Mortality among Australian Diabetes Patients

SDC / BakerIDI
December 2017
http://bendixcarstensen.com/SDC/IDI/mort)
Version 11

Compiled Friday 29th December, 2017, 19:08
from: /home/bendix/sdc/extn/IDI/DM-mort/r/AUS-DM-mort.tex

Bendix Carstensen Steno Diabetes Center, Gentofte, Denmark
& Department of Biostatistics, University of Copenhagen
bxc@steno.dk
http://BendixCarstensen.com

Contents

...now input from `theory.tex`

Chapter 1

Data acquisition and tabulation

The purpose of this analysis is to assess how the mortality among diabetes patients depend on current age (sometimes called attained age), duration of diabetes and age at diabetes diagnosis.

Since these three variables are linearly connected (current age = age at diagnosis + duration of diabetes) we cannot separate the effects of them without further assumptions (see e.g. [**?**]). For example, we may claim that mortality increases more by current age, if we are willing to assume that it increases less by diabetes duration and age at diabetes diagnosis. By including all three variable in the model we cannot make a claim as to an isolated effect of any particular of the three.

Suppose we describe the mortality rates as a function of current age, a; duration of diabetes, d and age at diagnosis, $e = a - d$ ("e" for **e**ntry into diabetes), then we have that $a - d - e = 0$. If we formally set up a model with only the effect of current age and age at diagnosis of diabetes:

$$\log\bigl(\mu(a,d)\bigr) = f(a) + h(e)$$

it is only superficially that this does not include duration; because since $d = a - e$, we may write:

$$\begin{aligned}
\log\bigl(\mu(a,d)\bigr) &= f(a) + h(e) + \beta d - \beta d \\
&= f(a) + h(e) + \beta(a-e) - \beta d \\
&= \bigl(f(a) + \beta a\bigr) + \bigl(h(e) - \beta e\bigr) - \beta d
\end{aligned}$$

Thus, even if duration is not formally included in the model we may claim that is has any linear effect we like, by simply asserting that the age and age at diagnosis effects are different. And there is no way to allocate a "correct" duration effect. One might of course on purely external grounds (*i.e.* unrelated to the data at hand) assert that there is no duration effect, for example. But this will never be founded in data.

Therefore, it makes more sense to set up a model with non-linear effects of all three variables. But we still have the problem from the linear dependence:

$$\begin{aligned}
\log\bigl(\mu(a,d)\bigr) &= f(a) + g(d) + h(e) \\
&= f(a) + g(d) + h(e) + \gamma(a-d-e) \\
&= \bigl(f(a) + \gamma a\bigr) + \bigl(g(d) - \gamma d\bigr) + \bigl(h(e) - \gamma e\bigr) \\
&= \tilde{f}(a) + \tilde{g}(d) + \tilde{h}(e)
\end{aligned}$$

so we have two *different* sets of three effects that together produce the same mortality rates; this would be valid for *any* value of γ we care to stick in the formula. This is essentially the age-period-cohort modeling problem once again, see [**?**].

However, even if we cannot separate the three effects in the model, we can still make perfectly valid predictions from the model, and certain contrasts will also be identifiable from the model. Notably we shall be able to estimate the mortality rate-ratio at a given age (a) between persons diagnosed at different ages, e_1 and e_0, and hence duration $a - e_1$ and $a - e_0$:

$$\begin{aligned}\log(\text{RR}) =& f(a) + g(a - e_1) + h(e_1) - \\ & f(a) - g(a - e_0) - h(e_0) \\ =& g(a - e_1) - g(a - e_0) + h(e_1) - h(e_0)\end{aligned}$$

Since any other possible set of effects $\tilde{f}$, $\tilde{g}$ and $\tilde{h}$ are distinguished from these by a term γ times the variable $(a - d - e)$, using these would yield:

$$\begin{aligned}\log(\text{RR}) =& \tilde{g}(a - e_1) - \tilde{g}(a - e_0) + \tilde{h}(e_1) - \tilde{h}(e_0) \\ =& \big(g(a - e_1) - \gamma(a - e_1)\big) - \\ & \big(g(a - e_0) - \gamma(a - e_0)\big) + \\ & \big(h(e_1) - \gamma e_1\big) - \\ & \big(h(e_0) - \gamma e_0\big) \\ =& g(a - e_1) - g(a - e_0) + h(e_1) - h(e_0) + \gamma(-a + e_1 + a - e_0 - e_1 + e_0) \\ =& g(a - e_1) - g(a - e_0) + h(e_1) - h(e_0)\end{aligned}$$

showing that these contrasts are invariant under *any* reparametrization, and hence *are* identifiable from the model.

1.1 Data entry

Here we read data and select only the variables we want

```
> library( readstata13 )
> library( Epi )
> library( popEpi )
> sessionInfo()
R version 3.4.2 (2017-09-28)
Platform: x86_64-pc-linux-gnu (64-bit)
Running under: Ubuntu 14.04.5 LTS

Matrix products: default
BLAS: /usr/lib/libblas/libblas.so.3.0
LAPACK: /usr/lib/lapack/liblapack.so.3.0

locale:
 [1] LC_CTYPE=en_US.UTF-8       LC_NUMERIC=C               LC_TIME=en_DK.UTF-8
 [4] LC_COLLATE=en_US.UTF-8     LC_MONETARY=en_US.UTF-8    LC_MESSAGES=en_US.UTF-8
 [7] LC_PAPER=en_US.UTF-8       LC_NAME=C                  LC_ADDRESS=C
[10] LC_TELEPHONE=C             LC_MEASUREMENT=en_US.UTF-8 LC_IDENTIFICATION=C
```

...now input from data.tex

```
attached base packages:
[1] utils     datasets  graphics  grDevices stats     methods   base

other attached packages:
[1] popEpi_0.4.1      Epi_2.19          readstata13_0.9.0

loaded via a namespace (and not attached):
 [1] Rcpp_0.12.12      lattice_0.20-35   zoo_1.8-0         MASS_7.3-47
 [5] grid_3.4.2        plyr_1.8.4        etm_0.6-2         data.table_1.10.4
 [9] Matrix_1.2-11     splines_3.4.2     cmprsk_2.2-7      numDeriv_2016.8-1
[13] survival_2.41-3   parallel_3.4.2    compiler_3.4.2
```

```
> system.time( dm <- read.dta13( "../data/AUS-DM2.dta", nonint.factor=TRUE ) )
```

```
   user  system elapsed
 17.072   1.805  18.875
```

```
> dim( dm )
```

```
[1] 1108420      49
```

```
> names( dm )
```

```
 [1] "aid_new"                "aid_old"                "asex"
 [4] "adob"                   "adiabtype"              "adiabtype_new"
 [7] "andss_status"           "adiagdate"              "aregdate"
[10] "aregdate2"              "areg_year"              "aagereg"
[13] "aagereg_c"              "aagediag"               "aagediag_c"
[16] "aagediag_reg"           "aagediag_reg_c"         "aage2012"
[19] "bidnum"                 "bndi_dod"               "bndi_dod_updated"
[22] "bdeath_year"            "bfullweight"            "bunderlying_updated"
[25] "bothercauses_updated"   "bagedeath"              "bdeath_weight_med"
[28] "ocod_part1_1"           "ocod_part1_2"           "ocod_part1_3"
[31] "ocod_part1_4"           "ocod_part1_5"           "ocod_part1_6"
[34] "ocod_part1_7"           "ocod_part1_8"           "ocod_part1_9"
[37] "ocod_part1_10"          "ocod_part1_11"          "bcensus"
[40] "cause_2_2"              "death"                  "death_date"
[43] "random_date"            "cause"                  "dox"
[46] "age_reg"                "age_diag"               "follow_up"
[49] "cause_3_2"
```

```
> wh <- c(3,4,8,9,42,44,49)
> nnam <- c("sex","doBth","doDM","doReg","doDth","caDth","c2Dth")
> cbind( names(dm)[wh], nnam )
```

```
                  nnam
[1,] "asex"       "sex"
[2,] "adob"       "doBth"
[3,] "adiagdate"  "doDM"
[4,] "aregdate"   "doReg"
[5,] "death_date" "doDth"
[6,] "cause"      "caDth"
[7,] "cause_3_2"  "c2Dth"
```

```
>        DM <- dm[,wh]
>  names(DM)         <- nnam
```

For convenience we transform dates to `cal.yr` format:

```
> DM <- cal.yr( DM )
```

We have two different classifications of cause of death, but it would simplify matters if there were only one, so we can easily repeat all analyses for different aggregate groups of relevance. So we combine the two to a 7-level factor:

```
> DM$caDth <- factor( DM$caDth, labels=c("CVD","Can","Infc","Othr") )
> levels( DM$c2Dth ) <- c("IHD","Str","PanC","ColC","Lung","OthC")
> comb <- factor( with( DM, interaction( caDth, c2Dth ) ) )
> levels( comb ) <- gsub(  "CVD.", "",
+                   gsub( ".OthC", "",
+                   gsub(  "Can.", "", levels( comb ) ) ) )
> table( DM$caDth, comb )
      comb
         IHD   Str  PanC  ColC  Lung  OthC  Infc  Othr
  CVD  51798 19025     0     0     0     0     0     0
  Can      0     0  6368  6173 10663 37033     0     0
  Infc     0     0     0     0     0     0  3513     0
  Othr     0     0     0     0     0     0     0 90024
> table( DM$c2Dth, comb )
      comb
         IHD   Str  PanC  ColC  Lung  OthC  Infc  Othr
  IHD  51798     0     0     0     0     0     0     0
  Str      0 19025     0     0     0     0     0     0
  PanC     0     0  6368     0     0     0     0     0
  ColC     0     0     0  6173     0     0     0     0
  Lung     0     0     0     0 10663     0     0     0
  OthC     0     0     0     0     0 37033  3513 90024
> DM$caDth <- comb
```

and we do not need `c2Dth` any more:

```
> DM <- DM[,-grep("2",names(DM))]
```

There are a few persons with a recorded date of death, but no cause of death; for these we code (till further notice) the cause of death as "Oth"

```
> DM$caDth[!is.na(DM$doDth) & is.na(DM$caDth)] <- "Othr"
```

This way we have the variable `caDth` (cause of death) with the subdivision of causes of death of relevance, so that CVD is the sum of `IHD` and `Str`, and cancer is the sum of `Lung` `ColC` `PanC` and `OthC`.

For convenience we define an eXit `status` for all, as well as a new date of DM, `doDMi`, where missing `doDM` is imputed by date of registration, `doReg`:

```
> DM <- transform( DM, doDMi = ifelse( is.na(doDM),
+                                      doReg,
+                                      doDM ),
+                      Xstat = Relevel( factor( ifelse( is.na(caDth),
+                                                       "Alive",
+                                                       as.character(caDth) ) ),
+                                       c(1,3,9,5,2,8,6,4,7) ) )
> str( DM )
'data.frame':        1108420 obs. of  8 variables:
 $ sex  : Factor w/ 2 levels "Men","Women": 1 2 2 1 1 1 1 2 1 2 ...
 $ doBth:Classes 'cal.yr', 'numeric'  num [1:1108420] 1930 1923 1927 1928 1938 ...
 $ doDM :Classes 'cal.yr', 'numeric'  num [1:1108420] NA 2001 NA 1997 2005 ...
```

```
 $ doReg:Classes 'cal.yr', 'numeric'  num [1:1108420] 1991 2001 1996 2001 2005 ...
 $ doDth:Classes 'cal.yr', 'numeric'  num [1:1108420] NA NA NA NA NA ...
 $ caDth: Factor w/ 8 levels "IHD","Str","PanC",..: NA NA NA NA NA NA NA NA NA 8 ...
 $ doDMi: num  1991 2001 1996 1997 2005 ...
 $ Xstat: Factor w/ 9 levels "Alive","IHD",..: 1 1 1 1 1 1 1 1 1 9 ...
> summary( DM )
    sex               doBth           doDM            doReg           doDth
 Men   :599649   Min.   :1891   Min.   :1912   Min.   :1988   Min.   :1997
 Women:508771    1st Qu.:1932   1st Qu.:2000   1st Qu.:1999   1st Qu.:2003
                 Median :1943   Median :2004   Median :2004   Median :2007
                 Mean   :1943   Mean   :2003   Mean   :2003   Mean   :2006
                 3rd Qu.:1953   3rd Qu.:2008   3rd Qu.:2008   3rd Qu.:2010
                 Max.   :2011   Max.   :2012   Max.   :2012   Max.   :2012
                                NA's   :364232                NA's   :882369
     caDth            doDMi          Xstat
 Othr    : 91478   Min.   :1913   Alive  :882369
 IHD     : 51798   1st Qu.:1997   Othr   : 91478
 OthC    : 37033   Median :2003   IHD    : 51798
 Str     : 19025   Mean   :2002   OthC   : 37033
 Lung    : 10663   3rd Qu.:2008   Str    : 19025
 (Other): 16054    Max.   :2012   Lung   : 10663
 NA's    :882369                  (Other): 16054
> addmargins( table( DM$Xstat, useNA="ifany" ) )

  Alive     IHD     Str    Lung    ColC    PanC    OthC    Infc    Othr     Sum
 882369   51798   19025   10663    6173    6368   37033    3513   91478 1108420
```

1.1.1 Dates

We check the exit status and plot histograms of the dates of birth, diabetes and death in order to check the sanity of the data

```
> addmargins( with( DM, table( floor(doDth), Xstat, useNA="ifany" ) ) )
      Xstat
        Alive     IHD     Str    Lung    ColC    PanC    OthC    Infc    Othr     Sum
  1997      0    2200     640     303     222     218     960      90    2626    7259
  1998      0    2409     707     348     260     246    1167      92    2781    8010
  1999      0    2614     887     399     263     272    1247     142    3334    9158
  2000      0    2820     887     456     301     267    1514     145    3879   10269
  2001      0    3072    1048     512     350     306    1759     166    4120   11333
  2002      0    3223    1109     583     365     353    1985     198    4754   12570
  2003      0    3490    1236     648     422     391    2230     203    5146   13766
  2004      0    3705    1312     705     401     454    2507     226    5735   15045
  2005      0    3652    1400     795     453     445    2685     248    6233   15911
  2006      0    3706    1477     818     459     486    3080     300    7079   17405
  2007      0    3941    1493     943     538     555    3122     267    7908   18767
  2008      0    4272    1686     995     535     558    3438     313    8792   20589
  2009      0    4353    1746     994     560     590    3795     310    9032   21380
  2010      0    4389    1783    1125     529     640    3917     392    9808   22583
  2011      0    3952    1614    1039     515     587    3627     421   10251   22006
  <NA> 882369       0       0       0       0       0       0       0       0  882369
  Sum  882369   51798   19025   10663    6173    6368   37033    3513   91478 1108420
> par( mfrow=c(1,2) )
> hist( DM$doBth, breaks=1890:2013, col="black", main="",
+       xlab="doBth - date of birth", ylab="", yaxs="i" )
```

```
> hist( DM$doDth, breaks=seq(1996,2014,1/12), col="black", main="",
+       xlab="doDth - date of death", ylab="", yaxs="i" )
> abline( v=1996:2014, col=gray(0.9) )
```

```
> par( mfrow=c(3,2) )
> hist( ifelse(DM$doDM>1985,DM$doDM,NA), breaks=seq(1985,2014,1/12),
+      col="black", main="", ylim=c(0,8000), yaxs="i",
+      xlab="doDM - date of DM diagnosis (after 1985)", ylab="" )
> abline( v=1985:2014, col=gray(0.9) )
> abline( v=1997, col="red" )
> hist( DM$doReg, breaks=seq(1985,2014,1/12), col="black", main="", yaxs="i",
+       xlab="doReg - date of registration", ylim=c(0,8000), ylab="" )
> abline( v=1985:2014, col=gray(0.9), yaxs="i" )
> abline( v=1997, col="red" )
> hist( ifelse(DM$doDMi>1985,DM$doDMi,NA), breaks=seq(1985,2014,1/12), yaxs="i",
+       col="black", main="", xlab="doDM imputed with doReg", ylim=c(0,8000), ylab="" )
> abline( v=1985:2014, col=gray(0.9) )
> abline( v=1997, col="red" )
> with( subset( DM, runif(nrow(DM))<0.025 ),
+       plot( doReg, doDM, pch=16, cex=0.4 ) )
> abline( v=1997, h=1997, col="red" )
> hist( DM[ is.na(DM$doDM),"doReg"], breaks=seq(1985,2014,1/12), yaxs="i",
+       col="black", main="", xlab="doReg - missing doDM", ylim=c(0,8000), ylab="" )
> abline( v=1985:2014, col=gray(0.9) )
> abline( v=1997, col="red" )
> hist( DM[!is.na(DM$doDM),"doReg"], breaks=seq(1985,2014,1/12), yaxs="i",
+       col="black", main="", xlab="doReg - non-missing doDM", ylim=c(0,8000), ylab="" )
> abline( v=1985:2014, col=gray(0.9) )
> abline( v=1997, col="red" )
```

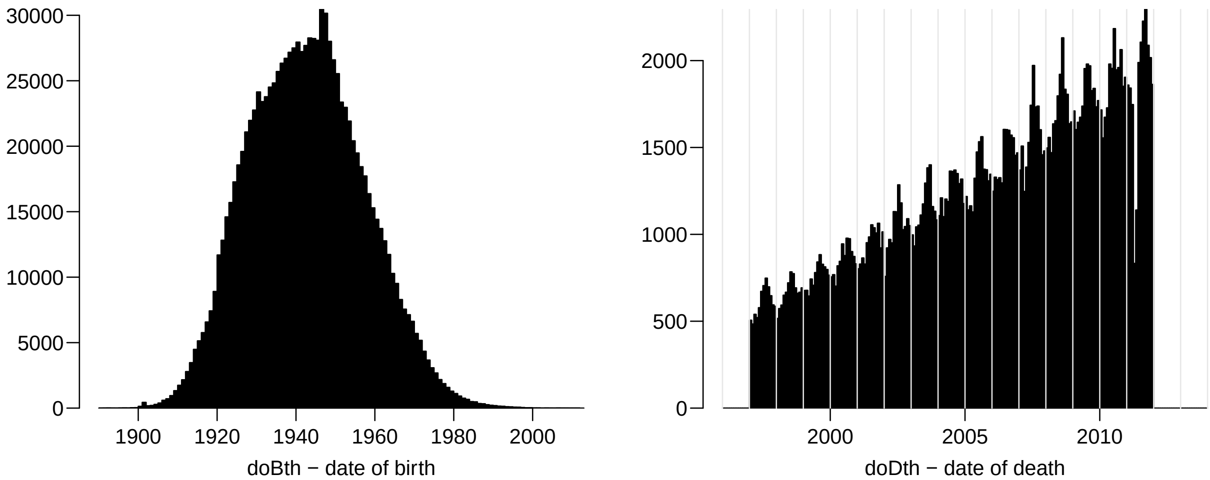

Figure 1.1: *Histograms of dates of birth and death. We see the clear seasonal variation in deaths as well as the unexplained hole in the dates of deaths in April/May 2011.* `../graph/data-dates1`

From figure 1.1 it appears that there are some dates of death that are weakly represented, they are sometime in the spring of 2011, so we track them down, and see that they are from mid-April to mid-May 2011.

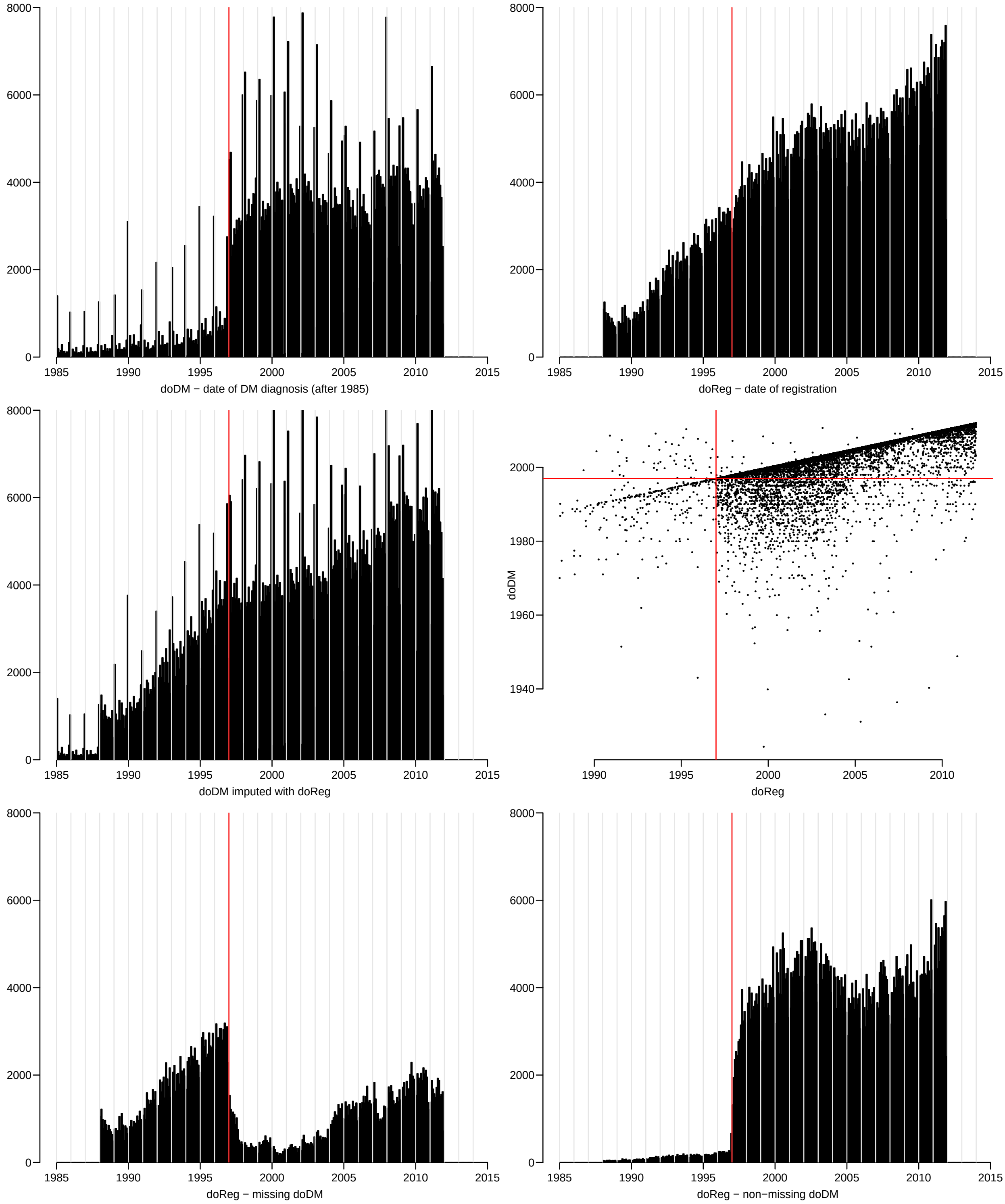

Figure 1.2: *Histograms of dates of diagnosis using different definitions: Only known date of diagnosis, purely date of registration, date of registration used for imputation of date of diagnosis. The vertical gray lines are located at 1 January each year, the red lines are at 1.1.1997, indicating that date of start of follow-up. The scatterplot is for a 2.5% sample of the data.* `../graph/data-dates2`

```
> # with( DM, addmargins( table( floor(doDth*50)/50, sex, useNA="ifany" ) ) )
> xx <- subset( DM, !is.na(doDth) & doDth>2011.27 & doDth<2011.39 )
> class( xx$doDth ) <- "cal.yr"
> with( xx, table( as.Date(doDth), sex ) )
```

```
            sex
             Men Women
  2011-04-10  25    24
  2011-04-11  25    26
  2011-04-12  33    23
  2011-04-13  31    17
  2011-04-14  23    19
  2011-04-15  23    15
  2011-04-16  13    18
  2011-04-17  14     9
  2011-04-18  10     6
  2011-04-19   6     6
  2011-04-20   2     3
  2011-04-21   5     4
  2011-04-22   6     1
  2011-04-23   4     3
  2011-04-24   6     1
  2011-04-25   6     5
  2011-04-26   1     1
  2011-04-27   2     0
  2011-04-28   2     3
  2011-04-29   4     3
  2011-04-30   1     4
  2011-05-01   2     2
  2011-05-02   2     1
  2011-05-03   4     0
  2011-05-04   6     5
  2011-05-05   9     9
  2011-05-06   6     5
  2011-05-07   3     2
  2011-05-08   5     4
  2011-05-09   6     1
  2011-05-10   8     5
  2011-05-11   5     3
  2011-05-12   6     8
  2011-05-13  14     5
  2011-05-14  11    13
  2011-05-15  14    10
  2011-05-16  10    13
  2011-05-17   4    15
  2011-05-18  22    15
  2011-05-19  29    14
  2011-05-20  23    21
  2011-05-21  40    33
  2011-05-22  35    22
  2011-05-23  28    20
```

Somewhat fishy, but no explanation as been supplied.

1.2 Lexis objects for follow-up data

We can now define the dates of entry and exit and set up a Lexis object for representation of the follow-up:

```
> DM <- transform( DM, doE  = pmax( doDM , 1997, na.rm=TRUE ),
+                      doEr = pmax( doReg, 1997, na.rm=TRUE ),
+                      doEi = pmax( doDMi, 1997, na.rm=TRUE ),
+                      doX  = pmin( doDth, 2012, na.rm=TRUE ) )
> with( DM, table( doX > doE , doDth > doE , exclude=NULL ) )
        FALSE   TRUE   <NA>
  FALSE   479      0      0
  TRUE      0 225572 882369

> with( DM, table( doX > doEr, doDth > doEr, exclude=NULL ) )
        FALSE   TRUE   <NA>
  FALSE   972      0      0
  TRUE      0 225079 882369

> with( DM, table( doX > doEi, doDth > doEi, exclude=NULL ) )
        FALSE   TRUE   <NA>
  FALSE   743      0      0
  TRUE      0 225308 882369
```

We see that there are a number of persons with date of death before the entry date, slightly varying according to the definition of the entry date:

```
> # The imputed date
> LDi <- Lexis( entry = list( per = doEi,
+                             age = doEi-doBth,
+                             dur = doEi-doDMi ),
+                exit = list( per = doX ),
+         exit.status = Xstat,
+                data = DM )
NOTE: entry.status has been set to "Alive" for all.
> summary( LDi )

Transitions:
     To
From      Alive   IHD   Str  Lung ColC PanC  OthC Infc  Othr  Records:  Events: Risk time:
  Alive 882369 51694 18991 10591 6134 6344 36870 3505 91179   1107677   225308    8500807

Transitions:
     To
From     Persons:
  Alive   1107677

> # Using the date of registration used as entry
> LDr <- Lexis( entry = list( per = doEr,
+                             age = doEr-doBth,
+                             dur = doEr-doReg ),
+                exit = list( per = doX ),
+         exit.status = Xstat,
+                data = DM )
NOTE: entry.status has been set to "Alive" for all.
> summary( LDr )
```

```
Transitions:
     To
From      Alive    IHD   Str  Lung ColC PanC  OthC Infc  Othr  Records:  Events: Risk time:
  Alive 882369 51635 18980 10578 6127 6336 36839 3498 91086   1107448   225079    7897156

Transitions:
     To
From     Persons:
  Alive   1107448
> # Only for those with recorded date of diagnosis
> LDx <- Lexis( entry = list( per = doE,
+                             age = doE-doBth,
+                             dur = doE-doDM ),
+                exit = list( per = doX ),
+         exit.status = Xstat,
+                data = subset(DM,!is.na(doDM)) )
NOTE: entry.status has been set to "Alive" for all.
> summary( LDx )
Transitions:
     To
From      Alive    IHD  Str Lung ColC PanC  OthC Infc  Othr  Records:  Events: Risk time:
  Alive 628346 23886 8808 6409 3500 4290 21808 1841 44821    743709   115363    5516529

Transitions:
     To
From     Persons:
  Alive    743709
```

To illustrate the total number of transitions to different causes of death we show box-diagrams, separately for the two sexes:

```
> one <-
+ function( dfr, clr )
+ {
+ ang <- seq( pi/2,-pi/2,,8 )
+ bxw <- list(x=c(20,70*cos(ang)+20),
+             y=c(50,40*sin(ang)+50))
+ boxes( dfr, boxpos=bxw, show.BE="nz", show=FALSE, show.Y=TRUE,
+        scale.Y=1000, pos.arr=rep(0.6,4), adj=1, hmult=1.35, wmult=1.10,
+        col.txt=clr, col.txt.arr=clr, col.arr=clr, eq.wd=FALSE, eq.ht=FALSE )
+ }
> two <-
+ function( LDi, txt )
+ {
+ one( subset(LDi,sex=="Men"), "blue" )
+ text( 100, 95, txt, adj=c(1,1), cex=1.5 )
+ one( subset(LDi,sex=="Women"), "red" )
+ }
> par( mfrow=c(3,2), mar=c(0,0,0,0) )
> two( LDi, "All persons in data\ndoDM imputed by doReg" )
> two( LDr ,"All persons in data\ndoReg used" )
> two( LDx, "Missing doDM\n excluded" )
```

Finally we save the three datasets, LD with date of diabetes imputed by date of registration, LDr using date of registration as proxy for date of diagnosis and LDx where persons without date of diagnosis are excluded:

```
> save( LDi, file="../data/LDi.Rda" )
> save( LDr, file="../data/LDr.Rda" )
> save( LDx, file="../data/LDx.Rda" )
```

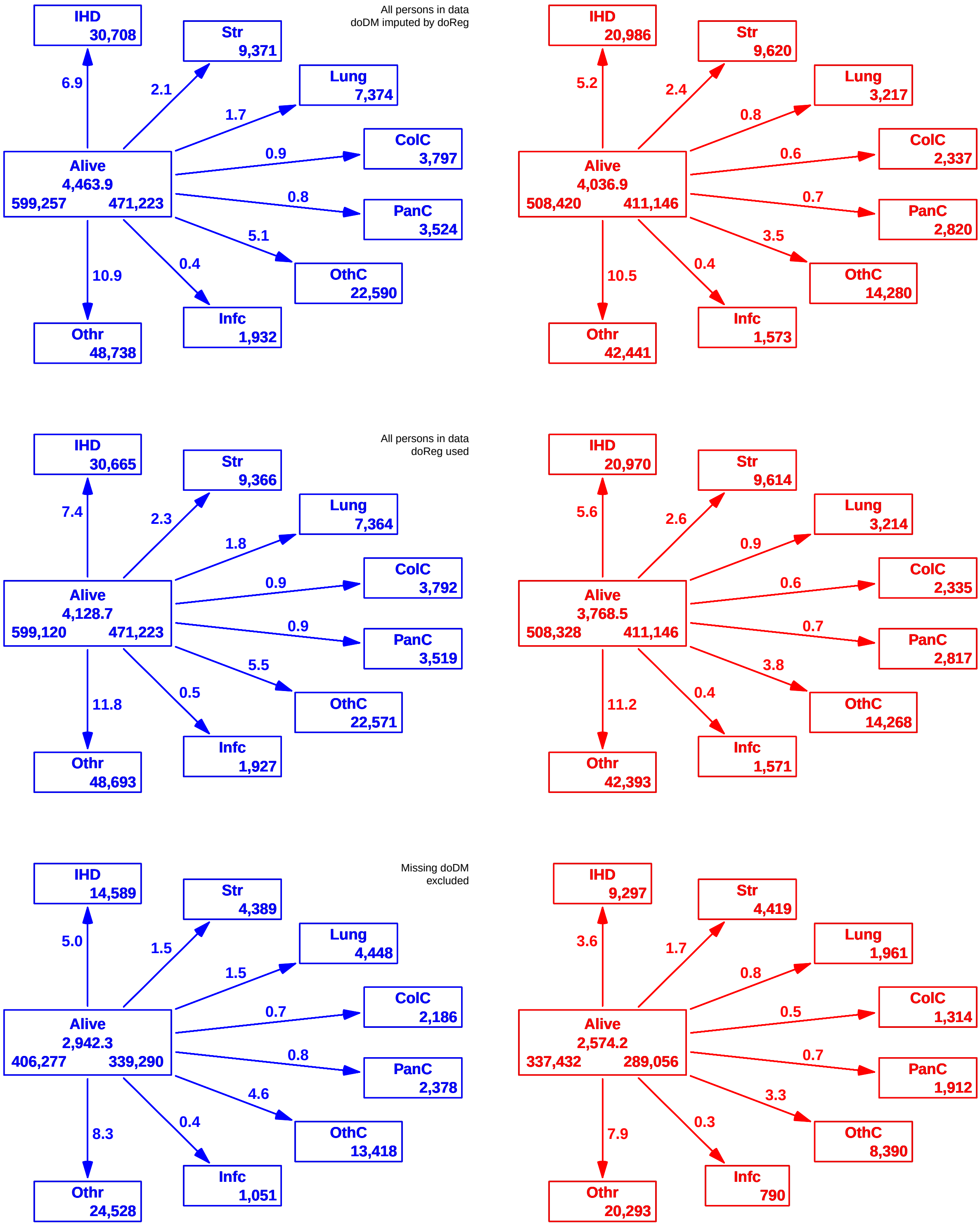

Figure 1.3: *The numbers in the "Alive" state are the total number of PY (in 1000) (middle), and number of persons starting, resp. ending follow up being alive (bottom left resp. right); the numbers on the arrows are the cause-specific mortality rates per 1000 PY, and the numbers in the cause of death boxes are the number of deaths. Data are for diabetic men (blue) and women (red) in Australia, using three different definitions of date of DM. The difference between the two upper sets of data comes from the fact that some dates of DM are* after *date of death, and this amount differs by definintion of the date of diabetes...* `./graph/data-LDboxes`

1.3 Table 1

Here we derive the numbers that goes table 1 for each of the three definitions of date of diabetes:

```
> library( Epi )
> load( file="../data/LDi.Rda" )
> load( file="../data/LDr.Rda" )
> load( file="../data/LDx.Rda" )
```

We wrap the desired tabulations in a function that computes all the relevant (*i.e.* potentially required) summaries from each of the Lexis objects.

```
> # Persons and deaths by CoD
> Ltab1 <-
+ function( Lx )
+ {
+ nl <- length(levels( Lx ))
+ mfs <- summary( Lx, by="sex" )
+ mf <- rbind( mfs[[1]][[1]], mfs[[2]][[1]] )[,c(1:nl,nl+2,nl+4)]
+ rownames( mf ) <- levels( Lx$sex )
+ mf <- addmargins( mf, 1 )
+ print( mf )
+ cat("\nRelative distribution of CoD (%):\n")
+ print( round(mf[,2:nl]/mf[,nl+1]*100,1) )
+ }
> # Summaries for different groupings, and overall summaries
> Ltab2 <-
+ function( Lx )
+ {
+ Ltab1( Lx )
+ cat("\nGrouped causes of death:\n")
+ Ltab1( Relevel(Lx,list(CVD=2:3,Can=4:7,Oth=8:9),f=F,p=F) )
+ # Age at doReg
+ aR <- with( Lx, rbind(
+           do.call( rbind, tapply( doReg-doBth, sex, quantile, 1:3/4 ) ),
+           quantile( doReg-doBth, 1:3/4 ) ) )
+ # Age at doDM
+ aD <- with( Lx, rbind(
+           do.call( rbind, tapply( doDM-doBth, sex, quantile, 1:3/4, na.rm=T ) ),
+           quantile( doDM-doBth, 1:3/4, na.rm=T ) ) )
+ # Age at imputed date doDM
+ aI <- with( Lx, rbind(
+           do.call( rbind, tapply( doDMi-doBth, sex, quantile, 1:3/4, na.rm=T ) ),
+           quantile( doDMi-doBth, 1:3/4, na.rm=T ) ) )
+ # Person-years
+ PY <-  with( Lx, rbind(
+           do.call( rbind, tapply( lex.dur, sex, quantile, 1:3/4, na.rm=T ) ),
+           quantile( lex.dur, 1:3/4, na.rm=T ) ) )
+ atab <- cbind( aD, aR, aI, PY )
+ colnames( atab )[1+0:3*3] <- paste( c("aDM","aReg","aImp","PY"),
+                                     colnames( atab )[1+0:3*3] )
+ rownames( atab )[3] <- "M+W"
+ cat("\nAge and PY distribution:\n")
+ print( round( atab, 1 ) )
+ wh <- levels( Lx )[-1]
+ print( wh )
```

```
                                              ...now input from tab1.tex
+ stab <-
+ stat.table( sex,
+             list( Persons = count(lex.id),
+                    Deaths =   sum(Dth),
+                     mRate = ratio(Dth,lex.dur,1000),
+                     medFU = quantile(lex.dur,2/4),
+                        Q1 = quantile(lex.dur,1/4),
+                        Q3 = quantile(lex.dur,3/4),
+                    medAge = quantile(doDMi-doBth,2/4),
+                        Q1 = quantile(doDMi-doBth,1/4),
+                        Q3 = quantile(doDMi-doBth,3/4) ),
+             margin=TRUE,
+             data = transform( Lx, Dth=lex.Xst %in% levels(lex.Xst)[-1] ) )
+ print( stab )
+ mm <- glm( lex.Xst %in% wh ~ sex-1,
+            offset = log(lex.dur/1000),
+            family = poisson,
+              data = Lx )
+ mt <- update( mm, . ~ 1 )
+ cat("\nOverall mortality rate per 1000 PY with 95% CI:\n")
+ print( round( rbind( ci.exp( mm ),
+                      ci.exp( mt ) ), 1 ) )
+ }
```

1.3.1 Only persons with valid date of DM

```
> Ltab2( LDx )
       Alive   IHD  Str Lung ColC PanC  OthC Infc  Othr  Events:  Persons:
Men   339290 14589 4389 4448 2186 2378 13418 1051 24528    66987    406277
Women 289056  9297 4419 1961 1314 1912  8390  790 20293    48376    337432
Sum   628346 23886 8808 6409 3500 4290 21808 1841 44821   115363    743709

Relative distribution of CoD (%):
       IHD Str Lung ColC PanC OthC Infc Othr
Men   21.8 6.6  6.6  3.3  3.5 20.0  1.6 36.6
Women 19.2 9.1  4.1  2.7  4.0 17.3  1.6 41.9
Sum   20.7 7.6  5.6  3.0  3.7 18.9  1.6 38.9

Grouped causes of death:
       Alive   CVD   Can   Oth  Events:  Persons:
Men   339290 18978 22430 25579    66987    406277
Women 289056 13716 13577 21083    48376    337432
Sum   628346 32694 36007 46662   115363    743709

Relative distribution of CoD (%):
       CVD  Can  Oth
Men   28.3 33.5 38.2
Women 28.4 28.1 43.6
Sum   28.3 31.2 40.4

Age and PY distribution:
      aDM 25%  50%  75% aReg 25%  50%  75% aImp 25%  50%  75% PY 25% 50%  75%
Men      49.4 58.2 67.0      51.0 59.7 68.6      49.4 58.2 67.0    3.3 6.9 11.0
Women    49.3 59.1 68.9      50.8 60.7 70.6      49.3 59.1 68.9    3.6 7.5 11.6
```

```
M+W      49.4 58.6 67.9      50.9 60.2 69.5      49.4 58.6 67.9     3.4 7.2 11.3
[1] "IHD"  "Str"  "Lung" "ColC" "PanC" "OthC" "Infc" "Othr"
 ---------------------------------------------------------------------------------
 sex      Persons     Deaths   mRate   medFU      Q1      Q3  medAge      Q1      Q3
 ---------------------------------------------------------------------------------
 Men       406277  66987.00   22.77    6.91    3.26   11.00   58.15   49.43   66.99
 Women     337432  48376.00   18.79    7.50    3.59   11.59   59.11   49.28   68.93

 Total     743709 115363.00   20.91    7.17    3.42   11.25   58.57   49.37   67.86
 ---------------------------------------------------------------------------------

Overall mortality rate per 1000 PY with 95% CI:
            exp(Est.) 2.5% 97.5%
sexMen           22.8 22.6  22.9
sexWomen         18.8 18.6  19.0
(Intercept)      20.9 20.8  21.0
```

1.3.2 Date of registration

```
> Ltab2( LDr )
       Alive   IHD   Str  Lung ColC PanC  OthC Infc  Othr  Events:  Persons:
Men   471223 30665  9366  7364 3792 3519 22571 1927 48693   127897    599120
Women 411146 20970  9614  3214 2335 2817 14268 1571 42393    97182    508328
Sum   882369 51635 18980 10578 6127 6336 36839 3498 91086   225079   1107448

Relative distribution of CoD (%):
       IHD Str Lung ColC PanC OthC Infc Othr
Men   24.0 7.3  5.8  3.0  2.8 17.6  1.5 38.1
Women 21.6 9.9  3.3  2.4  2.9 14.7  1.6 43.6
Sum   22.9 8.4  4.7  2.7  2.8 16.4  1.6 40.5

Grouped causes of death:
       Alive   CVD   Can   Oth  Events:  Persons:
Men   471223 40031 37246 50620   127897    599120
Women 411146 30584 22634 43964    97182    508328
Sum   882369 70615 59880 94584   225079   1107448

Relative distribution of CoD (%):
       CVD  Can  Oth
Men   31.3 29.1 39.6
Women 31.5 23.3 45.2
Sum   31.4 26.6 42.0

Age and PY distribution:
      aDM 25%  50%  75% aReg 25%  50%  75% aImp 25%  50%  75% PY 25% 50%  75%
Men      49.4 58.1 67.0      51.5 60.3 69.0      50.4 59.2 68.0     2.7 6.2 10.7
Women    49.3 59.1 68.9      51.1 61.2 71.0      50.0 60.1 70.0     3.1 7.0 11.6
M+W      49.4 58.6 67.9      51.3 60.7 69.9      50.2 59.6 68.9     2.9 6.6 11.1
[1] "IHD"  "Str"  "Lung" "ColC" "PanC" "OthC" "Infc" "Othr"
 ---------------------------------------------------------------------------------
 sex      Persons     Deaths   mRate   medFU      Q1      Q3  medAge      Q1      Q3
 ---------------------------------------------------------------------------------
 Men       599120 127897.00   30.98    6.24    2.70   10.66   59.23   50.38   68.00
 Women     508328  97182.00   25.79    6.99    3.07   11.59   60.14   49.98   69.96
```

```
 Total    1107448 225079.00    28.50     6.57     2.85    11.11    59.61    50.21    68.90
 ------------------------------------------------------------------------------------------

Overall mortality rate per 1000 PY with 95% CI:
            exp(Est.) 2.5% 97.5%
sexMen           31.0 30.8  31.1
sexWomen         25.8 25.6  26.0
(Intercept)      28.5 28.4  28.6
```

1.3.3 Date of DM imputed by date of registration

```
> Ltab2( LDi )
       Alive   IHD   Str  Lung ColC PanC  OthC Infc  Othr  Events:  Persons:
Men   471223 30708  9371  7374 3797 3524 22590 1932 48738   128034    599257
Women 411146 20986  9620  3217 2337 2820 14280 1573 42441    97274    508420
Sum   882369 51694 18991 10591 6134 6344 36870 3505 91179   225308   1107677

Relative distribution of CoD (%):
       IHD Str Lung ColC PanC OthC Infc Othr
Men   24.0 7.3  5.8  3.0  2.8 17.6  1.5 38.1
Women 21.6 9.9  3.3  2.4  2.9 14.7  1.6 43.6
Sum   22.9 8.4  4.7  2.7  2.8 16.4  1.6 40.5

Grouped causes of death:
       Alive   CVD   Can   Oth  Events:  Persons:
Men   471223 40079 37285 50670   128034    599257
Women 411146 30606 22654 44014    97274    508420
Sum   882369 70685 59939 94684   225308   1107677

Relative distribution of CoD (%):
       CVD  Can  Oth
Men   31.3 29.1 39.6
Women 31.5 23.3 45.2
Sum   31.4 26.6 42.0

Age and PY distribution:
      aDM 25%  50%  75% aReg 25%  50%  75% aImp 25%  50%  75% PY 25% 50%  75%
Men      49.4 58.2 67.0     51.5 60.3 69.0     50.4 59.2 68.0    3.1 6.8 11.8
Women    49.3 59.1 68.9     51.1 61.2 71.0     50.0 60.1 70.0    3.5 7.6 12.8
M+W      49.4 58.6 67.9     51.3 60.7 69.9     50.2 59.6 68.9    3.3 7.2 12.3
[1] "IHD"  "Str"  "Lung" "ColC" "PanC" "OthC" "Infc" "Othr"
 ------------------------------------------------------------------------------------------
 sex      Persons     Deaths   mRate    medFU       Q1       Q3  medAge       Q1       Q3
 ------------------------------------------------------------------------------------------
 Men       599257 128034.00    28.68     6.84     3.10    11.84    59.23    50.38    68.00
 Women     508420  97274.00    24.10     7.59     3.46    12.75    60.14    49.98    69.96

 Total    1107677 225308.00    26.50     7.17     3.25    12.25    59.61    50.21    68.90
 ------------------------------------------------------------------------------------------

Overall mortality rate per 1000 PY with 95% CI:
            exp(Est.) 2.5% 97.5%
sexMen           28.7 28.5  28.8
sexWomen         24.1 23.9  24.2
(Intercept)      26.5 26.4  26.6
```

... now input from `splitFU.tex`

1.4 Manageable data sets for analysis

We will set up aggregated data sets, where we classify the number of events and risk time in 200 age-classes (0–100 years by 6 months), some 40 duration classes (0–20 years by 6 months) and 30 calendar time classes (1997–2012 by 6 months), that is a total of $200 \times 40 \times 30 = 240,000$ cells. However not all of these are going to be populated by person-years (let alone deaths), but we shall further subdivide everything by social class and remoteness, another 20 possible levels, so a total table of some 5 mill cells.

First we load the Lexis object:

```
> library(    Epi )
> library( popEpi )
> clear()
> load( file="../data/LDx.Rda" )
> load( file="../data/LDr.Rda" )
> load( file="../data/LDi.Rda" )
> lls()
  name mode class             dim              size(Kb)
1 LDi  list Lexis data.frame 1107677 19      142,794.0
2 LDr  list Lexis data.frame 1107448 19      142,764.5
3 LDx  list Lexis data.frame 743709 19        95,876.3
```

We use the `splitMulti` function from `popEpi` to subdivide follow-up in 6-month intervals of age, calendar time and diabetes duration.

