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Estimating the burden of Coronary Heart Disease on the UK population and the impact of optimal public health interventions

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Executive Summary

Based on 2005 mortality data, we estimate that CHD will collectively cost the current male population of the UK more than **16 million years of life**. This represents approximately **0.84 years** (307 days) **of additional lifespan** for every man in Britain. Among those suffering fatal CHD, this represents over **13 years of additional lifespan**.

Optimum public health interventions could save approximately **4.3 million years of life** lost to CHD. This represents more that **4 years of life** for each person (on average) who would otherwise die as a result of CHD. Although optimum intervention is an unrealizable goal, any improvement in public health intervention will reduce the very substantial burden of CHD on the population as a whole.

Client Brief

The client is Citigate Dowe Rogerson, represented by Stieve de Lance.

The client has been engaged to co-ordinate a public health campaign to promote screening for risk factors of heart disease and improved health management among the general public (to include increased heart health checks, improved diet and exercise regimens and smoking cessation).

The client has approached TCP Innovations to provide an estimate of the current burden of heart disease on the UK male population. In addition, the fraction of the total burden which could be saved through optimal public health intervention will be estimated.

An important focus for reporting the results are headline figures relating to the total number of years of life lost to CHD in the population, as well as the number of years of life extension which could be achieved through optimal public health intervention.

Background

The term "heart disease" covers a number of different medical conditions of the heart, including coronary artery disease, cardiomyopathies, valve disease and heart failure. Of these, coronary artery disease and it consequences account for roughly 75% of the disease burden. As a result, in popular media the term "heart disease" is often used synonymously with coronary artery disease.

Coronary artery disease is caused by changes in the blood vessels that deliver vital oxygen to the heart muscle. These blood vessels (the coronary arteries) can become blocked, cutting off the oxygen supply. When this happens part of heart muscle dies, and this event is popularly termed a "heart attack". The medical term for a heart attack is a myocardial infarction (since "myocardium" is the medical term for the heart muscle and "infarction" means death). If a sufficiently large part of the heart muscle dies (so the remaining portion can no longer pump the blood around the body) then the heart attack will be fatal.

The process that causes the coronary arteries to become blocked is called "atherosclerosis" (or in the popular media sometimes "hardening of the arteries"). Atherosclerosis occurs in two stages: firstly, the wall of the blood vessel thickens and cholesterol from the blood becomes deposited in the blood vessel wall. This first phase is very slow, and the gradual accumulation of cholesterol may take years or even decades. Very many people (Fernandez-Britto[1] estimated at least 70% of the population over the age of 40) have these cholesterol deposits in their coronary arteries, but fewer than 10% have any symptoms. For the rest, the development of this atherosclerosis is entirely silent.

The second phase happens much more quickly. In parts of the vessel wall where a lot of cholesterol has deposited (which scientists call "plaques"), a local irritation can occur (which is properly called an "inflammatory reaction", and lots of white blood cells accumulate). This causes the plaque to become unstable, and eventually to rupture. When this happens, the debris from the ruptured plaque comes into contact with the blood in the artery, and a clot suddenly forms completely blocking the blood supply. If the blood vessel is not rapidly cleared (either naturally or through medical treatment) a heart attack will result.

It is not entirely clear why some people go onto have heart attacks while others remain perfectly healthy, but there are a few well-known "risk factors". The strongest risk factors are age (the older you are the more likely you are to have a heart attack), family history (death of a parent from a heart attack, for example) and male gender (men are between 2 and 5 times more likely than women to have a heart attack, depending on their age). However, there is not much you can do about any of these things – instead, if they apply to you, you should be even more careful to look after your heart and have regular check-ups.

But there are more risk factors that can be changed, both through lifestyle changes and medical treatments (scientists call these "modifiable risk factors"), and these include

untreated diabetes and high blood pressure, smoking, high levels of cholesterol in the blood, lack of exercise and an unhealthy diet. The risk factors listed here are in an approximate order of their impact on your risk of heart disease.

