>
<td>+$14.7</td>
<td>+$4444</td>
</tr>
<tr>
<td></td>
<td>Upper limit</td>
<td>-0.12%</td>
<td>-$20.8</td>
<td>-$6261</td>
</tr>
<tr>
<td>Presenteeism inputs*b</td>
<td>Lower limit</td>
<td>+0.205%</td>
<td>+$35.3</td>
<td>+$10 626</td>
</tr>
<tr>
<td></td>
<td>Upper limit</td>
<td>-0.203%</td>
<td>-$35.0</td>
<td>-$10 547</td>
</tr>
<tr>
<td>Hazard ratio of early labour force dropout due to CHD</td>
<td>Lower limit</td>
<td>+0.0009%</td>
<td>+$0.16</td>
<td>+$48</td>
</tr>
<tr>
<td></td>
<td>Upper limit</td>
<td>-0.0009%</td>
<td>-$0.16</td>
<td>-$49</td>
</tr>
<tr>
<td>Hazard ratio of all-cause mortality due to CHD</td>
<td>Lower limit</td>
<td>-0.00044%</td>
<td>-$0.08</td>
<td>-$23</td>
</tr>
<tr>
<td></td>
<td>Upper limit</td>
<td>+0.0004%</td>
<td>+$0.07</td>
<td>+$21</td>
</tr>
</tbody>
</table>

The base case analysis estimated the total PALYs lived and associated economics costs in the total Australian population of working-age over the next 10 years, assuming the current trajectory of CHD. The base case estimated 83 179 182 PALYs lived at an economic cost of A$17 212 525 495 965.

A$, Australian dollar; CHD, coronary heart disease; GDP, gross domestic product; PALY, productivity-adjusted life year.

*See Supplementary material online, Table S10 for year-specific results (over 10 years) and Supplementary material online, Table S11 for simulated results of reducing the incidence of CHD using a sliding scale in those aged 30–69 years.

*Absenteeism and presenteeism inputs were altered in both the CHD and no CHD (general population) cohort.
and outcomes were undiscounted, an extra 36 178 996 PALYs were accrued (43.5% increase). In terms of proportion of EFT workers, abolishing the risk of early labour force dropout due to CHD (i.e. applying a non-disease-specific proportion of EFT, see Supplementary material online, Table S3 for more information) reduced the total number of PALYs by 10.1% compared to the base case (Table 3).

Discussion

This study highlights that over the next 10 years, assuming current trends in CHD incidence, CHD will continue to cause a substantial burden in terms of years of life lost and reduced productivity among working-age Australians. Absolute prevention of future cases of CHD could potentially avert over 14 000 premature deaths, and save 8000 years of life lived, 100 000 PALYs and up to A$21.8 billion (US$14.8 billion) in terms of lost GDP. While ideal, absolute prevention of future cases is highly unlikely to hold true in real life. Nevertheless, more achievable reductions in incidence of 10% and 20% still suggest substantial economic benefit. Preventing 20% of new CHD cases (or 800 cases per year) over the next 10 years could potentially save over 20 600 PALYs, resulting in A$4.3 billion of GDP gained (Table 2). The respective values for a 10% reduction in incident cases of CHD (or 400 cases per year) are 10 200 PALYs and A$2.2 billion of GDP gained (Table 2).

Based on the age- and sex-specific extrapolation of CHD incidence reported by the AIHW,1 the overall incidence rate among Australians of working age is higher in males (range from 0.001% to 1.2%) compared to females (0.0002% to 0.6%) by two- to five-fold. This is in line with the literature wherein males are reported to have higher lifetime risk of acquiring CHD compared to females.29 Accordingly, the male cohort contributed more than 60% to the entire productivity-related GDP loss attributable to CHD. Labour force participation shortfall (or early workforce dropout) due to CHD was the highest contributor to productivity loss, followed by presenteeism. Mortality contributed the least to GDP loss, which is in line with recent trends of improved survival following an acute myocardial infarction.30 However, increased survival after an acute myocardial infarction may lead to an increase in future cases of heart failure. Future studies should consider balancing health outcomes of reducing mortality from myocardial infarction against increases in future morbidity among survivors.