We pack it all in a function that returns the aggregated dataset for analysis:

```
> aggLx <-
+ function( LDi, n.chunks=20 )
+ {
+ lm <- round( seq(0,nrow(LDi),,n.chunks+1) )
+ lst <- Sys.time()
+ for( k in 1:n.chunks )
+    {
+ mL <- splitMulti( LDi[(lm[k]+1):lm[k+1],],
+                    list( age=seq(   0, 100,0.5),
+                          per=seq(1997,2012,0.5),
+                          dur=seq(   0,   20,0.5) ) )
+ mA <- aggre( mL,
+               by = c("sex","age","per","dur"),
+       sum.values = list(IHD = 1*(lex.Xst=="IHD"),
+                         Str  = 1*(lex.Xst=="Str"),
+                         Lung= 1*(lex.Xst=="Lung"),
+                         ColC= 1*(lex.Xst=="ColC"),
+                         PanC= 1*(lex.Xst=="PanC"),
+                         OthC= 1*(lex.Xst=="OthC"),
+                         Infc= 1*(lex.Xst=="Infc"),
+                         Othr= 1*(lex.Xst=="Othr") ) )
+ mA <- mA[,(grep("fromAlive",names(mA))):=NULL][,at.risk:=NULL]
+ if( k==1 )
+   {
+   Dgg <- mA
+   Dgg$Y <- Dgg$pyrs
+   Dgg$pyrs <- NULL
+   }
```

```
+ if( k>1  )
+   {
+ names(mA) <- tolower( names(mA) )
+ Dgg <- merge( Dgg, mA, by=c("sex","age","per","dur"), all=TRUE )
+ Dgg <- Dgg[, ':='(Y    = pmax(Y   ,0,na.rm=TRUE)+pmax(pyrs,0,na.rm=TRUE),
+                    IHD  = pmax(IHD ,0,na.rm=TRUE)+pmax(ihd ,0,na.rm=TRUE),
+                    Str  = pmax(Str ,0,na.rm=TRUE)+pmax(str ,0,na.rm=TRUE),
+                    Lung = pmax(Lung,0,na.rm=TRUE)+pmax(lung,0,na.rm=TRUE),
+                    ColC = pmax(ColC,0,na.rm=TRUE)+pmax(colc,0,na.rm=TRUE),
+                    PanC = pmax(PanC,0,na.rm=TRUE)+pmax(panc,0,na.rm=TRUE),
+                    OthC = pmax(OthC,0,na.rm=TRUE)+pmax(othc,0,na.rm=TRUE),
+                    Infc = pmax(Infc,0,na.rm=TRUE)+pmax(infc,0,na.rm=TRUE),
+                    Othr = pmax(Othr,0,na.rm=TRUE)+pmax(othr,0,na.rm=TRUE) )
+          ][, ':='(pyrs = NULL,
+                    ihd  = NULL,
+                    str  = NULL,
+                    lung = NULL,
+                    colc = NULL,
+                    panc = NULL,
+                    othc = NULL,
+                    infc = NULL,
+                    othr = NULL ) ]
+   }
+ cat( "Merged in chunk", k, "now",
+      formatC( nrow(Dgg),big.mark=",",format="f",width=10,digits=0), "rows, at",
+      format ( nxt<-Sys.time(),format="%Y-%m-%d %H:%M:%S" ), "took",
+      formatC( unclass(nxt-lst), format="f",width=6, digits=2), "sec.\n" )
+ lst <- nxt
+ flush.console()
+   }
+ Dgg[,':='(CVD = IHD+Str,
+           Can = Lung+ColC+PanC+OthC,
+           Oth = Infc+Othr)
+   ][,D:=CVD+Can+Oth]
+ }
> Agx <- aggLx( LDx ) ; save( Agx, file="../data/Agx.Rda")
Merged in chunk 1 now    212,934 rows, at 2017-10-05 20:40:01 took   8.43 sec.
Merged in chunk 2 now    245,133 rows, at 2017-10-05 20:40:09 took   7.97 sec.
Merged in chunk 3 now    265,155 rows, at 2017-10-05 20:40:17 took   7.82 sec.
Merged in chunk 4 now    276,691 rows, at 2017-10-05 20:40:25 took   7.69 sec.
Merged in chunk 5 now    284,249 rows, at 2017-10-05 20:40:32 took   7.66 sec.
Merged in chunk 6 now    290,769 rows, at 2017-10-05 20:40:40 took   7.66 sec.
Merged in chunk 7 now    296,782 rows, at 2017-10-05 20:40:48 took   7.69 sec.
Merged in chunk 8 now    301,935 rows, at 2017-10-05 20:40:55 took   7.72 sec.
Merged in chunk 9 now    306,036 rows, at 2017-10-05 20:41:03 took   7.72 sec.
Merged in chunk 10 now    310,251 rows, at 2017-10-05 20:41:11 took   7.76 sec.
Merged in chunk 11 now    313,620 rows, at 2017-10-05 20:41:19 took   7.87 sec.
Merged in chunk 12 now    317,069 rows, at 2017-10-05 20:41:27 took   7.77 sec.
Merged in chunk 13 now    319,867 rows, at 2017-10-05 20:41:34 took   7.81 sec.
Merged in chunk 14 now    322,342 rows, at 2017-10-05 20:41:42 took   7.78 sec.
Merged in chunk 15 now    324,406 rows, at 2017-10-05 20:41:50 took   7.78 sec.
Merged in chunk 16 now    326,554 rows, at 2017-10-05 20:41:58 took   7.79 sec.
Merged in chunk 17 now    329,933 rows, at 2017-10-05 20:42:05 took   7.56 sec.
Merged in chunk 18 now    337,124 rows, at 2017-10-05 20:42:12 took   7.10 sec.
Merged in chunk 19 now    344,593 rows, at 2017-10-05 20:42:20 took   7.51 sec.
Merged in chunk 20 now    348,603 rows, at 2017-10-05 20:42:27 took   7.45 sec.
```

```
> Agr <- aggLx( LDr ) ; save( Agr, file="../data/Agr.Rda")
```

```
Merged in chunk 1 now    227,447 rows, at 2017-10-05 20:42:39 took  10.83 sec.
Merged in chunk 2 now    248,588 rows, at 2017-10-05 20:42:50 took  10.94 sec.
Merged in chunk 3 now    261,553 rows, at 2017-10-05 20:43:01 took  10.81 sec.
Merged in chunk 4 now    270,201 rows, at 2017-10-05 20:43:11 took  10.87 sec.
Merged in chunk 5 now    277,119 rows, at 2017-10-05 20:43:22 took  10.86 sec.
Merged in chunk 6 now    282,407 rows, at 2017-10-05 20:43:33 took  10.89 sec.
Merged in chunk 7 now    285,942 rows, at 2017-10-05 20:43:44 took  11.10 sec.
Merged in chunk 8 now    289,845 rows, at 2017-10-05 20:43:55 took  10.94 sec.
Merged in chunk 9 now    293,285 rows, at 2017-10-05 20:44:06 took  10.91 sec.
Merged in chunk 10 now    296,301 rows, at 2017-10-05 20:44:17 took  10.92 sec.
Merged in chunk 11 now    298,155 rows, at 2017-10-05 20:44:28 took  10.91 sec.
Merged in chunk 12 now    299,901 rows, at 2017-10-05 20:44:39 took  11.02 sec.
Merged in chunk 13 now    301,721 rows, at 2017-10-05 20:44:50 took  10.80 sec.
Merged in chunk 14 now    303,283 rows, at 2017-10-05 20:45:01 took  10.87 sec.
Merged in chunk 15 now    304,677 rows, at 2017-10-05 20:45:12 took  10.93 sec.
Merged in chunk 16 now    305,768 rows, at 2017-10-05 20:45:22 took  10.81 sec.
Merged in chunk 17 now    306,722 rows, at 2017-10-05 20:45:32 took   9.51 sec.
Merged in chunk 18 now    308,542 rows, at 2017-10-05 20:45:42 took  10.03 sec.
Merged in chunk 19 now    309,132 rows, at 2017-10-05 20:45:52 took   9.74 sec.
Merged in chunk 20 now    309,781 rows, at 2017-10-05 20:46:02 took  10.09 sec.
```

```
> Agi <- aggLx( LDi ) ; save( Agi, file="../data/Agi.Rda")
```

```
Merged in chunk 1 now    251,719 rows, at 2017-10-05 20:46:14 took  11.31 sec.
Merged in chunk 2 now    279,986 rows, at 2017-10-05 20:46:25 took  11.41 sec.
Merged in chunk 3 now    298,272 rows, at 2017-10-05 20:46:37 took  11.34 sec.
Merged in chunk 4 now    308,862 rows, at 2017-10-05 20:46:48 took  11.36 sec.
Merged in chunk 5 now    317,706 rows, at 2017-10-05 20:46:59 took  11.26 sec.
Merged in chunk 6 now    324,916 rows, at 2017-10-05 20:47:10 took  11.29 sec.
Merged in chunk 7 now    330,262 rows, at 2017-10-05 20:47:22 took  11.38 sec.
Merged in chunk 8 now    335,285 rows, at 2017-10-05 20:47:33 took  11.30 sec.
Merged in chunk 9 now    339,787 rows, at 2017-10-05 20:47:44 took  11.18 sec.
Merged in chunk 10 now    343,758 rows, at 2017-10-05 20:47:56 took  11.69 sec.
Merged in chunk 11 now    346,912 rows, at 2017-10-05 20:48:08 took  11.75 sec.
Merged in chunk 12 now    349,838 rows, at 2017-10-05 20:48:19 took  11.57 sec.
Merged in chunk 13 now    352,493 rows, at 2017-10-05 20:48:31 took  11.59 sec.
Merged in chunk 14 now    354,528 rows, at 2017-10-05 20:48:43 took  11.79 sec.
Merged in chunk 15 now    356,768 rows, at 2017-10-05 20:48:54 took  11.42 sec.
Merged in chunk 16 now    359,082 rows, at 2017-10-05 20:49:06 took  11.43 sec.
Merged in chunk 17 now    361,406 rows, at 2017-10-05 20:49:15 took   9.81 sec.
Merged in chunk 18 now    366,037 rows, at 2017-10-05 20:49:26 took  10.59 sec.
Merged in chunk 19 now    368,220 rows, at 2017-10-05 20:49:36 took  10.44 sec.
Merged in chunk 20 now    369,785 rows, at 2017-10-05 20:49:47 took  10.50 sec.
```

Thus we have now three aggregated data sets for mortality analyses.

The primary outcome of interest is of course `(D,Y)`, where `D` is the total death count; but all the 11 causes of death will be analyzed; they are (as can be seen from the code above):

`IHD` Ischaemic heart disease

`Str` Stroke

`Lung` Lung cancer

`ColC` Colon cancer

`PanC` Pancreatic cancer

`OthC` Other cancers

`Infc` Infections

`Othr` Other causes

`CVD` All cardiovascular disease (`IHD`+`Str`)

`Can` All cancers (`Lung`+`ColC`+`PanC`+`OthC`)

`Oth` Other causes (`Infc`+`Othr`)

```
> options( width=90,
+          SweaveHooks=list( fig=function()
+          par(mar=c(3,3,1,1),mgp=c(3,1,0)/1.6,las=1,bty="n") ) )
```

```
> library( Epi )
> library( popEpi )
> clear()
> load( file="../data/Agx.Rda" )
> lls()
  name mode class                 dim             size(Kb)
1 Agx  list data.table data.frame 348603 17       44,941.5
> head( Agx )
   sex age    per dur IHD Str Lung ColC PanC OthC Infc Othr         Y CVD Can Oth D
1: Men   0 1997.0 0.0   0   0    0    0    0    0    0    0 0.3377823   0   0   0 0
2: Men   0 1997.0 4.5   0   0    0    0    0    0    0    0 0.0119781   0   0   0 0
3: Men   0 1997.5 0.0   0   0    0    0    0    0    0    0 0.4332649   0   0   0 0
4: Men   0 1997.5 4.5   0   0    0    0    0    0    0    0 0.3336756   0   0   0 0
5: Men   0 1997.5 5.0   0   0    0    0    0    0    0    0 0.1543463   0   0   0 0
6: Men   0 1998.0 0.0   0   0    0    0    0    0    0    0 0.5390144   0   0   0 0
```

The dataset is basically a tabulation of the person-years (among diabetes patients) and number of deaths in 11 groups (`D` is the toal number of deaths,). Each record represents a sex× age× calendar time× DM duration entry in the table. Intervals for age, calendar time and DM duration are 6 months (0.5 year) wide, and they are coded by the left point of the interval for the interval, but we need them coded by the midpoint; for example:

```
> Agx <- Agx[,':='( age = age+0.25,
+                   per = per+0.25,
+                   dur = dur+0.25 )]
> Agx[D==9,][1:2,]
   sex   age     per  dur IHD Str Lung ColC PanC OthC Infc Othr        Y CVD Can Oth D
1: Men 76.25 2007.75 6.75   2   0    0    1    1    1    0    4 53.22690   2   3   4 9
2: Men 78.25 2008.25 9.75   3   1    1    0    0    2    0    2 52.44901   4   3   2 9
```

The latter shows that in the last half of 2007 there were 9 deaths among diabetic men in age 76.25 (*i.e.* between 76.0 amd 76.5 years) with diabetes duration 6.75 years (*i.e.* between 6.5 and 7.0 years). For analysis purposes we will treat the midpoints as quantitative predictors of mortality. Age at diagnosis will be determined by subtraction of duration from current age, so the persons referred to will have a mean age at diagnosis of 69.5 years.

A quick overview of the total number of person-years and deaths, by sex and year of death is (after a bit of formatting):

...now input from acMrates.tex

```
> fC <- function( x, w=11, d=1 ) formatC( x, format="f", big.mark=",", width=w, digits=d )
> ttt <- fC( tt <- addmargins( xtabs( cbind( D, Y ) ~
+                                     sex + floor(per),
+                                     data = Agx ),
+                             1:2 ), w=12 )
> tt0 <- fC( tt, d=0, w=12 )
> ttt[,,1] <- tt0[,,1]
> ftable( ttt, row.vars=2 )
```

sex	Men		Women		Sum	
	D	Y	D	Y	D	
floor(per)						
1997	258	50,312.3	178	44,254.9	436	94,567.
1998	802	70,318.2	530	63,320.3	1,332	133,638.
1999	1,401	91,747.4	868	82,706.9	2,269	174,454.
2000	1,979	113,233.0	1,359	101,252.4	3,338	214,485.
2001	2,606	134,606.8	1,845	119,416.4	4,451	254,023.
2002	3,299	156,572.2	2,249	138,231.4	5,548	294,803.
2003	3,813	176,574.2	2,744	156,150.9	6,557	332,725.
2004	4,488	194,710.0	3,089	172,182.6	7,577	366,892.
2005	4,888	211,822.2	3,368	187,005.8	8,256	398,828.
2006	5,182	227,743.8	3,788	200,149.6	8,970	427,893.
2007	5,824	244,941.5	4,101	214,112.0	9,925	459,053.
2008	6,418	266,543.7	4,677	231,121.1	11,095	497,664.
2009	6,783	285,694.0	4,943	246,317.8	11,726	532,011.
2010	7,063	301,085.8	5,241	257,939.2	12,304	559,025.
2011	7,167	319,635.3	5,134	271,923.3	12,301	591,558.
Sum	61,971	2,845,540.4	44,114	2,486,084.6	106,085	5,331,625.

These numbers differ slightly from those in the table 1 chapter, because these are restricted to follow-up with less than 20 years duration in ages under 100 years.

1.5 All-cause mortality

Note the we do not have any specific variable for age at diagnosis, but this is created on the fly in the modeling as `age-dur`.

We will model the effects of age and diabetes duration by smooth splines; calendar time (`per`) is only included as a linear effect, that is with a fixed annual in- or de-crease.

But first we need to specify the knots for age and duration; in order to accommodate the possible non-linearity of mortality in younger ages we put in a knot at age 30 years, and one at duration 0:

```
> ( a.kn <- with( subset(Agx,D>0), c(30,quantile( rep(age    ,D), (1:7-0.5)/7 ))) )
          7.142857% 21.42857% 35.71429%       50% 64.28571% 78.57143% 92.85714%
    30.00     56.75     66.75     72.75     77.25     81.25     84.75     90.25
> ( d.kn <- with( subset(Agx,D>0), c( 0,quantile( rep(    dur,D), (1:5-0.5)/5 ))) )
         10%   30%   50%   70%   90%
 0.00  0.75  3.25  5.75  9.25 13.75
> ( e.kn <- with( subset(Agx,D>0),      quantile( rep(age-dur,D), (1:5-0.5)/5 ) ) )
 10%  30%  50%  70%  90%
53.0 63.5 70.0 76.0 83.0
```

Once these are in place, we can fit models with current age and duration of diabetes. The particular paranetrization of the model is immaterial at this point; we shall only use the model for prediction of mortality rates:

```
> mM <- glm( D ~ Ns(age     ,knots=a.kn) +
+                Ns(     dur,knots=d.kn) +
+                Ns(age-dur,knots=e.kn) +
+                I(per-2005),
+            offset = log(Y),
+            family = poisson,
+              data = subset(Agx,sex=="Men") )
> mW <- update( mM, data=subset(Agx,sex=="Women") )
> round( ci.exp(mM,subset="per"), 3 )
               exp(Est.)  2.5% 97.5%
I(per - 2005)      1.004 1.002 1.007
> round( ci.exp(mW,subset="per"), 3 )
               exp(Est.)  2.5% 97.5%
I(per - 2005)      1.008 1.006 1.011
```

We see that the annual change in all-cause mortality rates is 0.4 pct. (0.7;0.2) for men and 0.8 pct. (1.1;0.6) for women.

The models are over-parametrized (the last parameter of the `age-dur` term is 1.000), but this has no impact on the predictions obtained; they will be the same regardless of the chosen parametriation. We can now make predictions of the mortality by specifying a prediction data frame, using a duration range of 20 years:

```
> d.pt <- 0:200/10
> nd <- data.frame( age = 50+d.pt,
+                   per = 2010,
+                   dur = d.pt,
+                     Y = 1000 )
> prm <- NULL
> for( aa in seq(40,70,5) )
+    {
+    nd$age <- aa+d.pt
+    prm <- rbind( prm, NA, cbind( age = nd$age, adx = aa,
+                                  ci.pred( mM, newdata=nd ),
+                                  ci.pred( mW, newdata=nd ) ) )
+    }
> head( prm[-1,] )
   age adx Estimate     2.5%    97.5% Estimate     2.5%    97.5%
1 40.0  40 3.892017 3.615028 4.190229 2.401915 2.196441 2.626610
2 40.1  40 3.866724 3.603631 4.149025 2.380346 2.185723 2.592300
3 40.2  40 3.841752 3.591064 4.109941 2.359188 2.174247 2.559860
4 40.3  40 3.817226 3.577278 4.073269 2.338650 2.162090 2.529629
5 40.4  40 3.793268 3.562316 4.039193 2.318937 2.149394 2.501854
6 40.5  40 3.769996 3.546329 4.007770 2.300246 2.136379 2.476681
> save( prm, file="../data/allx-prm.Rda" )
```

Here the variable `age` is the age at prediction, and `adx` is the age at diagnosis of diabetes. The two sets of columns are mortality rates for men and women, respectively.

Thus for each distinct value of `adx` we have a predicted age-specific mortality curve for men and women respectively.

```
> load( file="../data/allx-prm.Rda" )
> clr <- c("blue","red")
> plt <- function(){
+ par( mar=c(3,3,1,1), mgp=c(3,1,0)/1.6, las=1, bty="n")
+ matplot( prm[,1], prm[,-(1:2)],
+           type="l", lty=c(1,3,3), lwd=c(3,1,1), col=rep(clr,each=3),
+           log="y", xlab="Age at follow-up", xlim = c(40,85), ylim=c(1,200),
+           ylab="All cause mortality rate per 1000 PY" )
+ abline( v=seq(40,70,5), col=gray(0.8) )
+ axis( side=2, at=c(outer(c(1,1.5,2:10,12,15),0:1,function(x,y)x*10^y)), labels=NA, tcl=-0
+ axis( side=1, at=seq(40,85,5), labels=NA, tcl=-0.3 )
+ text( rep(41,2), c(150,120), c("Men","Women"), col=clr, adj=c(0,1) )
+     }
> plt()
```

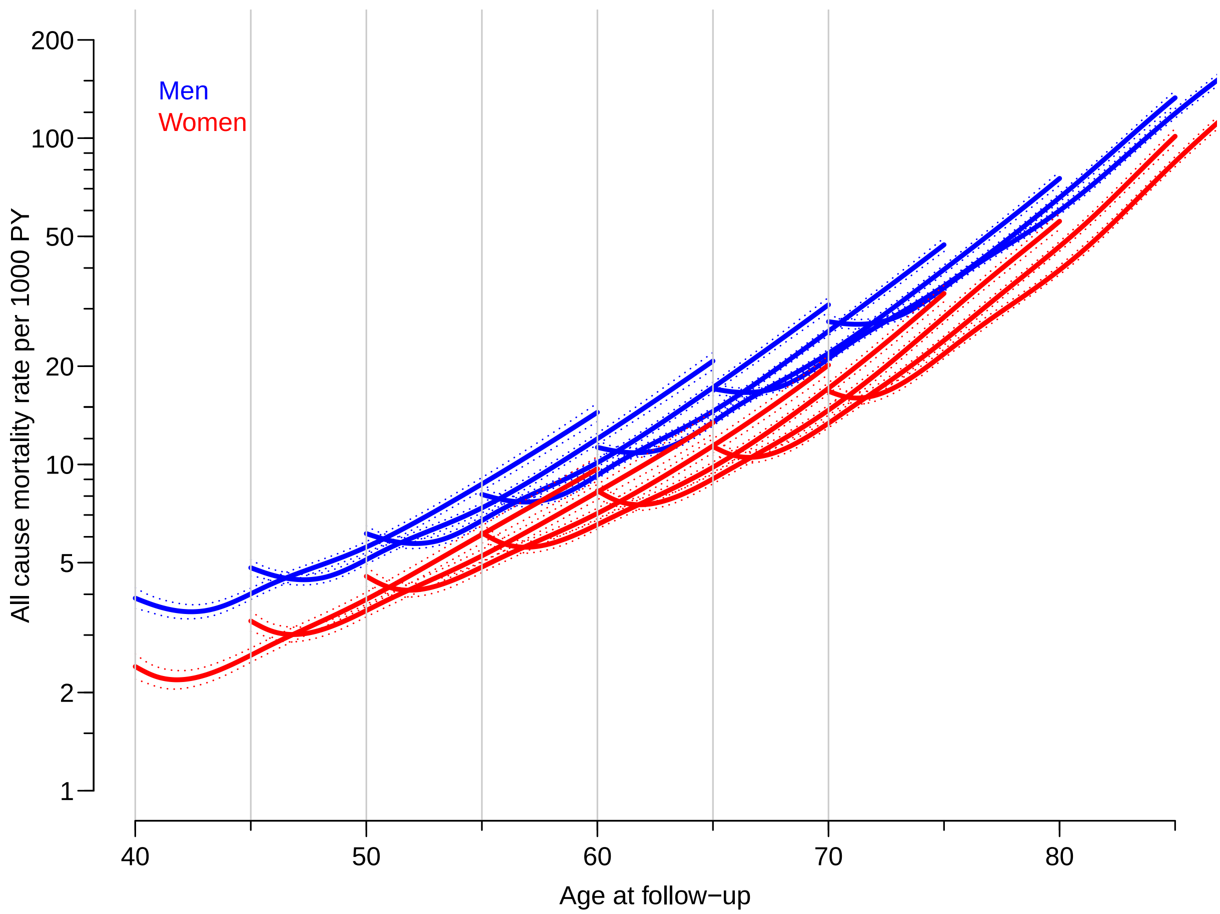

Figure 1.4: *Predicted mortality as a function of current age, for persons with diabetes diagnosed at ages 40, 45, 50, . . . , (curves starting at each if these ages).*
Estimates are from a model with non-linear effects of current age, diabetes duration, and age at diagnosis as well as a linear effect of calendar time. Duration of diabetes range from 0 to 20 years, as the 99% quantile of diabetes duration at death is 20 years. Estimates are for calendar time 1.1.2010. `../graph/acMx-prm`

1.5.1 Rate ratios

We also want to compare the mortality rates between persons diagnosed in different ages, in the first instance between men aged 50 and 60 at diagnosis, during the age-span 60 through 70 (that is to the age where the 50-year old person reached 20 years of duration), say. The reason for this age-span is that the comparisons only make sense in the population where there is information on the effect of duration on mortality, as seen above.

In order to fish out the RR between persons we need the relevant contrast matrices for the three effects, comparing persons diagnosed in age a_1 with persons diagnosed age a_0 (assuming $a_1 < a_0$), in ages from a_0 through $a_1 + 20$.

In order to get some flexibility we wrap this in a function that returns the RR between both men and women together with the ages at which we have the comparison. Here `a1` and `a0` are the ages at diagnosis, and `drg` is the maximal duration of diabete we will consider:

```
> RR <-
+ function( a1, a0, drg=20 )
+ {
+ if( a0<a1 ) stop("a1 must be smaller that a0")
+ cc <- seq(0,drg-(a0-a1),,100)
+ lc <- length(cc)
+ D1 <- Ns((a0-a1)+cc,knots=d.kn)
+ D0 <- Ns(        cc,knots=d.kn)
+ E1 <- Ns(rep(a1,lc),knots=e.kn)
+ E0 <- Ns(rep(a0,lc),knots=e.kn)
+ ci.exp( mM, subset="dur" )
+ RRM <- ci.exp( mM, subset="dur", ctr.mat=cbind(D1-D0,E1-E0) )
+ RRW <- ci.exp( mW, subset="dur", ctr.mat=cbind(D1-D0,E1-E0) )
+ cbind( age=a0+cc, RRM, RRW )
+ }
```

We can now compare persons diagnosed at ages a given time apart but in different ages; that is persons aged 50 and 60, persons aged 55 and 65, etc. We do this both for a difference in age at dignosis of 5 and 10 years:

```
> plt <- function(){
+ par( mfrow=c(1,2), oma=c(0,2,0,0), mar=c(3,1,1,1) )
+ for( ddif in c(5,10) )
+    {
+ plot( NA, xlim=c(50,85), ylim=c(0.5,2.0), log="y",
+           xlab="Age at follow-up", ylab="", xaxt="n" )
+ abline(h=5:17/10,col=gray(0.8))
+ abline(h=1)
+ axis( side=1, at=seq(50,80,10) )
+ axis( side=1, at=seq(50,85,5), labels=NA, tcl=-0.3 )
+ axis( side=2, at=5:20/10, labels=NA, tcl=-0.3 )
+ for( a0 in seq(50,75,5) )
+    {
+    rr <- RR( a0-ddif, a0 )
+    matlines( rr[,1], rr[,-1],
+              type="l", lty=c(1,3,3),
+              lwd=c(3,1,1), col=rep(c("blue","red"),3) )
+    }
+ abline( v=ahi<-5:7*10, col=gray(0.8) )
+ text( 50, 1.95, paste( "Age at diagnosis", ddif, "years apart:" ), adj=0 )
+ text( ahi, rep(1.8,3), paste(ahi-ddif,"vs.",ahi), adj=0 )
+    }
```

```
+ mtext( "All cause mortality RR", side=2,
+        outer=TRUE, las=0, line=1 )
+ }
> plt()
```

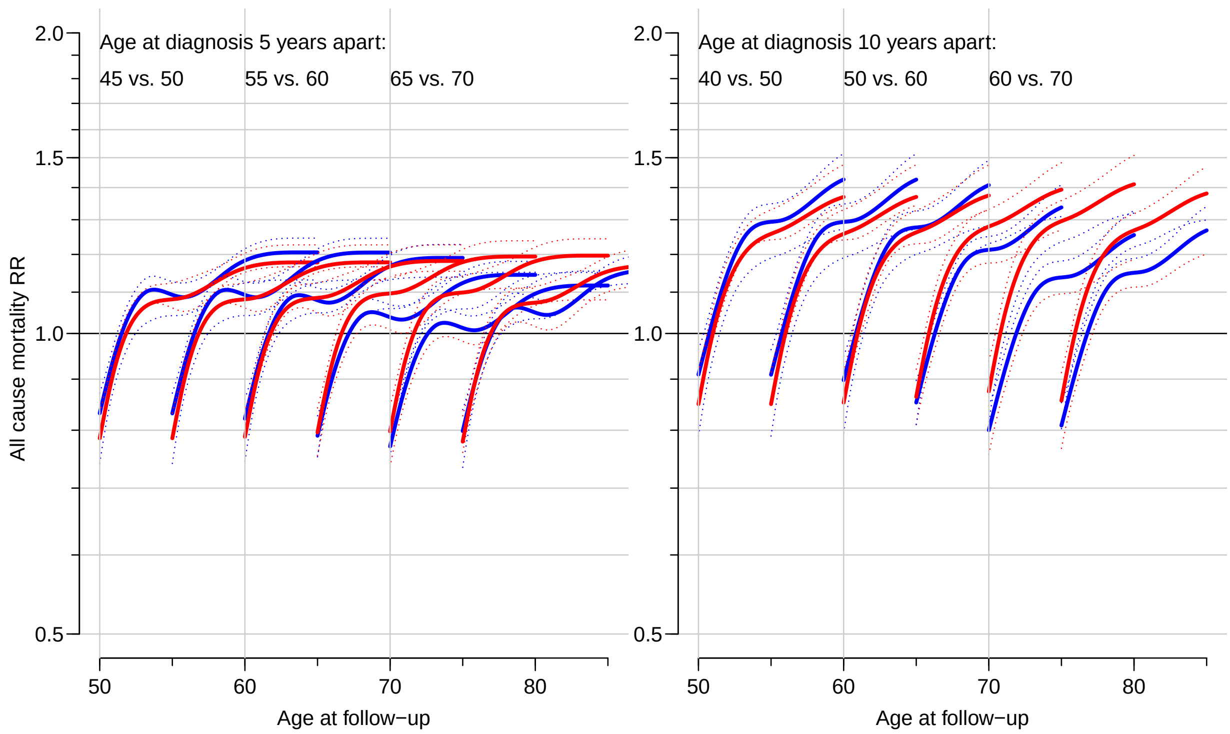

Figure 1.5: *All cause mortality RR of persons diagnosed in different ages, followed from the older age at diagnosis. These are mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel).* `../graph/acMx-RReqd`

From figure 5.24 we see that with the exception of the first 2 years after diagnosis, 5 years extra duration incurs an approximately 20% higher mortality rate; 10 years longer duration of diabetes incurs approximately 40% higher mortality rate; albeit slightly increasing by age at follow-up. Moreover these effects are declining by age at diagnosis for men, but not for women — if there were no effect of age at diagnosis, the 6 sets of curves in each panel would be identical except for a horizontal offset.

The curves in figure 5.24 are constructed as the *ratio* between curves starting 5, resp. 10 years apart.

1.5.2 Years difference

The rate-ratios attributable to 5 resp. 10 years difference in diabetes duration can be transformed into the extra aging required to produce the corresponding increase in mortality.

Or put differently, the rate-ratios in figure 5.24 are vertical distances between curves in figure 1.4, whereas the ageing effect of 5 or 10 years of duration is going to be the *horizontal* differences between pairs of curves. We will show these as a function of the age of the person diagnoses *youngest*, interpreting it as "this person now aged a diagnosed in age a_D has a mortality of a person aged $a + d$ diagnosed in age $a_D + 5$", say. So an age-disadvatage of d for 5 years duration of diabetes. As before this will be an effect reflecting the difference in duration in diabetes (we shall use 5 and 10 years), and we can show how this effect depends on the age at diagnosis to see the influence of this variable.

```
> load( file="../data/allx-prm.Rda" )
> # Difference in age at diagnosis
> Ddif <- 10
> # Range of duration for the oldest in the comparison
> # not stretching the duration of the youger beyond 20
> Drng <- 20 - Ddif
> # Data frame to collect results
> Ad10 <- NULL
> Aold <- seq(50,70,5)
> for( ai in Aold )
+    {
+ # where are the rates in ages 0 to 10 years after dx
+ WH <- ( prm[,"age"]>=ai & prm[,"age"]<=(ai+Drng) & prm[,"adx"]==ai )
+ AA <- prm[WH,1]
+ RM <- prm[WH,3]
+ RW <- prm[WH,6]
+ # Where are the rates in ages 10 to 20 years after (same ages) for those dx 10 years youn
+ wh <- ( prm[,"age"]>=ai & prm[,"age"]<=(ai+Drng) & prm[,"adx"]==(ai-Ddif) )
+ rm <- prm[wh,3]
+ rw <- prm[wh,6]
+ # Find the ages among those diagnosed oldest corresonding to the same
+ # mortality as the youngest diagnosed - thus the ageing penalty by 10
+ # years earlier diagnosis
+ am <- approx( x=RM, y=AA, xout=rm )$y
+ aw <- approx( x=RW, y=AA, xout=rw )$y
+ zz <- data.frame( age = AA,      # age of FU for both person
+                   ado = ai,      # adx for oldest  (earliest diagnosed)
+                   ady = ai-Ddif, # adx for youngest  (latest diagnosed)
+                   am, aw,        # age that the it takes younger
+                                  # diagnosed to have the same
+                                  # mortality as an AA year old
+                                  # diagnosed older
+                    dm = am - AA,
+                    dw = aw - AA )
+ ok <- !is.na(zz[,"am"]) & !is.na(zz[,"aw"])
+ zz <- zz[ok,]
+ Ad10 <- rbind( Ad10, NA, zz )
+ }
> str( Ad10 )
'data.frame':       308 obs. of  7 variables:
 $ age: num  NA 50.6 50.7 50.8 50.9 51 51.1 51.2 51.3 51.4 ...
 $ ado: num  NA 50 50 50 50 50 50 50 50 50 ...
 $ ady: num  NA 40 40 40 40 40 40 40 40 40 ...
 $ am : num  NA 51.6 52.3 52 52.4 ...
 $ aw : num  NA 52.3 52.2 52 51.2 ...
 $ dm : num  NA 1.04 1.61 1.22 1.51 ...
 $ dw : num  NA 1.694 1.515 1.186 0.262 ...
> head( Ad10 )
    age ado ady       am       aw         dm         dw
1    NA  NA  NA       NA       NA         NA         NA
```

```
10 50.6  50  40 51.64407 52.29377  1.0440721 1.6937740
11 50.7  50  40 52.31299 52.21530  1.6129909 1.5152958
12 50.8  50  40 52.02064 51.98553  1.2206387 1.1855254
13 50.9  50  40 52.41008 51.16233  1.5100783 0.2623332
14 51.0  50  40 50.11928 51.56449 -0.8807248 0.5644865
```

```
> Ddif <- 5
> # Range of duration for the oldest in the comparison
> # not stretching the duration of the youger beyond 20
> Drng <- 20 - Ddif
> # Data frame to collect results
> Ad05 <- NULL
> Aold <- seq(50,70,5)
> for( ai in Aold )
+    {
+ # where are the rates in ages 0 to 10 years after dx
+ WH <- ( prm[,"age"]>=ai & prm[,"age"]<=(ai+Drng) & prm[,"adx"]==ai )
+ AA <- prm[WH,1]
+ RM <- prm[WH,3]
+ RW <- prm[WH,6]
+ # Where are the rates in ages 10 to 20 years after (same ages) for those dx 10 years youn
+ wh <- ( prm[,"age"]>=ai & prm[,"age"]<=(ai+Drng) & prm[,"adx"]==(ai-Ddif) )
+ rm <- prm[wh,3]
+ rw <- prm[wh,6]
+ # Find the ages among those diagnosed oldest corresonding to the same
+ # mortality as the youngest diagnosed - thus the ageing penalty by 10
+ # years earlier diagnosis
+ am <- approx( x=RM, y=AA, xout=rm )$y
+ aw <- approx( x=RW, y=AA, xout=rw )$y
+ zz <- data.frame( age = AA,      # age of FU for both person
+                   ado = ai,      # adx for oldest  (earliest diagnosed)
+                   ady = ai-Ddif, # adx for youngest  (latest diagnosed)
+                   am, aw,        # age that the it takes younger
+                                  # diagnosed to have the same
+                                  # mortality as an AA year old
+                                  # diagnosed older
+                    dm = am - AA,
+                    dw = aw - AA )
+ ok <- !is.na(zz[,"am"]) & !is.na(zz[,"aw"])
+ zz <- zz[ok,]
+ Ad05 <- rbind( Ad05, NA, zz )
+ }
> str( Ad05 )
```

```
'data.frame':        586 obs. of  7 variables:
 $ age: num  NA 51.8 51.9 52 52.1 52.2 52.3 52.4 52.5 52.6 ...
 $ ado: num  NA 50 50 50 50 50 50 50 50 50 ...
 $ ady: num  NA 45 45 45 45 45 45 45 45 45 ...
 $ am : num  NA 52.5 52.7 51.5 50.3 ...
 $ aw : num  NA 51.6 52.3 51.1 52.7 ...
 $ dm : num  NA 0.68 0.804 -0.452 -1.812 ...
 $ dw : num  NA -0.193 0.383 -0.895 0.571 ...
```

```
> head( Ad05 )
```

```
    age ado ady       am       aw         dm         dw
1    NA  NA  NA       NA       NA         NA         NA
22 51.8  50  45 52.47952 51.60671  0.6795190 -0.1932861
```

```
23 51.9  50  45 52.70414 52.28299  0.8041401  0.3829864
24 52.0  50  45 51.54826 51.10490 -0.4517364 -0.8950968
25 52.1  50  45 50.28769 52.67122 -1.8123098  0.5712243
26 52.2  50  45 52.78496 53.14247  0.5849648  0.9424686
```

The object `Ad05` now contains the age difference corresponding to a 5 year difference in age at diagnosis between persons diagnosed in ages `ady` and `ado`, evaluated at age of follow-up `age`:

```
> par( mfrow=c(1,2), oma=c(0,2,0,0), mar=c(3,1,1,1) )#, mgp=c(3,1,0)/1.6, las=1, bty=0 )
> # 5 years
> Ddif <- 5
> sb <- with( Ad05, age-ado > 3 )
> matplot( Ad05[sb,"age"], Ad05[sb,c("dm","dw")],
+          type="l", lty=1, lwd=4, col=c("blue","red"),
+          ylim=c(0,4.0), xlim=c(53,83), yaxs="i", xlab="Age at follow-up",
+          ylab="" )
> jj <- match( 57, Ad05$age )
> points( Ad05[jj,"age"], Ad05[jj,"dm"], pch=16, col="white" )
> points( Ad05[jj,"age"], Ad05[jj,"dm"], pch=1, lwd=3, col="blue" )
> segments( c(45,Ad05[jj,"age"]),
+           rep(Ad05[jj,"dm"],2),
+           rep(Ad05[jj,"age"],2),
+           c(Ad05[jj,"dm"],0), col="blue", lty=3 )
> axis( side=2, at=seq(0,4,0.5), labels=NA, tcl=-0.3 )
> axis( side=2, at=Ad05[jj,"dm"], labels=round(Ad05[jj,"dm"],1), col.axis="blue" )
> axis( side=1, at=Ad05[jj,"age"], labels=round(Ad05[jj,"age"],1), col.axis="blue" )
> axis( side=1, at=53:83, tcl=-0.3, labels=NA )
> text( (Aold+3)[c(1,3,5)], 3.9,
+       paste( (Aold-Ddif)[c(1,3,5)], "vs.", Aold[c(1,3,5)] ), adj=0 )
> abline( v=Aold+3, col=gray(0.8) )
> # 10 years
> Ddif <- 10
> sb <- with( Ad10, age-ado > 3 )
> matplot( Ad10[sb,"age"], Ad10[sb,c("dm","dw")],
+          type="l", lty=1, lwd=4, col=c("blue","red"),
+          ylim=c(0,4.0), xlim=c(53,83), yaxs="i", xlab="Age at follow-up",
+          ylab="" )
> points( Ad10[jj,"age"], Ad10[jj,"dm"], pch=16, col="white" )
> points( Ad10[jj,"age"], Ad10[jj,"dm"], pch=1, lwd=3, col="blue" )
> segments( c(45,Ad10[jj,"age"]),
+            rep(Ad10[jj,"dm"],2),
+            rep(Ad10[jj,"age"],2),
+              c(Ad10[jj,"dm"],0), col="blue", lty=3 )
> axis( side=2, at=seq(0,4,0.5), labels=NA, tcl=-0.3 )
> axis( side=2, at=Ad10[jj,"dm"], labels=round(Ad10[jj,"dm"],1), col.axis="blue" )
> axis( side=1, at=Ad10[jj,"age"], labels=round(Ad10[jj,"age"],1), col.axis="blue" )
> axis( side=1, at=53:83, tcl=-0.3, labels=NA )
> text( (Aold+3)[c(1,3,5)], 3.9,
+       paste( (Aold-Ddif)[c(1,3,5)], "vs.", Aold[c(1,3,5)] ), adj=0 )
> abline( v=Aold+3, col=gray(0.8) )
> mtext( "Extra aging from 5/10 years longer DM duration (all-cause mortality)", side=2,
+       outer=TRUE, las=0, line=1 )
```

Thus, broadly speaking, for all-cause mortality we see that in terms of mortality for women, a 10 years extra DM duration translates into an extra aging of about 2–2.5 years, whereas 5 years longer translate to about 1.5 years ageing. For men this is only true for

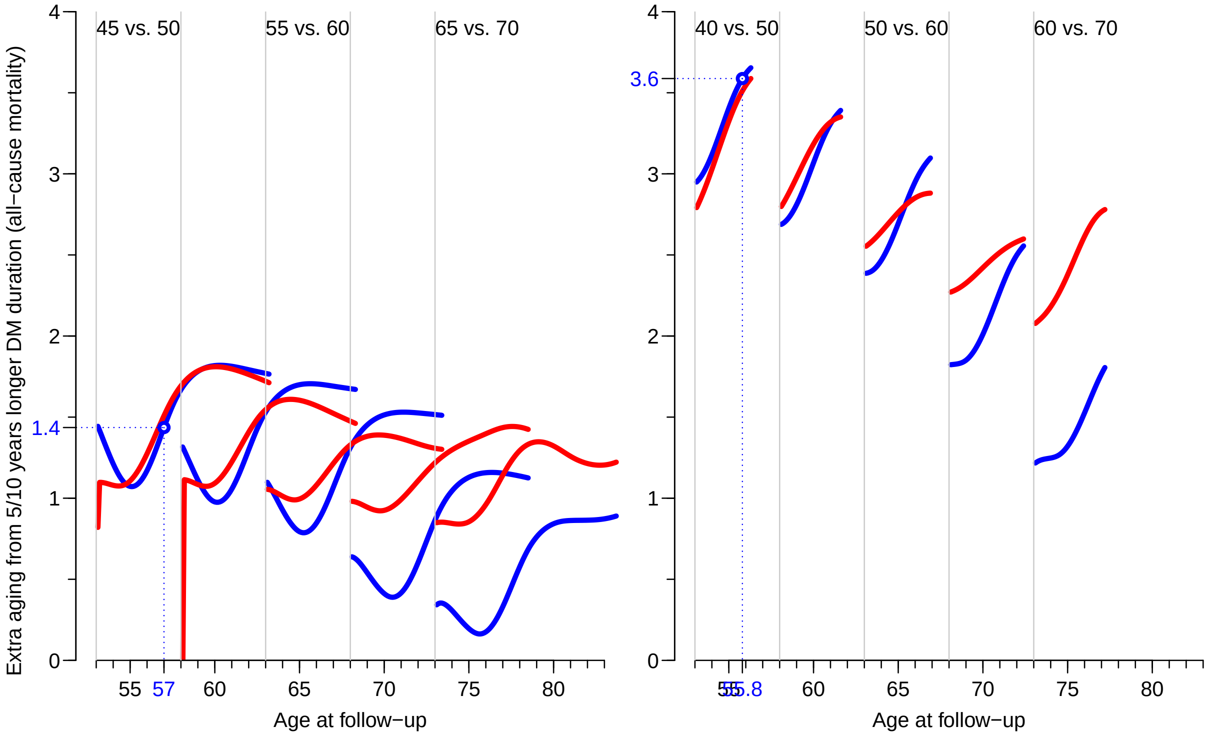

Figure 1.6: *The age-difference to attain the same mortality with 5, resp. 10 years of difference in duration of DM. Specifically for the point indicated: A man diagnosed at age 40 will at age 55.8 have a mortality as that of a man diagnosed at age 50 has in age 55.8 + 3.6 = 59.4.* `../graph/acMx-age-dif`

. . . now input from `Mrates.tex`

fairly young ages at diagnosis (< 50), whereas the ageing effect of longer duration attenuates with older age at diagnosis so that the effect of 5 years of duration is about 0.5 years for those dignosed in their 60es, where the effect of 10 years of duration about 1.5 years of ageing.

```
> options( width=90,
+          SweaveHooks=list( fig=function()
+          par(mar=c(3,3,1,1),mgp=c(3,1,0)/1.6,las=1,bty="n") ) )
```

Chapter 2

A function for analysis of causes of death

In order to produce the relevant graphs and figures for all different causes of death we pack the above analyses for all cause mortality into a function that will allow us to produce the graphs for a given data set and for a given cause of death.

```
> cod <-
+ function( dfr, # data frame
+           suf, # suffix for filename
+         cause, # cause of death (CoD) - character
+          ctxt, # text for CoD
+          Rmin = 1.0,  # minimum point for the mortality scale
+         RRmin = 0.5 ) # minimum point for the RR scale
+ {
+ rm( DTb )
+ # create the dataframe to use
+ DTb <- dfr
+ # rename so we can use (D,Y) as outcome
+ DTb$D <- DTb[,..cause]
+ # Convenience function for pring large numbers readable
+ fC <- function( x, w=11, d=1 ) formatC( x, format="f", big.mark=",", width=w, digits=d )
+ # Overview of deaths and PY by sex and year
+ tt <- addmargins( xtabs( cbind( D, Y ) ~
+                          sex + floor(per),
+                          data = DTb ),
+                   1:2 )
+ names( dimnames(tt) )[2] <- "Year"
+ ttt <- fC( tt, w=11 )
+ tt0 <- fC( tt, d=0, w=11 )
+ ttt[,,1] <- tt0[,,1]
+ cat( "\nAnalysis of", cause, ctxt,":\n" )
+ print( ftable( ttt, row.vars=2 ) )
+
+ # Knots for splines
+ ( a.kn <- with( subset(DTb,D>0), c(30,quantile( rep(age    ,D), (1:7-0.5)/7 ))) )
+ ( d.kn <- with( subset(DTb,D>0), c( 0,quantile( rep(    dur,D), (1:5-0.5)/5 ))) )
+ ( e.kn <- with( subset(DTb,D>0),      quantile( rep(age-dur,D), (1:5-0.5)/5 ) ) )
+
+ # Analysis of rates
+ mM <- glm( D ~ Ns(age    ,knots=a.kn) +
+                Ns(    dur,knots=d.kn) +
```

```
+                 Ns(age-dur,knots=e.kn) +
+                 I(per-2005),
+             offset = log(Y),
+             family = poisson,
+               data = subset(DTb,sex=="Men") )
+ mW <- update( mM, data=subset(DTb,sex=="Women") )
+
+ cat( "\nAnnual change in rates:\n")
+ achg <- rbind( ci.exp(mM,subset="per"),
+                 ci.exp(mW,subset="per") )
+ rownames( achg ) <- c("Men","Women")
+ print( round( achg, 3 ) )
+
+ # Prediction data frame
+ d.pt <- 0:200/10
+ nd <- data.frame( age = 50+d.pt,
+                    per = 2010,
+                    dur = d.pt,
+                      Y = 1000 )
+ # Predicted mortality rates
+ prm <- NULL
+ for( aa in seq(40,70,5) )
+    {
+    nd$age <- aa+d.pt
+    prm <- rbind( prm, NA, cbind( age = nd$age, adx = aa,
+                                  ci.pred( mM, newdata=nd ),
+                                  ci.pred( mW, newdata=nd ) ) )
+    }
+
+ # Plotting the mortality rates both on pdf and emf
+ clr <- c("blue","red")
+
+ plR <- function(){
+ yl <- c(1,200)*Rmin
+ par( mar=c(3,4,1,1), mgp=c(3,1,0)/1.6, las=1, bty="n")
+ matplot( prm[,1], prm[,-(1:2)],
+          type="l", lty=c(1,3,3), lwd=c(3,1,1), col=rep(clr,each=3),
+          log="y", xlab="Age at follow-up",
+          xlim = c(40,85), ylim=yl,
+          ylab="" )
+ mtext( paste( ctxt, "mortality rate per 1000 PY"), side=2, las=0, line=3 )
+ abline( v=seq(40,70,5), col=gray(0.8) )
+ axis( side=2, at=c(outer(c(1,1.5,2:10,12,15),0:1,function(x,y)x*10^y)), labels=NA, tcl=-0
+ axis( side=1, at=seq(40,85,5), labels=NA, tcl=-0.3 )
+ text( rep(41,2), yl[2]*c(0.85,0.68), c("Men","Women"), col=clr, adj=c(0,1) )
+     }
+
+ # Plots in different formats
+ pdf( file = paste("../graph/",suf,cause,"-prM.pdf",sep=""), height=6, width=8 )
+ par( mar=c(3,3,1,1), mgp=c(3,1,0)/1.6, las=1, bty="n" )
+ plR()
+ dev.off()
+
+ emf( file = paste("../graph/",suf,cause,"-prM.emf",sep=""), height=6, width=8 )
+ par( mar=c(3,3,1,1), mgp=c(3,1,0)/1.6, las=1, bty="n" )
+ plR()
+ dev.off()
```

```
+
+ # Function to compute RRs
+ RR <-
+ function( a1, a0, drg=20 )
+ {
+ if( a0<a1 ) stop("a1 must be smaller that a0")
+ cc <- seq(0,drg-(a0-a1),,100)
+ lc <- length(cc)
+ D1 <- Ns((a0-a1)+cc,knots=d.kn)
+ D0 <- Ns(        cc,knots=d.kn)
+ E1 <- Ns(rep(a1,lc),knots=e.kn)
+ E0 <- Ns(rep(a0,lc),knots=e.kn)
+ ci.exp( mM, subset="dur" )
+ RRM <- ci.exp( mM, subset="dur", ctr.mat=cbind(D1-D0,E1-E0) )
+ RRW <- ci.exp( mW, subset="dur", ctr.mat=cbind(D1-D0,E1-E0) )
+ cbind( age=a0+cc, RRM, RRW )
+ }
+
+ # Plot the RRs in a 1 x 2 layout
+ plRR <-
+ function()
+ {
+ par( mfrow=c(1,2), oma=c(0,2,0,0), mar=c(3,1,1,1) )
+ yl <- c(1,4)*RRmin
+ prrr <- list( "5"=NULL, "10"=NULL)
+ for( ddif in c(5,10) )
+    {
+ plot( NA, xlim=c(50,85), ylim=yl, log="y",
+           xlab="Age at follow-up", ylab="", xaxt="n" )
+ abline(h=outer(1:15,10^c(-2:2)),col=gray(0.8))
+ abline(h=1)
+ axis( side=1, at=seq(50,80,10) )
+ axis( side=1, at=seq(50,85,5), labels=NA, tcl=-0.3 )
+ # axis( side=2, at=5:20/10, labels=NA, tcl=-0.3 )
+ prrr[[paste(ddif)]] <- NULL
+ for( a0 in seq(50,75,5) )
+    {
+    rr <- RR( a0-ddif, a0 )
+    matlines( rr[,1], rr[,-1],
+              type="l", lty=c(1,3,3),
+              lwd=c(3,1,1), col=rep(c("blue","red"),3) )
+    prrr[[paste(ddif)]] <- rbind( prrr[[paste(ddif)]], NA, rr )
+    }
+ abline( v=ahi<-5:7*10, col=gray(0.8) )
+ text( 50, yl[2]*0.98, paste( "Age at diagnosis", ddif, "years apart:" ), adj=c(0,1) )
+ text( ahi, rep(yl[2]*0.90,3), paste(ahi-ddif,"vs.",ahi), adj=0 )
+    }
+ mtext( paste(ctxt,"mortality RR"), side=2, outer=TRUE, las=0, line=1 )
+ invisible( prrr )
+ }
+
+ pdf( file = paste("../graph/",suf,cause,"-RReqd.pdf",sep=""), height=6, width=10 )
+ par( mfrow=c(1,2), oma=c(0,2,0,0), mar=c(3,1,1,1), mgp=c(3,1,0)/1.6, las=1, bty="n" )
+ prrr <- plRR()
+ dev.off()
+
+ emf( file = paste("../graph/",suf,cause,"-RReqd.emf",sep=""), height=6, width=10 )
```

```
+ par( mfrow=c(1,2), oma=c(0,2,0,0), mar=c(3,1,1,1), mgp=c(3,1,0)/1.6, las=1, bty="n" )
+ plRR()
+ dev.off()
+ invisible( list( rates = prm,
+               rateratio = prrr ) )
+ }
> save( cod, file="../data/cod.Rda" )
```

```
> options( width=90,
+          SweaveHooks=list( fig=function()
+          par(mar=c(3,3,1,1),mgp=c(3,1,0)/1.6,las=1,bty="n") ) )
```