In conclusion, heart disease mostly results from the development of atherosclerosis in the coronary arteries. This process can take many years (it even starts in childhood in some people), but mostly causes no symptoms at all. However, lifestyle changes and medical treatments can halt or even reverse the process. Eating healthily, taking more exercise and having regular check-ups reduces the risk considerably. The purpose of this document to is estimate the benefits of optimal compliance with public health guidance including regular check-ups in the UK. Since the majority of heart disease occurs in men, the focus is on estimating the benefit in the male population.

Analysis

How many years of life would be saved if 'at risk' or all men looked after their hearts?

This question can be divided into two halves. We can estimate the total number of years lost to premature coronary artery disease, and then ask what fraction of those years could be saved by intervention (screening, medical treatments or lifestyle intervention).

Taking the most recent figures for CHD deaths by age (from 2005[2]), shown in Table 1, then if we assume that each individual would have lived to the national average age had they not had heart disease, and we also assume that on average the deaths occurred 66% of the way through each range (thereby allowing for the exponentially increasing rate of CHD mortality with age), then we calculate the number of years of life lost.

	<36	**36-45**	**46-55**	**56-65**	**66-75**	**>75**	**Total**
Men	104	878	2,790	7,046	13,331	31,978	56,127
Women	30	186	623	1,939	5,983	36,048	44,809
Ratio[a]	3.5	4.7	4.5	3.6	2.2	0.9	

[a]Excess risk for men over women in the age-group (expressed as the ratio of events in males to events in females)

Table 1 : Distribution of deaths from CHD by age group in the UK in 2005

Excluding the extreme groups, the average age of the people in this distribution is 55 years old in 2005, so were born in 1950. The average lifespan for men born in 1950 is estimated to be 77.25 years[3]. The number of years lost to heart disease by men, classified by age of death, based on deaths occurring only in the year 2005, is shown in Table 2.

	<36	36-45	46-55	56-65	66-75	>75
Average age at death	30	42.6	52.6	62.6	72.6	n/a
Years lost (A)	47.25	34.65	24.65	14.65	4.65	n/a
Male CHD deaths (B)	104	878	2,790	7,046	13,331	31,978
*Total years lost (A*B)*	4,914	30,423	68,774	103,223	61,989	n/a

Table 2 : Years lost to CHD mortality among males in the UK in 2005

Note that the majority of the individuals dying of CHD post age 75 reached the average lifespan of the population so are considered not to have "lost" any years due to CHD for the purposes of this analysis. Indeed, if premature CHD events were delayed by improved medicine or public health practice, one would expect to see a substantial increase in the CHD deaths in the post age 75 group.

Assuming no further improvement in public health or medicines, then we must project this one year profile to estimate the overall impact of CHD on the population. The most meaningful number would be to estimate the number of lives gained from today onwards in the cohort of people who are currently 35 years old (those born in 1973) if the CHD rates fell from those observed in 2005 to zero.

Initially, the number of males of this age in the cohort in the UK is 381,900 (based on the 2001 UK National Census[4]).

Combining the data from the Census and the absolute number of CHD deaths, we can calculate an age-specific death rate for males (expressed as deaths per 100,000 of population). These death rates are shown in Table 3.

	<36	36-45	46-55	56-65	66-75	>75
Male CHD deaths (A)	104	878	2,790	7,046	13,331	31,978
Number of males (B)	12,313,734	3,982,289	3,169,880	3,139,036	2,683,493	2,134,939
*(A/B)*100,000*	0.84	22.04	88.01	224.13	496.77	1497.84

Table 3 : Age-specific death rates from CHD in the UK in 2005

Thus, for the 381,900 individuals aged 35 today, we expect 84 deaths from CHD each year for the next 10 years (840 deaths in total, equivalent to 29,106 years of life lost), followed by 3,353 deaths in the next 10 years (another 82,651 years of life lost), then 8,472 CHD deaths in the next 10 years (124,115 years lost) and finally 18,355 deaths (85,351 years lost) before this cohort reaches 75 years of age.

On this analysis, the number of years lost are 321,223 years (or, put another way, almost one year of life per person is lost). Eradication of premature CHD would extend male lifespan by 0.84 years (which is 307 days).

We conclude that CHD will reduce the lifespan of the average male in the UK who is currently 35 years old by 0.84 years (or 307 days). Among those who actually suffer a premature fatal heart attack, this represents 13.3 years reduced lifespan each.