Recently, an Australian study by Schofield et al.9 suggested a loss of A$1.1 billion in GDP attributed to lost productivity due to CHD by 2030. These estimates were derived from a detailed microsimulation of labour force participation losses due to lost income, lost tax revenue and increased welfare benefits in Australians aged 45–64 years old with CHD, but did not account for productivity losses due to absenteeism and presenteeism. The study reported a potential gain of 0.05% in GDP if those with CHD were to remain in the labour force.9 In comparison, our model accounted for losses attributed to labour force dropout, as well as absenteeism and presenteeism associated with CHD. We also generated projections of new cases of CHD using incidence rates rather than prevalence (which was employed in the study by Schofield et al.). Our analyses indicated more than A$12 billion in lost GDP could be saved (0.21% increase) if all future CHD cases in those aged 45–64 years were prevented over the next 10 years. While not entirely comparable, the difference in our estimate is at least in part due to the consideration of absenteeism and presenteeism, which accounted for nearly one-third of the estimated total GDP loss in our model (Figure 1).

Despite improvements in behavioural modifications and treatment options, CHD was the highest individual disease burden in Australia in 2015, accounting for 7% of the total disease burden.3 According to the National Heart Foundation of Australia, an estimated 80% of CHD cases in Australia are preventable, mainly due to the highly modifiable risk factors associated with the disease.1 The present study highlights the potential economic benefits from prevention of CHD. Therefore, A$17.4 billion could be spent as a break-even investment to address the potentially preventable 80% of future cases of CHD,3 or A$2.2 billion to conservatively prevent 10% of future cases in Australia over the next 10 years. Interventions that target individuals (e.g. exercise programmes, smoking cessation programmes, blood pressure control, and cholesterol reduction),31,32 primary care services (e.g. increasing the uptake of timely cardiac rehabilitation)33,34 and the general population (e.g. banning industrial fats, modification of the built environment to facilitate active transport and exercise),35,36 are cost-effective for CHD prevention and a much cheaper alternative when considering the time and costs needed to develop new therapies. Thus, the suggested cost of preventive investment based our model likely overestimates the actual costs needed and presents a potential for economic return. Indeed, the National Heart Foundation of Australia reported for every A$1 invested for heart disease, the economic return amounts to A$9.8.9

We have previously studied the impact of other chronic diseases on PALYs using closed-cohort life table models.10,11 The dynamic life table model allows for movement into and out of the model due to birth, death, migration, and the defined working age, as well as into the CHD cohort (incident cases). This model has the ability to be adapted to evaluate the impact of other health conditions in Australia or other countries. In addition, by measuring the impact of ill health on productivity, we consider the broader implications which are important for healthcare decision-making as these often exceed the healthcare impacts.

Limitations

There are several limitations that warrant mention. The incidence of CHD obtained from the AIHW did not include less-severe cases of CHD that did not result in hospitalisation,1 suggesting an underestimation of CHD incidence in our model. CHD incidence may also vary by job type or socioeconomic status due to differences in risk factors, which was not accounted for. Additionally, confounders such as comorbidities that may have contributed to the development of CHD and may also affect productivity (e.g. diabetes, smoking and the associated pulmonary disease), were not accounted for and as such might underestimate the true burden. The HR of CHD mortality adapted from Majed et al.15 was the best available evidence for the model input, however, it was derived in a cohort of middle-aged men (Supplementary material online, Table S1).

In terms of productivity data, there was a lack of Australian-specific estimates on absenteeism and presenteeism impacts of CHD, therefore we used the best available evidence from a study in the USA.23 As these estimates may not be directly applicable to the Australian
population, the model may not have completely and accurately represented the productivity loss associated with CHD in Australia. Furthermore, these productivity estimates reflected the chronic impact of CHD,\(^{23}\) and therefore did not account for acute episodes of CHD which could result in substantially longer absenteeism and greater loss in terms of GDP.\(^{37}\) However, others have reported that absenteeism rates decline and reach a plateau 1-year post-acute CHD,\(^{38}\) supporting our decision to model the chronic impact of CHD on absenteeism. There was a lack of studies reporting the rate of absenteeism and presenteeism in a cohort without CHD. Therefore, we used general population estimates of absenteeism and presenteeism in a cohort without CHD on absenteeism. There was a lack of studies reporting the rate of absenteeism and presenteeism derived from the USA as reported by Stewart et al.\(^{25}\) to match the USA-derived CHD-specific estimates by Goetzel et al.\(^{39}\) Notably, the presenteeism estimate reported by Stewart et al. is similar to Australian data (6.5 days per person per year).\(^{40}\) Lastly, in terms of labour force participation, we employed 2019 Australian labour force participation rates throughout the simulated time horizon and did not account for temporal changes. However, labour force participation rates from 2008 to 2019 remained stable across all age groups.\(^{16}\)

In conclusion, prevention of incident cases of CHD results in prolonged life, increased productivity and substantial economic benefit. The present study highlights the need for investment in identification and preventive measures to reduce future cases of CHD.

**Supplementary material**

Supplementary material is available at European Journal of Preventive Cardiology online.

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**References**