Chapter 3

Only persons with valid date of DM

First we load the relevant data

```
> library( Epi )
> library( popEpi )
> library( devEMF )
> clear()
> load( file="../data/Agx.Rda" )
> Agx <- Agx[,':='( age = age+0.25, per = per+0.25, dur = dur+0.25 )]
> load( file="../data/cod.Rda" )
> lls()
  name mode     class                 dim              size(Kb)
1 Agx  list     data.table data.frame 348603 17        44,941.1
2 cod  function function              1                   192.2
```

3.1 All causes of death

```
> ac.res <- cod( Agx, "x", "D" , "All cause", Rmin=1, RRmin=0.5 )
Analysis of D All cause :
     sex          Men                      Women                      Sum
                    D           Y              D           Y             D           Y
Year
1997              258    50,312.3            178    44,254.9           436    94,567.3
1998              802    70,318.2            530    63,320.3         1,332   133,638.4
1999            1,401    91,747.4            868    82,706.9         2,269   174,454.3
2000            1,979   113,233.0          1,359   101,252.4         3,338   214,485.4
2001            2,606   134,606.8          1,845   119,416.4         4,451   254,023.1
2002            3,299   156,572.2          2,249   138,231.4         5,548   294,803.6
2003            3,813   176,574.2          2,744   156,150.9         6,557   332,725.1
2004            4,488   194,710.0          3,089   172,182.6         7,577   366,892.6
2005            4,888   211,822.2          3,368   187,005.8         8,256   398,828.0
2006            5,182   227,743.8          3,788   200,149.6         8,970   427,893.4
2007            5,824   244,941.5          4,101   214,112.0         9,925   459,053.5
2008            6,418   266,543.7          4,677   231,121.1        11,095   497,664.8
2009            6,783   285,694.0          4,943   246,317.8        11,726   532,011.9
2010            7,063   301,085.8          5,241   257,939.2        12,304   559,025.0
2011            7,167   319,635.3          5,134   271,923.3        12,301   591,558.6
Sum            61,971 2,845,540.4         44,114 2,486,084.6       106,085 5,331,625.0
```

```
Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       1.004 1.002 1.007
Women     1.008 1.006 1.011
```

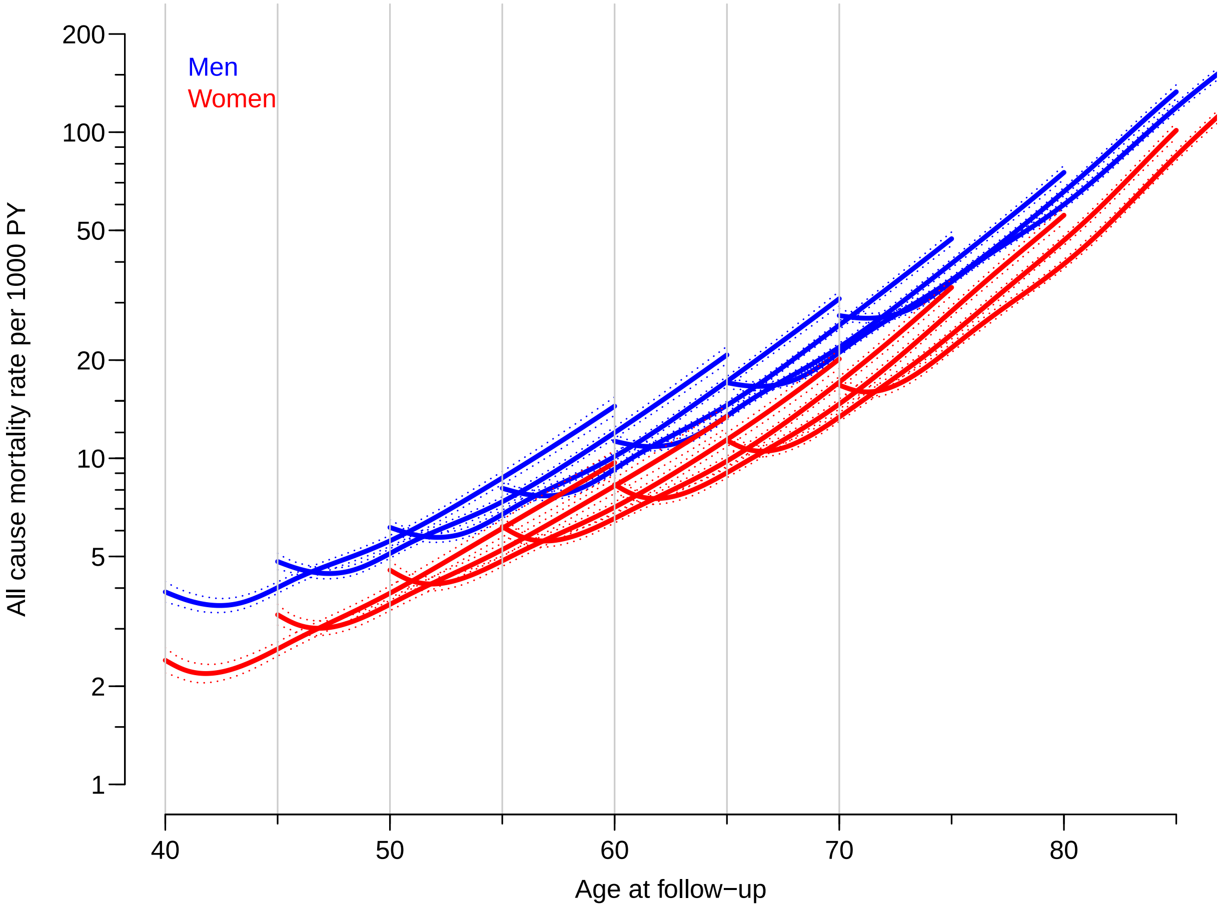

Figure 3.1: *Mortality rates from any cause in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women...* `/graph/xD-prM`

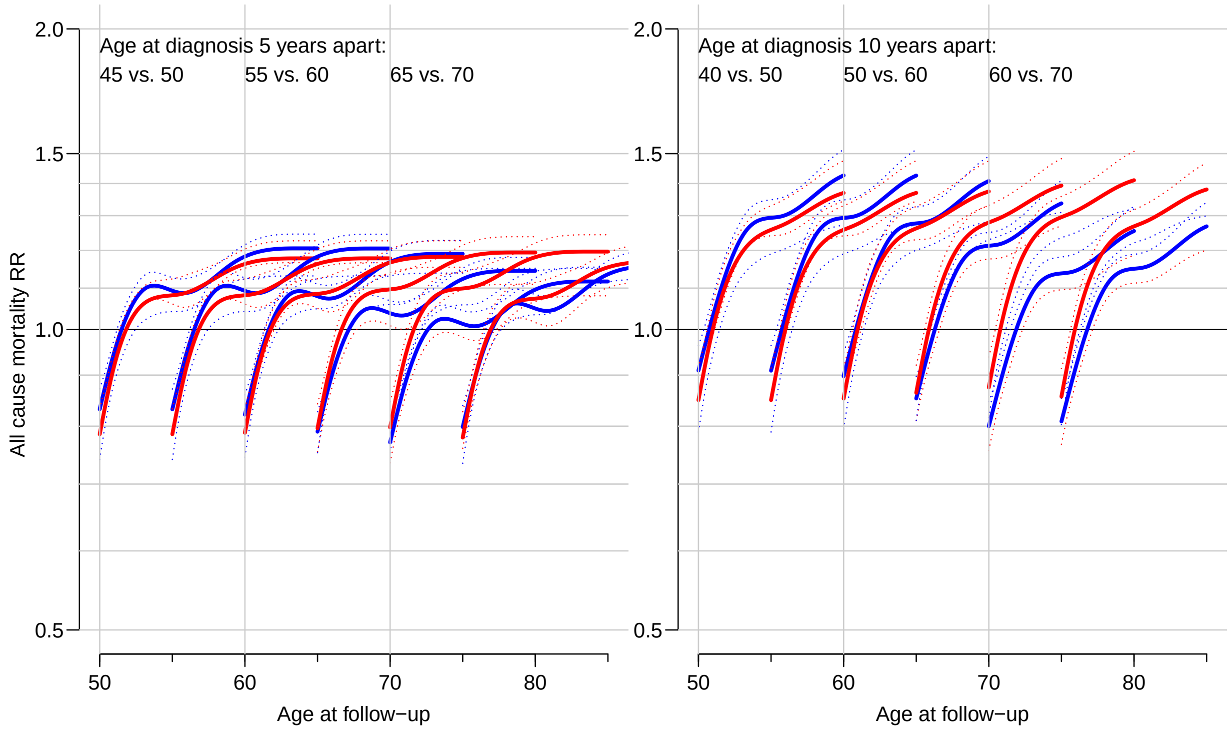

Figure 3.2: *All cause mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/xD-RReqd`

3.2 Three causes of death

The following three section represent a subdivision of causes of death in three different causes: CVD, Cancer and other, together making up all deaths among diabetes patients in Australia.

```
> load( file="../data/cod.Rda" )
```

3.2.1 CVD

```
> cv.res <- cod( Agx, "x", "CVD" , "CVD", Rmin=1/8, RRmin=0.8 )
Analysis of CVD CVD :
     sex          Men                     Women                   Sum
                    D            Y            D           Y           D            Y
Year
1997               88     50,312.3           37    44,254.9         125     94,567.3
1998              264     70,318.2          160    63,320.3         424    133,638.4
1999              460     91,747.4          281    82,706.9         741    174,454.3
2000              618    113,233.0          441   101,252.4       1,059    214,485.4
2001              793    134,606.8          647   119,416.4       1,440    254,023.1
2002            1,024    156,572.2          729   138,231.4       1,753    294,803.6
2003            1,217    176,574.2          829   156,150.9       2,046    332,725.1
2004            1,318    194,710.0          949   172,182.6       2,267    366,892.6
2005            1,456    211,822.2          958   187,005.8       2,414    398,828.0
2006            1,431    227,743.8        1,007   200,149.6       2,438    427,893.4
2007            1,566    244,941.5        1,087   214,112.0       2,653    459,053.5
2008            1,755    266,543.7        1,234   231,121.1       2,989    497,664.8
2009            1,820    285,694.0        1,311   246,317.8       3,131    532,011.9
2010            1,753    301,085.8        1,354   257,939.2       3,107    559,025.0
2011            1,640    319,635.3        1,235   271,923.3       2,875    591,558.6
Sum            17,203 2,845,540.4       12,259 2,486,084.6      29,462 5,331,625.0

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.969 0.965 0.973
Women     0.969 0.964 0.974
```

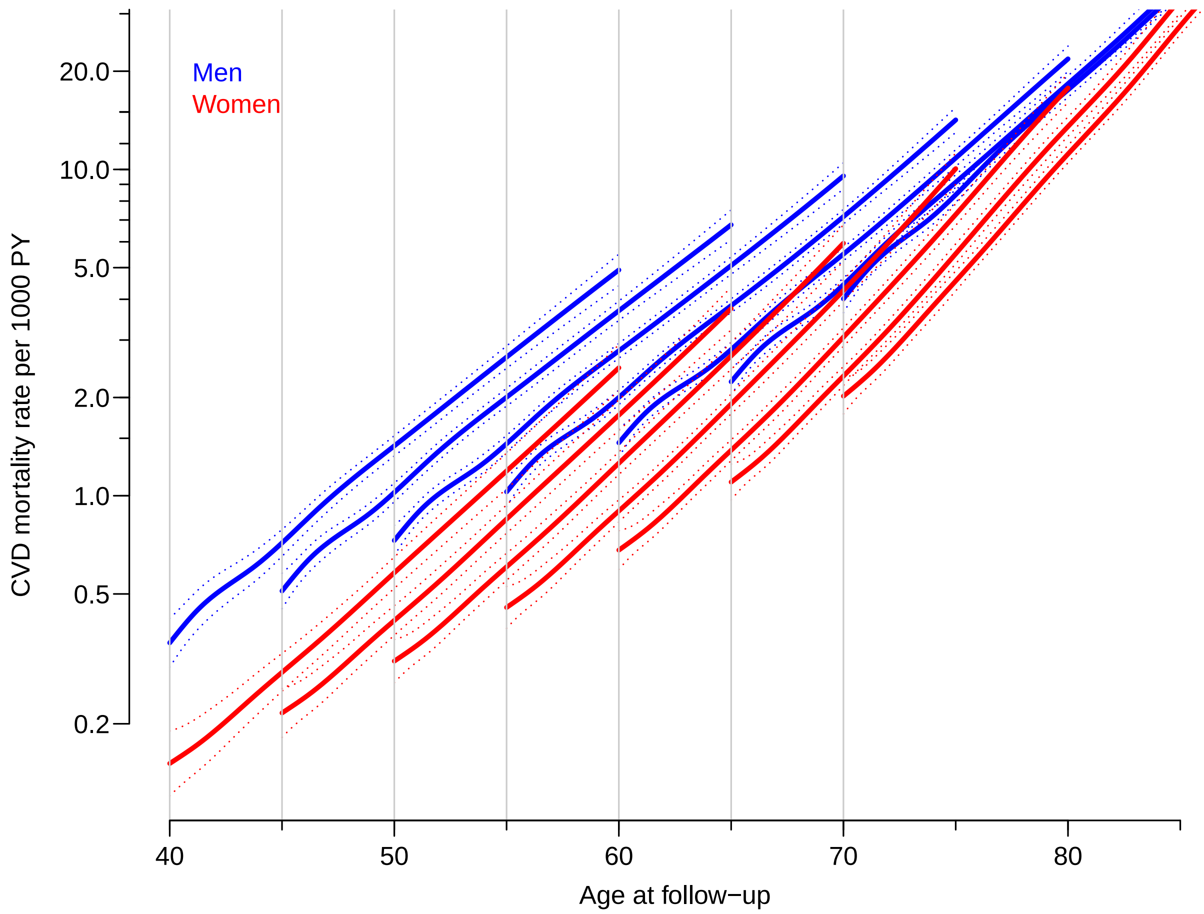

Figure 3.3: *Mortality rates from CVD in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/xCVD-prM`

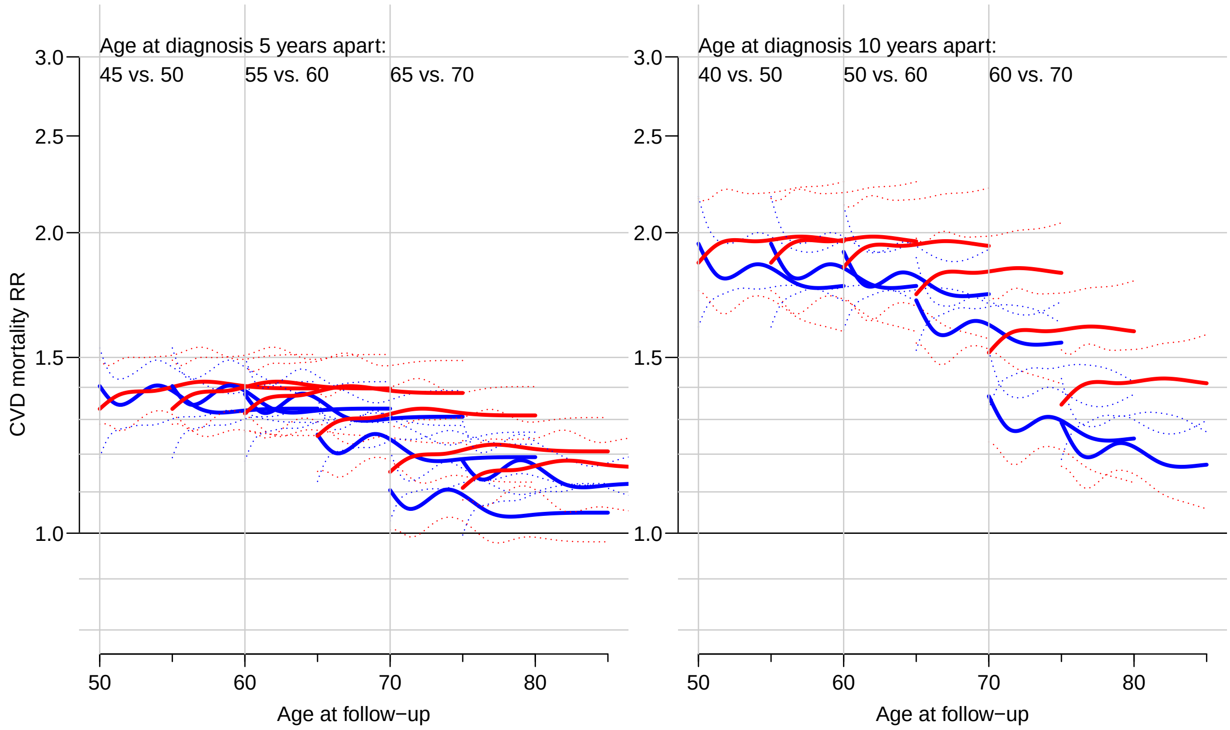

Figure 3.4: *CVD mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/xCVD-RReqd`

3.2.2 Cancer

```
> ca.res <- cod( Agx, "x", "Can" , "Cancer", Rmin=0.5, RRmin=0.4 )
Analysis of Can Cancer :
     sex        Men                     Women                     Sum
                  D           Y             D           Y           D           Y
Year
1997             89    50,312.3            67    44,254.9         156    94,567.3
1998            318    70,318.2           195    63,320.3         513   133,638.4
1999            501    91,747.4           285    82,706.9         786   174,454.3
2000            707   113,233.0           430   101,252.4       1,137   214,485.4
2001            906   134,606.8           566   119,416.4       1,472   254,023.1
2002          1,113   156,572.2           648   138,231.4       1,761   294,803.6
2003          1,319   176,574.2           846   156,150.9       2,165   332,725.1
2004          1,565   194,710.0           942   172,182.6       2,507   366,892.6
2005          1,713   211,822.2         1,017   187,005.8       2,730   398,828.0
2006          1,817   227,743.8         1,172   200,149.6       2,989   427,893.4
2007          2,011   244,941.5         1,230   214,112.0       3,241   459,053.5
2008          2,219   266,543.7         1,295   231,121.1       3,514   497,664.8
2009          2,297   285,694.0         1,421   246,317.8       3,718   532,011.9
2010          2,504   301,085.8         1,460   257,939.2       3,964   559,025.0
2011          2,362   319,635.3         1,366   271,923.3       3,728   591,558.6
Sum          21,441 2,845,540.4        12,940 2,486,084.6      34,381 5,331,625.0

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       1.019 1.015 1.022
Women     1.023 1.018 1.028
```

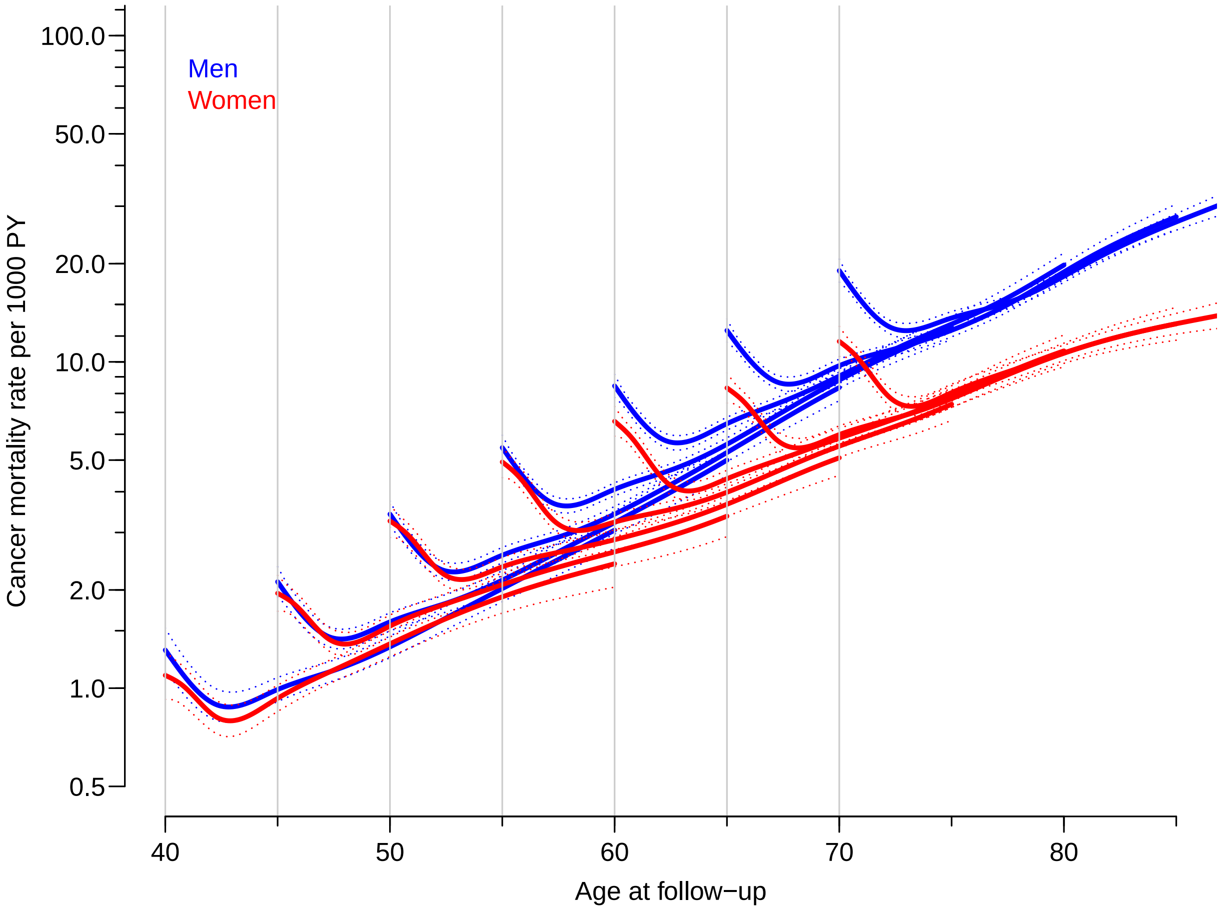

Figure 3.5: *Mortality rates from cancer in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* ../graph/xCan-prM

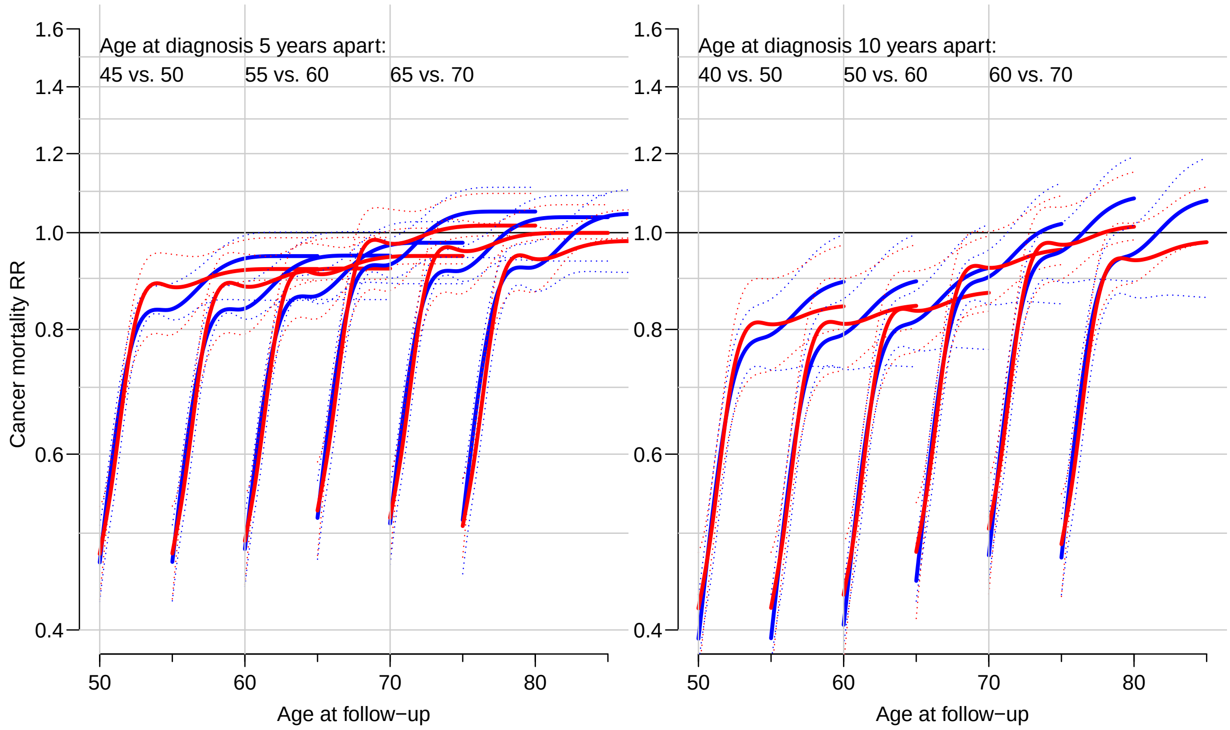

Figure 3.6: *Cancer mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/xCan-RReqd`

3.2.3 Other causes

```
> ot.res <- cod( Agx, "x", "Oth" , "Non-CVD, non-cancer", Rmin=0.5, RRmin=0.7 )
Analysis of Oth Non-CVD, non-cancer :
     sex         Men                     Women                     Sum
                   D           Y             D           Y            D           Y
Year
1997              81    50,312.3            74    44,254.9          155    94,567.3
1998             220    70,318.2           175    63,320.3          395   133,638.4
1999             440    91,747.4           302    82,706.9          742   174,454.3
2000             654   113,233.0           488   101,252.4        1,142   214,485.4
2001             907   134,606.8           632   119,416.4        1,539   254,023.1
2002           1,162   156,572.2           872   138,231.4        2,034   294,803.6
2003           1,277   176,574.2         1,069   156,150.9        2,346   332,725.1
2004           1,605   194,710.0         1,198   172,182.6        2,803   366,892.6
2005           1,719   211,822.2         1,393   187,005.8        3,112   398,828.0
2006           1,934   227,743.8         1,609   200,149.6        3,543   427,893.4
2007           2,247   244,941.5         1,784   214,112.0        4,031   459,053.5
2008           2,444   266,543.7         2,148   231,121.1        4,592   497,664.8
2009           2,666   285,694.0         2,211   246,317.8        4,877   532,011.9
2010           2,806   301,085.8         2,427   257,939.2        5,233   559,025.0
2011           3,165   319,635.3         2,533   271,923.3        5,698   591,558.6
Sum           23,327 2,845,540.4        18,915 2,486,084.6       42,242 5,331,625.0

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       1.019 1.015 1.022
Women     1.025 1.021 1.029
```

3.3 Saving results for the publication graphs

```
> save( ac.res,
+       cv.res,
+       ca.res,
+       ot.res, file="../data/all-res.Rda")
```

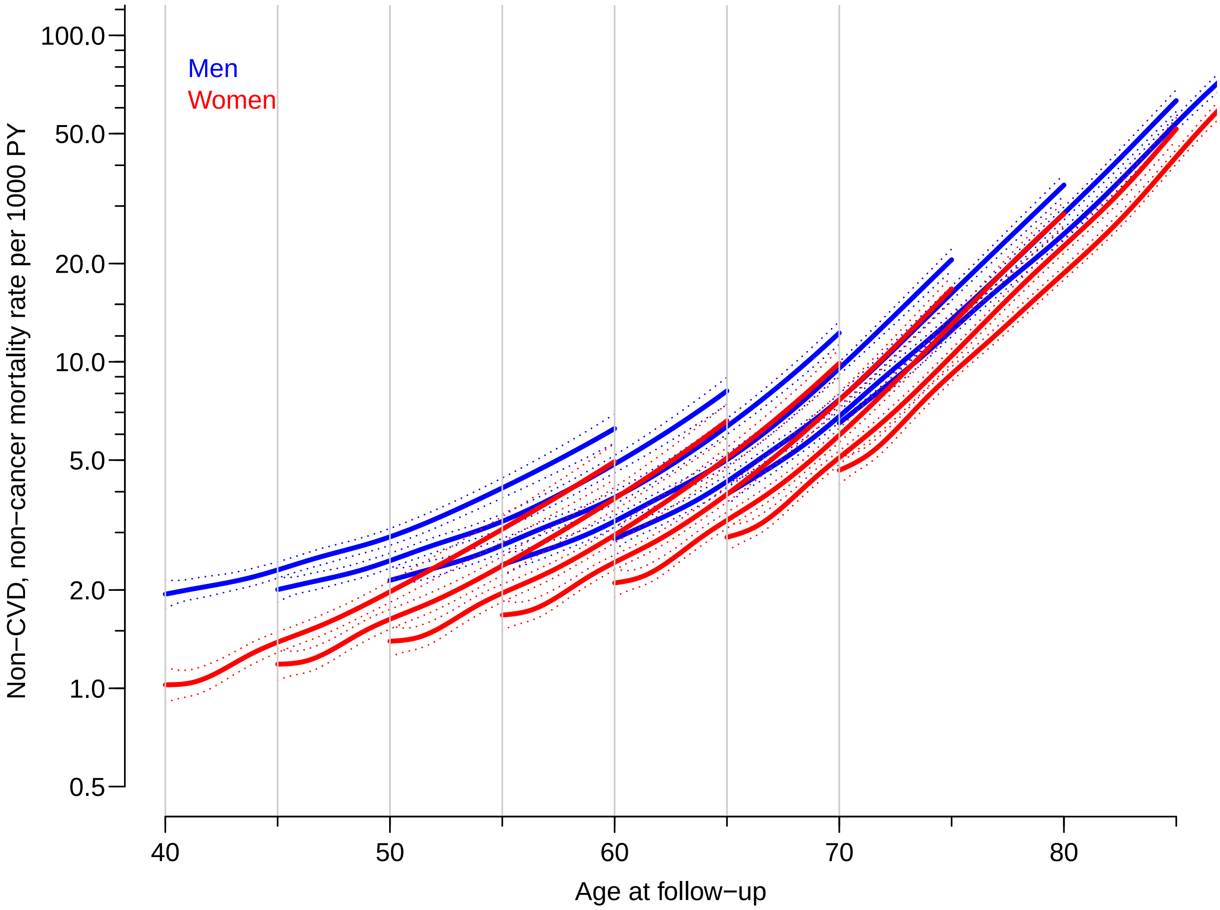

Figure 3.7: *Mortality rates from other causes (non-CVD, non-cancer) in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/xOth-prM`

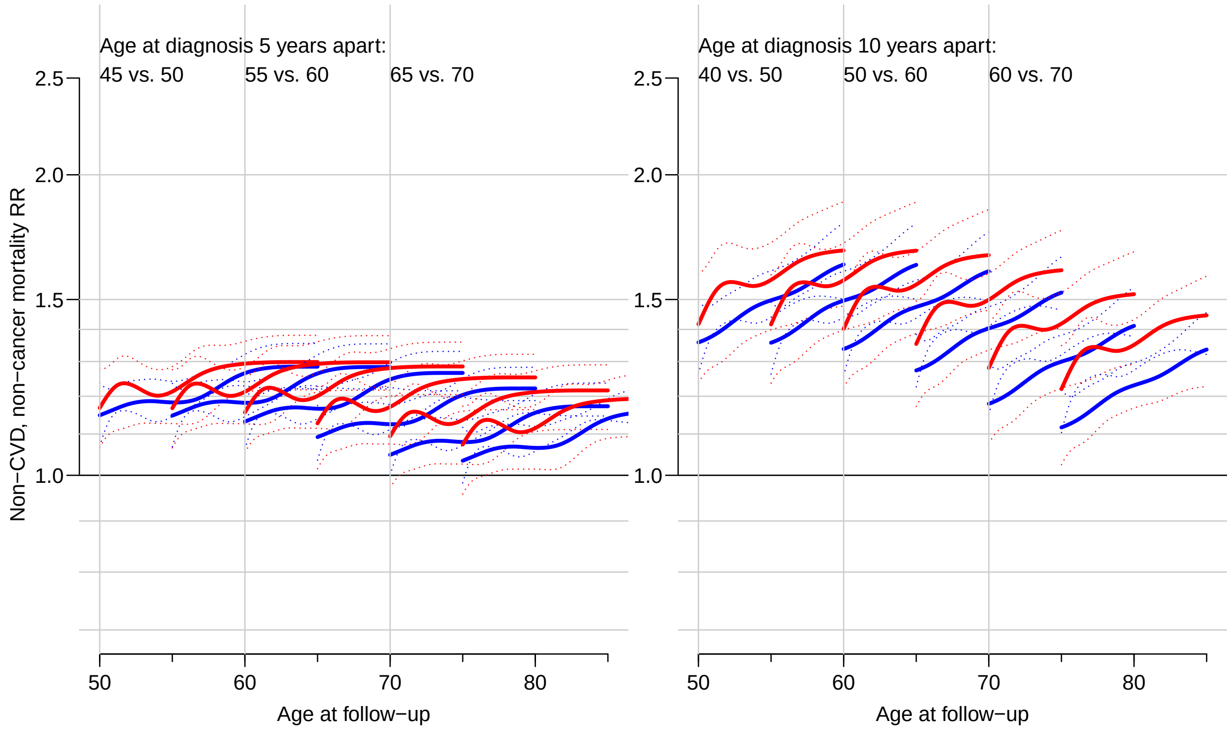

Figure 3.8: *Other mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/xOth-RReqd`

3.4 Eight causes of death

The following eight sections represent a subdivision of causes of death in twelve different causes, together making up all deaths among diabetes patients in Australia.

3.4.1 Ischemic heart disease

```
> cod( Agx, "x", "IHD" , "IHD", Rmin=0.1, RRmin=0.8 )
Analysis of IHD IHD :
     sex        Men                 Women                 Sum
                  D           Y         D           Y        D           Y
Year
1997             78    50,312.3        27    44,254.9      105    94,567.3
1998            213    70,318.2       114    63,320.3      327   133,638.4
1999            362    91,747.4       205    82,706.9      567   174,454.3
2000            490   113,233.0       308   101,252.4      798   214,485.4
2001            612   134,606.8       481   119,416.4    1,093   254,023.1
2002            803   156,572.2       516   138,231.4    1,319   294,803.6
2003            941   176,574.2       560   156,150.9    1,501   332,725.1
2004          1,050   194,710.0       671   172,182.6    1,721   366,892.6
2005          1,100   211,822.2       658   187,005.8    1,758   398,828.0
2006          1,088   227,743.8       656   200,149.6    1,744   427,893.4
2007          1,203   244,941.5       721   214,112.0    1,924   459,053.5
2008          1,313   266,543.7       810   231,121.1    2,123   497,664.8
2009          1,381   285,694.0       842   246,317.8    2,223   532,011.9
2010          1,338   301,085.8       859   257,939.2    2,197   559,025.0
2011          1,246   319,635.3       802   271,923.3    2,048   591,558.6
Sum          13,218 2,845,540.4     8,230 2,486,084.6   21,448 5,331,625.0

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.969 0.964 0.973
Women     0.962 0.956 0.967
```

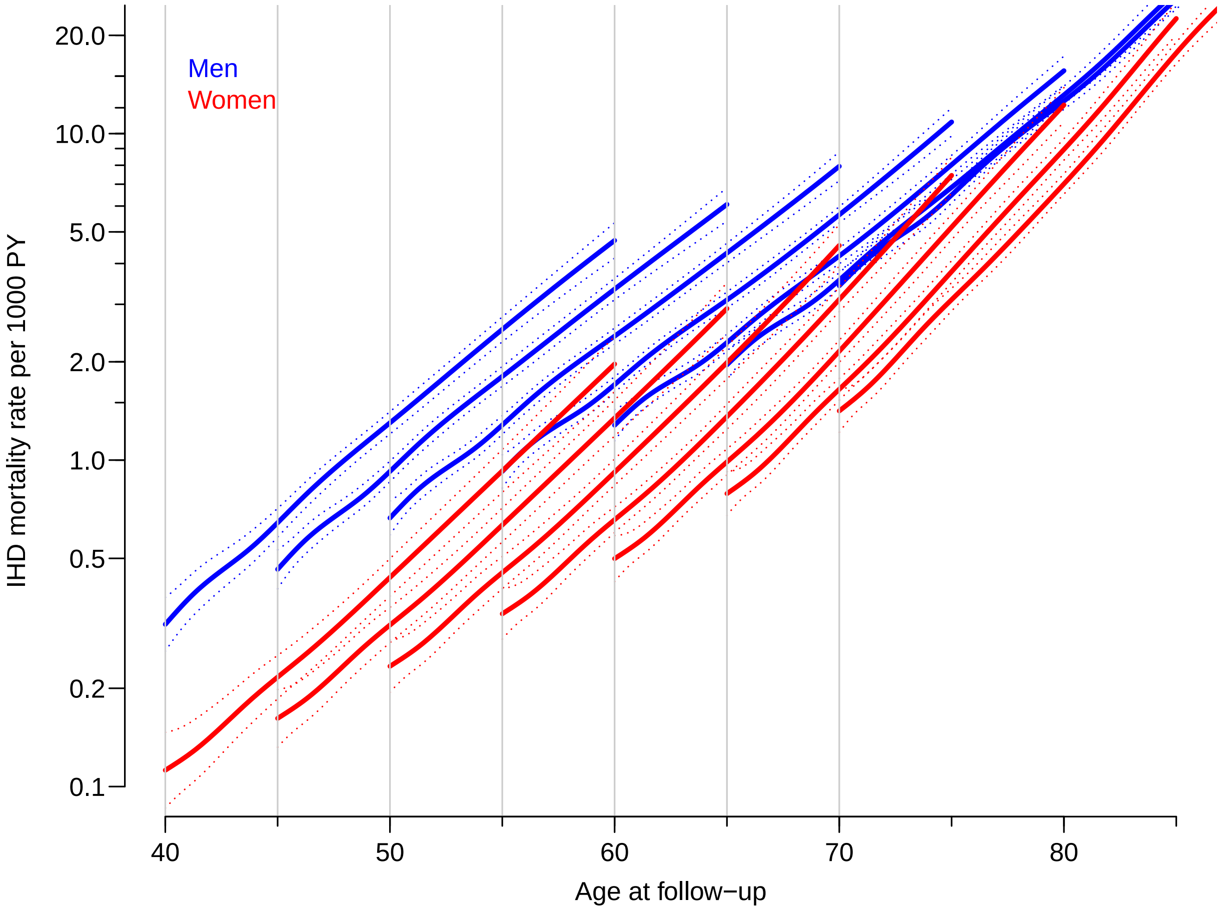

Figure 3.9: *Mortality rates from ischemic heart disease in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/xIHD-prM`

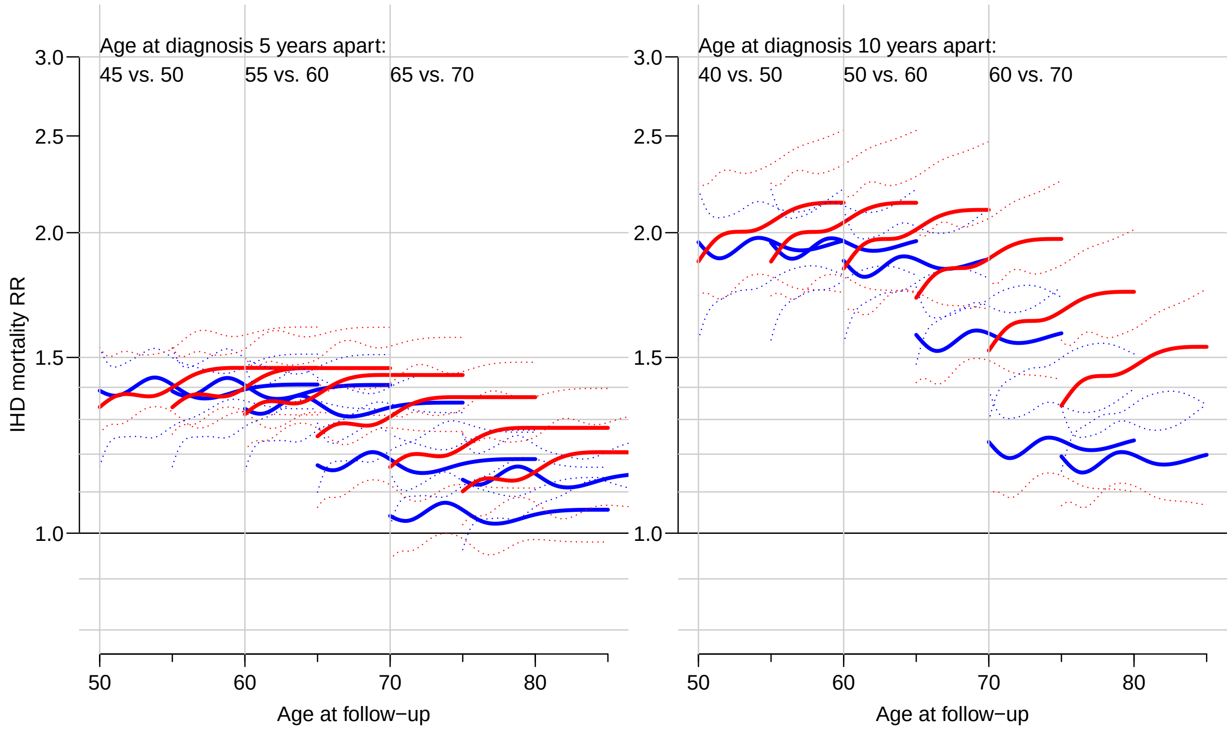

Figure 3.10: *IHD mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/xIHD-RReqd`

3.4.2 Stroke

```
> cod( Agx, "x", "Str" , "Stroke", Rmin=0.04, RRmin=0.8 )
Analysis of Str Stroke :
     sex         Men                    Women                   Sum
                   D            Y          D            Y         D            Y
Year
1997              10     50,312.3         10     44,254.9        20     94,567.3
1998              51     70,318.2         46     63,320.3        97    133,638.4
1999              98     91,747.4         76     82,706.9       174    174,454.3
2000             128    113,233.0        133    101,252.4       261    214,485.4
2001             181    134,606.8        166    119,416.4       347    254,023.1
2002             221    156,572.2        213    138,231.4       434    294,803.6
2003             276    176,574.2        269    156,150.9       545    332,725.1
2004             268    194,710.0        278    172,182.6       546    366,892.6
2005             356    211,822.2        300    187,005.8       656    398,828.0
2006             343    227,743.8        351    200,149.6       694    427,893.4
2007             363    244,941.5        366    214,112.0       729    459,053.5
2008             442    266,543.7        424    231,121.1       866    497,664.8
2009             439    285,694.0        469    246,317.8       908    532,011.9
2010             415    301,085.8        495    257,939.2       910    559,025.0
2011             394    319,635.3        433    271,923.3       827    591,558.6
Sum            3,985 2,845,540.4      4,029 2,486,084.6     8,014 5,331,625.0

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.971 0.963 0.980
Women     0.985 0.977 0.994
```

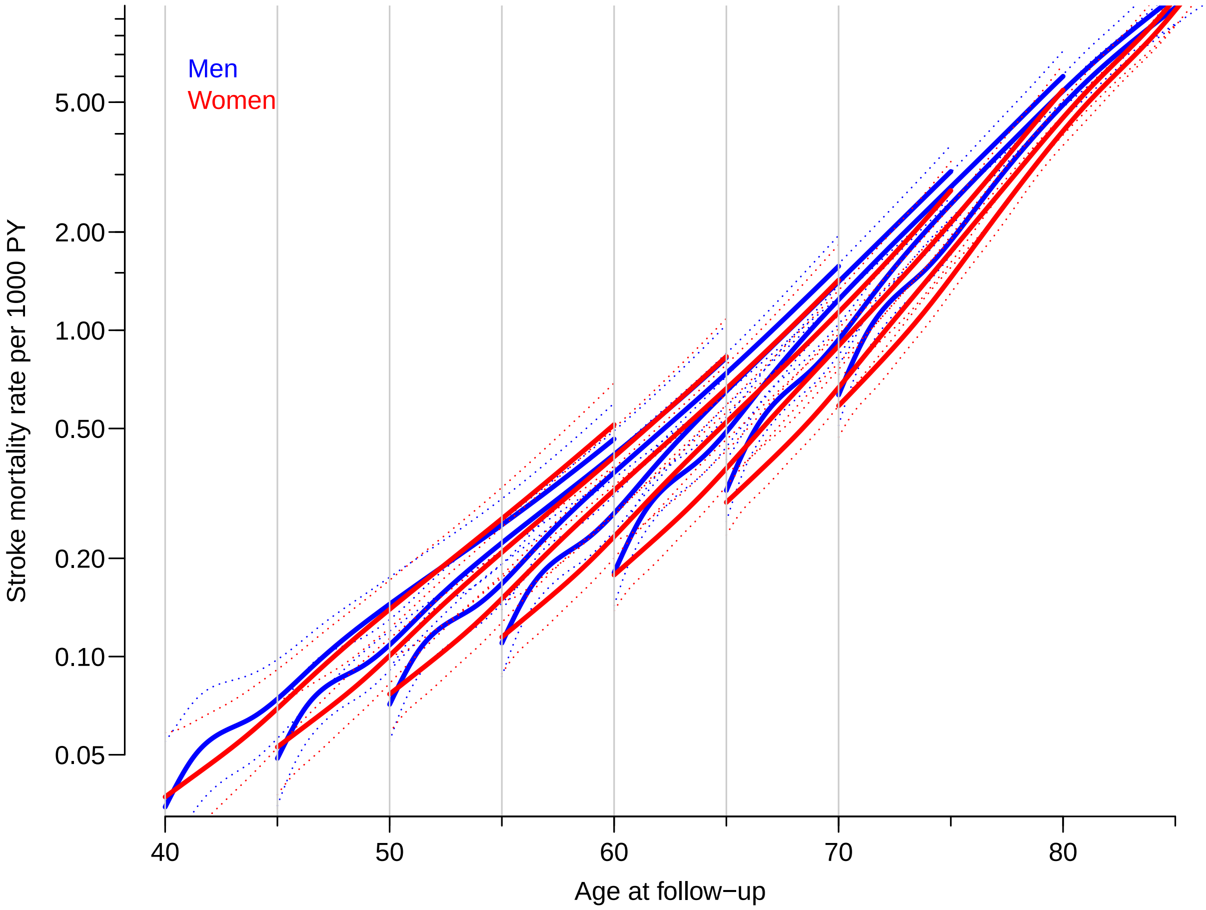

Figure 3.11: *Mortality rates from stroke in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* ../graph/xStr-prM