There are a number of assumptions in this calculation: it assumes that no CHD occurs before age 35, and that the number of years gained among individuals between 75 years old and 77.25 years old is negligible. More importantly, it assumes that the cohort as it ages suffers no attrition from other causes (other diseases, suicide, murder and so forth). A sensitivity analysis, however, suggests that these sources of error are unlikely to exceed 5% so a more complex model is not warranted.

It is not straightforward to extend this figure to the population as a whole, simply by multiplying up the number of years saved by the total number of males. This is because males who are already older than 35 can have (on average) less years saved since they have lived some of them already without succumbing to heart disease. However, because the number of years saved varies by less than 3-fold across the age range 35 years to 75 years (see Table 2), it is reasonable to treat the number of years saved as linearly (and inversely) related to age from 35 years old onwards.

Thus, everyone up to and including age 35 (12,313,734) individuals will save an average of 10,343,536 years of life between them if premature CHD were eradicated today (that is 0.84 years each). Those aged 36-45 will save on average 5/42.5 less years (11.7%) less, which is 0.75 years each (a total of 2,986,717 years). The same calculation for the remaining age groups is shown in Table 4.

	<36	**36-45**	**46-55**	**56-65**	**66-75**	**>75**
Number of males	12,313,734	3,982,289	3,169,880	3,139,036	2,683,493	2,134,939
Correction factor	1.00	0.89	0.65	0.41	0.18	0
Years saved / person	0.84	0.75	0.55	0.34	0.15	0
Total years saved	10,343,536	2,986,717	1,743,434	1,067,272	402,524	0

Table 4 : Total years saved by premature CHD eradication by decade cohorts

On the basis of this model, we estimate that a total of 16,543,482 years (more than 16 million years) of live would be saved among the current UK male population if premature CHD were eradicated today.

We conclude that more than 16.5 million years of lifespan will be lost by the male population of the UK alive today, as a result of CHD

This represents a fairly accurate estimate of the number of years of extra life that would be enjoyed by the male population of the UK if heart disease were eradicated today. It is, however, considerably more tricky to estimate the number of years of extra life which could be obtained through concerted action to improve modifiable risk factors. In part, this is because it is difficult to estimate the extent to which different interventions are coincident (for example, if the same people who would benefit from a blood pressure check would also benefit from a diabetes check or treatment with statins). Estimates for the impact of changing each modifiable risk factor independently of the others, but perforce the estimate of the combined impact of all of them is subject to considerable inaccuracy.

The list of modifiable risk factors which will be considered here (which together, based on current knowledge, are likely to represent 80-90% of the impact achievable) are:

* Universal treatment with statins
* Identification of type II diabetes, and subsequent treatment
* Identification of high blood pressure and subsequent treatment
* Stop all smoking
* Increase exercise and improve diet to optimum

A further complication in the analysis which must be recognized is that there is little available data to indicate whether the impact of a given intervention acts specifically on particular age groups. It is possible, for example, that increased exercise is more effective against later onset CHD (say, in individuals over 50) than in the early onset disease (which probably has a higher genetic predisposition). In the absence of such an analysis (which would, in any case, be severely limited by the available dataset), we have here assumed that the benefit is approximately equally distributed across all age groups.

(a) Treatment with statins

The benefit of treating with statins is relatively straightforward to estimate. There have been dozens of well-controlled clinical trials (such as 4S, WOSCOPS, AFCAPS and TexCAPS) published since the early 1990s.

Here we use the data from AFCAPS[5] as the best estimate of the impact of broadening statin use since (a) this trial of 5600 US men had the least restrictive entry criteria, even treating men with normal blood cholesterol levels (b) the trial was conducted in a primary prevention setting (c) Caucasian men were a major subgroup of the trial population and (d) the trial was conducted in the early 1990s when it was possible to assemble an appropriate control group not receiving statins.

AFCAPS reported a reduction in myocardial infarction of 37% for 20-40mg lovastatin versus current standard treatment (183 vs 116 events; relative risk [RR], 0.63; 95% confidence interval [CI], 0.50-0.79; P<.001).