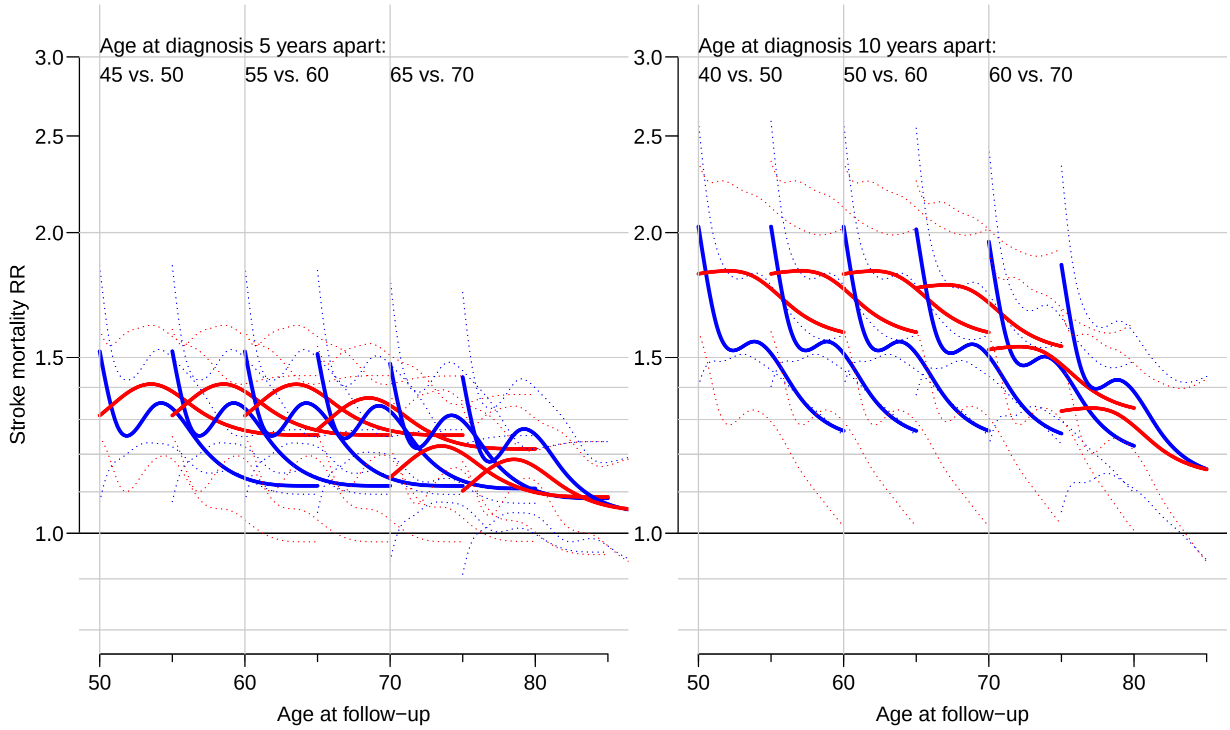

Figure 3.12: *Stroke mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/xStr-RReqd`

3.4.3 Lung cancer

```
> cod( Agx, "x", "Lung" , "Lung cancer", Rmin=0.03, RRmin=0.4 )
Analysis of Lung Lung cancer :
     sex         Men                     Women                     Sum
                   D           Y             D           Y             D           Y
Year
1997              16    50,312.3            11    44,254.9            27    94,567.3
1998              60    70,318.2            23    63,320.3            83   133,638.4
1999             102    91,747.4            38    82,706.9           140   174,454.3
2000             136   113,233.0            54   101,252.4           190   214,485.4
2001             171   134,606.8            73   119,416.4           244   254,023.1
2002             219   156,572.2            92   138,231.4           311   294,803.6
2003             276   176,574.2           117   156,150.9           393   332,725.1
2004             313   194,710.0           118   172,182.6           431   366,892.6
2005             352   211,822.2           144   187,005.8           496   398,828.0
2006             349   227,743.8           167   200,149.6           516   427,893.4
2007             421   244,941.5           172   214,112.0           593   459,053.5
2008             455   266,543.7           189   231,121.1           644   497,664.8
2009             418   285,694.0           208   246,317.8           626   532,011.9
2010             506   301,085.8           236   257,939.2           742   559,025.0
2011             455   319,635.3           230   271,923.3           685   591,558.6
Sum            4,249 2,845,540.4         1,872 2,486,084.6         6,121 5,331,625.0

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       1.018 1.010 1.027
Women     1.041 1.028 1.055
```

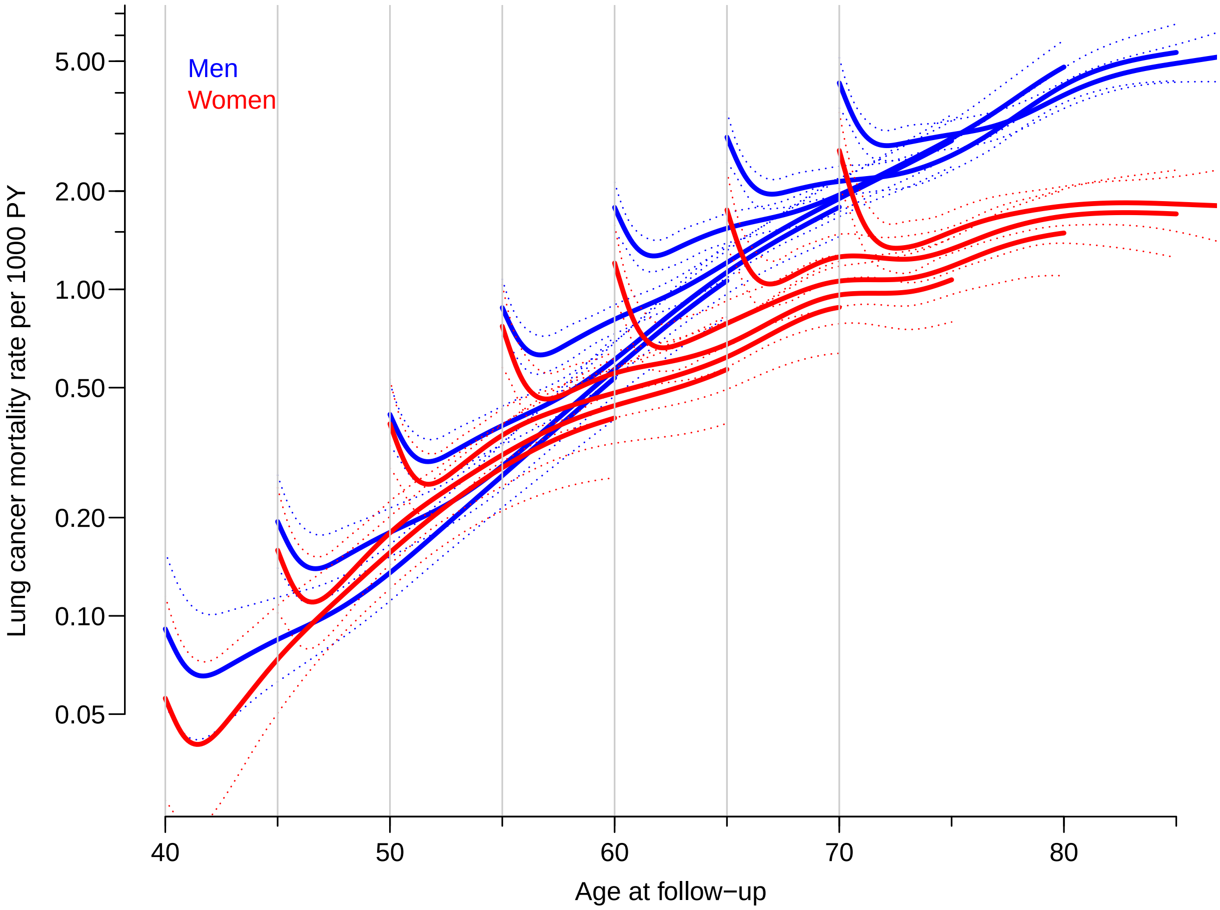

Figure 3.13: *Mortality rates from lung cancer in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/xLung-prM`

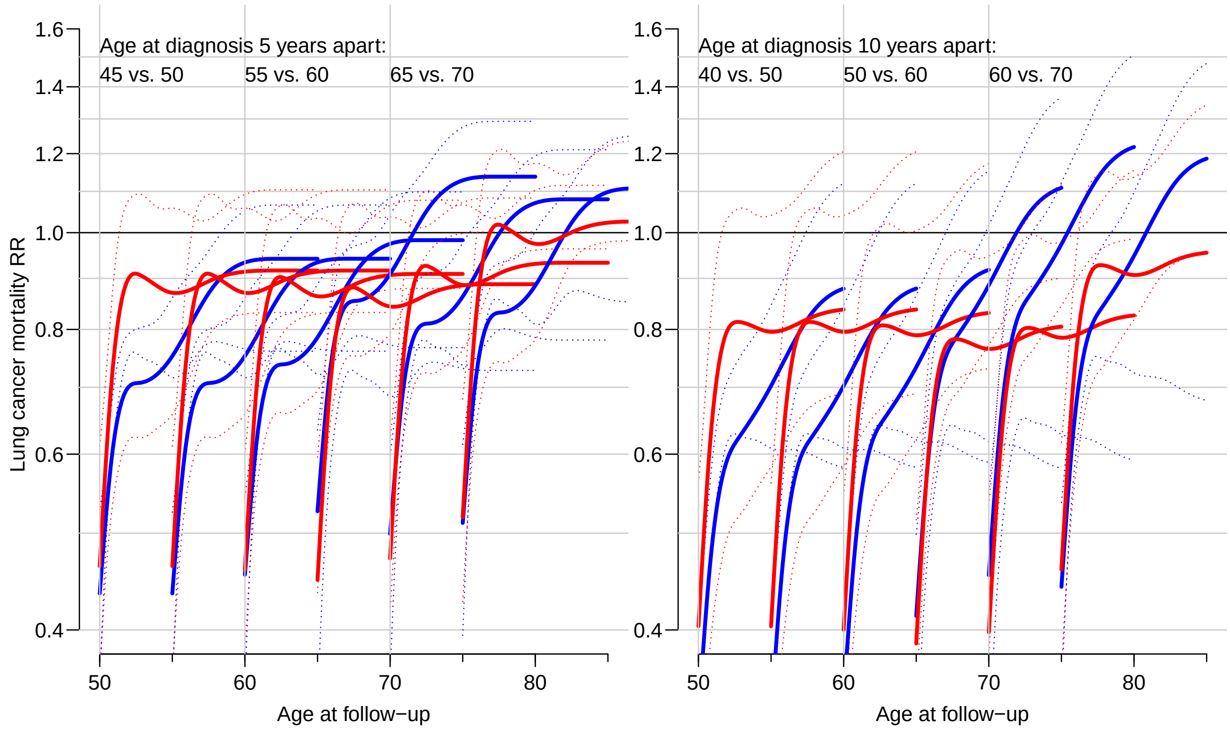

Figure 3.14: *Lung cancer mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/xLung-RReqd`

3.4.4 Colon cancer

```
> cod( Agx, "x", "ColC", "Colon cancer", Rmin=0.03, RRmin=0.4 )
Analysis of ColC Colon cancer :
     sex         Men                     Women                     Sum
                   D           Y           D           Y             D           Y
Year
1997               9    50,312.3           5    44,254.9            14    94,567.3
1998              28    70,318.2          14    63,320.3            42   133,638.4
1999              60    91,747.4          32    82,706.9            92   174,454.3
2000              72   113,233.0          42   101,252.4           114   214,485.4
2001             110   134,606.8          71   119,416.4           181   254,023.1
2002             115   156,572.2          67   138,231.4           182   294,803.6
2003             161   176,574.2          96   156,150.9           257   332,725.1
2004             148   194,710.0          83   172,182.6           231   366,892.6
2005             180   211,822.2          83   187,005.8           263   398,828.0
2006             171   227,743.8         118   200,149.6           289   427,893.4
2007             208   244,941.5         131   214,112.0           339   459,053.5
2008             209   266,543.7         124   231,121.1           333   497,664.8
2009             213   285,694.0         128   246,317.8           341   532,011.9
2010             214   301,085.8         125   257,939.2           339   559,025.0
2011             198   319,635.3         114   271,923.3           312   591,558.6
Sum            2,096 2,845,540.4       1,233 2,486,084.6         3,329 5,331,625.0

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.999 0.987 1.010
Women     0.993 0.978 1.009
```

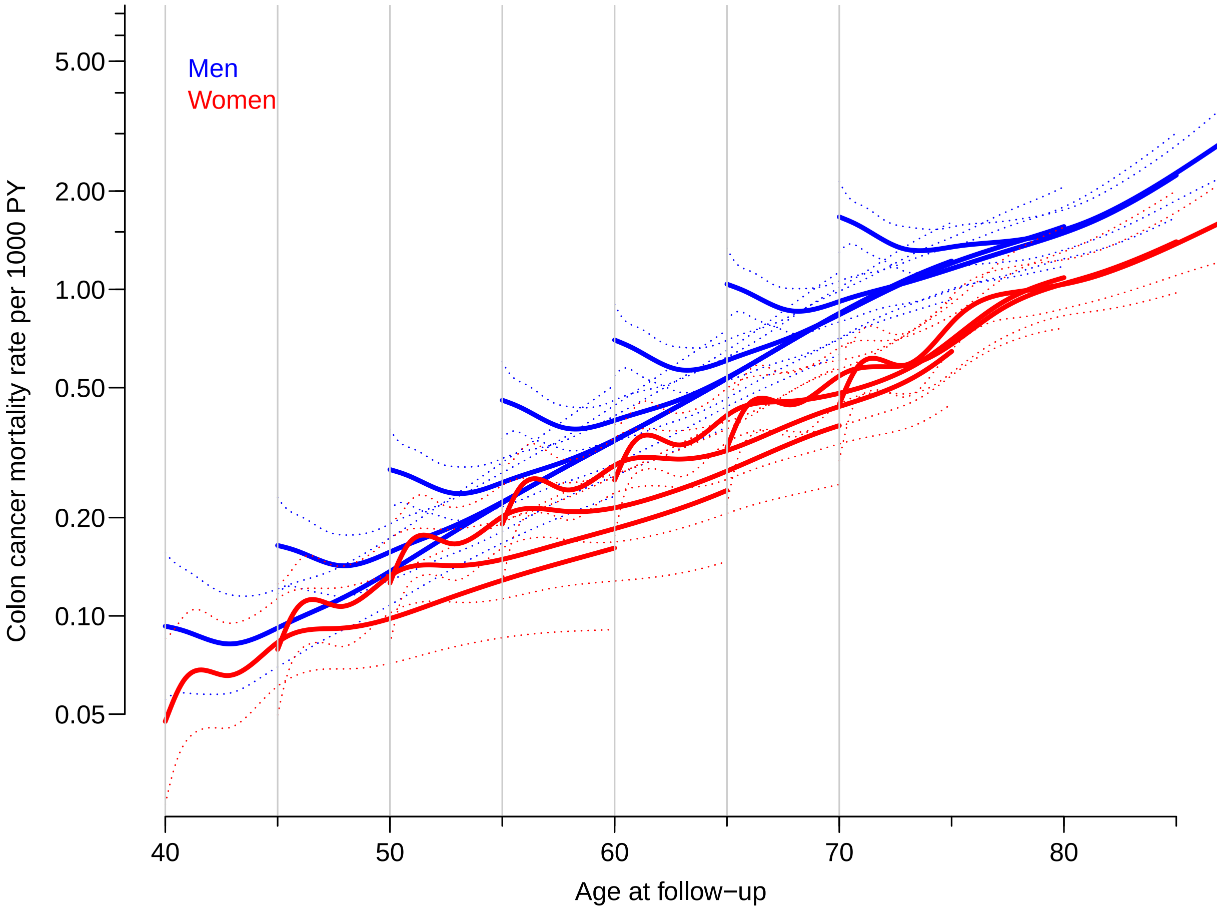

Figure 3.15: *Mortality rates from colon cancer in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/xColC-prM`

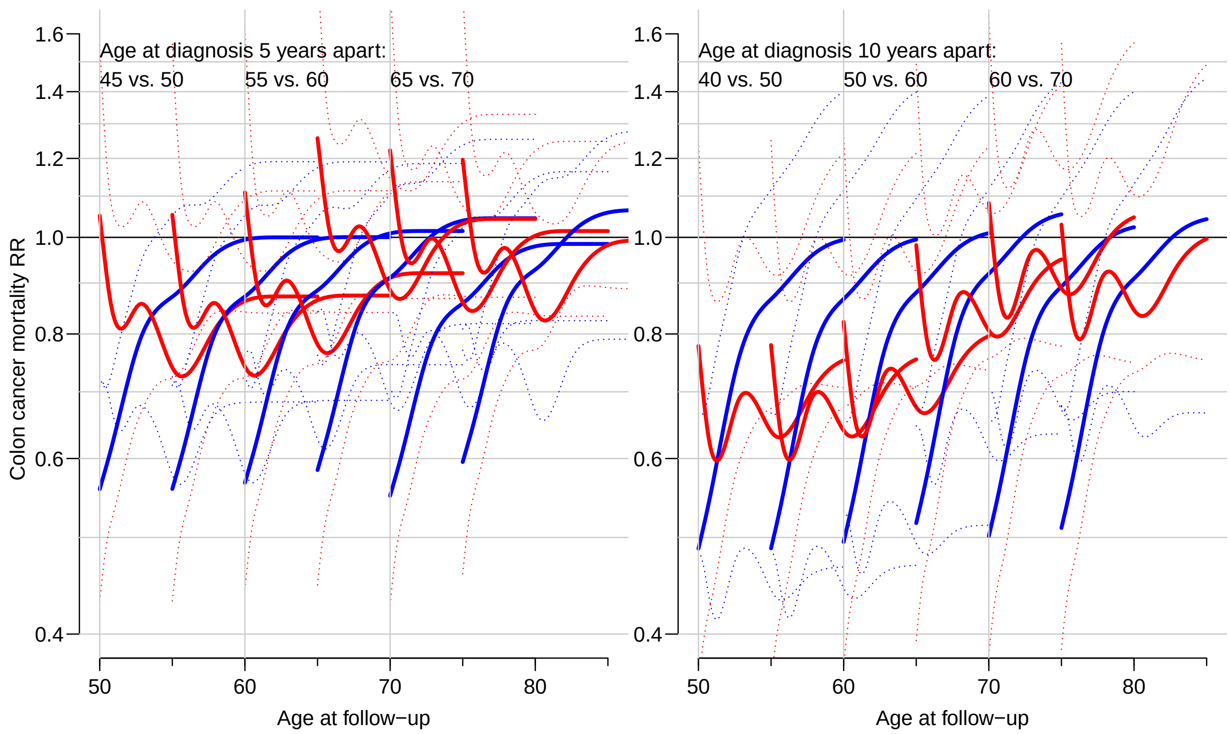

Figure 3.16: *Colon cancer mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/xColC-RReqd`

3.4.5 Pancreas cancer

```
> cod( Agx, "x", "PanC", "Pancreas cancer", Rmin=0.03, RRmin=0.4 )
Analysis of PanC Pancreas cancer :
     sex         Men                     Women                     Sum
                   D            Y            D            Y            D            Y
Year
1997              21     50,312.3           18     44,254.9           39     94,567.3
1998              56     70,318.2           53     63,320.3          109    133,638.4
1999              81     91,747.4           68     82,706.9          149    174,454.3
2000              80    113,233.0           83    101,252.4          163    214,485.4
2001             124    134,606.8           81    119,416.4          205    254,023.1
2002             156    156,572.2           80    138,231.4          236    294,803.6
2003             154    176,574.2          137    156,150.9          291    332,725.1
2004             179    194,710.0          144    172,182.6          323    366,892.6
2005             167    211,822.2          154    187,005.8          321    398,828.0
2006             183    227,743.8          162    200,149.6          345    427,893.4
2007             218    244,941.5          165    214,112.0          383    459,053.5
2008             228    266,543.7          152    231,121.1          380    497,664.8
2009             227    285,694.0          173    246,317.8          400    532,011.9
2010             232    301,085.8          186    257,939.2          418    559,025.0
2011             205    319,635.3          190    271,923.3          395    591,558.6
Sum            2,311  2,845,540.4        1,846  2,486,084.6        4,157  5,331,625.0

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       1.013 1.002 1.024
Women     1.025 1.012 1.037
```

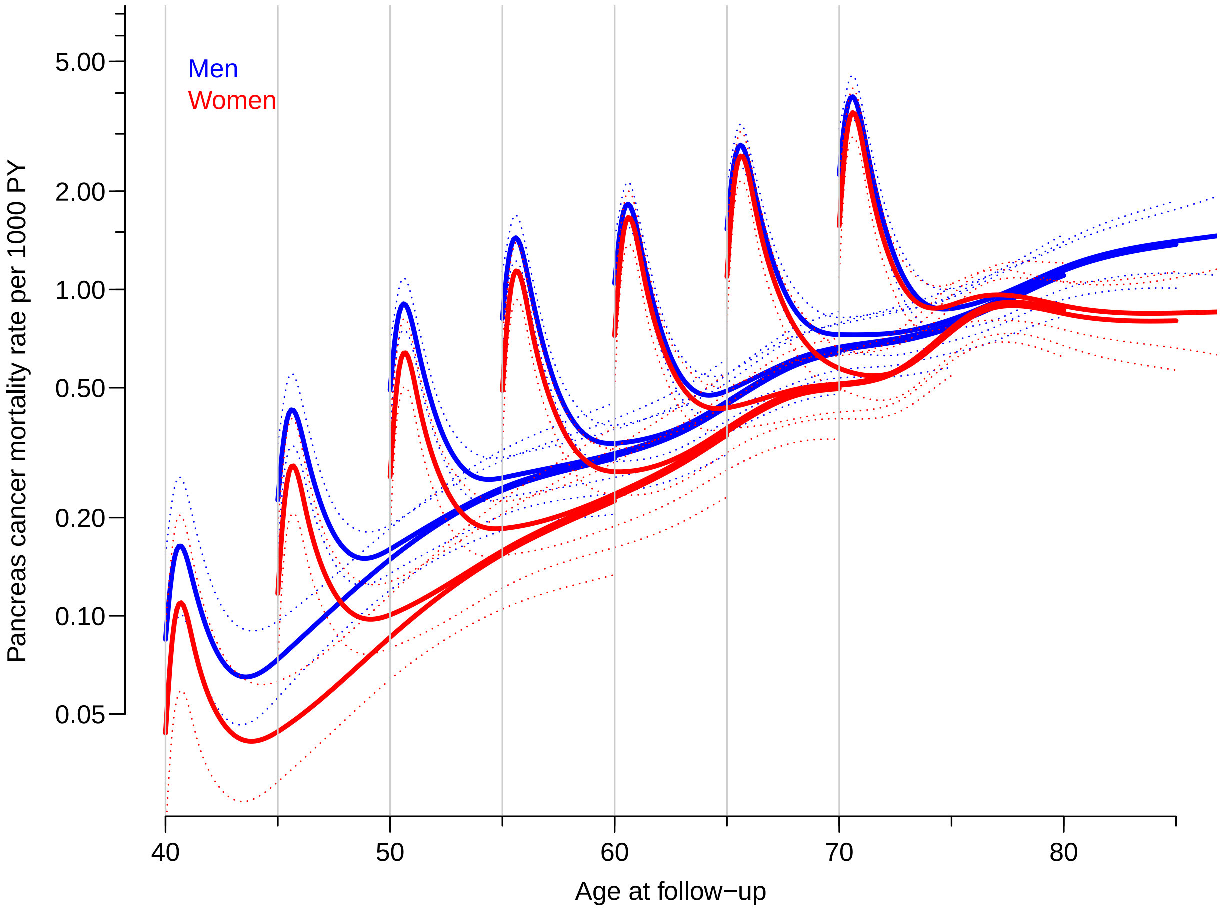

Figure 3.17: *Mortality rates from pancreatic cancer in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/xPanC-prM`

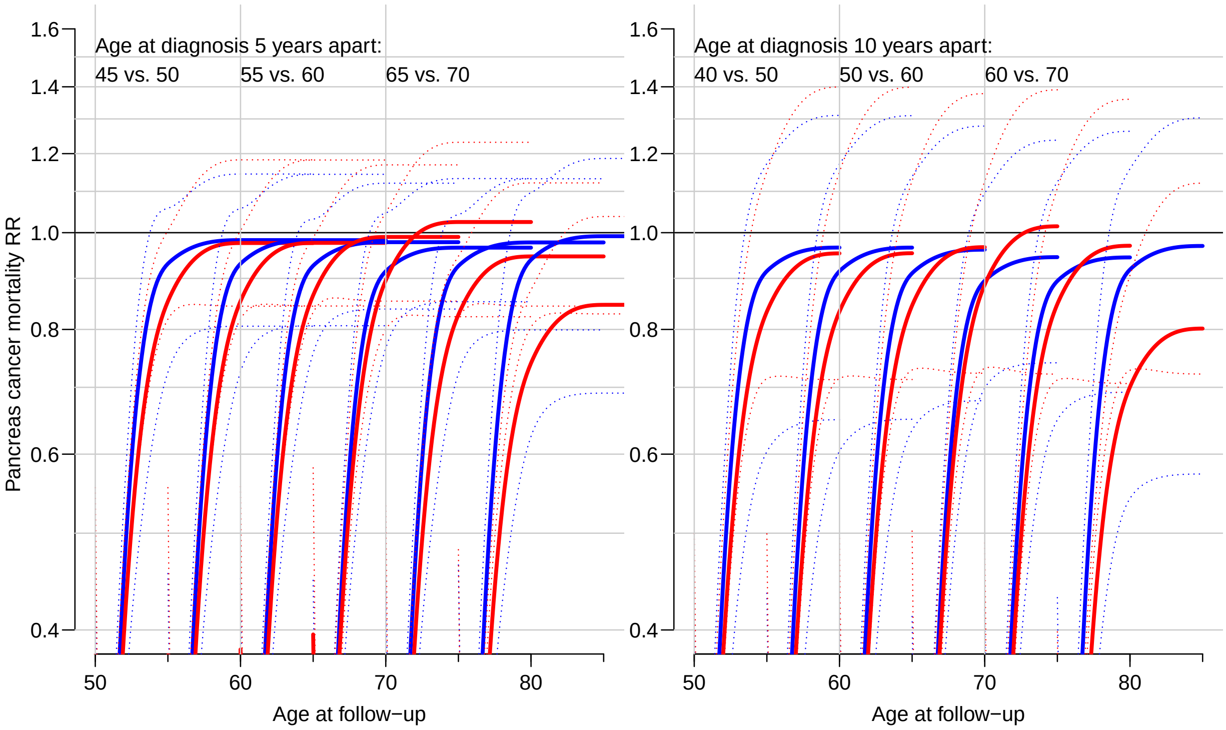

Figure 3.18: *Pancreas cancer mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/xPanC-RReqd`

3.4.6 Other cancers

```
> cod( Agx, "x", "OthC", "Other cancer", Rmin=0.2, RRmin=0.4 )
Analysis of OthC Other cancer :
     sex         Men                     Women                     Sum
                   D           Y           D           Y           D           Y
Year
1997              43    50,312.3          33    44,254.9          76    94,567.3
1998             174    70,318.2         105    63,320.3         279   133,638.4
1999             258    91,747.4         147    82,706.9         405   174,454.3
2000             419   113,233.0         251   101,252.4         670   214,485.4
2001             501   134,606.8         341   119,416.4         842   254,023.1
2002             623   156,572.2         409   138,231.4       1,032   294,803.6
2003             728   176,574.2         496   156,150.9       1,224   332,725.1
2004             925   194,710.0         597   172,182.6       1,522   366,892.6
2005           1,014   211,822.2         636   187,005.8       1,650   398,828.0
2006           1,114   227,743.8         725   200,149.6       1,839   427,893.4
2007           1,164   244,941.5         762   214,112.0       1,926   459,053.5
2008           1,327   266,543.7         830   231,121.1       2,157   497,664.8
2009           1,439   285,694.0         912   246,317.8       2,351   532,011.9
2010           1,552   301,085.8         913   257,939.2       2,465   559,025.0
2011           1,504   319,635.3         832   271,923.3       2,336   591,558.6
Sum           12,785 2,845,540.4       7,989 2,486,084.6      20,774 5,331,625.0

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       1.023 1.018 1.028
Women     1.023 1.016 1.029
```

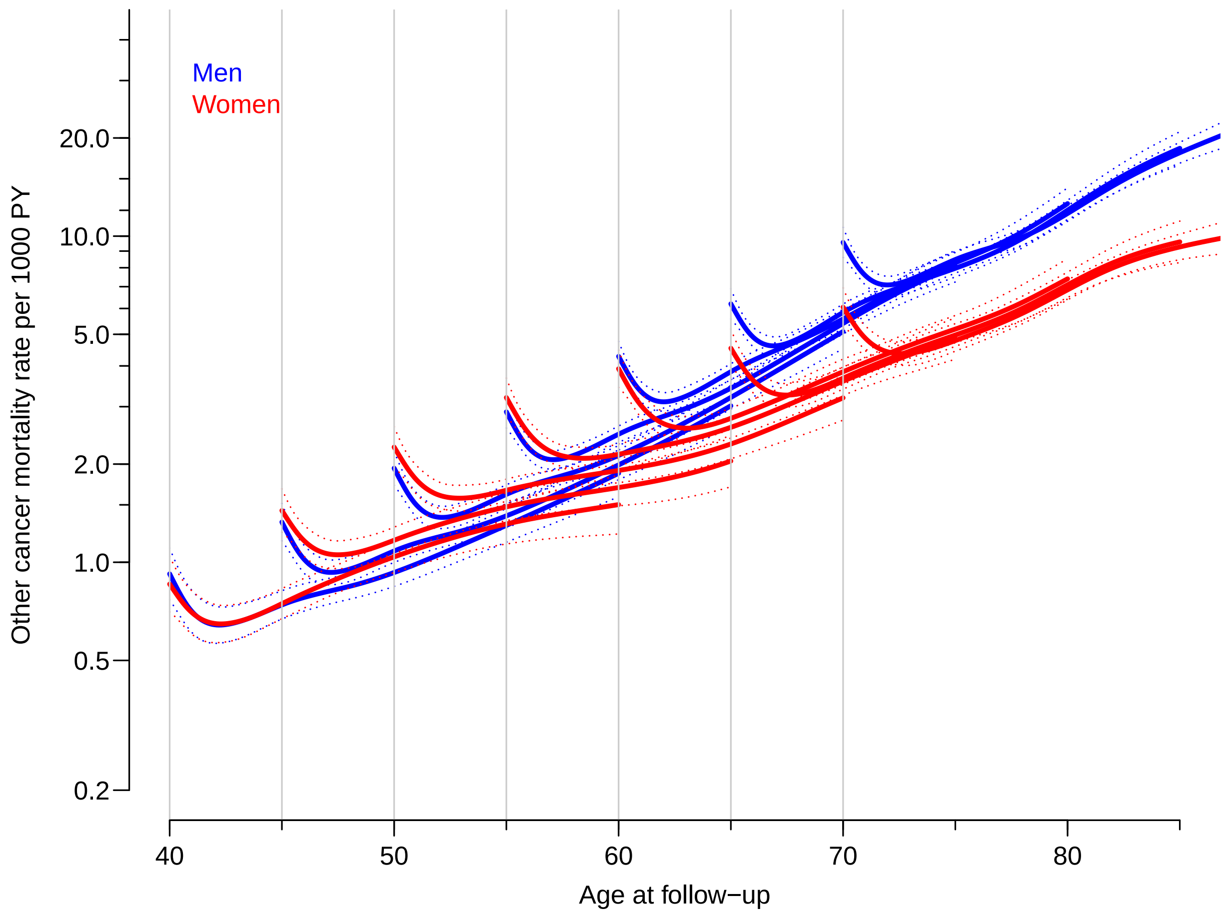

Figure 3.19: *Mortality rates from other cancers in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/xOthC-prM`

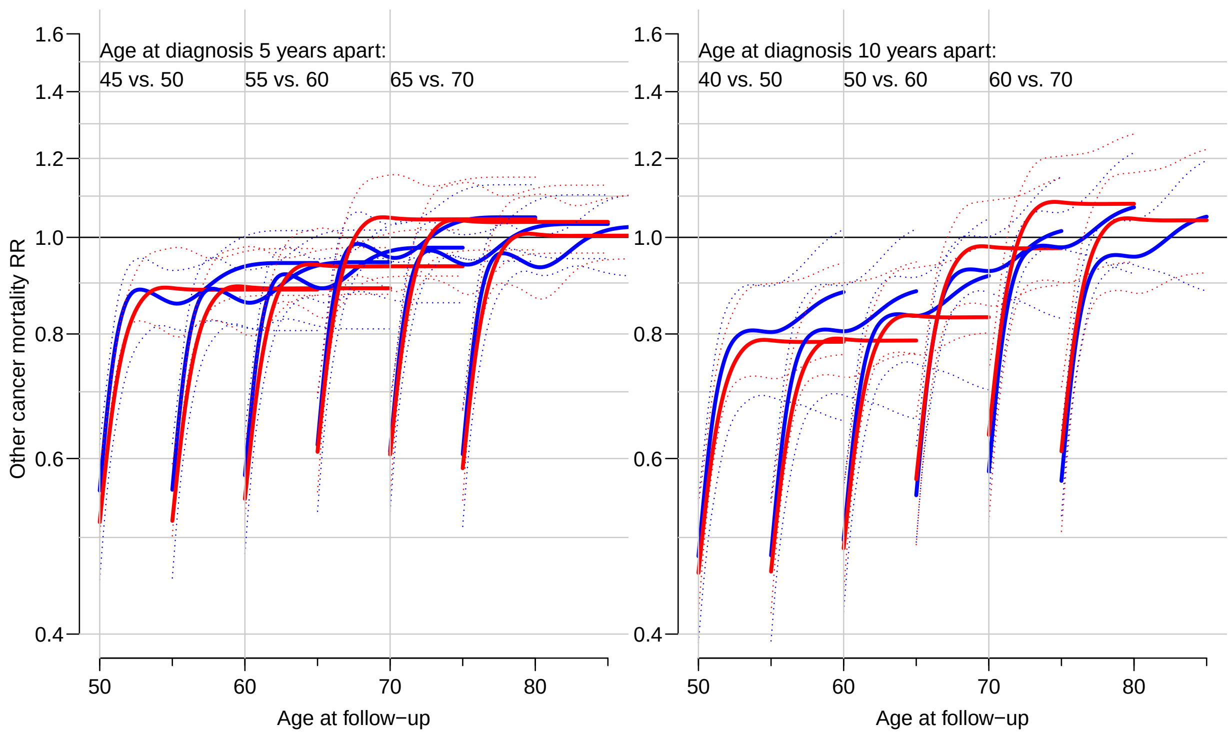

Figure 3.20: *Other cancer mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/xOthC-RReqd`

3.4.7 Infections

```
> cod( Agx, "x", "Infc", "Infections", Rmin=0.02, RRmin=0.6 )
Analysis of Infc Infections :
     sex         Men                     Women                     Sum
                   D            Y          D            Y            D            Y
Year
1997               3     50,312.3          1     44,254.9            4     94,567.3
1998              12     70,318.2         10     63,320.3           22    133,638.4
1999              18     91,747.4         17     82,706.9           35    174,454.3
2000              34    113,233.0         19    101,252.4           53    214,485.4
2001              32    134,606.8         24    119,416.4           56    254,023.1
2002              45    156,572.2         35    138,231.4           80    294,803.6
2003              52    176,574.2         41    156,150.9           93    332,725.1
2004              81    194,710.0         56    172,182.6          137    366,892.6
2005              87    211,822.2         49    187,005.8          136    398,828.0
2006              90    227,743.8         66    200,149.6          156    427,893.4
2007              86    244,941.5         52    214,112.0          138    459,053.5
2008              93    266,543.7         80    231,121.1          173    497,664.8
2009             104    285,694.0         69    246,317.8          173    532,011.9
2010             127    301,085.8         78    257,939.2          205    559,025.0
2011             121    319,635.3        122    271,923.3          243    591,558.6
Sum              985 2,845,540.4        719 2,486,084.6        1,704 5,331,625.0

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       1.022 1.003  1.04
Women     1.028 1.007  1.05
```

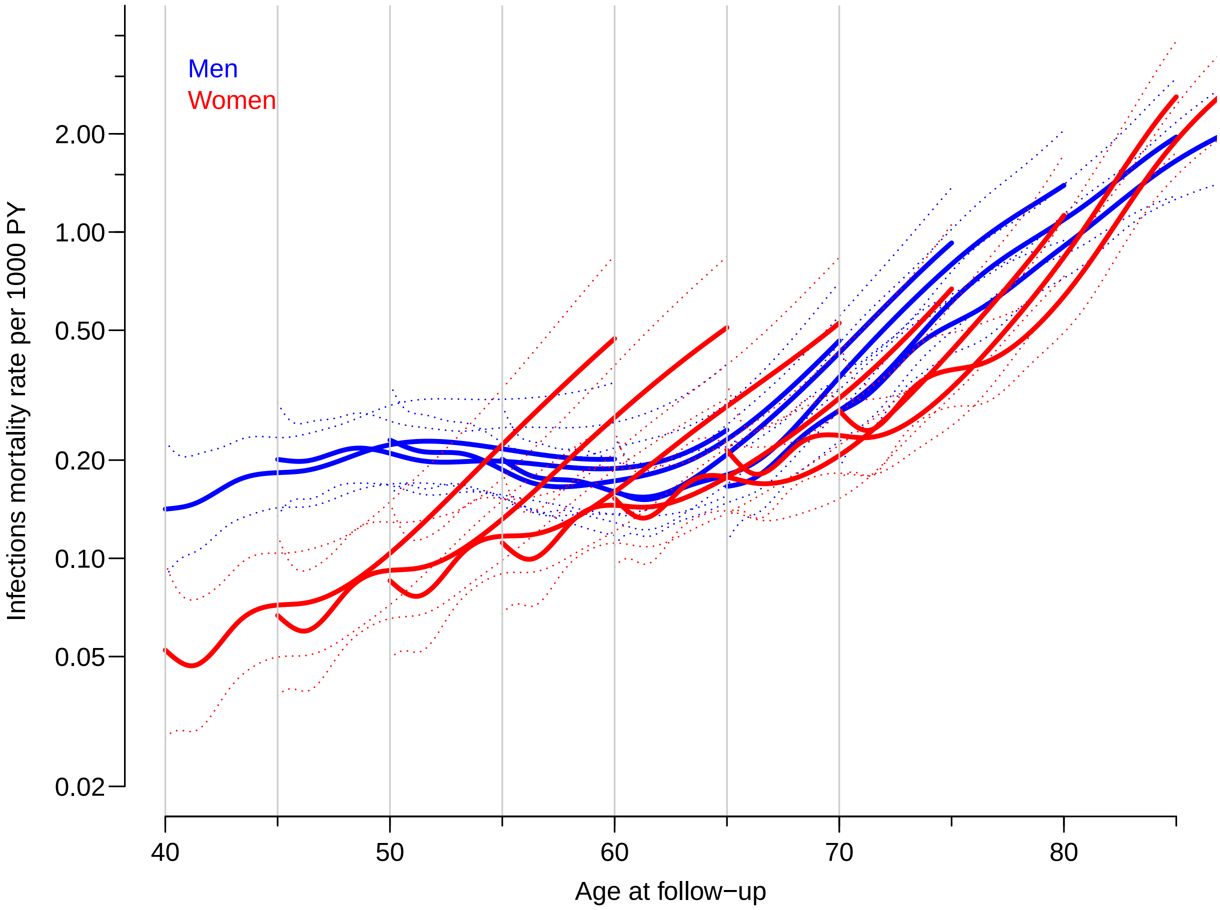

Figure 3.21: *Mortality rates from infections in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women...* `./graph/xInfc-prM`

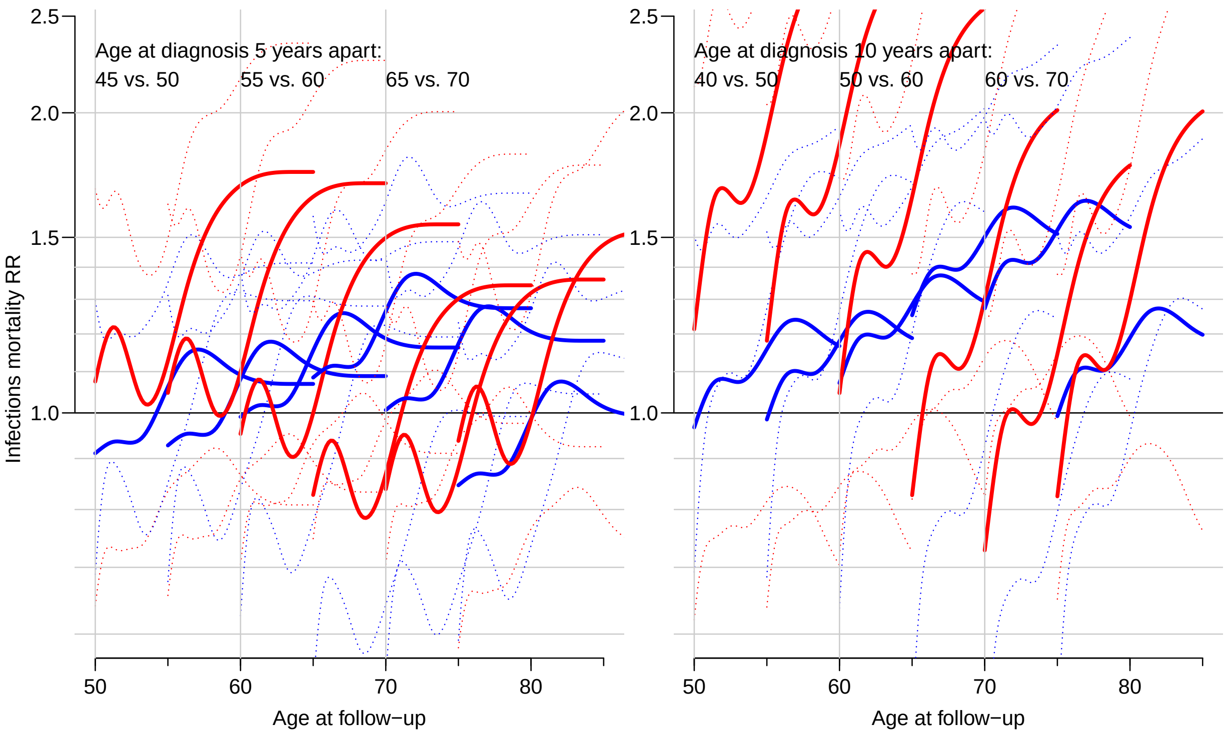

Figure 3.22: *Infections mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/xInfc-RReqd`

3.4.8 Other causes (excluding infections)

```
> cod( Agx, "x", "Othr", "Other causes (excl. inf.)", Rmin=0.5, RRmin=0.8 )
Analysis of Othr Other causes (excl. inf.) :
     sex        Men                     Women                    Sum
                  D            Y            D            Y           D            Y
Year
1997             78     50,312.3           73     44,254.9         151     94,567.3
1998            208     70,318.2          165     63,320.3         373    133,638.4
1999            422     91,747.4          285     82,706.9         707    174,454.3
2000            620    113,233.0          469    101,252.4       1,089    214,485.4
2001            875    134,606.8          608    119,416.4       1,483    254,023.1
2002          1,117    156,572.2          837    138,231.4       1,954    294,803.6
2003          1,225    176,574.2        1,028    156,150.9       2,253    332,725.1
2004          1,524    194,710.0        1,142    172,182.6       2,666    366,892.6
2005          1,632    211,822.2        1,344    187,005.8       2,976    398,828.0
2006          1,844    227,743.8        1,543    200,149.6       3,387    427,893.4
2007          2,161    244,941.5        1,732    214,112.0       3,893    459,053.5
2008          2,351    266,543.7        2,068    231,121.1       4,419    497,664.8
2009          2,562    285,694.0        2,142    246,317.8       4,704    532,011.9
2010          2,679    301,085.8        2,349    257,939.2       5,028    559,025.0
2011          3,044    319,635.3        2,411    271,923.3       5,455    591,558.6
Sum          22,342  2,845,540.4       18,196  2,486,084.6      40,538  5,331,625.0

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       1.018 1.015 1.022
Women     1.025 1.020 1.029
```

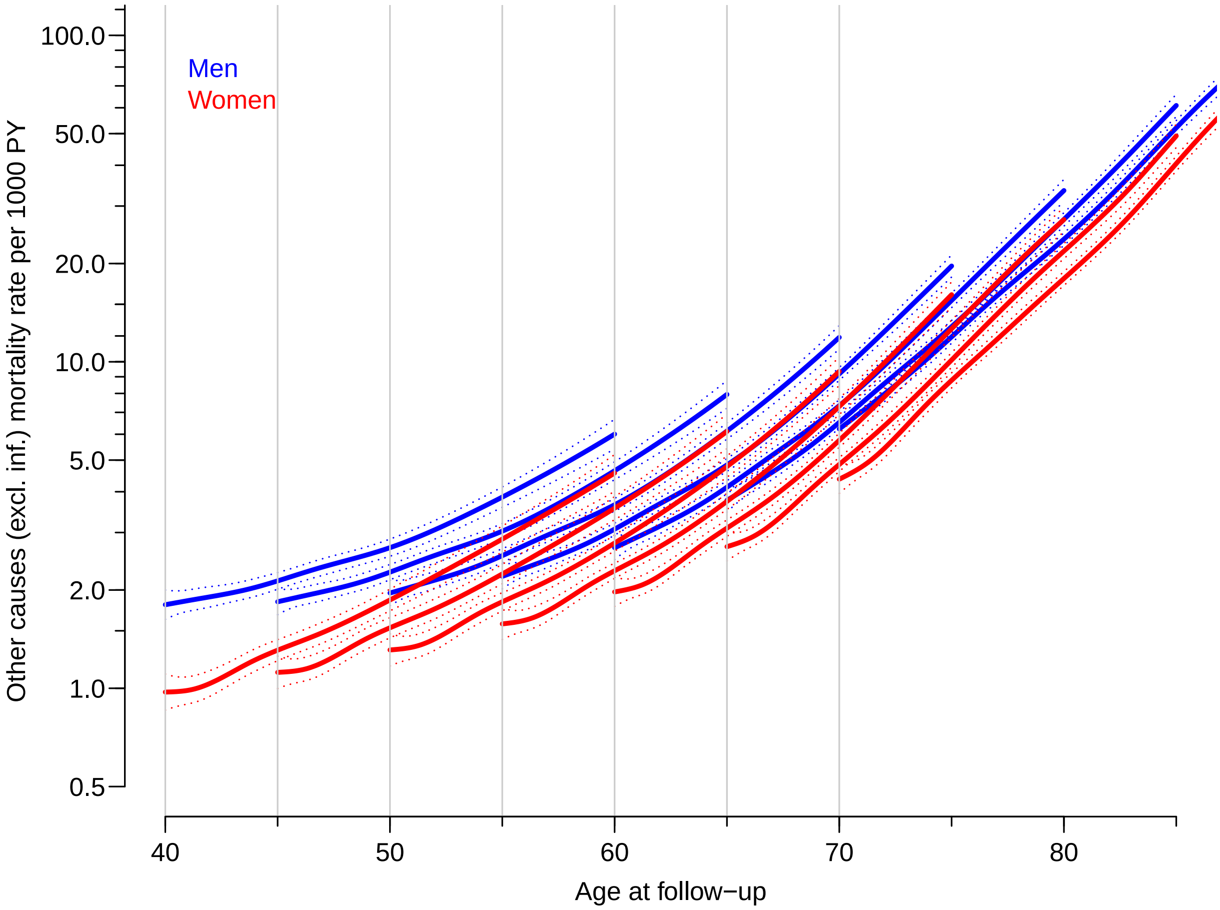

Figure 3.23: *Mortality rates from other causes (excluding infections) in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/xOthr-prM`

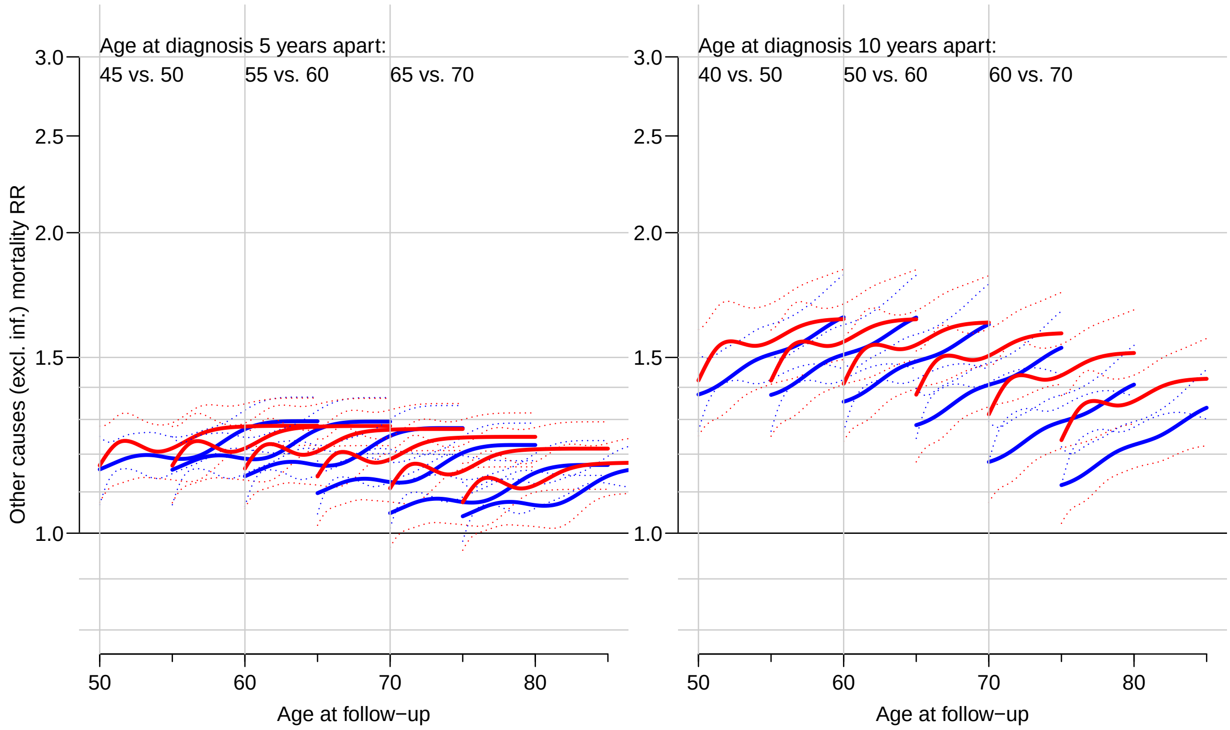

Figure 3.24: *Infections mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/xOthr-RReqd`