However, most trials have only limited follow-up duration (5.2 years average follow-up in the case of AFCAPS) so it is difficult to estimate whether the events that are

"prevented" during the period of follow-up would still occur prior to age 77.25 years (the notional 'normal' lifespan used in this analysis). Since the average age at recruitment in AFCAPS was 57 years (62.2 years at the end of follow-up), the impact of continuing treatment for a further 15 years is difficult to estimate.

A Health Technology Assessment conducted for the National Institute of Clinical Excellence in the UK[6], however, estimated this gain to be 0.16 years of life over the lifespan of the patient. This represents removal of 20% of the 0.84 years of life lost to CAD.

Note that by 2005 (the year for which the CHD incidence data was used in this analysis), statin use had become widespread in the UK. Some fraction of the 0.16 years of life saved had already been achieved and was incorporated into the mortality data used. It is difficult to estimate what fraction of impact had already been achieved by current statin use, but the available evidence strongly suggests that less than half of the possible gain is been achieved in practice: (a) more than half of all heart attacks occur in individuals who were not receiving any medical treatment for CHD and (b) current diagnostic procedures for identifying high risk sub-groups are relatively inefficient, so targeting treatment with statins using these diagnostic paradigms will achieve a benefit which is scarcely higher than the proportion of the overall population currently taking statins.

On this basis, we estimate that between 0.08 years (half the total saving remaining to be gained, based on the 50% of events that occur in individuals not taking statins) and 0.14 years (88% of the total saving remaining to be gained based on the 12% of males in the age range who are currently treated with statins) remain to be gained. An average of these two estimates will be adopted here: 0.11 years gained.

It should be noted that the NICE assessment[6] concluded that statin use for primary prevention did not meet the usual criteria adopted for value-for-money, and did not recommend expanding statin use in primary prevention beyond current levels. As a result, without a significant change in government policy it seems unlikely that a gain of 0.11 years saved could be achieved in practice even if the population were mobilized to attend regular check-ups with their doctor.

(b) Identification of type II diabetes and subsequent treatment

Diabetes is a major risk factor for CHD, particularly if the diabetes is untreated. Unfortunately, type II diabetes is often undetected without biochemical screening. As a result, it was estimated that 4.7% of people previously thought to have normal glucose metabolism have undiagnosed diabetes[7], and a further 16.7% have "impaired glucose tolerance", which can be thought of as 'pre-diabetes'.

The extent to which diabetes increases heart disease is difficult to estimate because there is no available prospective death rate data available for undiagnosed (and therefore untreated diabetics). However, the risk excess for all diabetics can be assessed using any of the well-established CHD risk calculators. Here we have used

the excellent PROCAM risk calculator[8] in part because we believe the risk factors applicable to the German population are more similar to the UK than for the US population that underpins the Framingham Risk Score. The excess risk at each age level is shown in Table 5 for an individual with median risk factor profile (in terms of serum cholesterol and hypertension).

	<36[a]	**36-45**	**46-55**	**56-65**	**66-75**	**>75[a]**
Risk without diabetes	-	20	60	160	460	-
Risk with diabetes	-	30	90	230	330	-
Fold-risk[b]	-	1.5	1.5	1.45	1.4	-

Table 5 : Age specific predicted death rates from CHD from the PROCAM model.
Rates are expressed as deaths/100,000 for individuals with median levels of other risk factors (LDL-C = 160mg/dl; HDL-C = 40mg/dl; Trigs = 160mg/dl; SBP = 140mmHg; non-smoker; no family history of heart disease). [a] The PROCAM Risk model is limited to the age range of the underlying dataset. [b] Fold-risk is the excess risk associated with diabetes.

It is clear that diabetes accounts for a 1.4 to 1.5-fold increase of risk of CHD death across the whole age range.

Once again, it is not straightforward to combine the excess risk with the prevalence of untreated diabetes, since the untreated diabetes is likely to be more common among the older subjects (indeed, Wareham and colleagues[7] note that the undiagnosed diabetic individuals are, on average older than the normoglycemic individuals in the same population), and as such have less years left to be saved following diagnosis and optimal treatment. In addition, no information is available to guide an estimate of the relative risk for untreated impaired glucose tolerance (which will, in many cases, progress to frank diabetes with time), nor to assess the impact of achieving glycemic control in this population on CHD mortality (since the appropriate control group – undiagnosed and untreated diabetics cannot be studied, for if they were identified treatment would begin).

For the purpose of this analysis, however, we estimate that risk could be reduced 1.45 fold for 4.7% of the population (undiagnosed diabetics) and 1.15 fold for the 16.7% with undiagnosed impaired glucose tolerance. However, we recognize that there is considerable margin for error on these assumptions.

On that basis, the overall risk of disease is reduced by 4%. This would translate to 0.06 years of life saved for each individual, assuming the risk reduction were distributed equally over the age range.

(c) Identification of hypertension and subsequent treatment

As with diabetes, high blood pressure (termed hypertension) is also a significant risk factor for CHD. A similar analysis can therefore be performed. It has been estimated that 6% of individuals in the community have hypertension, of which only 26% had previously been diagnosed and were taking medication[9]. This suggests that 4.5% of

individuals in the community have undiagnosed hypertension (a very similar proportion to those with undiagnosed diabetes).

Using the PROCAM model, we can estimate the impact on risk of reducing the blood pressure of these individuals from SBP 160mmHg to 140mmHg (a reasonable therapeutic goal).

	<36[a]	**36-45**	**46-55**	**56-65**	**66-75**	**>75[a]**
Risk without hypertension	-	20	60	160	460	-
Risk with hypertension	-	30	80	200	550	-
Fold-risk[b]	-	1.5	1.33	1.25	1.2	-

Table 6 : Age specific predicted death rates from CHD from the PROCAM model.
Rates are expressed as deaths/100,000 for individuals with median levels of other risk factors (LDL-C = 160mg/dl; HDL-C = 40mg/dl; Trigs = 160mg/dl; no diabetes; non-smoker; no family history of heart disease). [a]The PROCAM Risk model is limited to the age range of the underlying dataset. [b]Fold-risk is the excess risk associated with hypertension.

The increased risk associated with moderate hypertension is lower than for diabetes, and shows a more pronounced trend with age (being a greater risk factor for those who are younger). As a result, it is necessary to recalculate the predicted years lost to heart disease reducing the estimated death rate by the fold-risk for each age group multiplied by the prevalence of undiagnosed hypertension (assumed to be 4.5% across all ages).

	<36	**36-45**	**46-55**	**56-65**	**66-75**	**>75**
Number of males	12,313,734	3,982,289	3,169,880	3,139,036	2,683,493	2,134,939
Years saved / person	0.84	0.75	0.55	0.34	0.15	0
Adjusted [a]	0.827	0.738	0.544	0.337	0.149	0
Total years saved	10,183,458	2,938,929	1,724,415	1,057,855	399,840	0

Table 7 : Effect of treating undiagnosed hypertension on the total years lost of CHD in the UK. [a] Adjusted' is the Years saved per person applying the age-specific reduction in CHD death due to lowering blood pressure for the 4.5% of the population estimated to have undiagnosed hypertension.

According to this analysis, the some 238,985 less years would be lost to CHD with treatment of undiagnosed hypertension, representing, on average, a further 0.01 years saved.

(d) *Cessation of cigarette smoking*

Potentially the biggest modifiable risk factor for CHD is cigarette smoking, because not only is it associated with a significant (1.5 to 2-fold) increase in the rate of CHD among

smokers[10] but it is also prevalent in the population, with more than 23% of males currently smoking in the UK[3].

Combining these figures (assuming an equal distribution of both prevalence and risk across the age ranges studied) suggests that complete abolition of smoking would save 0.10 years for each individual.

(e) *Optimum diet and exercise*

Of all the modifiable risk factors associated with CHD, the impact of diet and exercise is the hardest to quantify. In part, this is because both diet and exercise are multifactorial and hence difficult to define and measure as exposures. Additionally, both are highly correlated with each other and with other measures of socioeconomic status. Interestingly, Marmot et al[11] concluded that lack of control in the work environment, smoking and childhood nutrition were the major contributors to the well-established socioeconomic gradient if CHD risk, suggesting that diet as an adult and exercise duration have only small effects by comparison.

This conclusion is also borne out by the finding that women eating a low diet for 8 years had no reduction in CHD (or, indeed, in all cause mortality) compared to women left to select their own diet, despite consuming fewer calories, less fat and having a modest reduction in body weight.