3.5 Figures for the published article

First we read the mortality rates and the RRs as computed

```
> library( Epi )
> clear()
> load( file="../data/all-res.Rda" )
> lls()
  name   mode class dim       size(Kb)
1 ac.res list list  2            177.9
2 ca.res list list  2            177.9
3 cv.res list list  2            177.9
4 ot.res list list  2            177.9
```

3.5.1 Mortality rates

The mortality rates are in the objects `ac.res$rates` (etc.), and these are just handed to the *ad hoc* function `panel` that draws the rates in a panel.

```
> clr <- c("blue","red")
> panel <-
+ function( prm, Rmin, ctxt, ltr )
+     {
+ yl <- c(1,200)*Rmin
+ matplot( prm[,1], prm[,-(1:2)],
+          type="l", lty=c(1,3,3), lwd=c(2,1,1), col=rep(clr,each=3),
+          log="y", xlab="Age at follow-up",
+          xlim = c(38,90), ylim=yl, xaxs="i",
+          ylab="")
+ abline( v=seq(40,70,5), col=gray(0.8) )
+ matlines( prm[,1], prm[,-(1:2)],
+          type="l", lty=c(1,3,3), lwd=c(2,1,1), col=rep(clr,each=3) )
+ mtext( paste( ctxt, "mortality rate per 1000 patient-years"),
+        side=2, las=0, line=2.5, cex=0.83 )
+ axis( side=2, at=c(outer(c(1,1.5,2:10,12,15),0:1,function(x,y)x*10^y)), labels=NA, tcl=-0
+ axis( side=1, at=seq(40,85,5), labels=NA, tcl=-0.3 )
+ mtext( paste("(",ltr,")",sep=""), side=2, at=10^par("usr")[4]*1.15, srt=90, line=1/1.6 )
+     }
> par( mfrow=c(2,2),
+      mar=c(3,3.5,1,0.5), mgp=c(3,1,0)/1.6, las=1, bty="l")
> panel( ac.res$rates, 1, "All-cause", "a" )
> panel( cv.res$rates, 0.2, "CVD", "b" )
> panel( ca.res$rates, 0.2, "Cancer", "c" )
> panel( ot.res$rates, 1, "Other-cause", "d" )
> pdf( "Fig1.pdf", height=8, width=8 )
> par( mfrow=c(2,2),
+      mar=c(3,3.5,1,0.5), mgp=c(3,1,0)/1.6, las=1, bty="l")
> panel( ac.res$rates, 1, "All-cause", "a" )
> panel( cv.res$rates, 0.2, "CVD", "b" )
> panel( ca.res$rates, 0.2, "Cancer", "c" )
> panel( ot.res$rates, 1, "Other-cause", "d" )
> dev.off()
pdf
  2
```

...now input from artPlots.tex

```
> postscript( "Fig1.eps", height=8, width=8 )
> par( mfrow=c(2,2),
+      mar=c(3,3.5,1,0.5), mgp=c(3,1,0)/1.6, las=1, bty="l")
> panel( ac.res$rates, 1, "All-cause", "a" )
> panel( cv.res$rates, 0.2, "CVD", "b" )
> panel( ca.res$rates, 0.2, "Cancer", "c" )
> panel( ot.res$rates, 1, "Other-cause", "d" )
> dev.off()
```

```
pdf
  2
```

3.5.2 Rate ratios

The mortality rate ratios are in the objects `ac.res$rateratio` (etc.), which has two components "5" and "10" with the rate-ratios corresponding to 5 resp. 10 years of difference in duration.

```
> str( ac.res$rateratio$"5" )
```

```
 num [1:606, 1:7] NA 50 50.2 50.3 50.5 ...
 - attr(*, "dimnames")=List of 2
  ..$ : NULL
  ..$ : chr [1:7] "age" "exp(Est.)" "2.5%" "97.5%" ...
```

```
> head( ac.res$rateratio$"5" )
```

```
          age exp(Est.)      2.5%     97.5% exp(Est.)      2.5%     97.5%
[1,]       NA        NA        NA        NA        NA        NA        NA
[2,] 50.00000 0.8318797 0.7938183 0.8717661 0.7852674 0.7408267 0.8323741
[3,] 50.15152 0.8497442 0.8154495 0.8854812 0.8062585 0.7658184 0.8488341
[4,] 50.30303 0.8678532 0.8366820 0.9001857 0.8275689 0.7904294 0.8664535
[5,] 50.45455 0.8860247 0.8570307 0.9159996 0.8488789 0.8139934 0.8852596
[6,] 50.60606 0.9040616 0.8761486 0.9328639 0.8698366 0.8359870 0.9050568
```

```
> rrpan <-
+ function( rr, RRmin, ctxt, ltr )
+     {
+ yl <- c(1,3)*RRmin
+ plot( NA, xlim=c(50,85), ylim=yl, log="y",
+           xlab="Age at follow-up", ylab="", xaxt="n" )
+ # abline(h=outer(1:15,10^c(-2:2)),col=gray(0.8))
+ abline( v=seq(50,75,5), col=gray(0.8) )
+ abline(h=1)
+ axis( side=1, at=seq(50,80,10) )
+ axis( side=1, at=seq(50,85,5), labels=NA, tcl=-0.3 )
+ matlines( rr[,1], rr[,-1],
+           type="l", lty=c(1,3,3),
+           lwd=c(2,1,1), col=rep(c("blue","red"),3) )
+ # text( 50, yl[2]*0.98, paste( "Age at diagnosis", ddif, "years apart:" ), adj=c(0,1) )
+ # text( ahi, rep(yl[2]*0.90,3), paste(ahi-ddif,"vs.",ahi), adj=0 )
+ mtext( paste("(",ltr,")",sep=""), side=2, at=10^par("usr")[4]*1.05,
+        srt=90, line=1/1.6, cex=0.67 )
+ mtext( paste(ctxt,"mortality rate ratio"), side=2, las=0, line=2, cex=0.67 )
+     }
> doRR <- function(){
+ rrpan( ac.res$rateratio$"5" , 0.5, "All-cause", "a" )
+ rrpan( ac.res$rateratio$"10", 0.5, "All-cause", "b" )
```

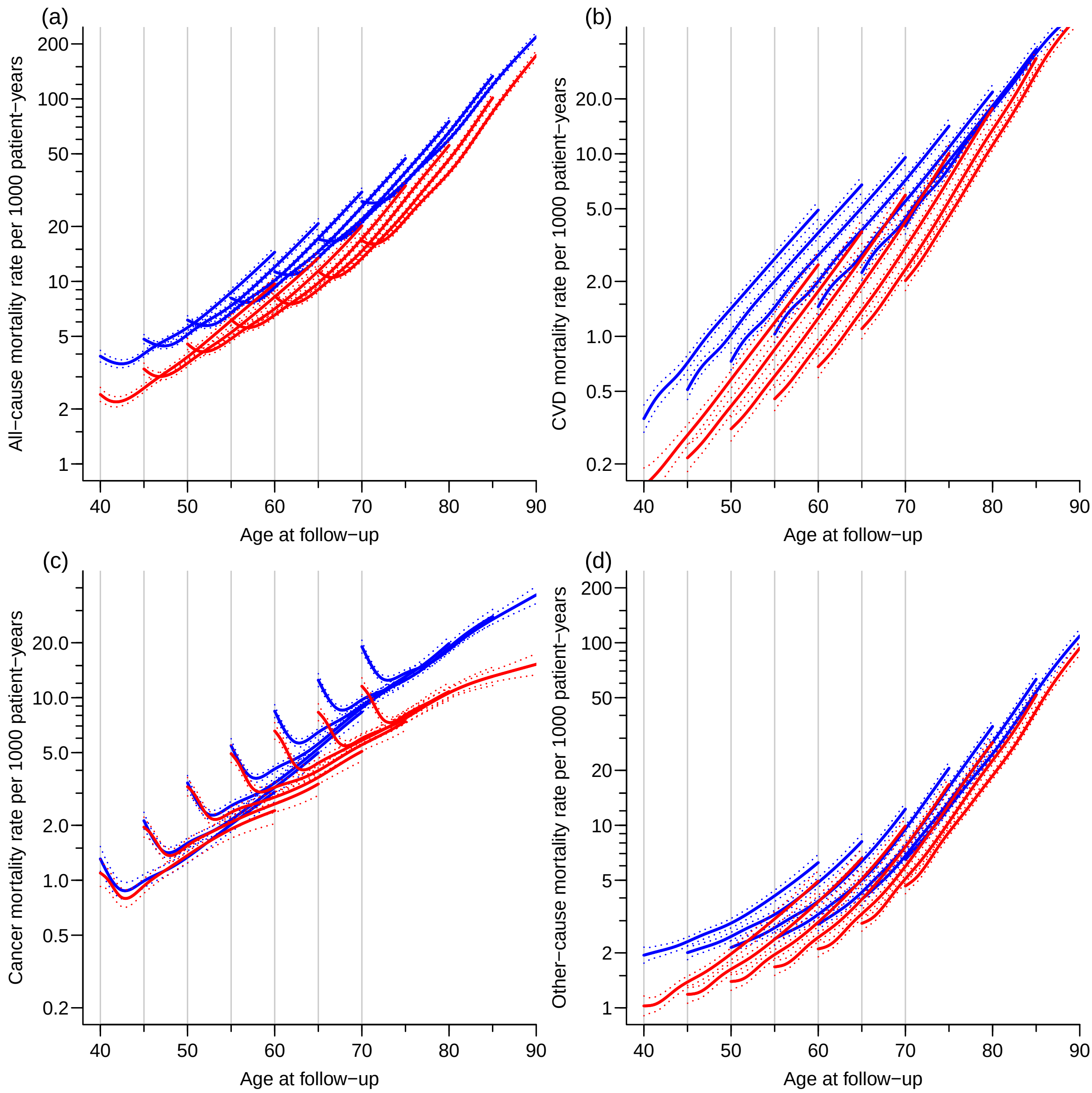

Figure 3.25: *(Article figure 1) Mortality rates among Australian diabetes patients diagnosed in ages 40, 45, ..., 70. 95% confidence intervals are given as dotted lines. Blue, men; red, women.* ./artPlots-rates

```
+ rrpan( cv.res$rateratio$"5" , 0.9, "CVD", "c" )
+ rrpan( cv.res$rateratio$"10", 0.9, "CVD", "d" )
+ rrpan( ca.res$rateratio$"5" , 0.4, "Cancer", "e" )
+ rrpan( ca.res$rateratio$"10", 0.4, "Cancer", "f" )
+ rrpan( ot.res$rateratio$"5" , 0.9, "Other-cause", "g" )
+ rrpan( ot.res$rateratio$"10", 0.9, "Other-cause", "h" )
+                  }
> par( mfrow=c(2,4), mar=c(3,3.5,1,0.5), mgp=c(3,1,0)/1.6, las=1, bty="l" )
> doRR()
> pdf( "Fig2.pdf", height=5, width=8 )
> par( mfrow=c(2,4), mar=c(3,3.5,1,0.5), mgp=c(3,1,0)/1.6, las=1, bty="l" )
```

```
> doRR()
> dev.off()
pdf
  2
> postscript( "Fig2.eps", height=5, width=8 )
> par( mfrow=c(2,4), mar=c(3,3.5,1,0.5), mgp=c(3,1,0)/1.6, las=1, bty="l" )
> doRR()
> dev.off()
pdf
  2
```

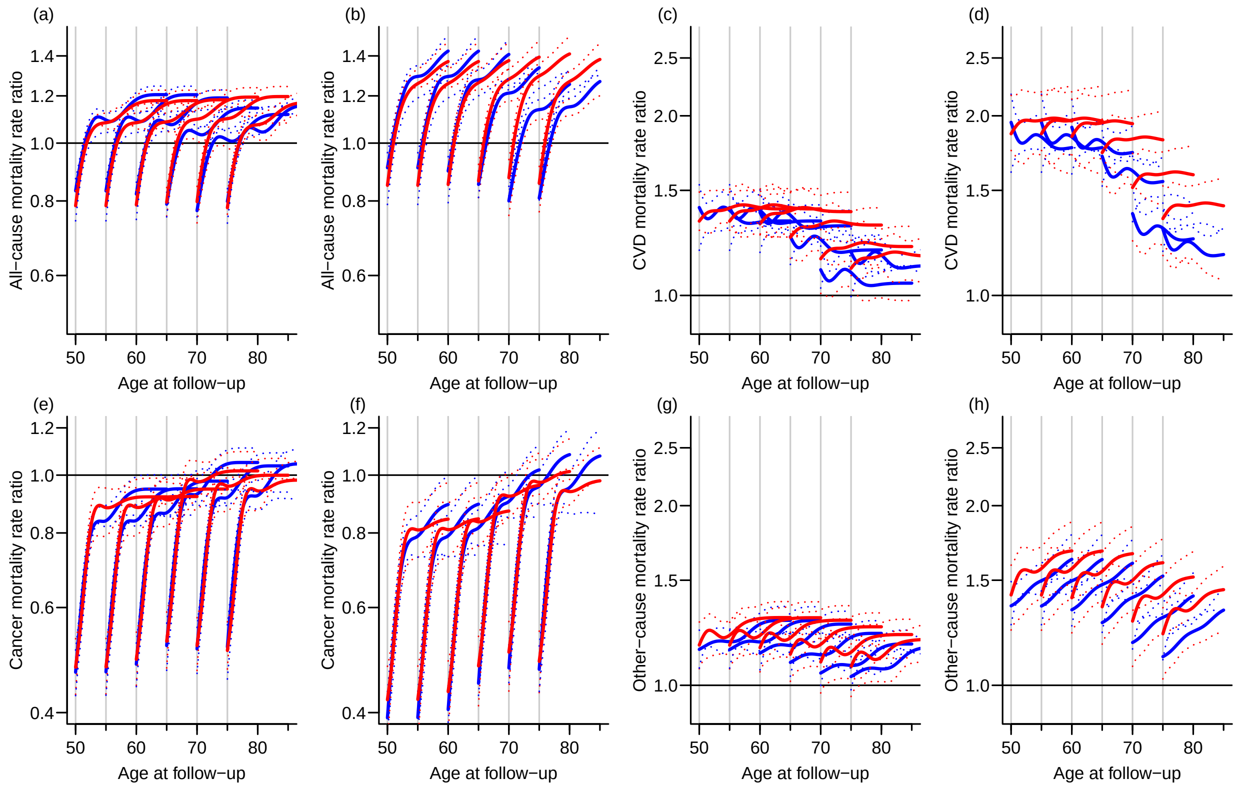

Figure 3.26: *(Article figure 2) Mortality rate ratios between Australian diabetes patients diagnosed with DM in ages 45, 50, . . . , 70 relative to patients diagnosed in ages 50, 55, . . . , 75 — 5 years difference in diabetes duration (panels a,c,e,g); and between patients diagnosed with DM in ages 40, 45, . . . , 65 relative to patients diagnosed in ages 50, 55, . . . , 75 (b,d,f,h) — 10 years difference in diabetes duration. 95% confidence intervals are given as dotted lines. Blue, men; red, women.* ./artPlots-RR

```
> options( width=90,
+          SweaveHooks=list( fig=function()
+          par(mar=c(3,3,1,1),mgp=c(3,1,0)/1.6,las=1,bty="n") ) )
```

Chapter 4

Date of registration used

First we load the relevant data

```
> library( Epi )
> library( popEpi )
> library( devEMF )
> clear()
> load( file="../data/Agr.Rda" )
> Agr <- Agr[,':='( age = age+0.25, per = per+0.25, dur = dur+0.25 )]
> load( file="../data/cod.Rda" )
> lls()
  name mode     class                 dim              size(Kb)
1 Agr  list     data.table data.frame 309781 17        39,936.7
2 cod  function function              1                   184.4
```

4.1 All causes of death

```
> cod( Agr, "r", "D" , "All cause", Rmin=1, RRmin=0.5 )
Analysis of D All cause :
     sex         Men                    Women                   Sum
                   D           Y           D           Y          D           Y
Year
1997           4,146   111,974.9       3,075   105,250.7      7,221   217,225.6
1998           4,622   131,143.7       3,317   124,729.2      7,939   255,872.9
1999           5,298   151,829.8       3,809   144,835.1      9,107   296,665.0
2000           5,906   174,813.2       4,300   165,669.0     10,206   340,482.1
2001           6,464   198,260.2       4,831   186,359.2     11,295   384,619.4
2002           7,239   224,522.9       5,238   209,094.9     12,477   433,617.9
2003           7,802   250,112.0       5,881   232,270.2     13,683   482,382.2
2004           8,501   274,075.7       6,447   253,728.7     14,948   527,804.4
2005           9,075   297,477.3       6,758   274,259.6     15,833   571,736.9
2006           9,687   320,496.7       7,567   293,503.1     17,254   613,999.8
2007          10,486   344,334.0       8,130   312,890.8     18,616   657,224.9
2008          11,345   367,626.1       8,950   330,906.1     20,295   698,532.1
2009          11,919   391,700.4       9,010   349,580.9     20,929   741,281.3
2010          12,212   417,026.0       9,532   368,447.4     21,744   785,473.4
2011          11,948   444,867.6       8,985   388,439.3     20,933   833,306.9
Sum          126,650 4,100,260.4      95,830 3,739,964.3    222,480 7,840,224.7
```

```
Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.966 0.964 0.967
Women     0.966 0.965 0.968
null device
          1
```

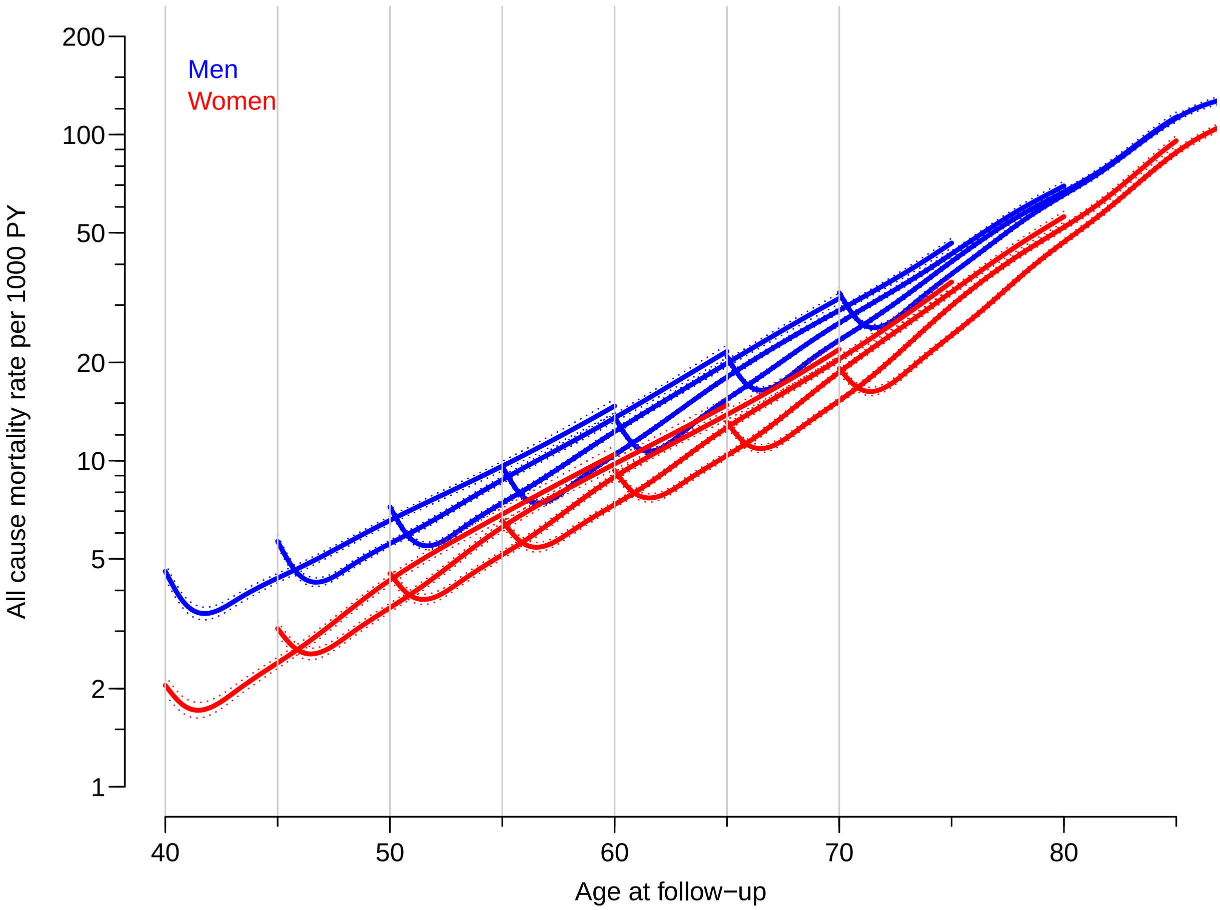

Figure 4.1: *Mortality rates from any cause in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.*`../graph/rD-prM`

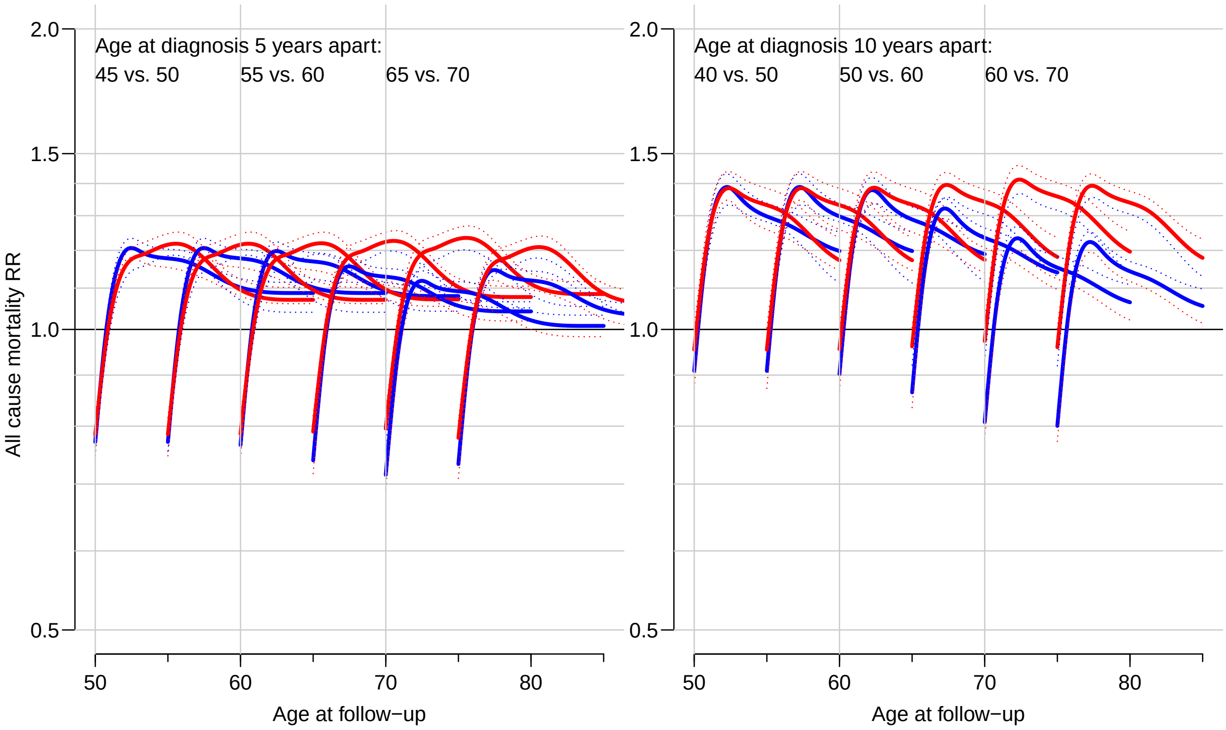

Figure 4.2: *All cause mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/rD-RReqd`

4.2 Three causes of death

The following three sections represent a subdivision of causes of death in three different causes: CVD, Cancer and other, together making up all deaths among diabetes patients in Australia.

4.2.1 CVD

```
> cod( Agr, "r", "CVD" , "CVD", Rmin=1/8, RRmin=0.8 )
```

```
Analysis of CVD CVD :
     sex         Men                    Women                    Sum
                   D           Y           D           Y           D           Y
Year
1997           1,614   111,974.9       1,218   105,250.7       2,832   217,225.6
1998           1,776   131,143.7       1,318   124,729.2       3,094   255,872.9
1999           2,044   151,829.8       1,442   144,835.1       3,486   296,665.0
2000           2,136   174,813.2       1,559   165,669.0       3,695   340,482.1
2001           2,269   198,260.2       1,840   186,359.2       4,109   384,619.4
2002           2,480   224,522.9       1,823   209,094.9       4,303   433,617.9
2003           2,691   250,112.0       2,018   232,270.2       4,709   482,382.2
2004           2,806   274,075.7       2,178   253,728.7       4,984   527,804.4
2005           2,871   297,477.3       2,172   274,259.6       5,043   571,736.9
2006           2,943   320,496.7       2,207   293,503.1       5,150   613,999.8
2007           3,067   344,334.0       2,346   312,890.8       5,413   657,224.9
2008           3,315   367,626.1       2,550   330,906.1       5,865   698,532.1
2009           3,396   391,700.4       2,569   349,580.9       5,965   741,281.3
2010           3,260   417,026.0       2,650   368,447.4       5,910   785,473.4
2011           2,965   444,867.6       2,266   388,439.3       5,231   833,306.9
Sum           39,633 4,100,260.4      30,156 3,739,964.3      69,789 7,840,224.7

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.928 0.926 0.930
Women     0.926 0.924 0.929
null device
          1
```

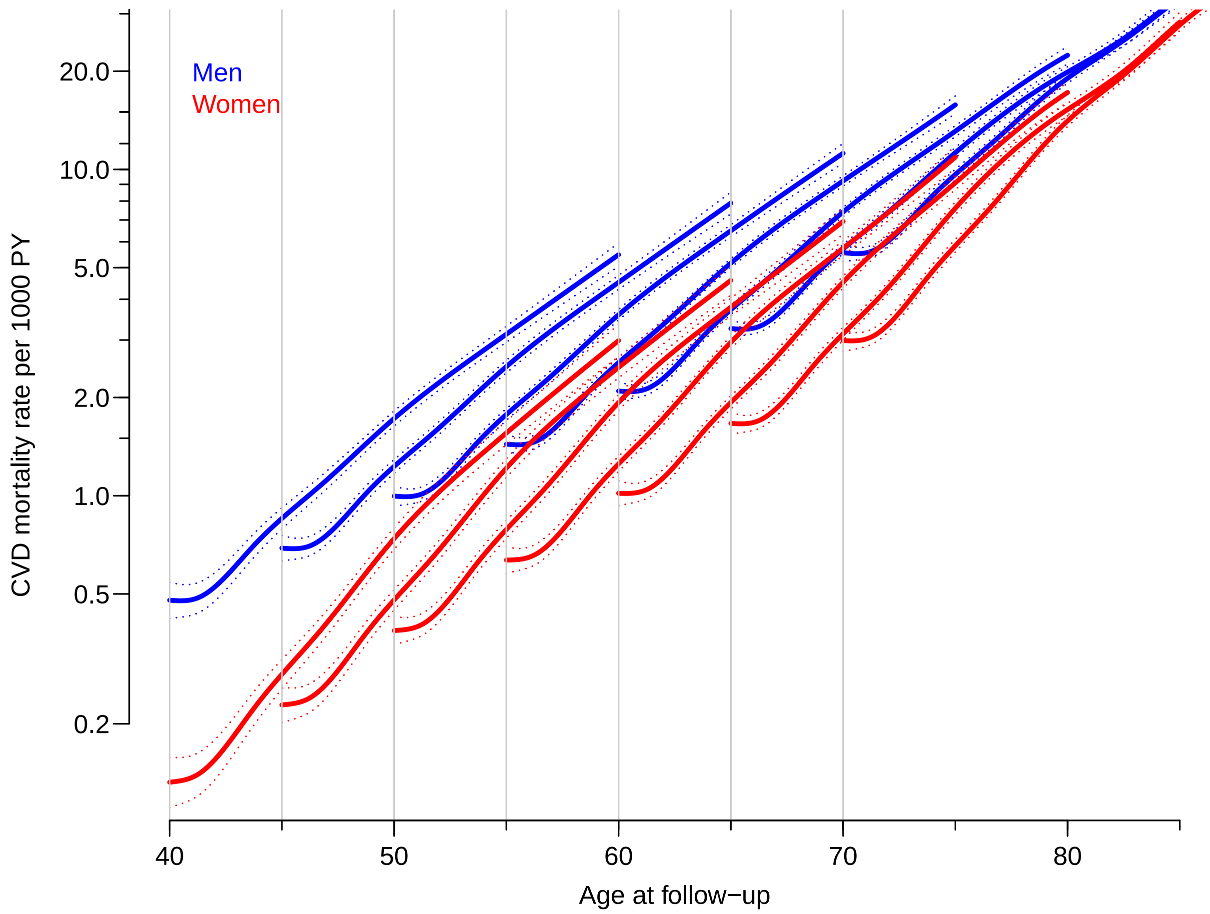

Figure 4.3: *Mortality rates from CVD in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* ../`graph/rCVD-prM`

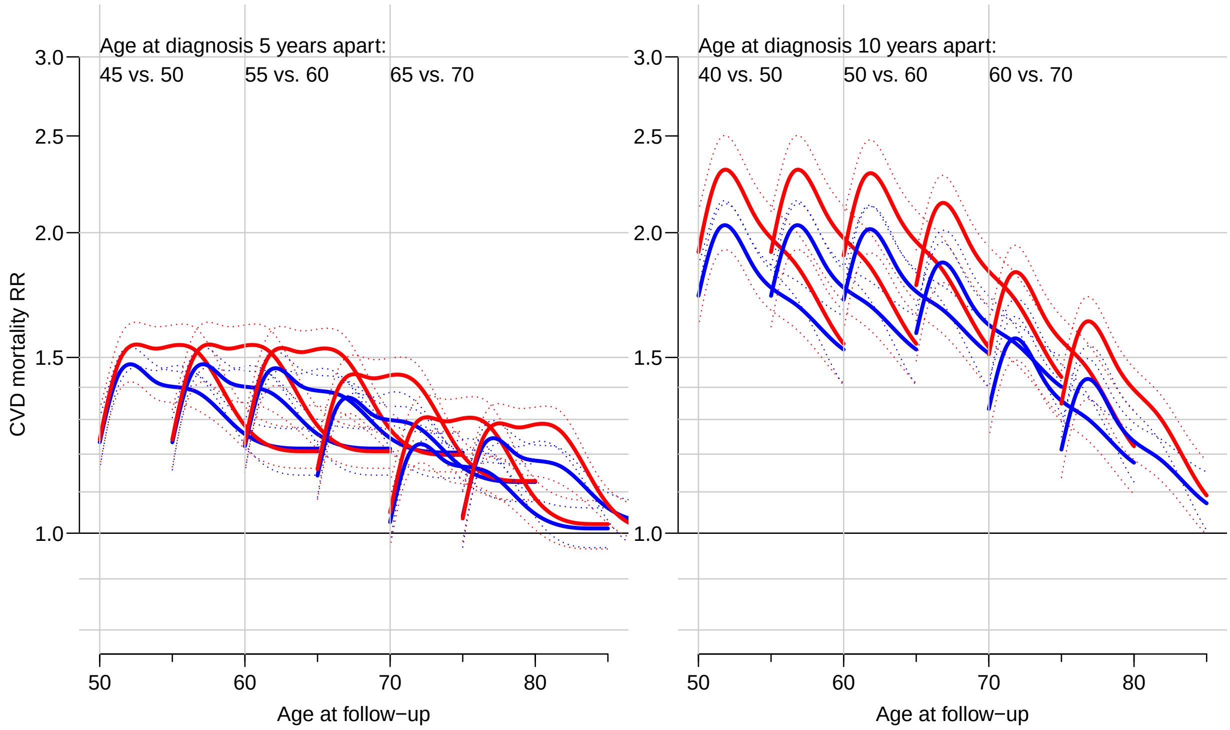

Figure 4.4: *CVD mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/rCVD-RReqd`

4.2.2 Cancer

```
> cod( Agr, "r", "Can" , "Cancer", Rmin=0.5, RRmin=0.4 )
Analysis of Can Cancer :
     sex         Men                        Women                        Sum
                   D             Y              D             Y            D             Y
Year
1997           1,064   111,974.9            631   105,250.7        1,695   217,225.6
1998           1,302   131,143.7            700   124,729.2        2,002   255,872.9
1999           1,352   151,829.8            813   144,835.1        2,165   296,665.0
2000           1,586   174,813.2            927   165,669.0        2,513   340,482.1
2001           1,823   198,260.2          1,093   186,359.2        2,916   384,619.4
2002           2,060   224,522.9          1,207   209,094.9        3,267   433,617.9
2003           2,219   250,112.0          1,448   232,270.2        3,667   482,382.2
2004           2,483   274,075.7          1,553   253,728.7        4,036   527,804.4
2005           2,743   297,477.3          1,609   274,259.6        4,352   571,736.9
2006           2,891   320,496.7          1,901   293,503.1        4,792   613,999.8
2007           3,148   344,334.0          1,967   312,890.8        5,115   657,224.9
2008           3,386   367,626.1          2,087   330,906.1        5,473   698,532.1
2009           3,623   391,700.4          2,230   349,580.9        5,853   741,281.3
2010           3,813   417,026.0          2,256   368,447.4        6,069   785,473.4
2011           3,533   444,867.6          2,070   388,439.3        5,603   833,306.9
Sum           37,026 4,100,260.4         22,492 3,739,964.3       59,518 7,840,224.7

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.991 0.988 0.993
Women     0.995 0.992 0.999
null device
          1
```

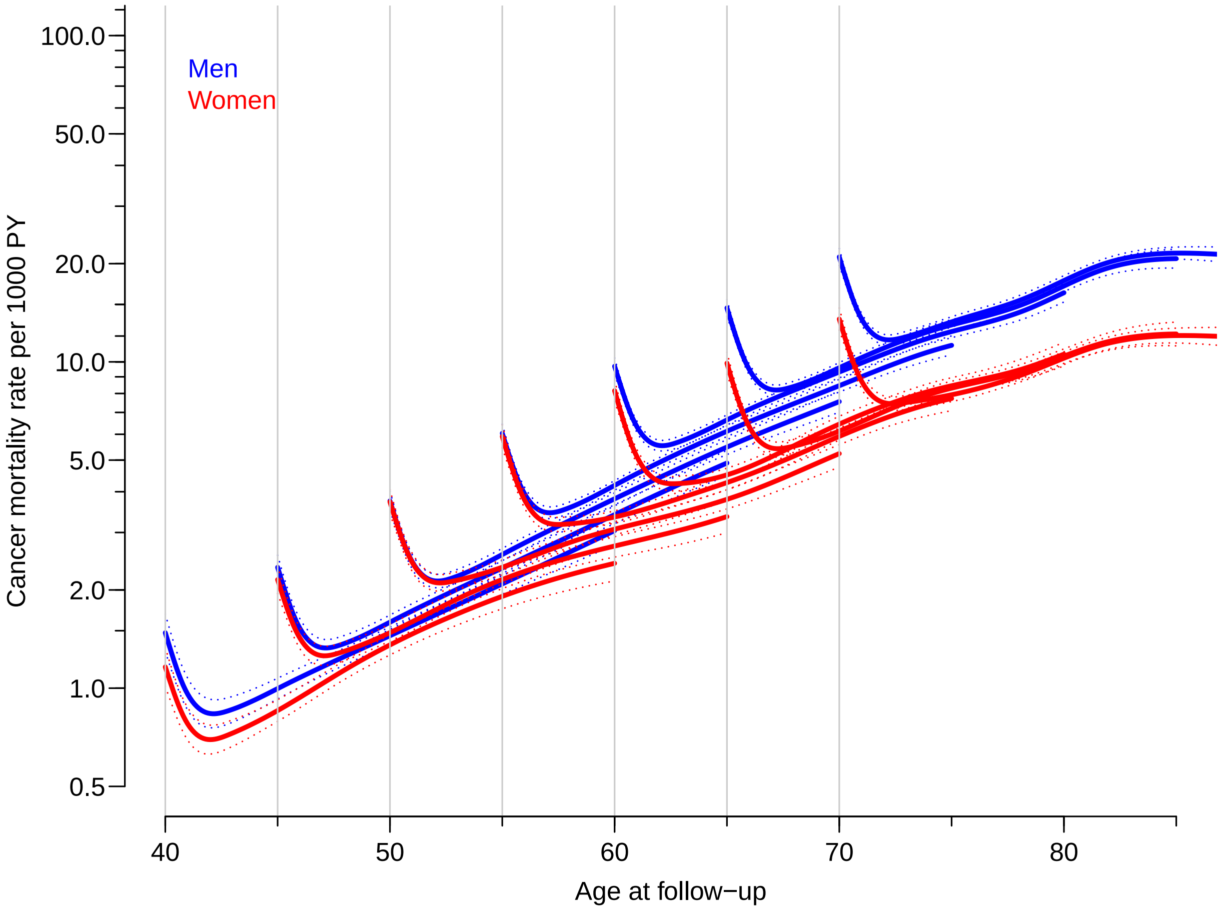

Figure 4.5: *Mortality rates from cancer in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* ../graph/rCan-prM

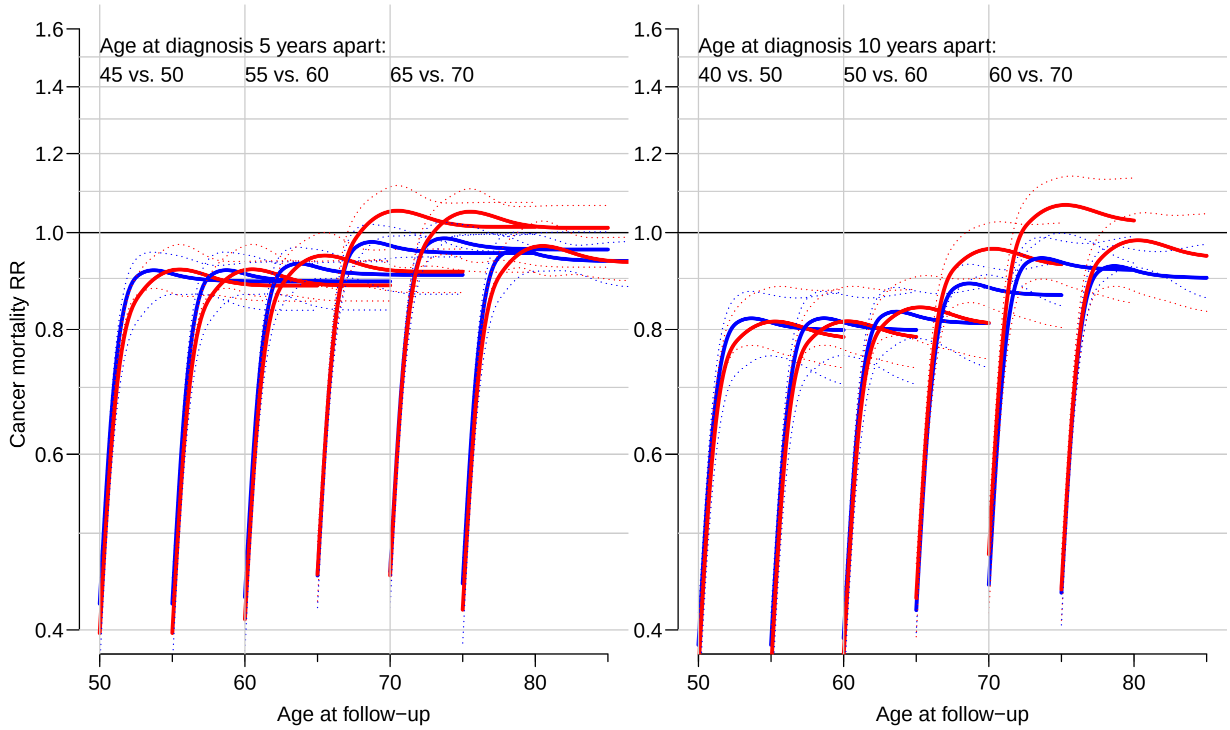

Figure 4.6: *Cancer mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/rCan-RReqd`

4.2.3 Other causes

```
> cod( Agr, "r", "Oth" , "Non-CVD, non-cancer", Rmin=0.5, RRmin=0.7 )
Analysis of Oth Non-CVD, non-cancer :
     sex         Men                     Women                     Sum
                   D           Y           D           Y           D           Y
Year
1997           1,468   111,974.9       1,226   105,250.7       2,694   217,225.6
1998           1,544   131,143.7       1,299   124,729.2       2,843   255,872.9
1999           1,902   151,829.8       1,554   144,835.1       3,456   296,665.0
2000           2,184   174,813.2       1,814   165,669.0       3,998   340,482.1
2001           2,372   198,260.2       1,898   186,359.2       4,270   384,619.4
2002           2,699   224,522.9       2,208   209,094.9       4,907   433,617.9
2003           2,892   250,112.0       2,415   232,270.2       5,307   482,382.2
2004           3,212   274,075.7       2,716   253,728.7       5,928   527,804.4
2005           3,461   297,477.3       2,977   274,259.6       6,438   571,736.9
2006           3,853   320,496.7       3,459   293,503.1       7,312   613,999.8
2007           4,271   344,334.0       3,817   312,890.8       8,088   657,224.9
2008           4,644   367,626.1       4,313   330,906.1       8,957   698,532.1
2009           4,900   391,700.4       4,211   349,580.9       9,111   741,281.3
2010           5,139   417,026.0       4,626   368,447.4       9,765   785,473.4
2011           5,450   444,867.6       4,649   388,439.3      10,099   833,306.9
Sum           49,991 4,100,260.4      43,182 3,739,964.3      93,173 7,840,224.7

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.978 0.975 0.980
Women     0.980 0.978 0.983
null device
          1
```

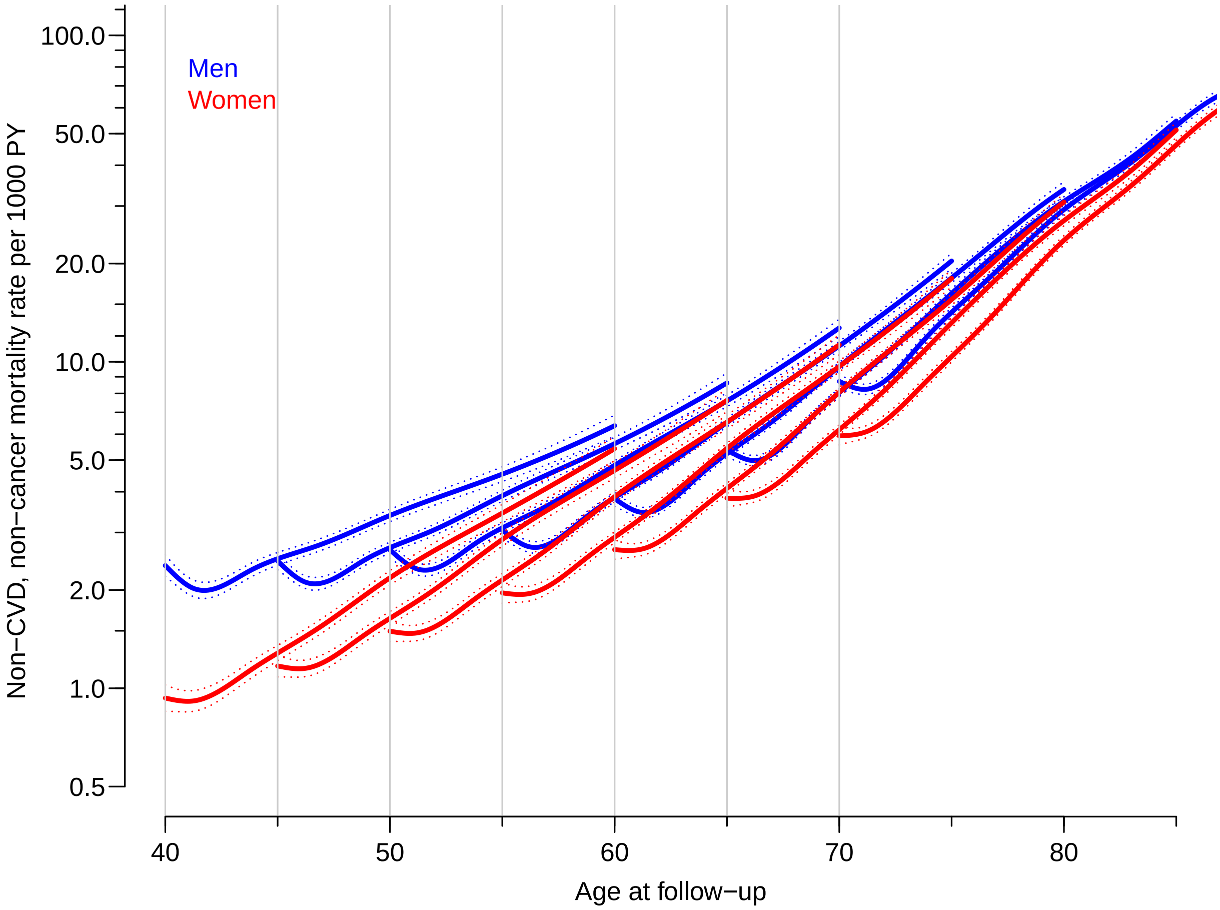

Figure 4.7: *Mortality rates from other causes (non-CVD, non-cancer) in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/rOth-prM`

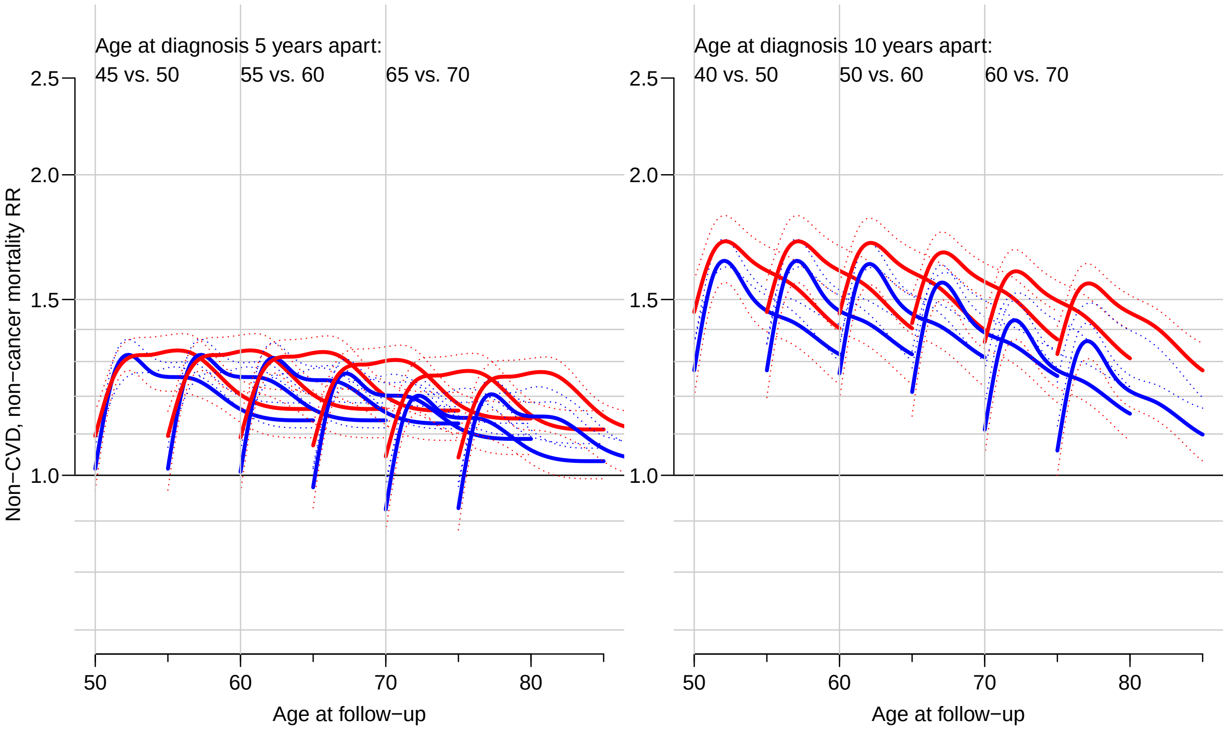

Figure 4.8: *Other mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/rOth-RReqd`

4.3 Eight causes of death

The following eight sections represent a subdivision of causes of death in twelve different causes, together making up all deaths among diabetes patients in Australia.

4.3.1 Ischemic heart disease

```
> cod( Agr, "r", "IHD" , "IHD", Rmin=0.1, RRmin=0.8 )
Analysis of IHD IHD :
     sex         Men                     Women                     Sum
                   D           Y           D           Y           D           Y
Year
1997           1,298   111,974.9         894   105,250.7       2,192   217,225.6
1998           1,420   131,143.7         969   124,729.2       2,389   255,872.9
1999           1,569   151,829.8       1,030   144,835.1       2,599   296,665.0
2000           1,708   174,813.2       1,102   165,669.0       2,810   340,482.1
2001           1,736   198,260.2       1,329   186,359.2       3,065   384,619.4
2002           1,902   224,522.9       1,299   209,094.9       3,201   433,617.9
2003           2,058   250,112.0       1,419   232,270.2       3,477   482,382.2
2004           2,184   274,075.7       1,497   253,728.7       3,681   527,804.4
2005           2,177   297,477.3       1,470   274,259.6       3,647   571,736.9
2006           2,225   320,496.7       1,456   293,503.1       3,681   613,999.8
2007           2,349   344,334.0       1,575   312,890.8       3,924   657,224.9
2008           2,485   367,626.1       1,716   330,906.1       4,201   698,532.1
2009           2,551   391,700.4       1,713   349,580.9       4,264   741,281.3
2010           2,468   417,026.0       1,729   368,447.4       4,197   785,473.4
2011           2,230   444,867.6       1,471   388,439.3       3,701   833,306.9
Sum           30,360 4,100,260.4      20,669 3,739,964.3      51,029 7,840,224.7

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.925 0.922 0.927
Women     0.917 0.914 0.921
null device
          1
```

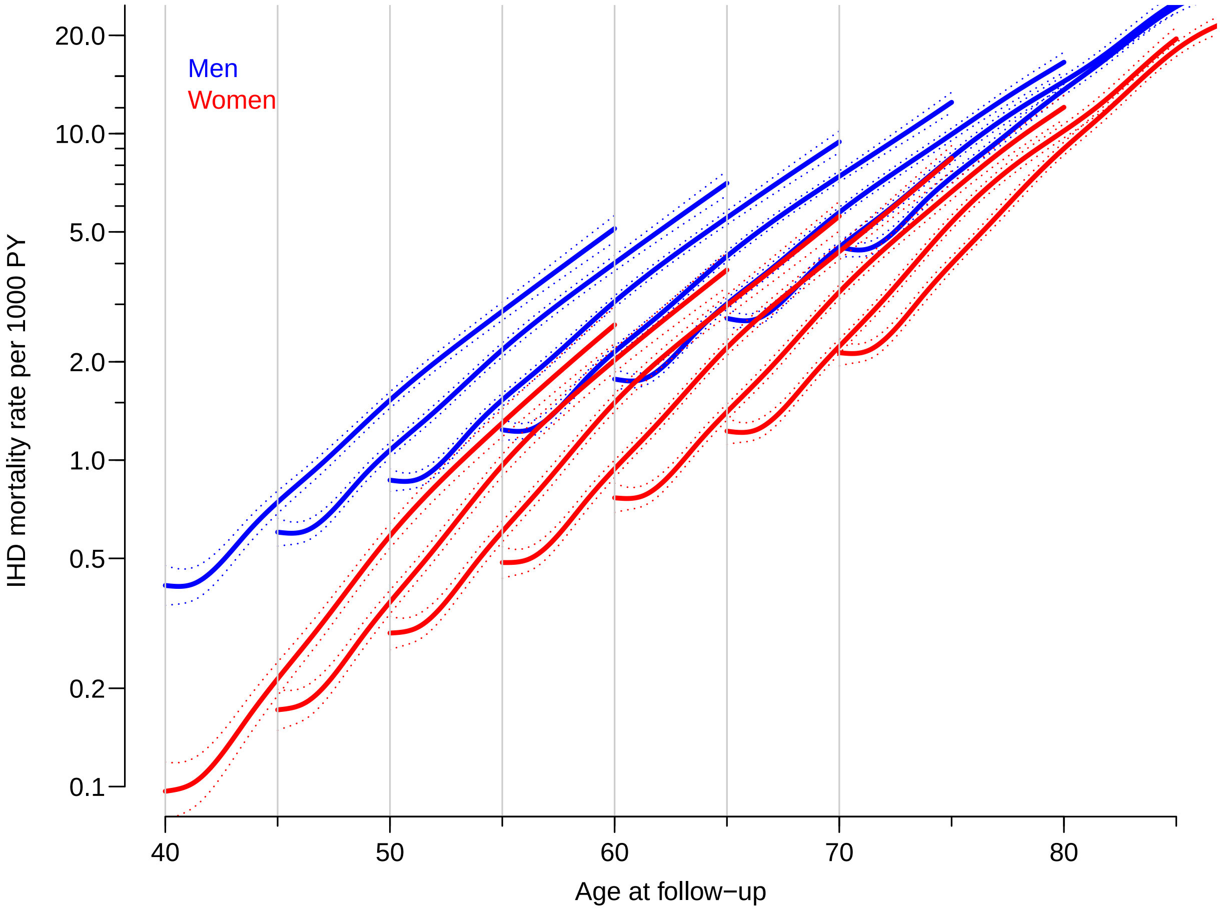

Figure 4.9: *Mortality rates from Ischemic heart disease in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/rIHD-prM`

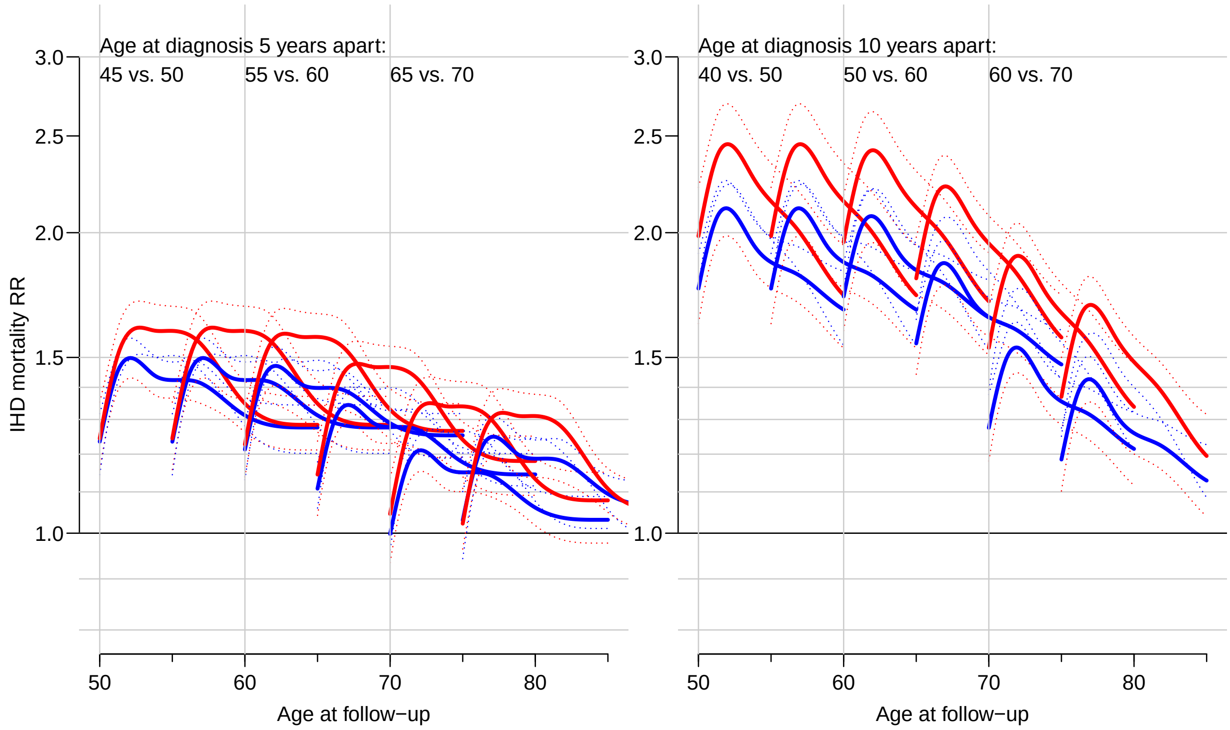

Figure 4.10: *IHD mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/rIHD-RReqd`

4.3.2 Stroke

```
> cod( Agr, "r", "Str" , "Stroke", Rmin=0.04, RRmin=0.8 )
Analysis of Str Stroke :
     sex         Men                    Women                    Sum
                   D           Y            D           Y            D           Y
Year
1997             316   111,974.9          324   105,250.7          640   217,225.6
1998             356   131,143.7          349   124,729.2          705   255,872.9
1999             475   151,829.8          412   144,835.1          887   296,665.0
2000             428   174,813.2          457   165,669.0          885   340,482.1
2001             533   198,260.2          511   186,359.2        1,044   384,619.4
2002             578   224,522.9          524   209,094.9        1,102   433,617.9
2003             633   250,112.0          599   232,270.2        1,232   482,382.2
2004             622   274,075.7          681   253,728.7        1,303   527,804.4
2005             694   297,477.3          702   274,259.6        1,396   571,736.9
2006             718   320,496.7          751   293,503.1        1,469   613,999.8
2007             718   344,334.0          771   312,890.8        1,489   657,224.9
2008             830   367,626.1          834   330,906.1        1,664   698,532.1
2009             845   391,700.4          856   349,580.9        1,701   741,281.3
2010             792   417,026.0          921   368,447.4        1,713   785,473.4
2011             735   444,867.6          795   388,439.3        1,530   833,306.9
Sum            9,273 4,100,260.4        9,487 3,739,964.3       18,760 7,840,224.7

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.939 0.934 0.944
Women     0.946 0.941 0.951
null device
          1
```

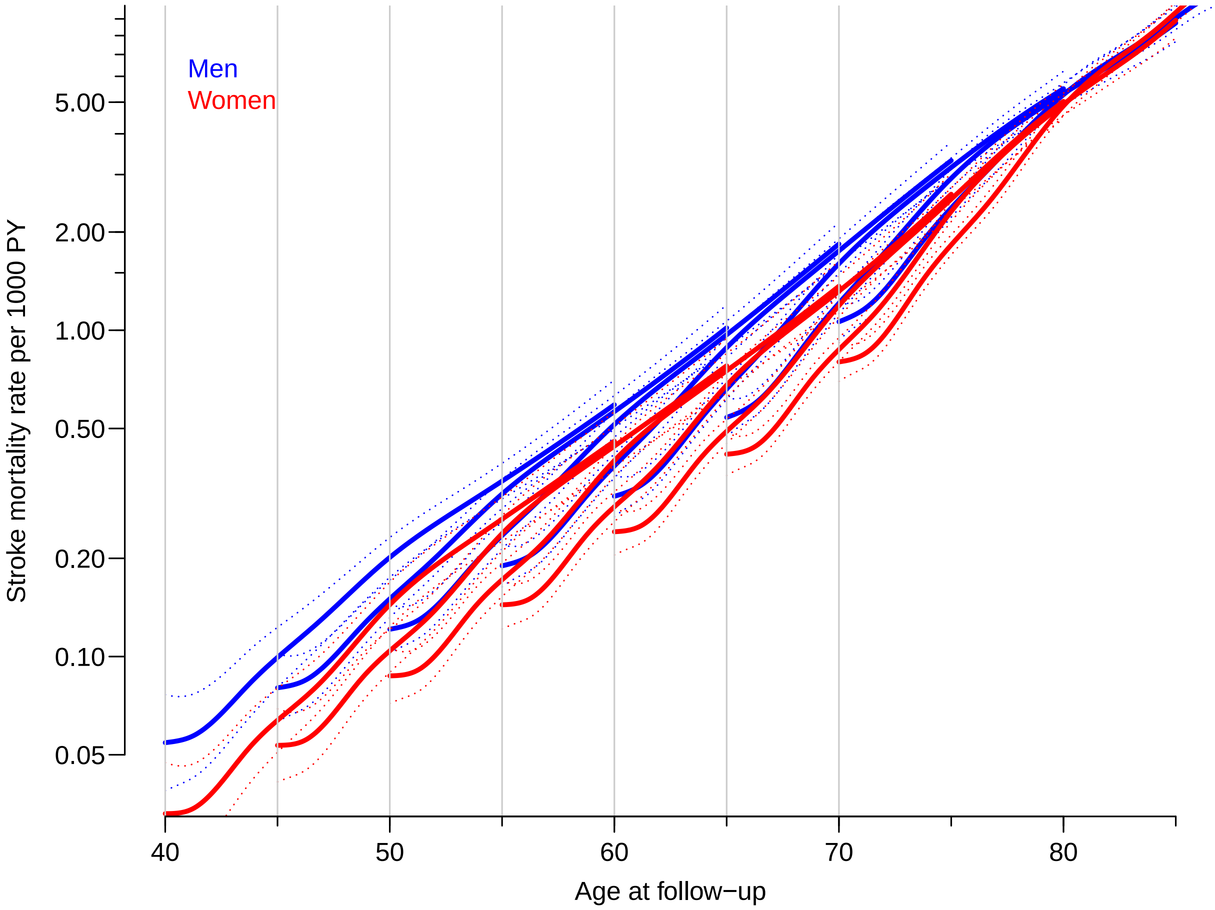

Figure 4.11: *Mortality rates from stroke in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* ../graph/rStr-prM

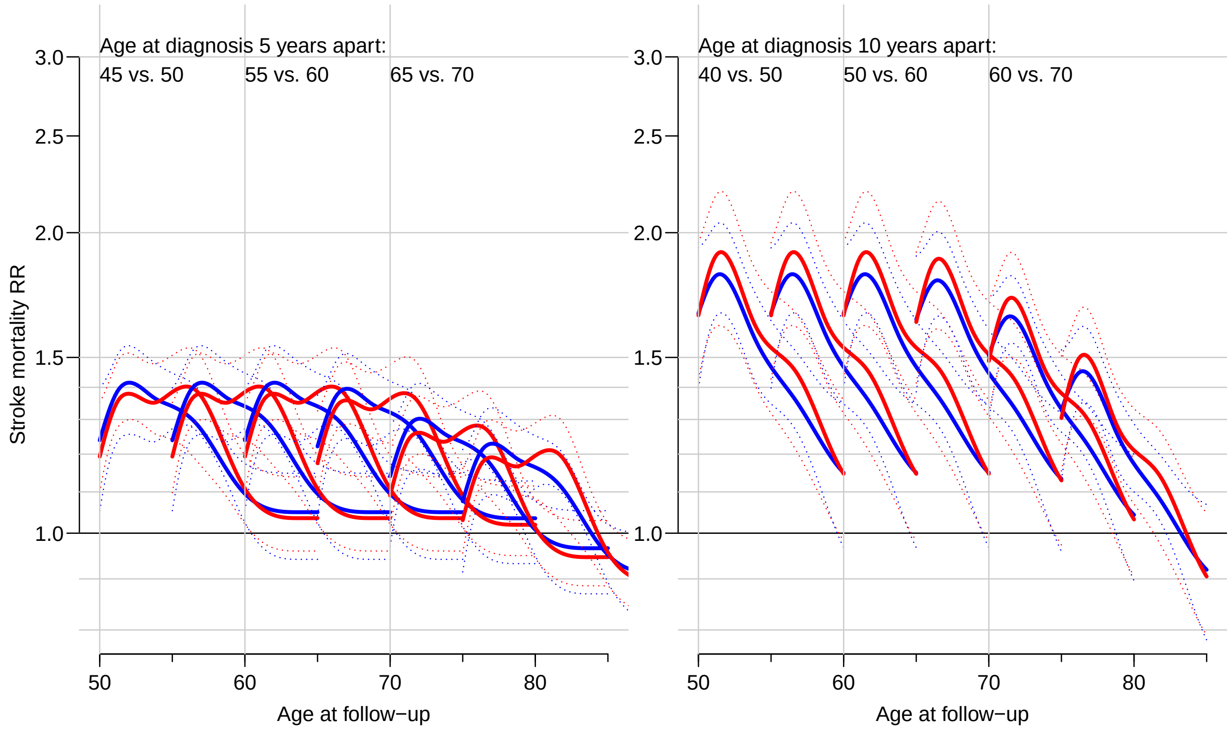

Figure 4.12: *Stroke mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/rStr-RReqd`

4.3.3 Lung cancer

```
> cod( Agr, "r", "Lung" , "Lung cancer", Rmin=0.03, RRmin=0.4 )
Analysis of Lung Lung cancer :
     sex          Men                        Women                        Sum
                    D            Y              D            Y              D            Y
Year
1997              221    111,974.9             79    105,250.7            300    217,225.6
1998              265    131,143.7             81    124,729.2            346    255,872.9
1999              288    151,829.8            110    144,835.1            398    296,665.0
2000              321    174,813.2            130    165,669.0            451    340,482.1
2001              377    198,260.2            134    186,359.2            511    384,619.4
2002              415    224,522.9            165    209,094.9            580    433,617.9
2003              438    250,112.0            200    232,270.2            638    482,382.2
2004              490    274,075.7            204    253,728.7            694    527,804.4
2005              555    297,477.3            235    274,259.6            790    571,736.9
2006              545    320,496.7            258    293,503.1            803    613,999.8
2007              649    344,334.0            281    312,890.8            930    657,224.9
2008              683    367,626.1            306    330,906.1            989    698,532.1
2009              661    391,700.4            318    349,580.9            979    741,281.3
2010              743    417,026.0            359    368,447.4          1,102    785,473.4
2011              673    444,867.6            334    388,439.3          1,007    833,306.9
Sum             7,324  4,100,260.4          3,194  3,739,964.3         10,518  7,840,224.7

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.986 0.981 0.992
Women     1.017 1.007 1.026
null device
          1
```

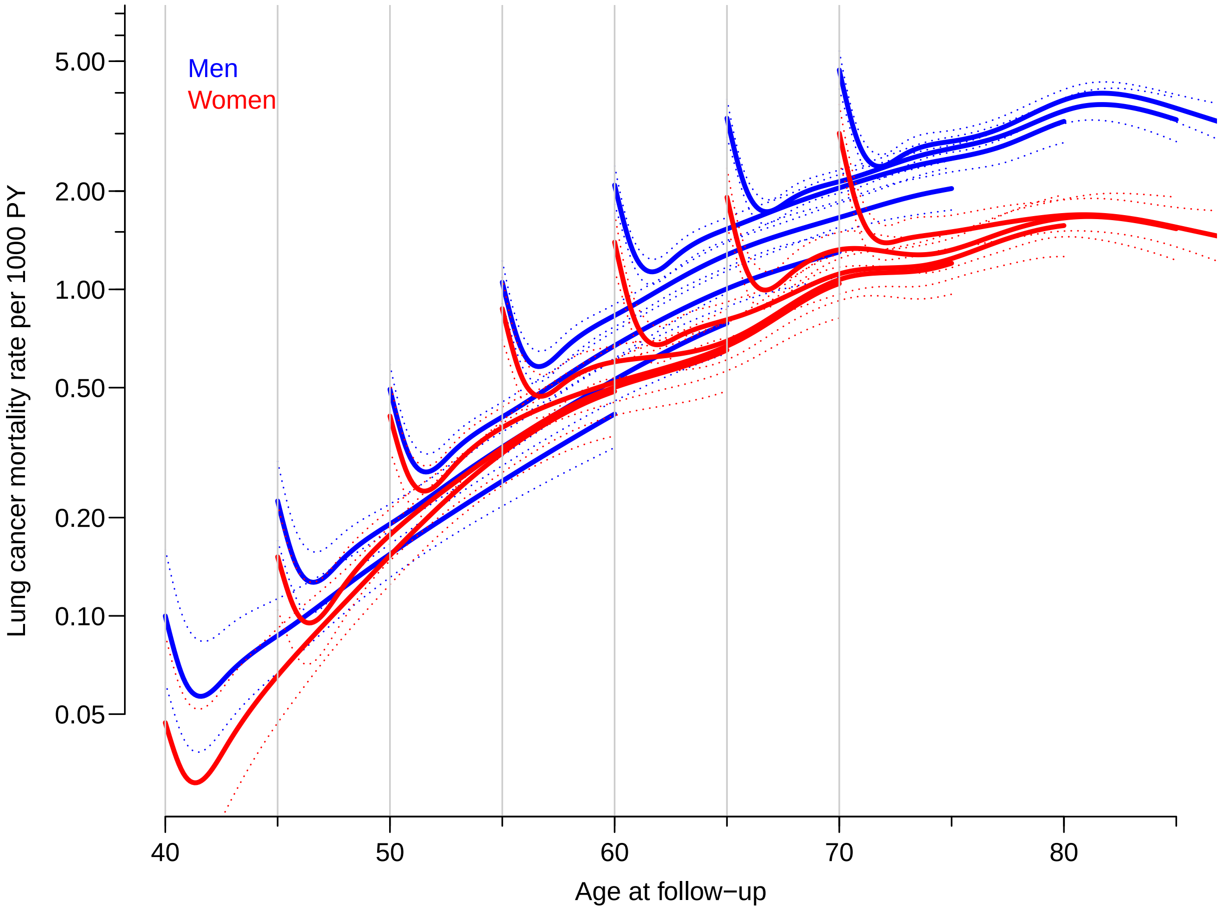

Figure 4.13: *Mortality rates from lung cancer in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/rLung-prM`

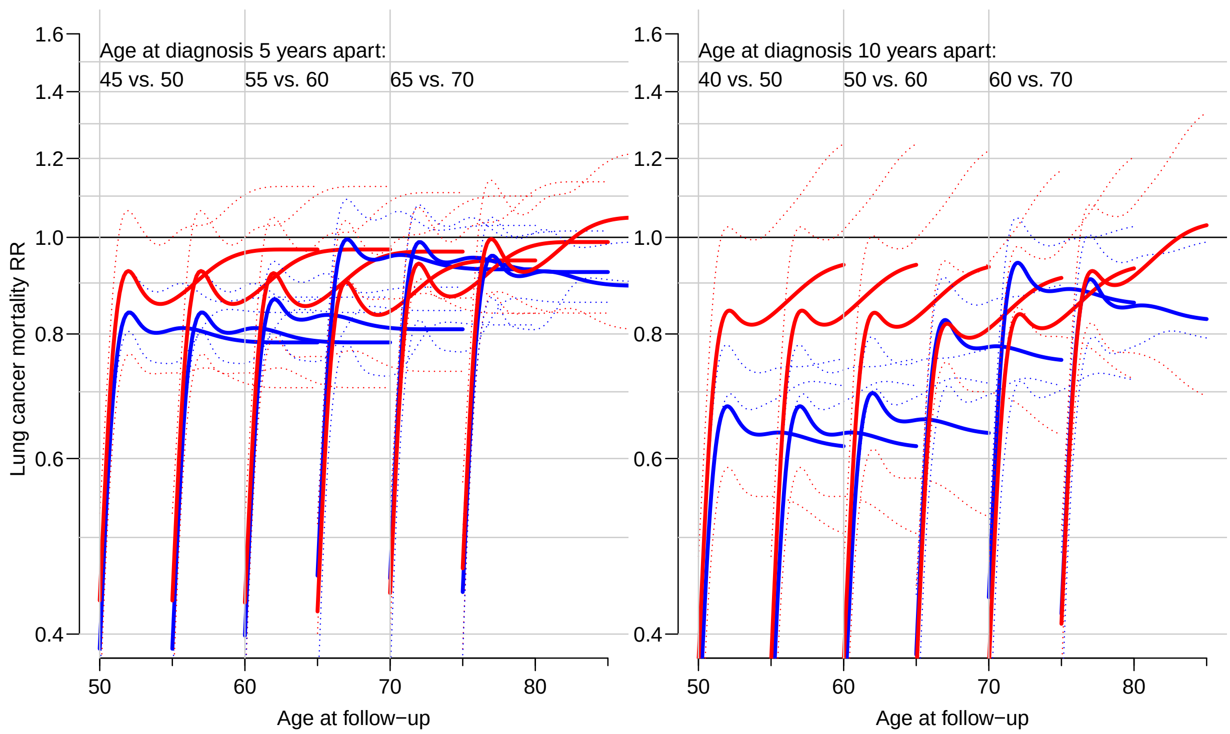

Figure 4.14: *Lung cancer mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/rLung-RReqd`

4.3.4 Colon cancer

```
> cod( Agr, "r", "ColC", "Colon cancer", Rmin=0.03, RRmin=0.4 )
Analysis of ColC Colon cancer :
     sex         Men                     Women                   Sum
                   D           Y           D           Y           D           Y
Year
1997             128   111,974.9          92   105,250.7         220   217,225.6
1998             168   131,143.7          87   124,729.2         255   255,872.9
1999             156   151,829.8         106   144,835.1         262   296,665.0
2000             186   174,813.2         110   165,669.0         296   340,482.1
2001             213   198,260.2         135   186,359.2         348   384,619.4
2002             221   224,522.9         143   209,094.9         364   433,617.9
2003             262   250,112.0         156   232,270.2         418   482,382.2
2004             250   274,075.7         147   253,728.7         397   527,804.4
2005             293   297,477.3         159   274,259.6         452   571,736.9
2006             277   320,496.7         177   293,503.1         454   613,999.8
2007             322   344,334.0         212   312,890.8         534   657,224.9
2008             309   367,626.1         221   330,906.1         530   698,532.1
2009             344   391,700.4         206   349,580.9         550   741,281.3
2010             320   417,026.0         198   368,447.4         518   785,473.4
2011             324   444,867.6         178   388,439.3         502   833,306.9
Sum            3,773 4,100,260.4       2,327 3,739,964.3       6,100 7,840,224.7

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.965 0.957 0.973
Women     0.961 0.951 0.971
null device
          1
```

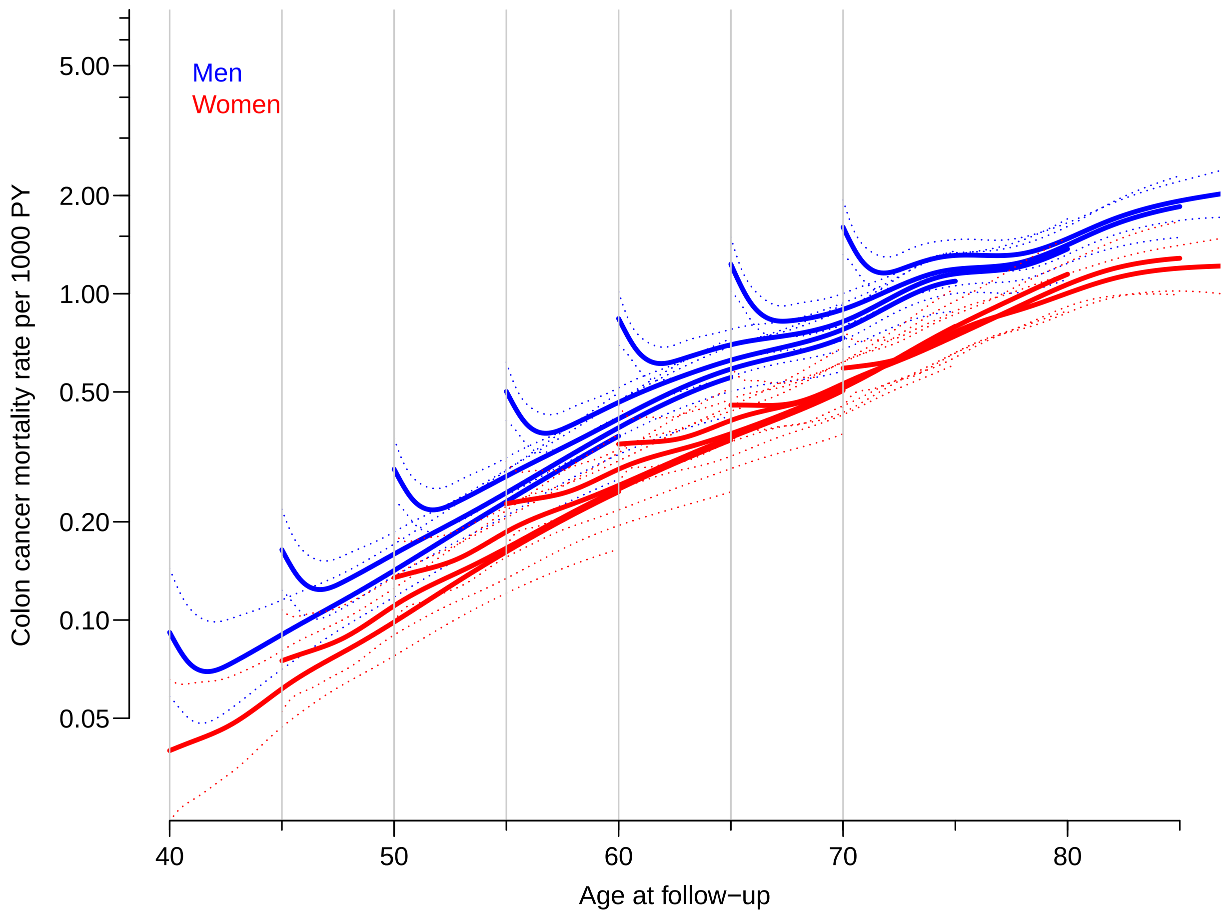

Figure 4.15: *Mortality rates from colon cancer in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/rColC-prM`

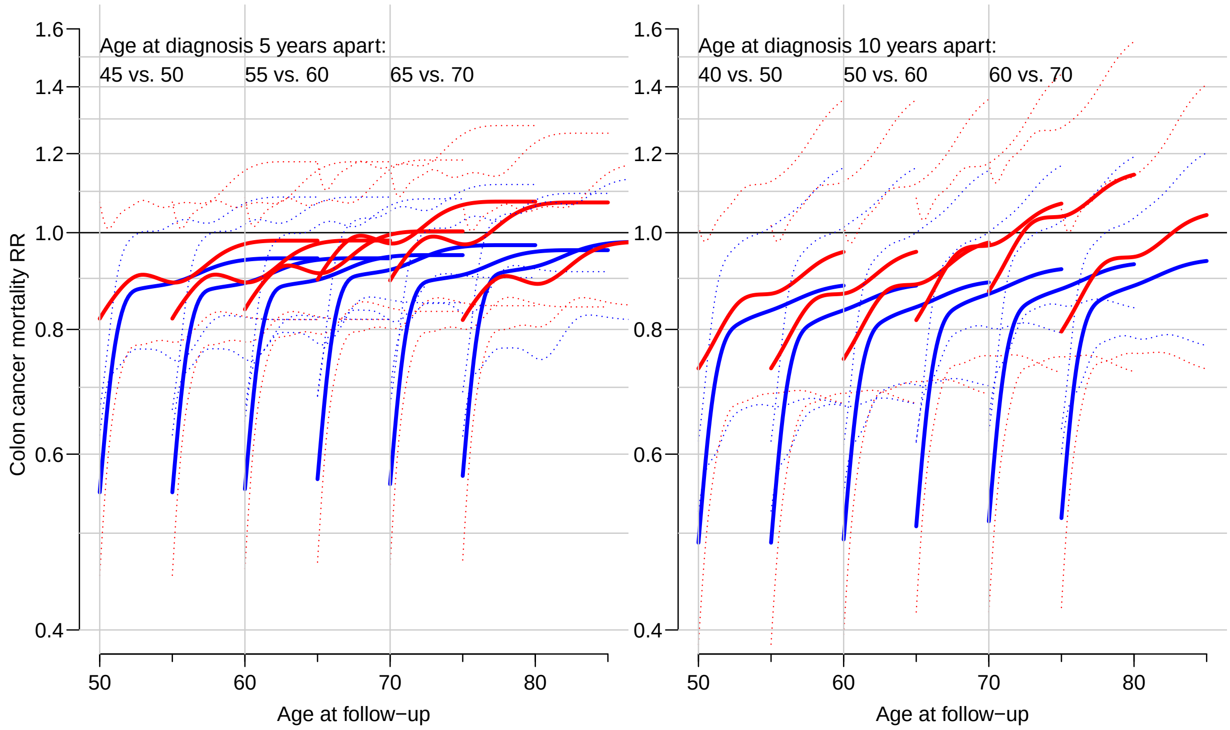

Figure 4.16: *Colon cancer mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/rColC-RReqd`

4.3.5 Pancreas cancer

```
> cod( Agr, "r", "PanC", "Pancreas cancer", Rmin=0.03, RRmin=0.4 )
Analysis of PanC Pancreas cancer :
     sex         Men                     Women                    Sum
                   D           Y           D           Y            D           Y
Year
1997             116   111,974.9         103   105,250.7          219   217,225.6
1998             132   131,143.7         110   124,729.2          242   255,872.9
1999             151   151,829.8         120   144,835.1          271   296,665.0
2000             132   174,813.2         131   165,669.0          263   340,482.1
2001             187   198,260.2         118   186,359.2          305   384,619.4
2002             222   224,522.9         130   209,094.9          352   433,617.9
2003             207   250,112.0         183   232,270.2          390   482,382.2
2004             256   274,075.7         198   253,728.7          454   527,804.4
2005             227   297,477.3         214   274,259.6          441   571,736.9
2006             254   320,496.7         228   293,503.1          482   613,999.8
2007             310   344,334.0         240   312,890.8          550   657,224.9
2008             328   367,626.1         226   330,906.1          554   698,532.1
2009             329   391,700.4         254   349,580.9          583   741,281.3
2010             350   417,026.0         277   368,447.4          627   785,473.4
2011             303   444,867.6         272   388,439.3          575   833,306.9
Sum            3,504 4,100,260.4       2,804 3,739,964.3        6,308 7,840,224.7

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.998 0.990 1.006
Women     1.004 0.995 1.014
null device
          1
```

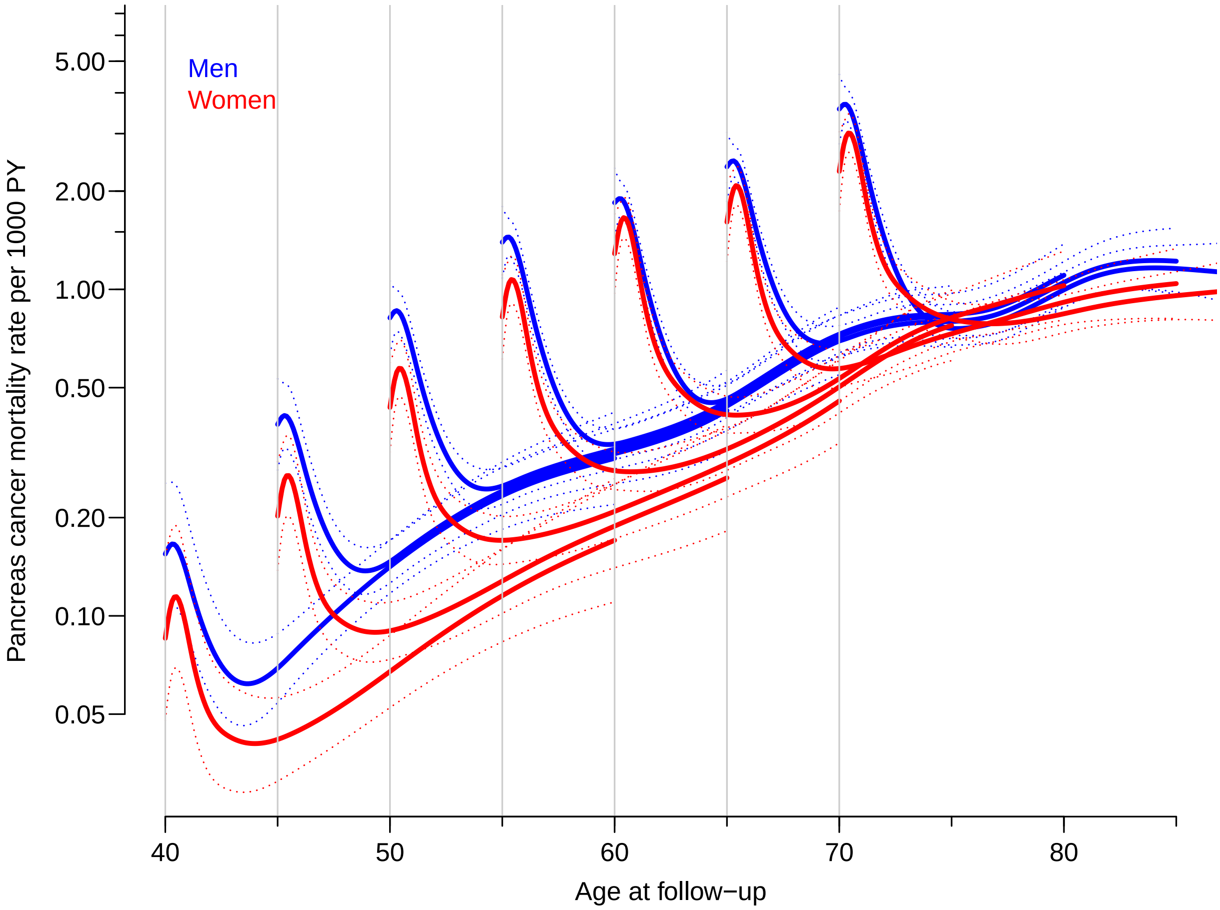

Figure 4.17: *Mortality rates from pancreatic cancer in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/rPanC-prM`

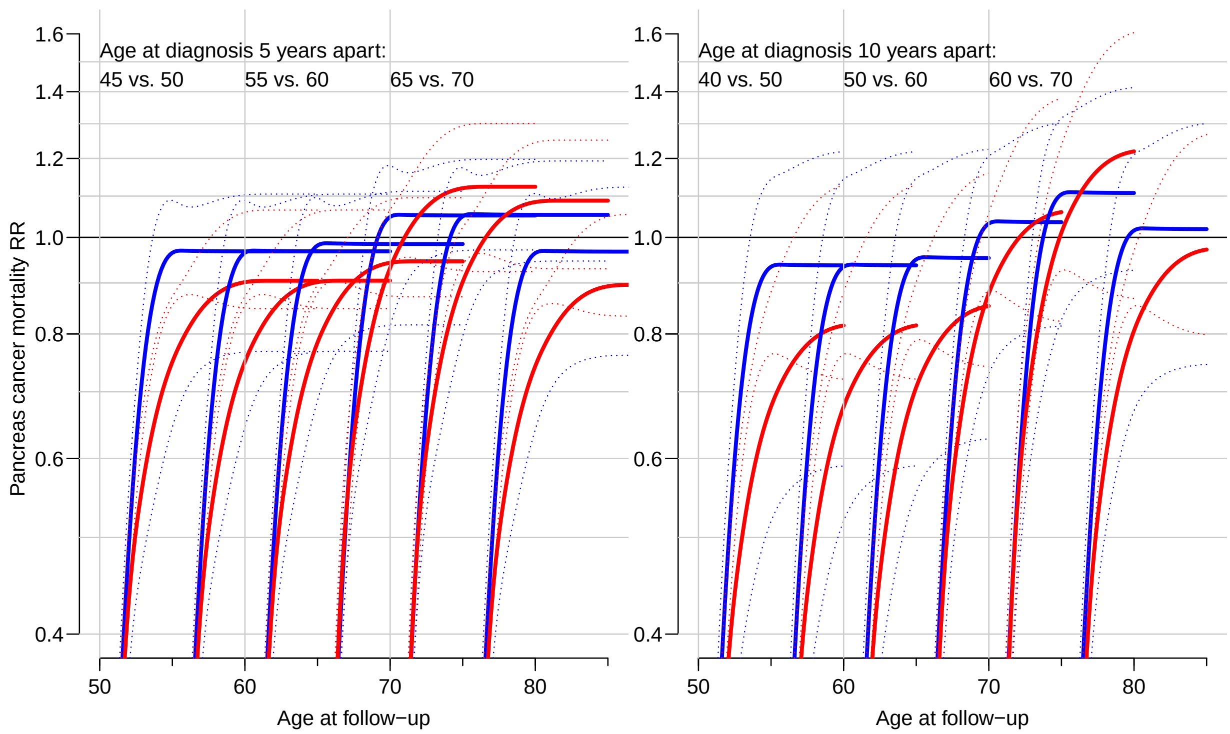

Figure 4.18: *Pancreas cancer mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/rPanC-RReqd`

4.3.6 Other cancers

```
> cod( Agr, "r", "OthC", "Other cancer", Rmin=0.2, RRmin=0.4 )
Analysis of OthC Other cancer :
     sex          Men                     Women                     Sum
                    D           Y             D           Y             D           Y
Year
1997              599   111,974.9           357   105,250.7           956   217,225.6
1998              737   131,143.7           422   124,729.2         1,159   255,872.9
1999              757   151,829.8           477   144,835.1         1,234   296,665.0
2000              947   174,813.2           556   165,669.0         1,503   340,482.1
2001            1,046   198,260.2           706   186,359.2         1,752   384,619.4
2002            1,202   224,522.9           769   209,094.9         1,971   433,617.9
2003            1,312   250,112.0           909   232,270.2         2,221   482,382.2
2004            1,487   274,075.7         1,004   253,728.7         2,491   527,804.4
2005            1,668   297,477.3         1,001   274,259.6         2,669   571,736.9
2006            1,815   320,496.7         1,238   293,503.1         3,053   613,999.8
2007            1,867   344,334.0         1,234   312,890.8         3,101   657,224.9
2008            2,066   367,626.1         1,334   330,906.1         3,400   698,532.1
2009            2,289   391,700.4         1,452   349,580.9         3,741   741,281.3
2010            2,400   417,026.0         1,422   368,447.4         3,822   785,473.4
2011            2,233   444,867.6         1,286   388,439.3         3,519   833,306.9
Sum            22,425 4,100,260.4        14,167 3,739,964.3        36,592 7,840,224.7

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.995 0.992 0.999
Women     0.995 0.991 0.999
null device
          1
```

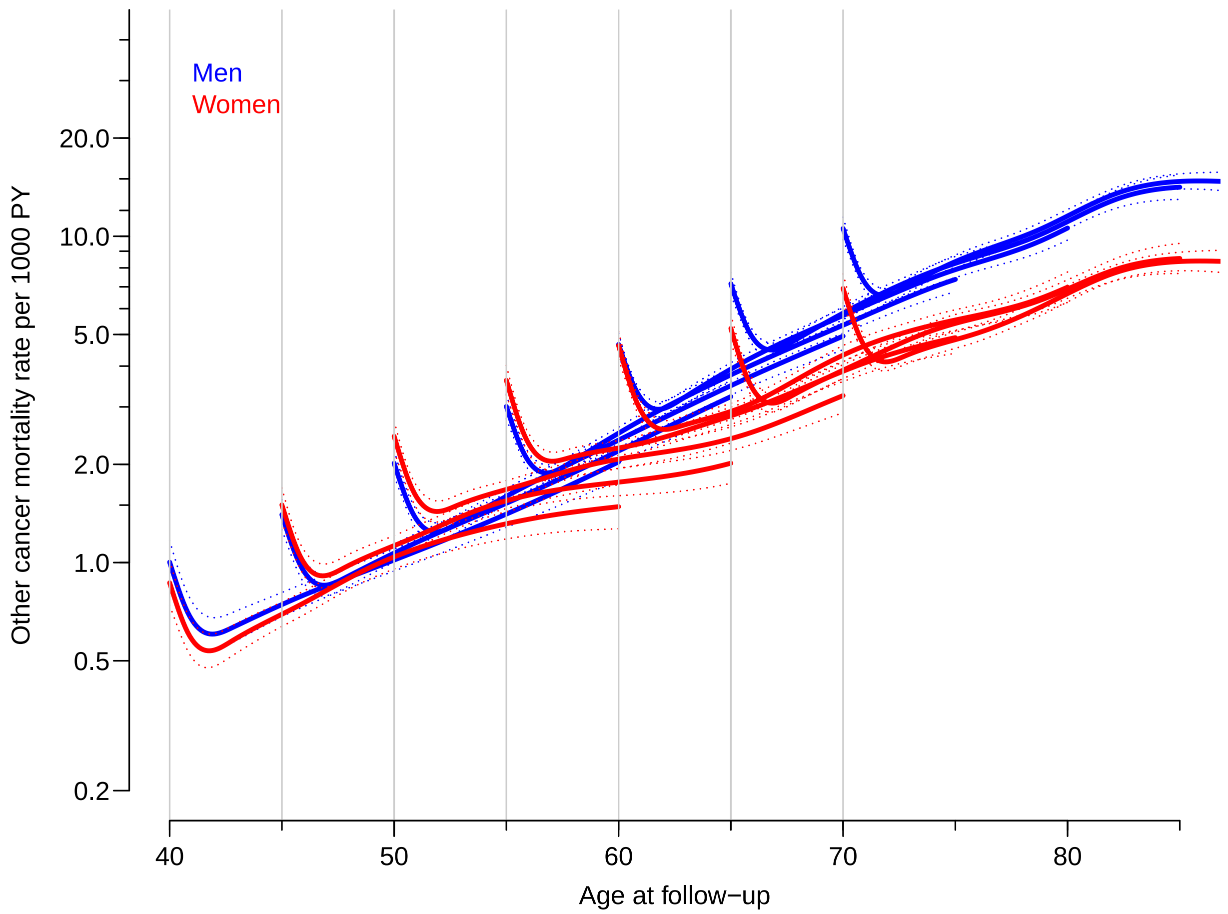

Figure 4.19: *Mortality rates from other cancers in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/rOthC-prM`

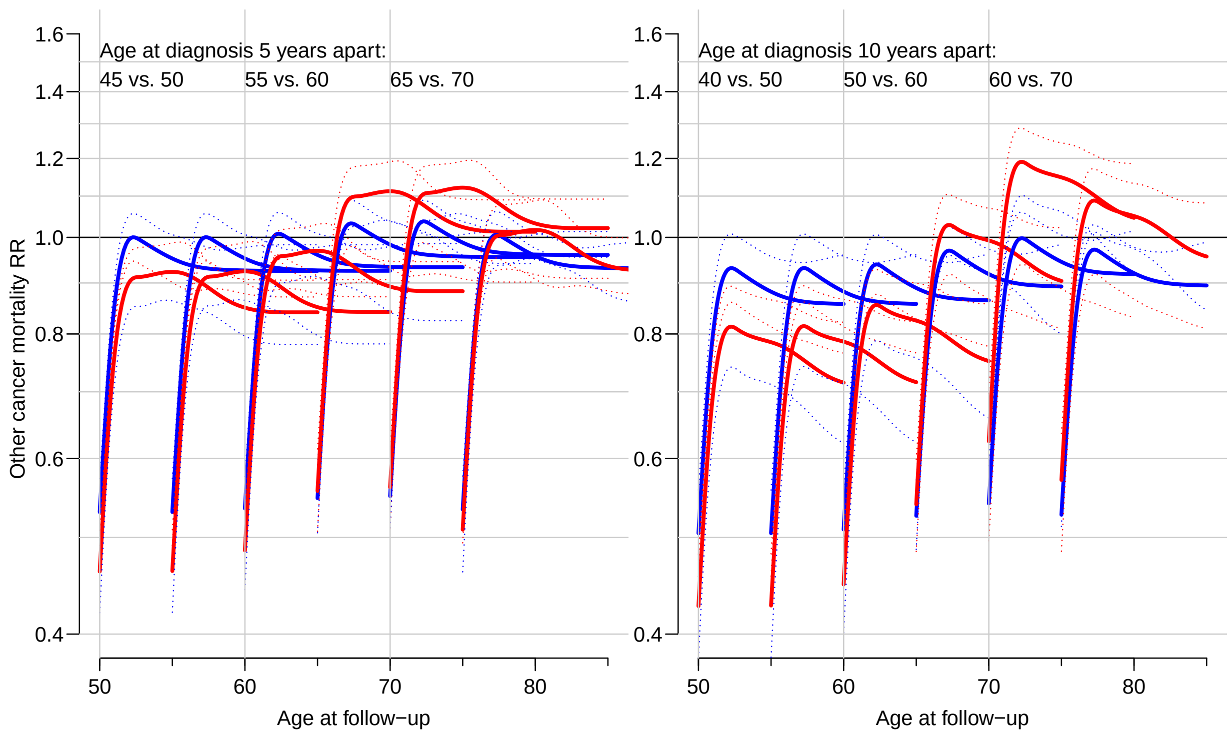

Figure 4.20: *Other cancer mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/rOthC-RReqd`