At first sight, these findings are paradoxical because we hear in the popular media continually that improved diet and increased exercise reduce CHD. Unfortunately, such conclusions have been drawn from an over-reliance on cross-sectional observations (where the increased rate of CHD among individuals with a poor diet and taking little exercise is wrongly assumed to imply that modifying those risk factors would necessarily reduce the CHD burden). The difficulty of performing large scale intervention studies in the human population mean that we often have little or no causal information to support public health drives based on correlative data (such as the present focus on five portions of fruit and vegetables per day).

Taken together, these factors suggest that the impact of optimized diet and exercise regimens will be relatively small. That said, the prevalence of sub-optimal diet and exercise regimens is probably very high. Some estimate that as many as 70% of males have poor diet and lack exercise[3]. Based on Marmot's conclusion that the maximum contribution from diet and exercise is likely to be a 10% reduction in CHD[11], we calculate that adoption of an optimum diet and exercise programme would result in 0.05 less years lost to heart disease for each individual in the UK.

Summary

We concluded that the mortality burden of CHD in the UK today is 16,543,482 years in total. For a 35 year old, therefore, abolition of premature heart disease would result, on average, in 0.84 years of life gained.

We have examined the contribution of a number of modifiable risk factors to this burden, and the contributions from the five major classes of risk factors are shown in Table 8.

Modifiable Risk Factor	Estimated burden (years/individual)	Estimated burden (total years)
Extended statin use	0.11	2,166,407
Treatment of undiagnosed diabetes	0.06	1,181,676
Treatment of undiagnosed hypertension	0.01	196,945
Smoking cessation	0.10	1,969,462
Optimum diet and exercise	0.05	984,731

Table 8 : Separate estimates of the CHD burden caused by each modifiable risk factor based on prevalence in 2005.

It is not reasonable, however, to simply sum these benefits. Many of the risk factors will be coincident in the same individuals and the benefits are unlikely to be additive. A more conservative approach would be to assume a 33% overlap in the impact of each modified risk factor. On this basis the total impact of risk factor modification is estimated to be 0.22 years of life gained per person (at age 35). This represents just over one quarter of the total burden of CHD that could be avoided by the optimization of all the major modifiable risk factors currently known.

Expressed another way, every man in the UK would live 80 days longer, representing a total of 4,332,816 (more than 4 million) years of life saved.

We conclude that optimum public health interventions would result in a saving of more than 4.3 million years of lifespan that will be lost to CHD, among the current UK male population

Table 8 is also useful to guide the most beneficial efforts in public health intervention. It is clear that smoking cessation would represent the most cost-effective public health intervention, contributing almost half of the total saving in mortality (ignoring, of course, the additional benefits from reduced cancer rates). Increasing statin use would have a similar impact, but would cost considerably more given the poor performance of most risk algorithms for targeting treatment (risk algorithms identify low prevalence high risk subgroups; the majority of CHD still occurs outside of these groups).

Several notes of caution are required in interpreting this data. Firstly, a gain of 80 days of life does not sound like a worthwhile gain (it represents only 0.3% of a typical lifespan). However, the gain is not distributed equally: a few individuals will gain many years as a result of the interventions while most will gain nothing at all. For the individuals affected, the gain will be very substantial and worthwhile. This only

underlines the major limitation in cardiovascular medicine at present, which is the ability to identify the majority of people who will go on to suffer CHD (so that the interventions can be properly targeted at those who will benefit from them).

Solely among the individuals who will, without intervention, die from CHD, the impact of optimal public health intervention would result in an increase of 4.14 years of lifespan. Unfortunately, without better diagnostics than currently exist, everyone would have to participate in improved heart health programmes to deliver this substantial benefit for the few.

Secondly, the assumption underlying these figures (a complete optimization of each modifiable risk factor) is completely unrealizable in practice. Richardson[12] and Ebrahim[13] both highlight this problem. A meta-analysis of 39 different risk factor interventions suggested that the average improvement is between 5 and 10% of the maximum change possible (presumably because giving up smoking, increasing exercise and so forth are difficult to achieve in practice). The smaller scale changes that could be realized in practice will likely result in much smaller gains than the theoretical maxima which have been estimated here.

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