4.3.7 Infections

```
> cod( Agr, "r", "Infc", "Infections", Rmin=0.02, RRmin=0.6 )
Analysis of Infc Infections :
     sex         Men                     Women                     Sum
                   D           Y            D           Y            D           Y
Year
1997              49   111,974.9           41   105,250.7           90   217,225.6
1998              52   131,143.7           38   124,729.2           90   255,872.9
1999              74   151,829.8           68   144,835.1          142   296,665.0
2000              90   174,813.2           53   165,669.0          143   340,482.1
2001              91   198,260.2           76   186,359.2          167   384,619.4
2002             106   224,522.9           88   209,094.9          194   433,617.9
2003             112   250,112.0           88   232,270.2          200   482,382.2
2004             132   274,075.7           93   253,728.7          225   527,804.4
2005             150   297,477.3           98   274,259.6          248   571,736.9
2006             168   320,496.7          131   293,503.1          299   613,999.8
2007             139   344,334.0          128   312,890.8          267   657,224.9
2008             149   367,626.1          161   330,906.1          310   698,532.1
2009             174   391,700.4          129   349,580.9          303   741,281.3
2010             213   417,026.0          160   368,447.4          373   785,473.4
2011             205   444,867.6          196   388,439.3          401   833,306.9
Sum            1,904 4,100,260.4        1,548 3,739,964.3        3,452 7,840,224.7

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.981 0.969 0.992
Women     0.987 0.974 1.001
null device
          1
```

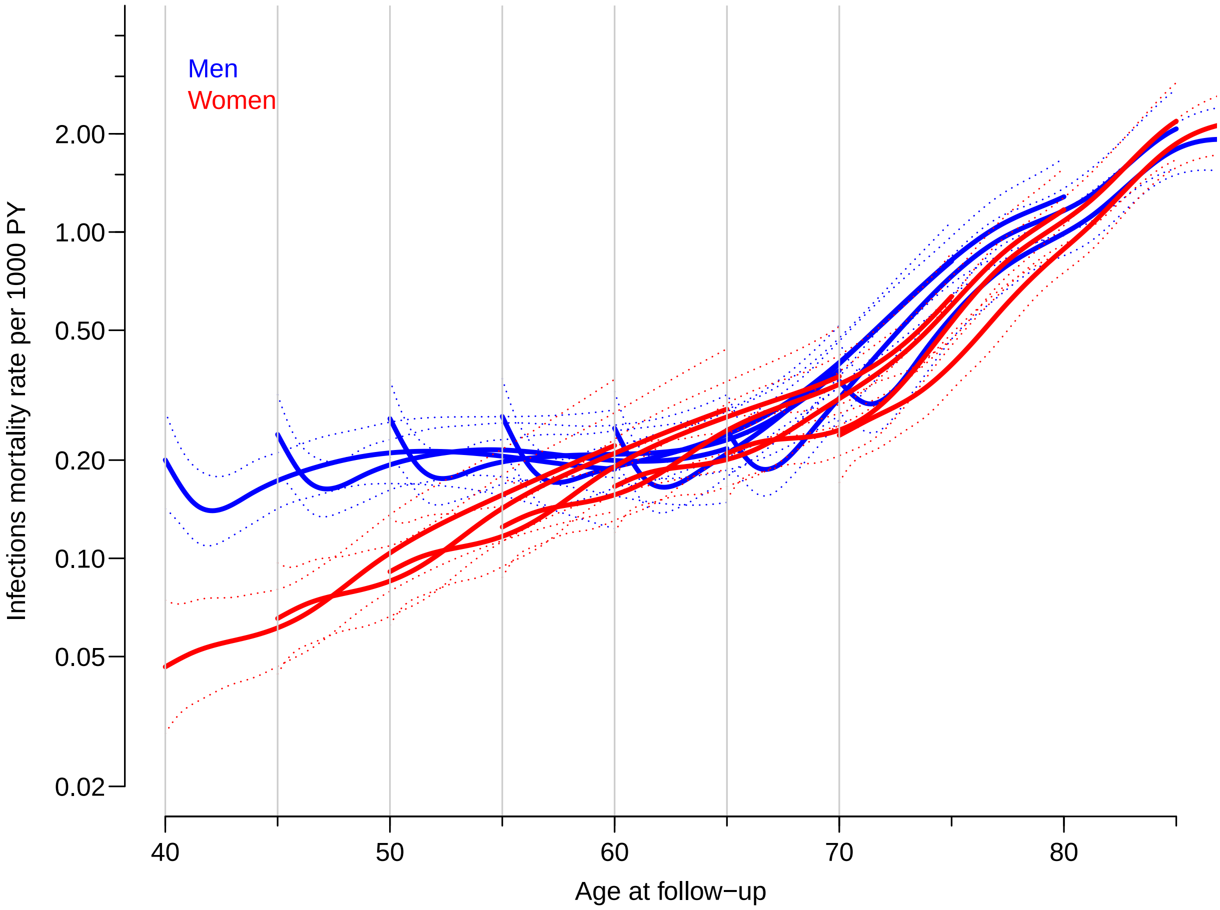

Figure 4.21: *Mortality rates from infections in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.*../graph/rInfc-prM

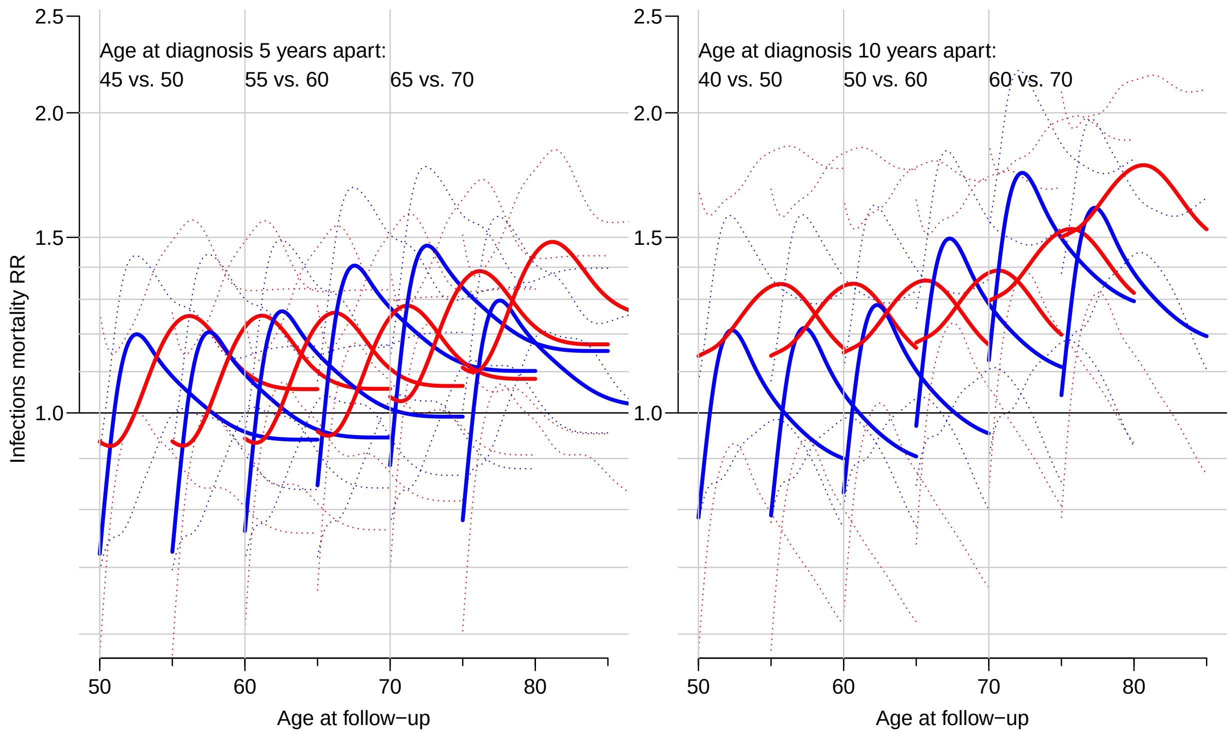

Figure 4.22: *Infections mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/rInfc-RReqd`

4.3.8 Other causes (excluding infections)

```
> cod( Agr, "r", "Othr", "Other causes (excl. inf.)", Rmin=0.5, RRmin=0.8 )
Analysis of Othr Other causes (excl. inf.) :
     sex         Men                    Women                   Sum
                   D            Y           D            Y           D            Y
Year
1997           1,419    111,974.9       1,185    105,250.7       2,604    217,225.6
1998           1,492    131,143.7       1,261    124,729.2       2,753    255,872.9
1999           1,828    151,829.8       1,486    144,835.1       3,314    296,665.0
2000           2,094    174,813.2       1,761    165,669.0       3,855    340,482.1
2001           2,281    198,260.2       1,822    186,359.2       4,103    384,619.4
2002           2,593    224,522.9       2,120    209,094.9       4,713    433,617.9
2003           2,780    250,112.0       2,327    232,270.2       5,107    482,382.2
2004           3,080    274,075.7       2,623    253,728.7       5,703    527,804.4
2005           3,311    297,477.3       2,879    274,259.6       6,190    571,736.9
2006           3,685    320,496.7       3,328    293,503.1       7,013    613,999.8
2007           4,132    344,334.0       3,689    312,890.8       7,821    657,224.9
2008           4,495    367,626.1       4,152    330,906.1       8,647    698,532.1
2009           4,726    391,700.4       4,082    349,580.9       8,808    741,281.3
2010           4,926    417,026.0       4,466    368,447.4       9,392    785,473.4
2011           5,245    444,867.6       4,453    388,439.3       9,698    833,306.9
Sum           48,087  4,100,260.4      41,634  3,739,964.3      89,721  7,840,224.7

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.977 0.975 0.980
Women     0.980 0.977 0.982
null device
          1
```

```
> options( width=90,
+          SweaveHooks=list( fig=function()
+          par(mar=c(3,3,1,1),mgp=c(3,1,0)/1.6,las=1,bty="n") ) )
```

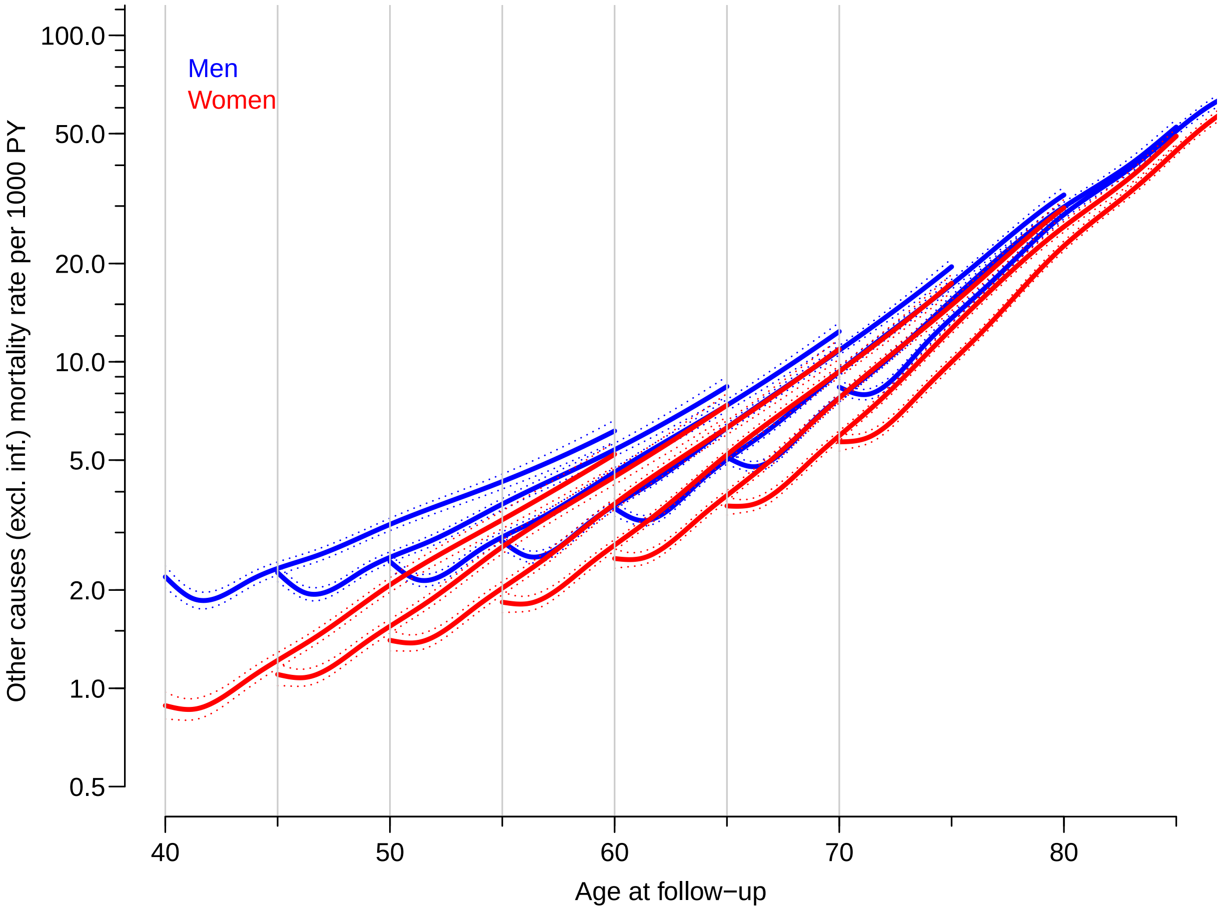

Figure 4.23: *Mortality rates from other causes (excluding infections) in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/rOthr-prM`

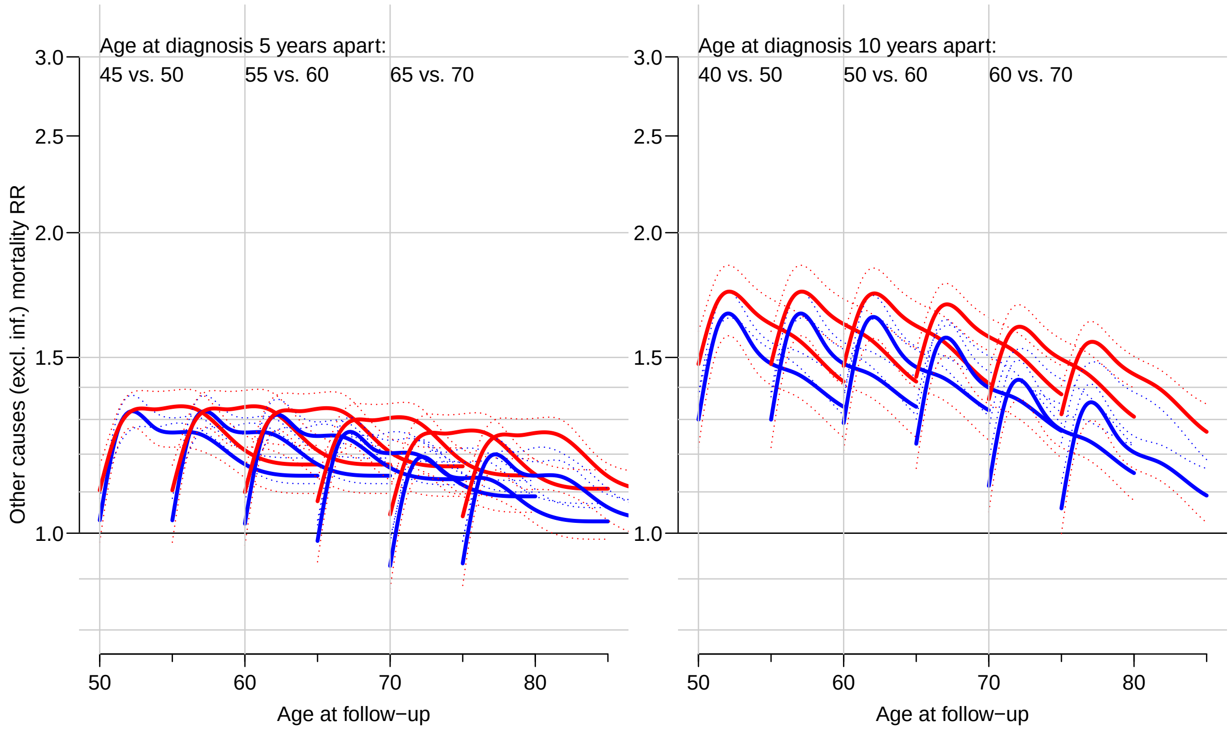

Figure 4.24: *Infections mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/rOthr-RReqd`

Chapter 5

Date of DM imputed with date of registration

First we load the relevant data

```
> library( Epi )
> library( popEpi )
> library( devEMF )
> clear()
> load( file="../data/Agi.Rda" )
> Agi <- Agi[,':='( age = age+0.25, per = per+0.25, dur = dur+0.25 )]
> load( file="../data/cod.Rda" )
> lls()
  name mode     class                 dim           size(Kb)
1 Agi  list     data.table data.frame 369785 17     47,671.6
2 cod  function function              1                184.4
```

5.1 All causes of death

```
> cod( Agi, "i", "D" , "All cause", Rmin=1, RRmin=0.5 )
Analysis of D All cause :
     sex          Men                     Women                    Sum
                    D            Y            D            Y           D            Y
Year
1997            4,154    147,860.8        3,075    135,650.4       7,229    283,511.2
1998            4,600    167,287.3        3,306    154,893.8       7,906    322,181.1
1999            5,250    187,256.1        3,777    173,769.1       9,027    361,025.2
2000            5,799    207,056.9        4,204    191,510.2      10,003    398,567.1
2001            6,292    226,264.5        4,699    208,364.3      10,991    434,628.7
2002            6,988    246,932.1        5,073    226,507.1      12,061    473,439.2
2003            7,525    266,494.1        5,659    244,572.0      13,184    511,066.1
2004            8,171    285,837.8        6,149    262,096.8      14,320    547,934.7
2005            8,683    306,749.1        6,474    280,423.9      15,157    587,173.0
2006            9,281    327,017.7        7,231    297,280.1      16,512    624,297.8
2007           10,032    348,717.7        7,752    314,814.7      17,784    663,532.4
2008           10,825    373,177.9        8,496    333,565.5      19,321    706,743.4
2009           11,362    395,625.0        8,544    351,061.2      19,906    746,686.2
2010           11,577    416,259.6        8,976    366,239.3      20,553    782,498.9
2011           11,342    438,395.4        8,449    381,920.9      19,791    820,316.3
```

```
Sum           121,881 4,340,931.9      91,864 3,922,669.3     213,745 8,263,601.2

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men        0.977 0.976 0.978
Women      0.977 0.976 0.979
null device
          1
```

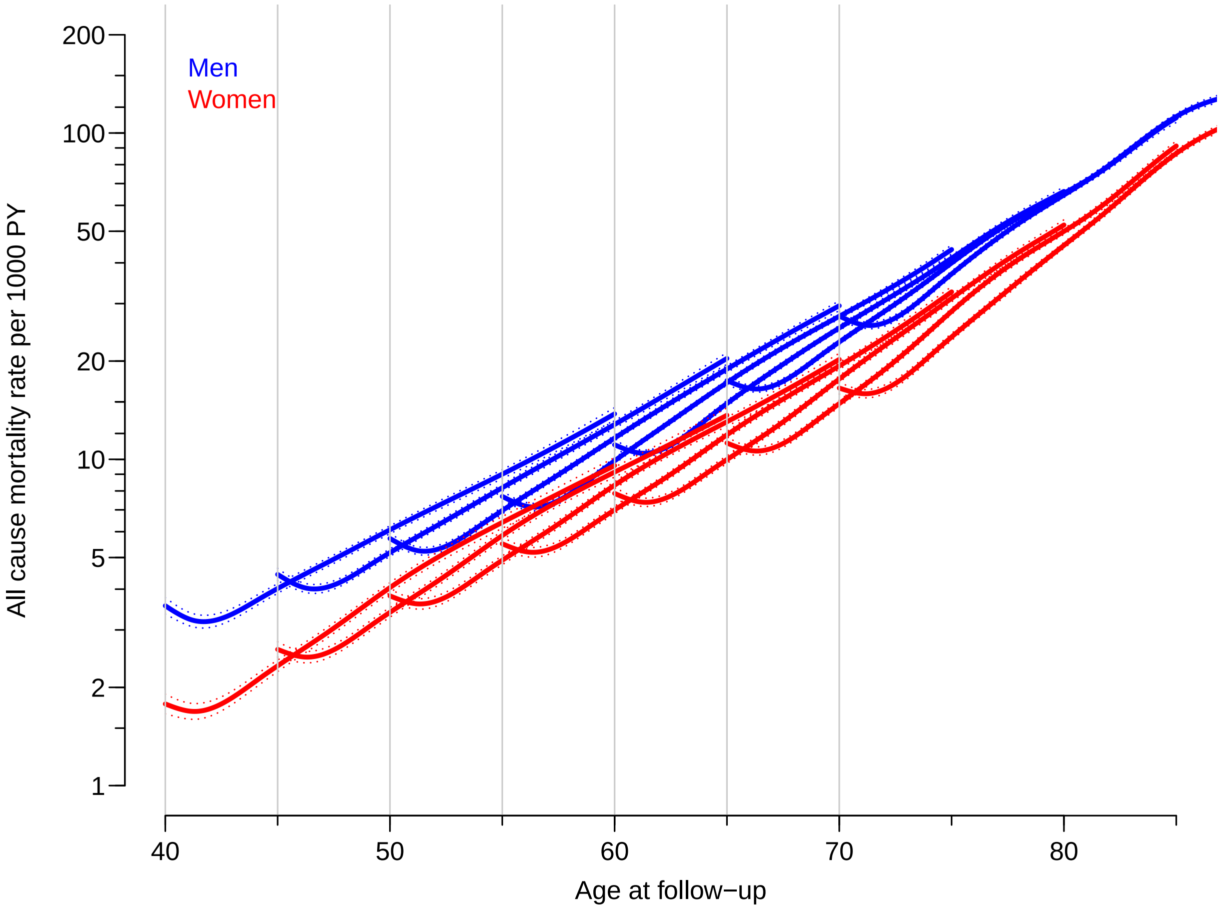

Figure 5.1: *Mortality rates from any cause in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.*../graph/iD-prM

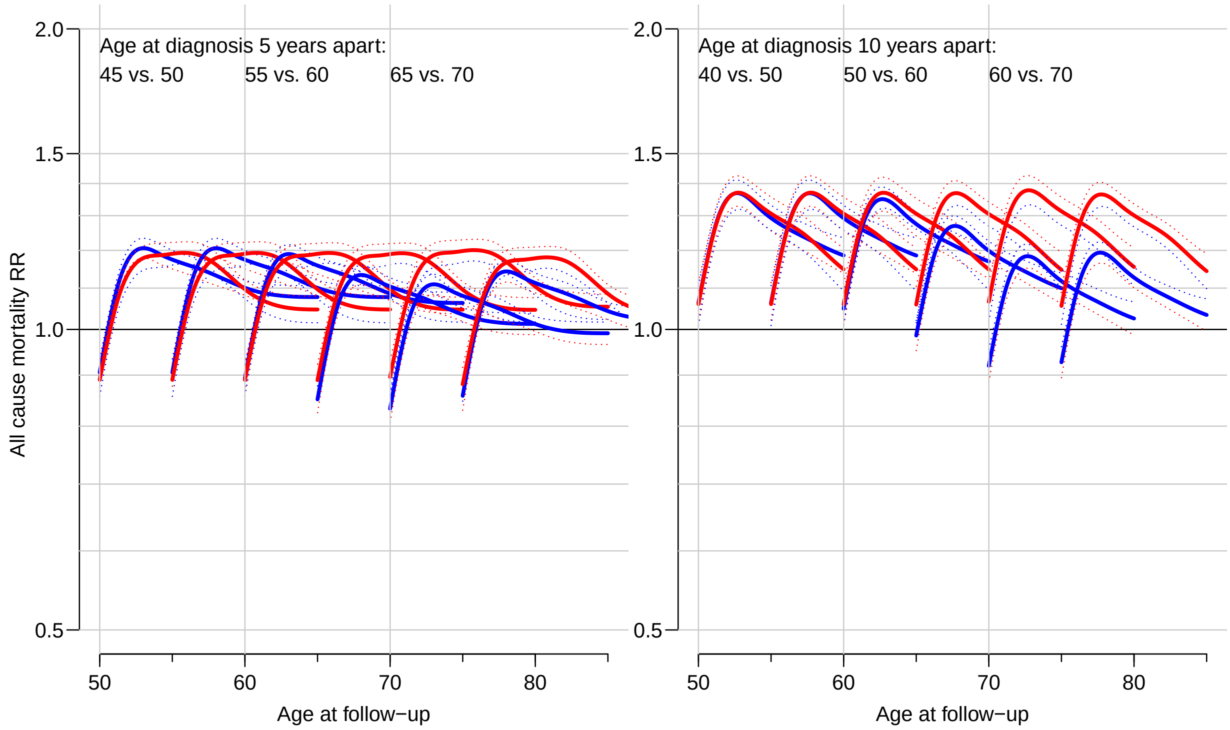

Figure 5.2: *All cause mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/iD-RReqd`

5.2 Three causes of death

The following three section represent a subdivision of causes of death in three different causes: CVD, Cancer and other, together making up all deaths among diabetes patients in Australia.

5.2.1 CVD

```
> cod( Agi, "i", "CVD" , "CVD", Rmin=1/8, RRmin=0.8 )
Analysis of CVD CVD :
     sex          Men                     Women                     Sum
                    D            Y            D            Y            D            Y
Year
1997             1,618   147,860.8       1,216   135,650.4       2,834   283,511.2
1998             1,769   167,287.3       1,311   154,893.8       3,080   322,181.1
1999             2,027   187,256.1       1,430   173,769.1       3,457   361,025.2
2000             2,101   207,056.9       1,527   191,510.2       3,628   398,567.1
2001             2,192   226,264.5       1,784   208,364.3       3,976   434,628.7
2002             2,382   246,932.1       1,754   226,507.1       4,136   473,439.2
2003             2,581   266,494.1       1,942   244,572.0       4,523   511,066.1
2004             2,672   285,837.8       2,069   262,096.8       4,741   547,934.7
2005             2,731   306,749.1       2,071   280,423.9       4,802   587,173.0
2006             2,806   327,017.7       2,086   297,280.1       4,892   624,297.8
2007             2,905   348,717.7       2,222   314,814.7       5,127   663,532.4
2008             3,119   373,177.9       2,400   333,565.5       5,519   706,743.4
2009             3,210   395,625.0       2,400   351,061.2       5,610   746,686.2
2010             3,061   416,259.6       2,459   366,239.3       5,520   782,498.9
2011             2,764   438,395.4       2,118   381,920.9       4,882   820,316.3
Sum             37,938 4,340,931.9      28,789 3,922,669.3      66,727 8,263,601.2

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.940 0.937 0.942
Women     0.937 0.934 0.940
null device
          1
```

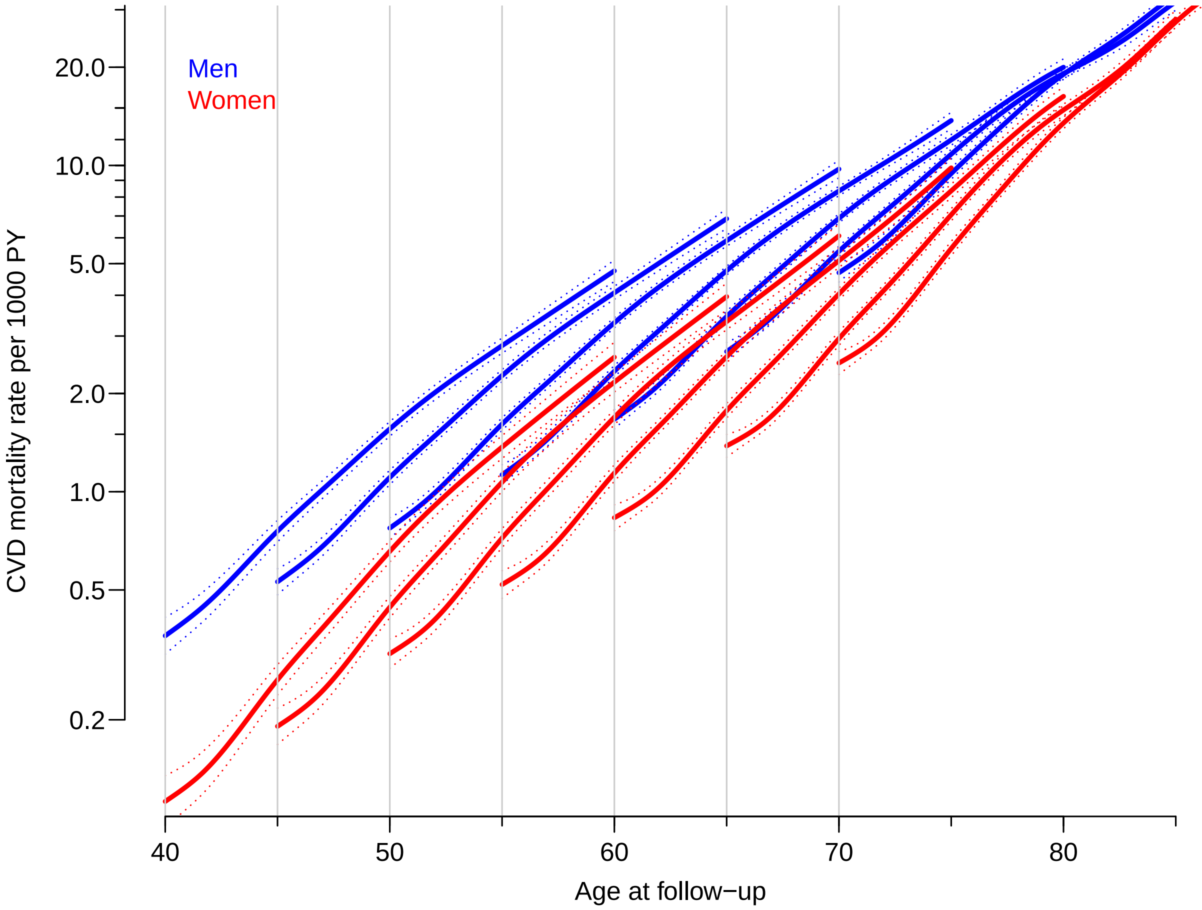

Figure 5.3: *Mortality rates from CVD in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* ../graph/iCVD-prM

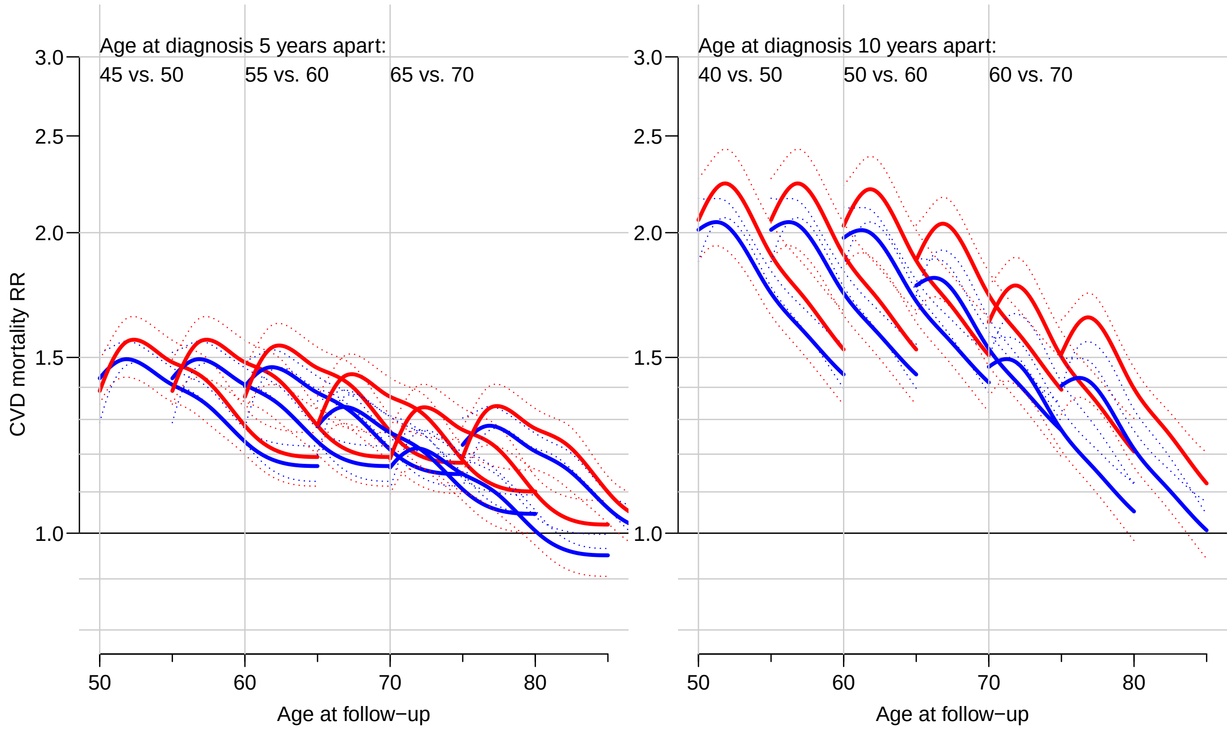

Figure 5.4: *CVD mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/iCVD-RReqd`

5.2.2 Cancer

```
> cod( Agi, "i", "Can" , "Cancer", Rmin=0.5, RRmin=0.4 )
Analysis of Can Cancer :
     sex         Men                     Women                     Sum
                   D           Y             D           Y           D           Y
Year
1997           1,063   147,860.8           631   135,650.4       1,694   283,511.2
1998           1,294   167,287.3           694   154,893.8       1,988   322,181.1
1999           1,344   187,256.1           809   173,769.1       2,153   361,025.2
2000           1,561   207,056.9           911   191,510.2       2,472   398,567.1
2001           1,797   226,264.5         1,071   208,364.3       2,868   434,628.7
2002           1,997   246,932.1         1,183   226,507.1       3,180   473,439.2
2003           2,165   266,494.1         1,406   244,572.0       3,571   511,066.1
2004           2,419   285,837.8         1,504   262,096.8       3,923   547,934.7
2005           2,663   306,749.1         1,576   280,423.9       4,239   587,173.0
2006           2,813   327,017.7         1,864   297,280.1       4,677   624,297.8
2007           3,056   348,717.7         1,903   314,814.7       4,959   663,532.4
2008           3,278   373,177.9         2,018   333,565.5       5,296   706,743.4
2009           3,514   395,625.0         2,158   351,061.2       5,672   746,686.2
2010           3,688   416,259.6         2,178   366,239.3       5,866   782,498.9
2011           3,440   438,395.4         1,986   381,920.9       5,426   820,316.3
Sum           36,092 4,340,931.9        21,892 3,922,669.3      57,984 8,263,601.2

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       1.002 0.999 1.004
Women     1.007 1.003 1.010
null device
          1
```

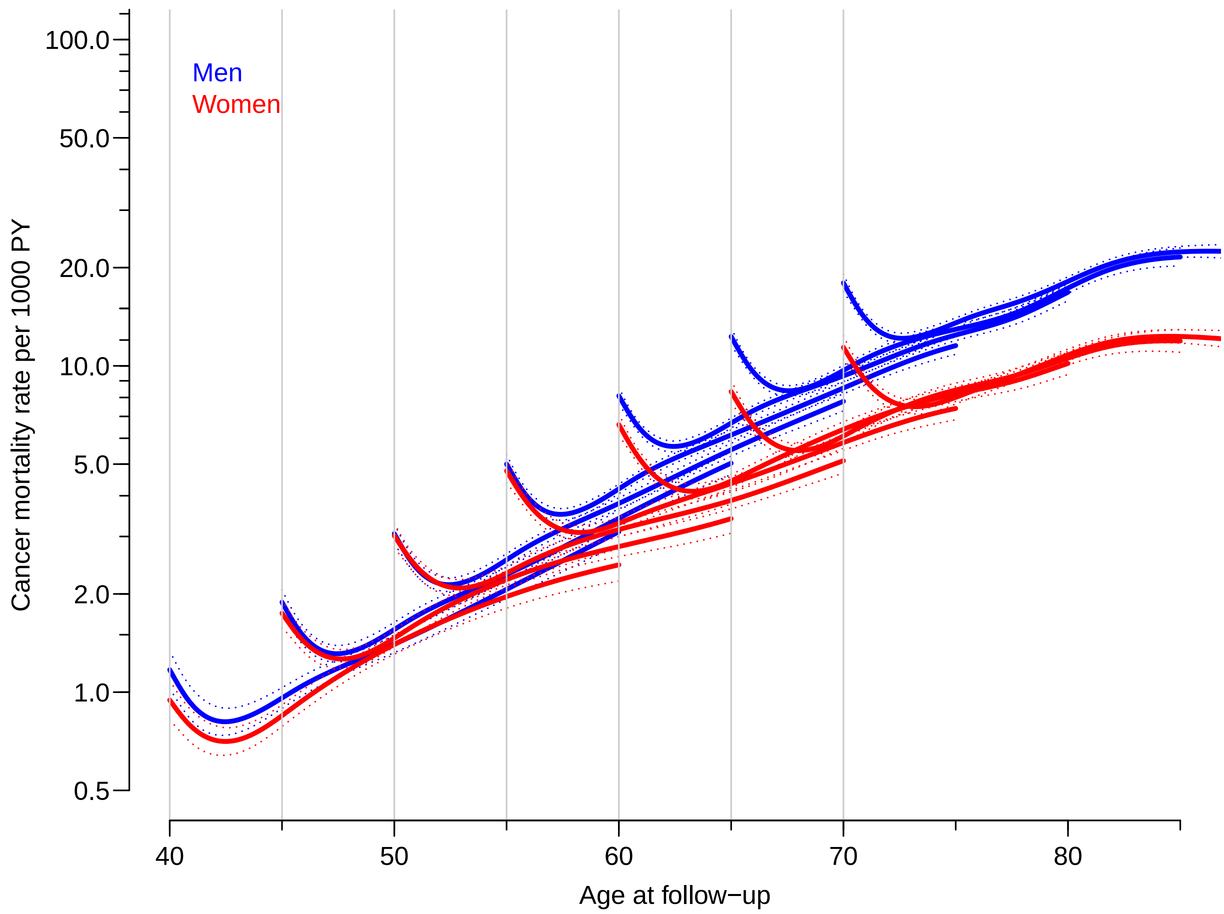

Figure 5.5: *Mortality rates from cancer in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/iCan-prM`

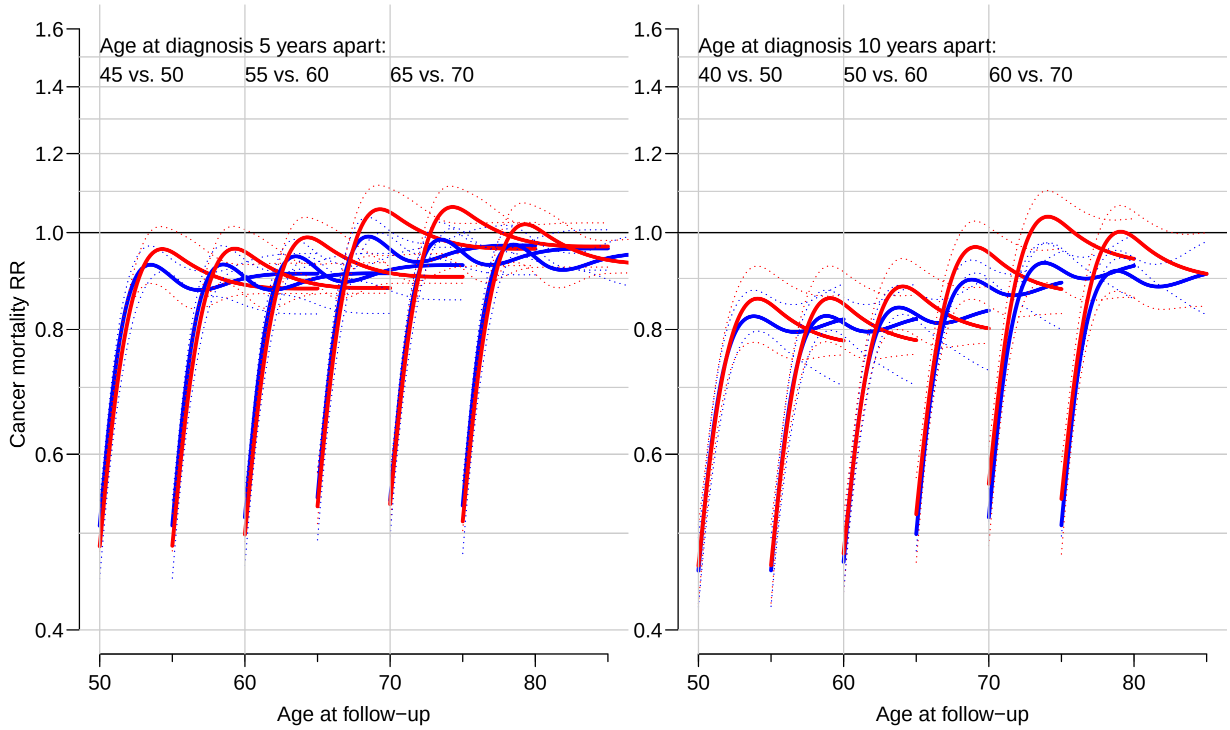

Figure 5.6: *Cancer mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/iCan-RReqd`

5.2.3 Other causes

```
> cod( Agi, "i", "Oth" , "Non-CVD, non-cancer", Rmin=0.5, RRmin=0.7 )
Analysis of Oth Non-CVD, non-cancer :
     sex         Men                     Women                    Sum
                   D            Y            D            Y           D            Y
Year
1997           1,473    147,860.8        1,228    135,650.4        2,701    283,511.2
1998           1,537    167,287.3        1,301    154,893.8        2,838    322,181.1
1999           1,879    187,256.1        1,538    173,769.1        3,417    361,025.2
2000           2,137    207,056.9        1,766    191,510.2        3,903    398,567.1
2001           2,303    226,264.5        1,844    208,364.3        4,147    434,628.7
2002           2,609    246,932.1        2,136    226,507.1        4,745    473,439.2
2003           2,779    266,494.1        2,311    244,572.0        5,090    511,066.1
2004           3,080    285,837.8        2,576    262,096.8        5,656    547,934.7
2005           3,289    306,749.1        2,827    280,423.9        6,116    587,173.0
2006           3,662    327,017.7        3,281    297,280.1        6,943    624,297.8
2007           4,071    348,717.7        3,627    314,814.7        7,698    663,532.4
2008           4,428    373,177.9        4,078    333,565.5        8,506    706,743.4
2009           4,638    395,625.0        3,986    351,061.2        8,624    746,686.2
2010           4,828    416,259.6        4,339    366,239.3        9,167    782,498.9
2011           5,138    438,395.4        4,345    381,920.9        9,483    820,316.3
Sum           47,851  4,340,931.9       41,183  3,922,669.3       89,034  8,263,601.2

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.989 0.986 0.991
Women     0.991 0.989 0.994
null device
          1
```

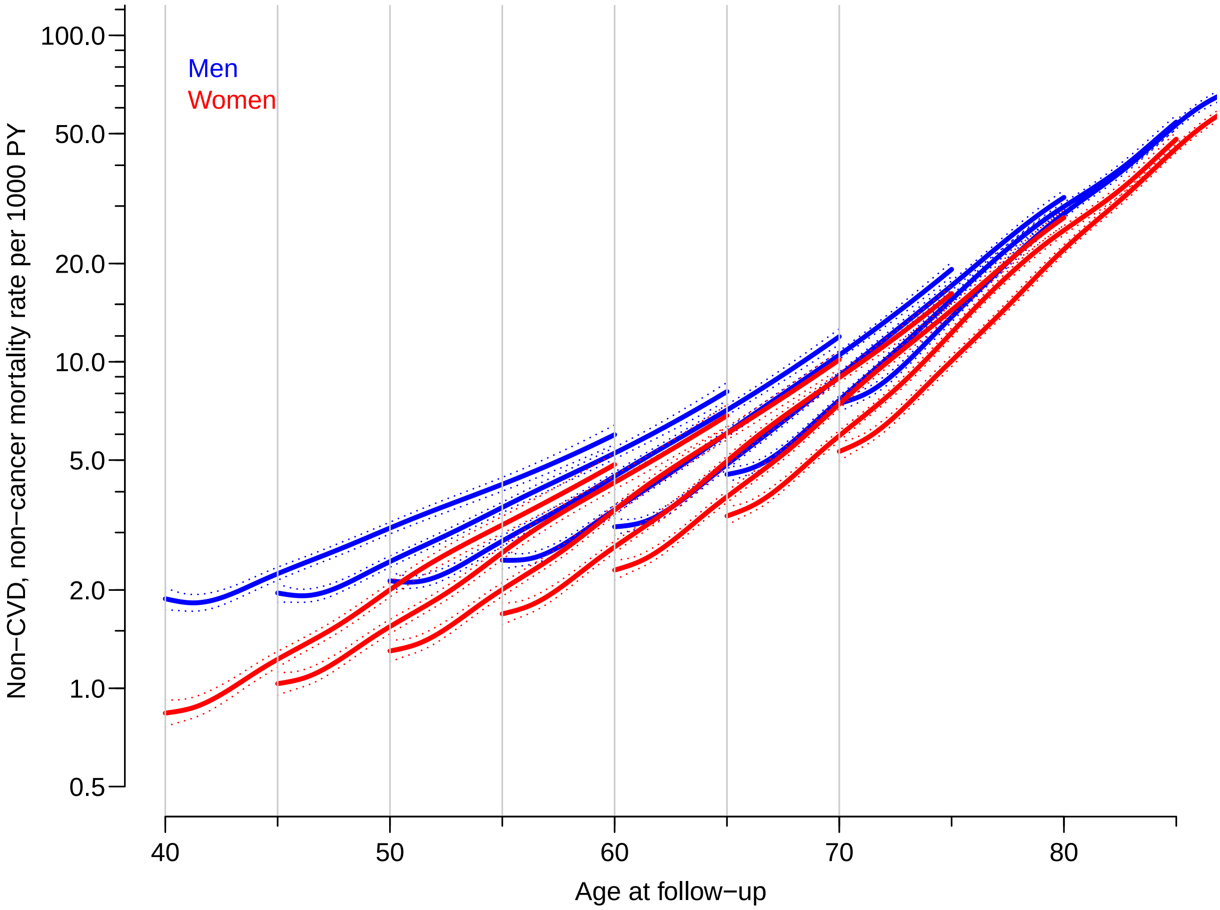

Figure 5.7: *Mortality rates from other causes (non-CVD, non-cancer) in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/iOth-prM`

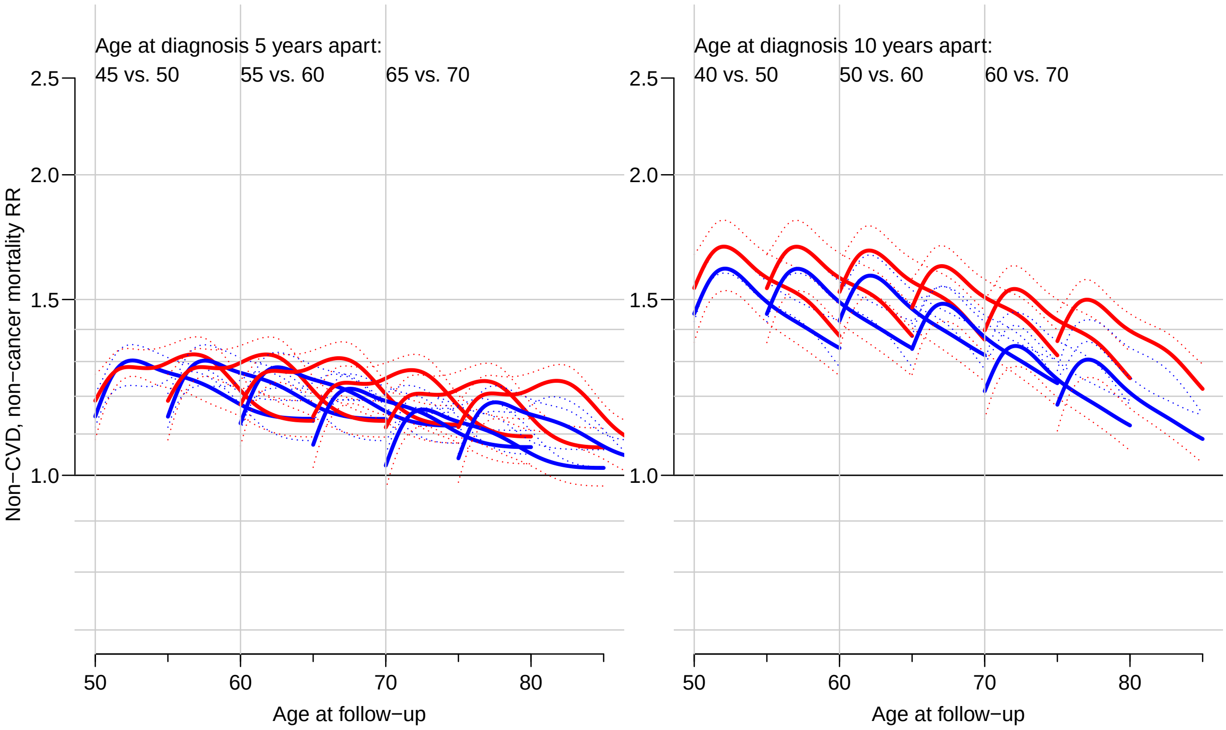

Figure 5.8: *Other mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/i0th-RReqd`

5.3 Eight causes of death

The following eight sections represent a subdivision of causes of death in twelve different causes, together making up all deaths among diabetes patients in Australia.

5.3.1 Iscahemic heart disease

```
> cod( Agi, "i", "IHD" , "IHD", Rmin=0.1, RRmin=0.8 )
Analysis of IHD IHD :
     sex         Men                     Women                     Sum
                   D           Y            D           Y            D           Y
Year
1997           1,302   147,860.8          892   135,650.4        2,194   283,511.2
1998           1,416   167,287.3          963   154,893.8        2,379   322,181.1
1999           1,554   187,256.1        1,024   173,769.1        2,578   361,025.2
2000           1,679   207,056.9        1,074   191,510.2        2,753   398,567.1
2001           1,680   226,264.5        1,285   208,364.3        2,965   434,628.7
2002           1,824   246,932.1        1,247   226,507.1        3,071   473,439.2
2003           1,977   266,494.1        1,361   244,572.0        3,338   511,066.1
2004           2,075   285,837.8        1,422   262,096.8        3,497   547,934.7
2005           2,073   306,749.1        1,396   280,423.9        3,469   587,173.0
2006           2,117   327,017.7        1,362   297,280.1        3,479   624,297.8
2007           2,227   348,717.7        1,490   314,814.7        3,717   663,532.4
2008           2,335   373,177.9        1,608   333,565.5        3,943   706,743.4
2009           2,404   395,625.0        1,588   351,061.2        3,992   746,686.2
2010           2,319   416,259.6        1,592   366,239.3        3,911   782,498.9
2011           2,073   438,395.4        1,360   381,920.9        3,433   820,316.3
Sum           29,055 4,340,931.9       19,664 3,922,669.3       48,719 8,263,601.2

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.937 0.934 0.940
Women     0.928 0.925 0.931
null device
          1
```

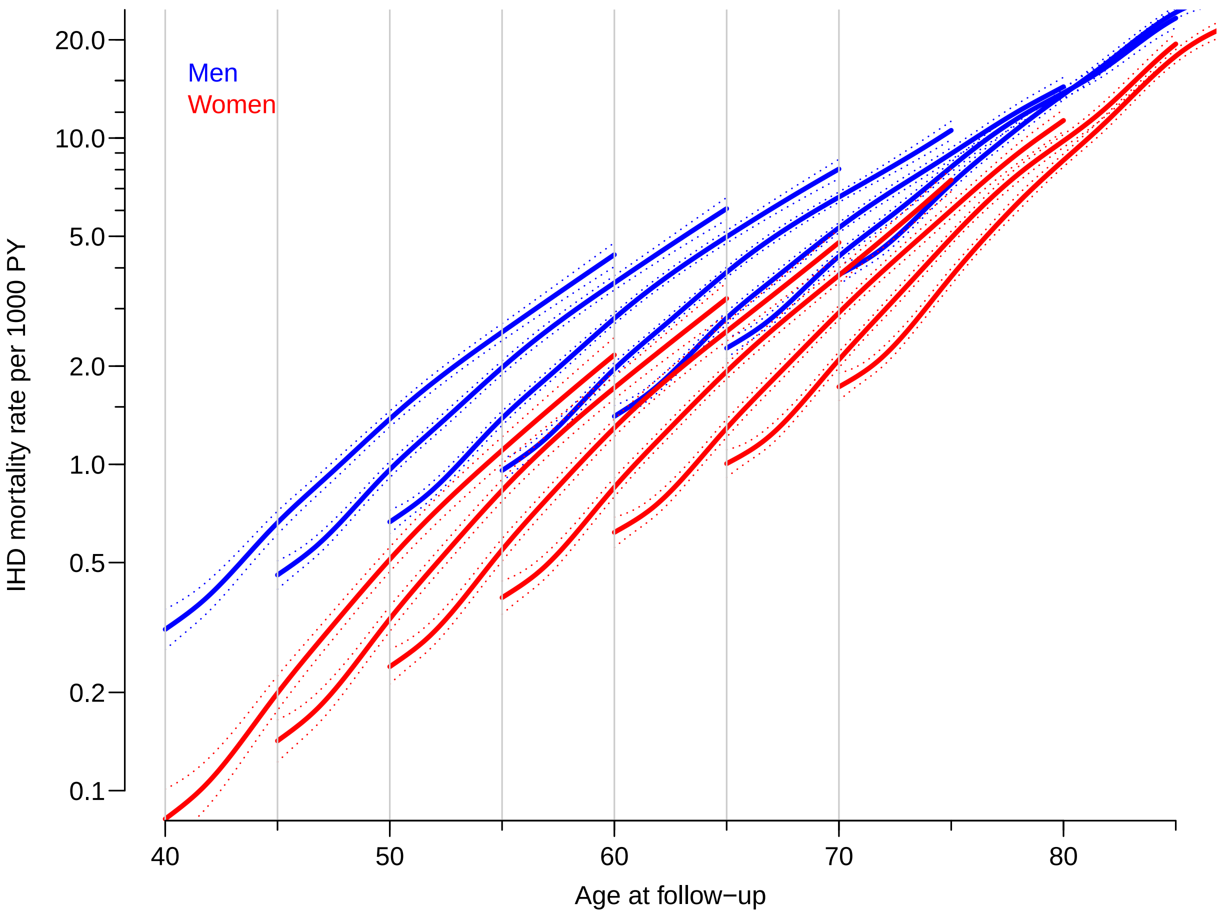

Figure 5.9: *Mortality rates from Iscahemic heart disease in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/iIHD-prM`

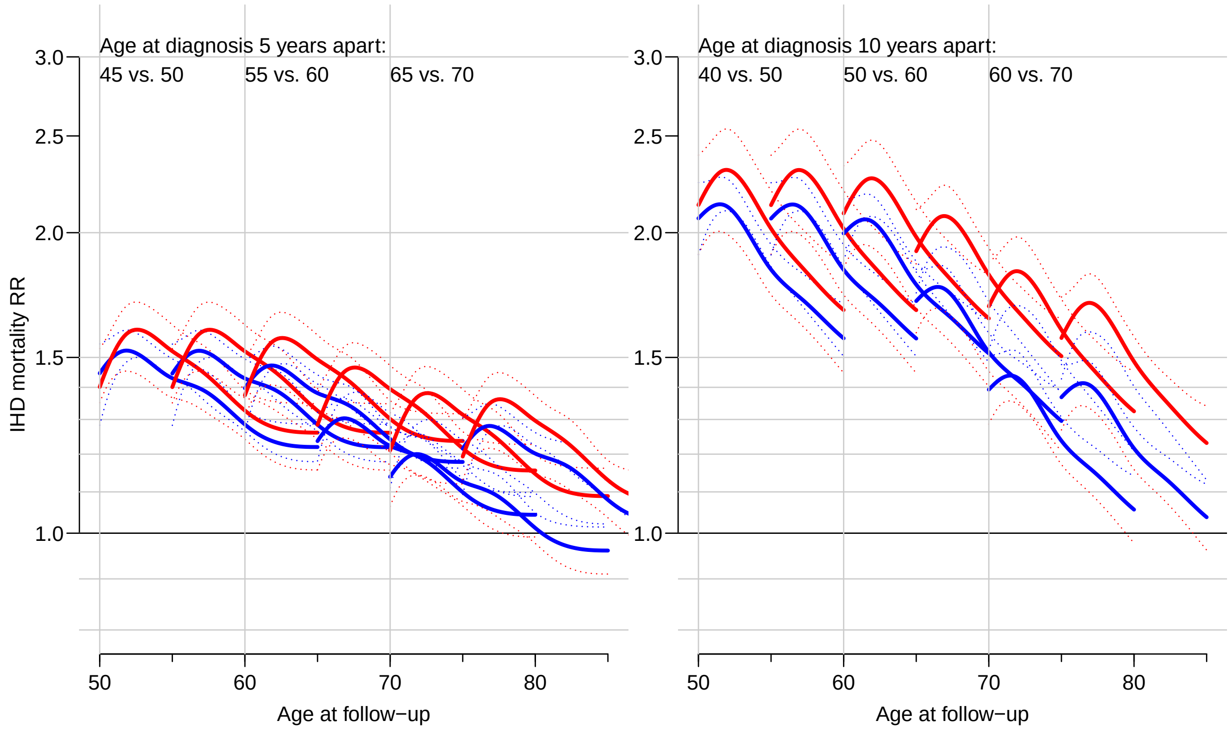

Figure 5.10: *IHD mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/iIHD-RReqd`

5.3.2 Stroke

```
> cod( Agi, "i", "Str" , "Stroke", Rmin=0.04, RRmin=0.8 )
Analysis of Str Stroke :
     sex         Men                     Women                   Sum
                   D           Y             D           Y           D           Y
Year
1997             316   147,860.8           324   135,650.4         640   283,511.2
1998             353   167,287.3           348   154,893.8         701   322,181.1
1999             473   187,256.1           406   173,769.1         879   361,025.2
2000             422   207,056.9           453   191,510.2         875   398,567.1
2001             512   226,264.5           499   208,364.3       1,011   434,628.7
2002             558   246,932.1           507   226,507.1       1,065   473,439.2
2003             604   266,494.1           581   244,572.0       1,185   511,066.1
2004             597   285,837.8           647   262,096.8       1,244   547,934.7
2005             658   306,749.1           675   280,423.9       1,333   587,173.0
2006             689   327,017.7           724   297,280.1       1,413   624,297.8
2007             678   348,717.7           732   314,814.7       1,410   663,532.4
2008             784   373,177.9           792   333,565.5       1,576   706,743.4
2009             806   395,625.0           812   351,061.2       1,618   746,686.2
2010             742   416,259.6           867   366,239.3       1,609   782,498.9
2011             691   438,395.4           758   381,920.9       1,449   820,316.3
Sum            8,883 4,340,931.9         9,125 3,922,669.3      18,008 8,263,601.2

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.949 0.945 0.955
Women     0.956 0.951 0.961
null device
          1
```

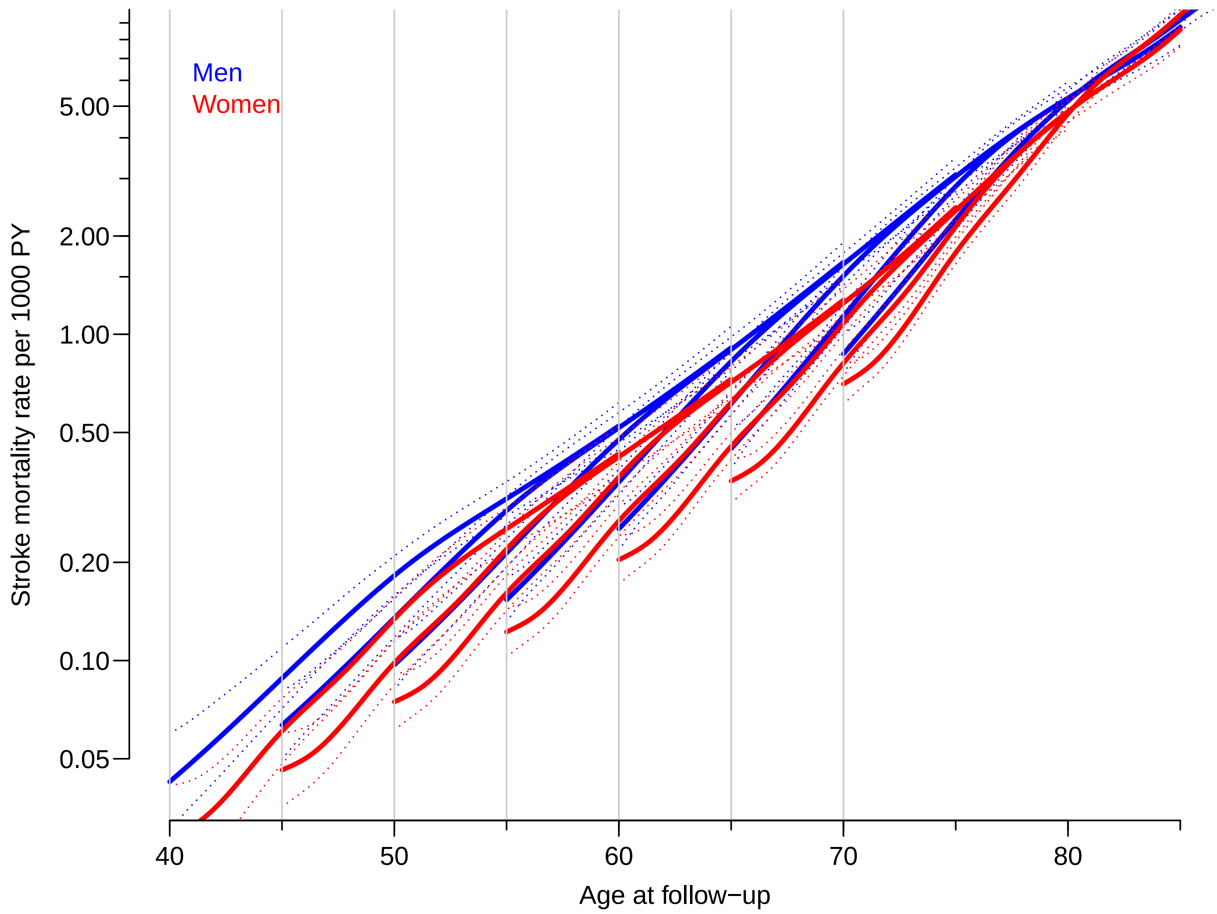

Figure 5.11: *Mortality rates from stroke in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* ../`graph/iStr-prM`

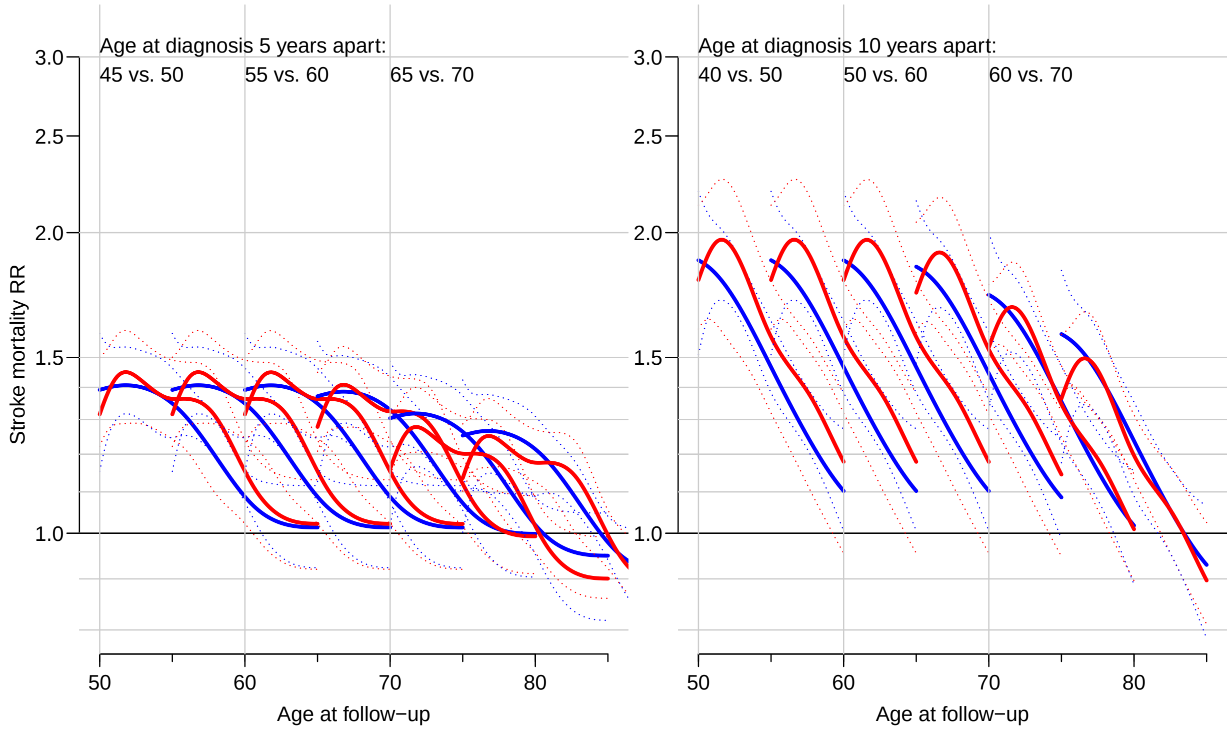

Figure 5.12: *Stroke mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/iStr-RReqd`

5.3.3 Lung cancer

```
> cod( Agi, "i", "Lung" , "Lung cancer", Rmin=0.03, RRmin=0.4 )
Analysis of Lung Lung cancer :
     sex         Men                       Women                      Sum
                   D           Y             D           Y              D           Y
Year
1997             221   147,860.8            79   135,650.4            300   283,511.2
1998             265   167,287.3            81   154,893.8            346   322,181.1
1999             288   187,256.1           110   173,769.1            398   361,025.2
2000             314   207,056.9           129   191,510.2            443   398,567.1
2001             372   226,264.5           131   208,364.3            503   434,628.7
2002             405   246,932.1           164   226,507.1            569   473,439.2
2003             431   266,494.1           194   244,572.0            625   511,066.1
2004             476   285,837.8           192   262,096.8            668   547,934.7
2005             537   306,749.1           228   280,423.9            765   587,173.0
2006             529   327,017.7           251   297,280.1            780   624,297.8
2007             628   348,717.7           271   314,814.7            899   663,532.4
2008             664   373,177.9           298   333,565.5            962   706,743.4
2009             640   395,625.0           307   351,061.2            947   746,686.2
2010             713   416,259.6           349   366,239.3          1,062   782,498.9
2011             656   438,395.4           324   381,920.9            980   820,316.3
Sum            7,139 4,340,931.9         3,108 3,922,669.3         10,247 8,263,601.2

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.997 0.991 1.003
Women     1.029 1.019 1.038
null device
          1
```

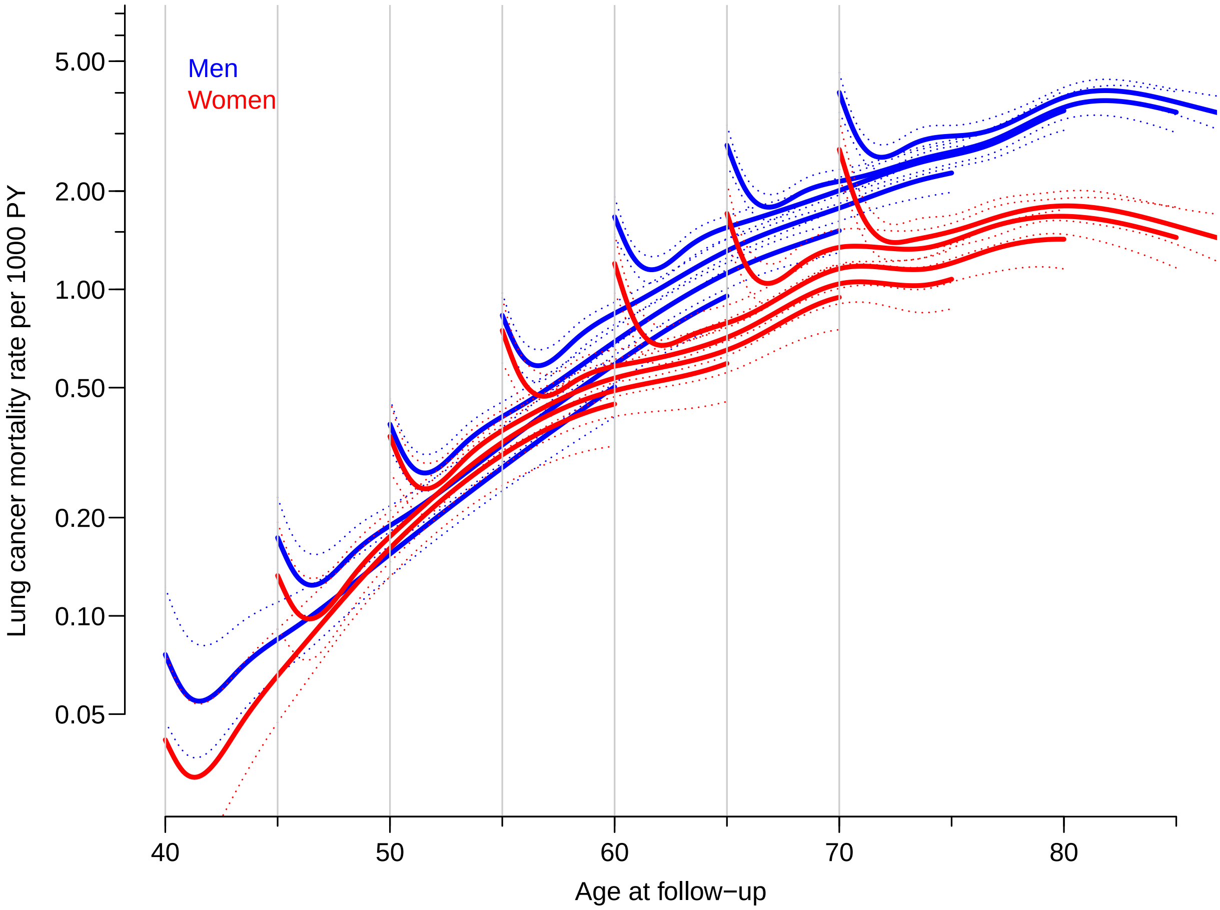

Figure 5.13: *Mortality rates from lung cancer in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/iLung-prM`

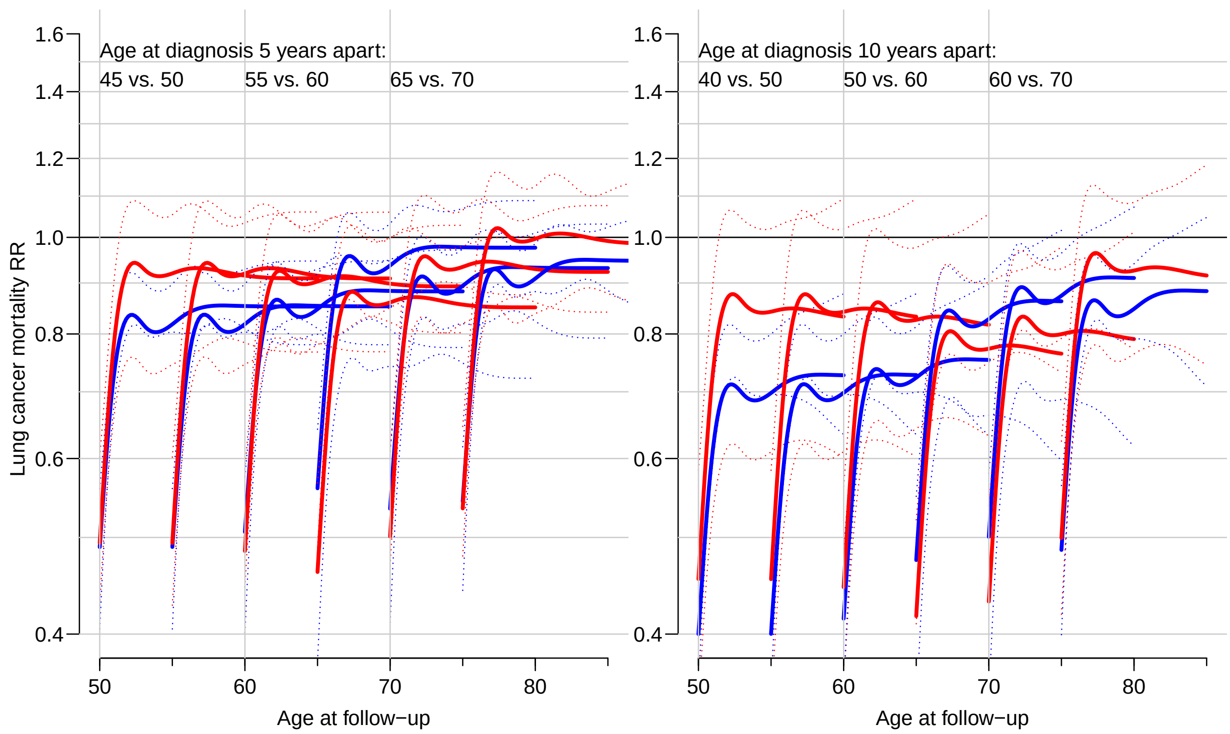

Figure 5.14: *Lung cancer mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/iLung-RReqd`

5.3.4 Colon cancer

```
> cod( Agi, "i", "ColC", "Colon cancer", Rmin=0.03, RRmin=0.4 )
Analysis of ColC Colon cancer :
     sex         Men                     Women                     Sum
                   D           Y           D           Y           D           Y
Year
1997             128   147,860.8          92   135,650.4         220   283,511.2
1998             167   167,287.3          84   154,893.8         251   322,181.1
1999             155   187,256.1         106   173,769.1         261   361,025.2
2000             185   207,056.9         106   191,510.2         291   398,567.1
2001             211   226,264.5         131   208,364.3         342   434,628.7
2002             215   246,932.1         137   226,507.1         352   473,439.2
2003             254   266,494.1         153   244,572.0         407   511,066.1
2004             240   285,837.8         143   262,096.8         383   547,934.7
2005             283   306,749.1         155   280,423.9         438   587,173.0
2006             270   327,017.7         176   297,280.1         446   624,297.8
2007             315   348,717.7         201   314,814.7         516   663,532.4
2008             298   373,177.9         211   333,565.5         509   706,743.4
2009             339   395,625.0         197   351,061.2         536   746,686.2
2010             311   416,259.6         191   366,239.3         502   782,498.9
2011             318   438,395.4         165   381,920.9         483   820,316.3
Sum            3,689 4,340,931.9       2,248 3,922,669.3       5,937 8,263,601.2

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.978 0.970 0.986
Women     0.973 0.963 0.983
null device
          1
```

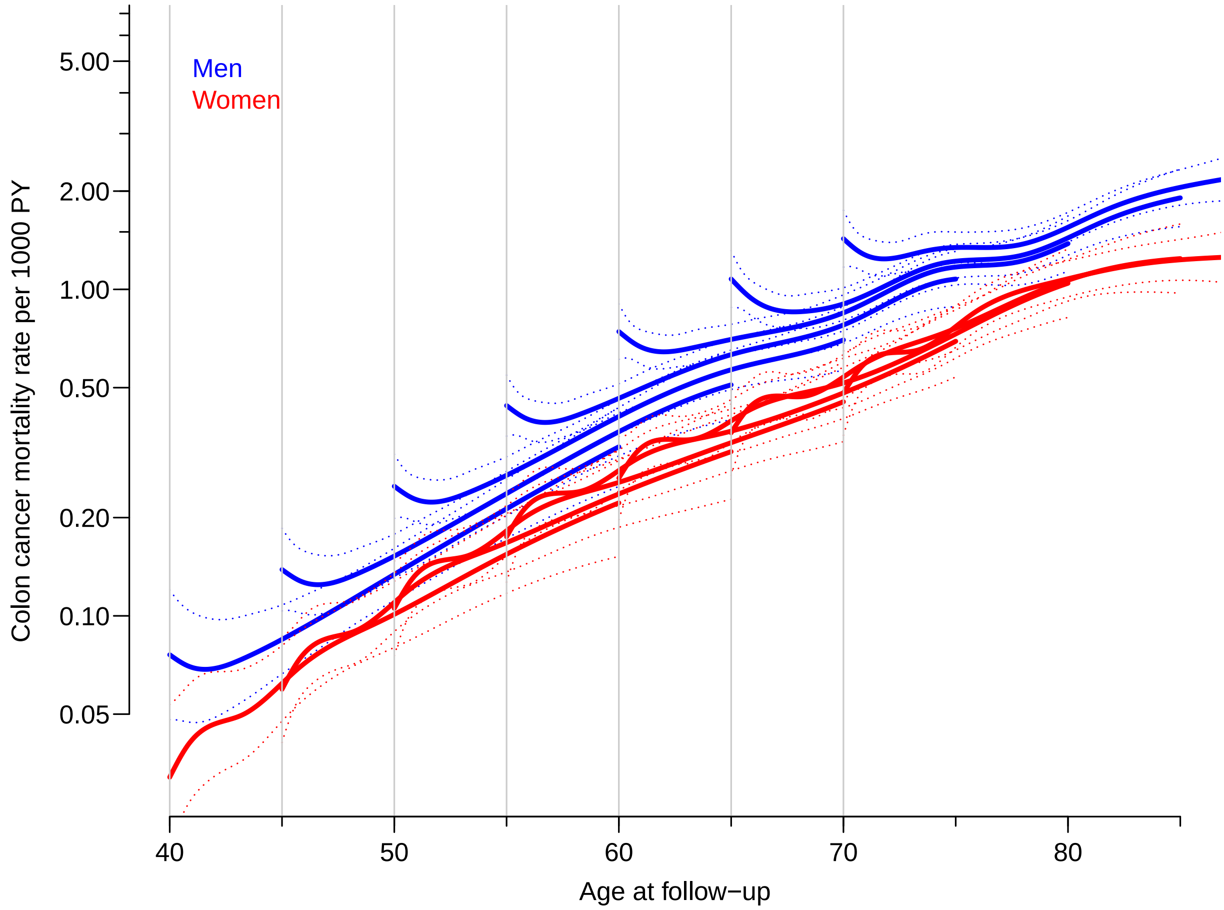

Figure 5.15: *Mortality rates from colon cancer in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/iColC-prM`

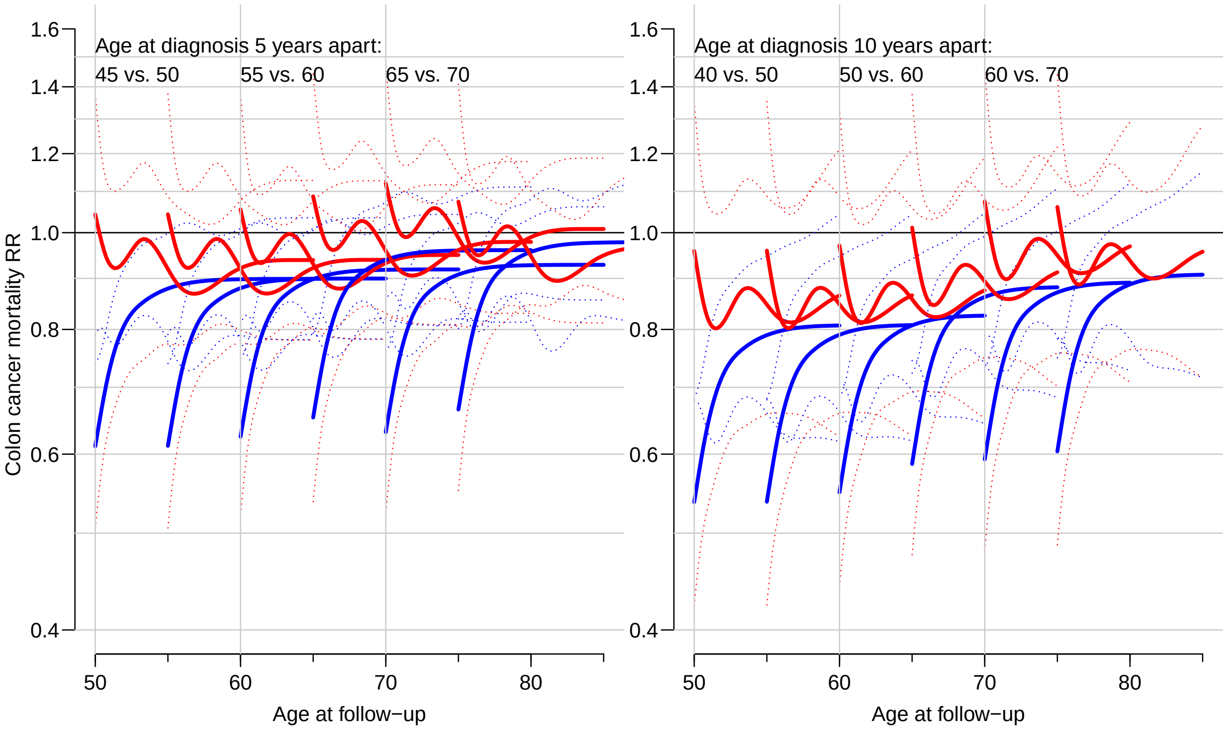

Figure 5.16: *Colon cancer mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/iColC-RReqd`

5.3.5 Pancreas cancer

```
> cod( Agi, "i", "PanC", "Pancreas cancer", Rmin=0.03, RRmin=0.4 )
Analysis of PanC Pancreas cancer :
     sex         Men                     Women                    Sum
                   D            Y            D            Y           D            Y
Year
1997             116    147,860.8          103    135,650.4         219    283,511.2
1998             132    167,287.3          109    154,893.8         241    322,181.1
1999             150    187,256.1          119    173,769.1         269    361,025.2
2000             131    207,056.9          129    191,510.2         260    398,567.1
2001             181    226,264.5          117    208,364.3         298    434,628.7
2002             220    246,932.1          128    226,507.1         348    473,439.2
2003             201    266,494.1          179    244,572.0         380    511,066.1
2004             253    285,837.8          192    262,096.8         445    547,934.7
2005             225    306,749.1          209    280,423.9         434    587,173.0
2006             249    327,017.7          224    297,280.1         473    624,297.8
2007             305    348,717.7          236    314,814.7         541    663,532.4
2008             315    373,177.9          222    333,565.5         537    706,743.4
2009             324    395,625.0          245    351,061.2         569    746,686.2
2010             343    416,259.6          272    366,239.3         615    782,498.9
2011             297    438,395.4          259    381,920.9         556    820,316.3
Sum            3,442  4,340,931.9        2,743  3,922,669.3       6,185  8,263,601.2

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       1.005 0.997 1.014
Women     1.010 1.001 1.020
null device
          1
```

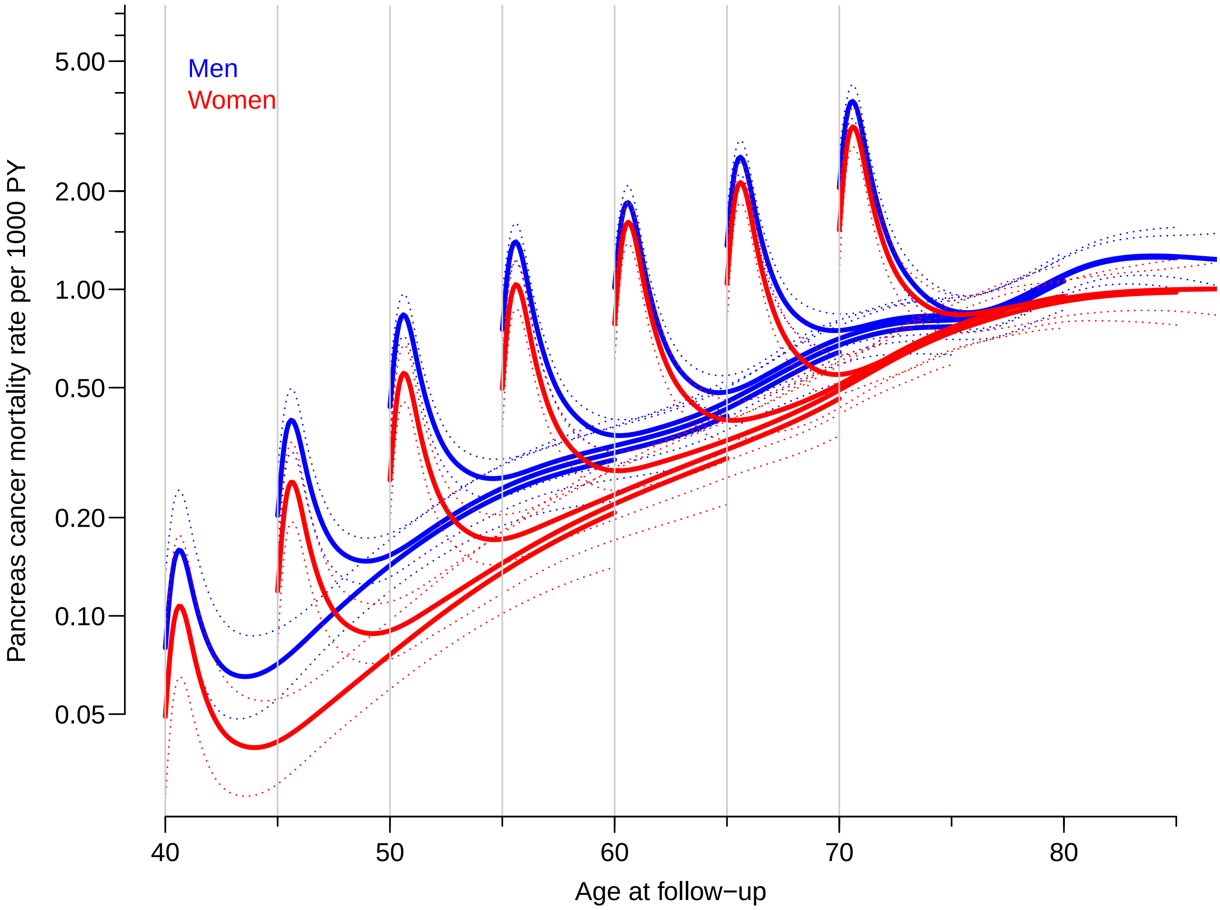

Figure 5.17: *Mortality rates from pancreatic cancer in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/iPanC-prM`

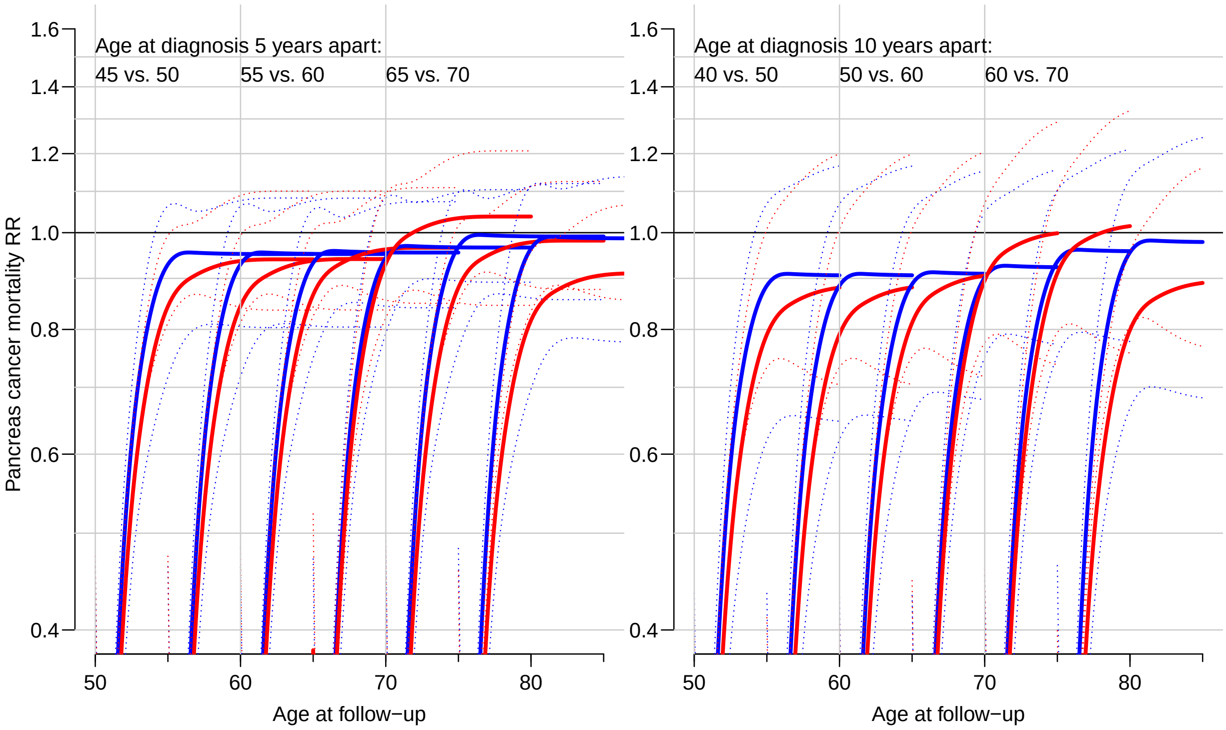

Figure 5.18: *Pancreas cancer mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/iPanC-RReqd`

5.3.6 Other cancers

```
> cod( Agi, "i", "OthC", "Other cancer", Rmin=0.2, RRmin=0.4 )
Analysis of OthC Other cancer :
     sex         Men                     Women                    Sum
                   D           Y             D           Y            D           Y
Year
1997             598   147,860.8           357   135,650.4          955   283,511.2
1998             730   167,287.3           420   154,893.8        1,150   322,181.1
1999             751   187,256.1           474   173,769.1        1,225   361,025.2
2000             931   207,056.9           547   191,510.2        1,478   398,567.1
2001           1,033   226,264.5           692   208,364.3        1,725   434,628.7
2002           1,157   246,932.1           754   226,507.1        1,911   473,439.2
2003           1,279   266,494.1           880   244,572.0        2,159   511,066.1
2004           1,450   285,837.8           977   262,096.8        2,427   547,934.7
2005           1,618   306,749.1           984   280,423.9        2,602   587,173.0
2006           1,765   327,017.7         1,213   297,280.1        2,978   624,297.8
2007           1,808   348,717.7         1,195   314,814.7        3,003   663,532.4
2008           2,001   373,177.9         1,287   333,565.5        3,288   706,743.4
2009           2,211   395,625.0         1,409   351,061.2        3,620   746,686.2
2010           2,321   416,259.6         1,366   366,239.3        3,687   782,498.9
2011           2,169   438,395.4         1,238   381,920.9        3,407   820,316.3
Sum           21,822 4,340,931.9        13,793 3,922,669.3       35,615 8,263,601.2

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       1.007 1.004 1.011
Women     1.007 1.003 1.011
null device
          1
```

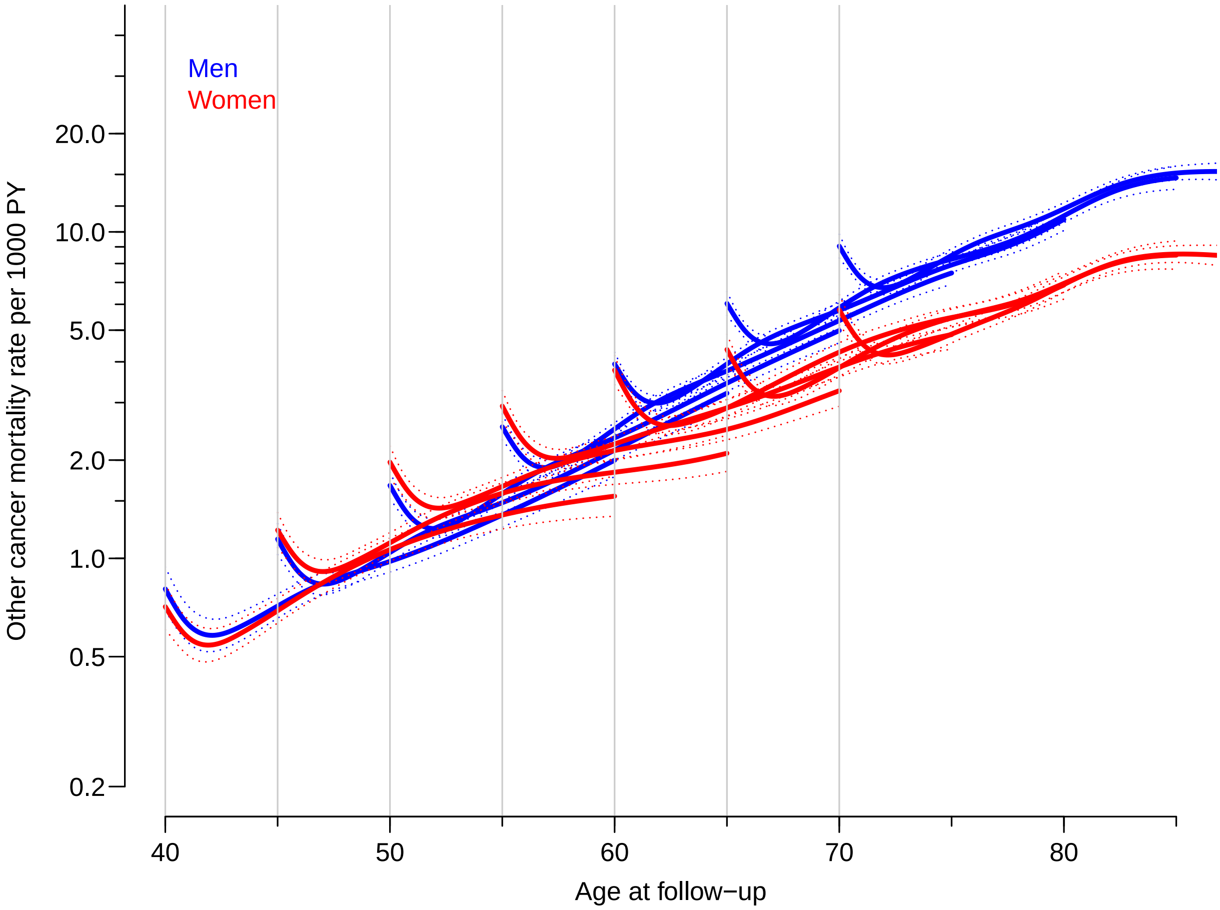

Figure 5.19: *Mortality rates from other cancers in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/i0thC-prM`

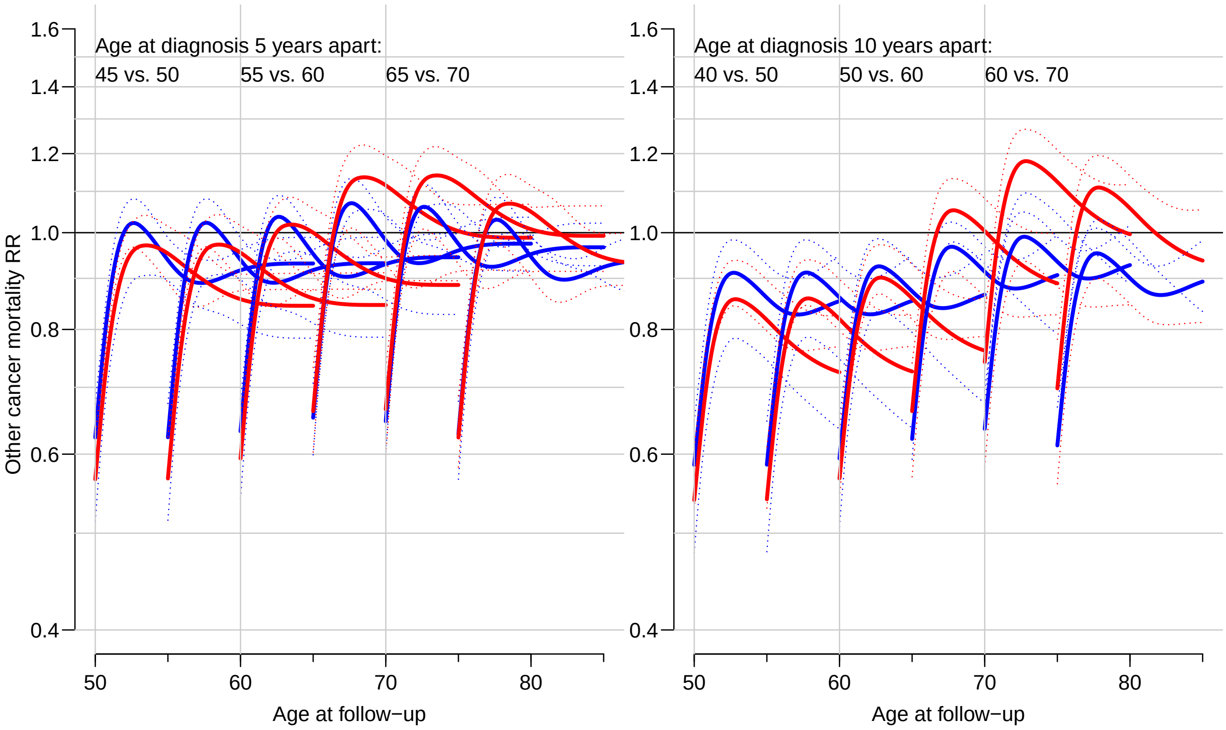

Figure 5.20: *Other cancer mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/iOthC-RReqd`

5.3.7 Infections

```
> cod( Agi, "i", "Infc", "Infections", Rmin=0.02, RRmin=0.6 )
Analysis of Infc Infections :
     sex         Men                    Women                    Sum
                   D            Y           D            Y           D            Y
Year
1997              49    147,860.8          41    135,650.4          90    283,511.2
1998              52    167,287.3          39    154,893.8          91    322,181.1
1999              73    187,256.1          67    173,769.1         140    361,025.2
2000              90    207,056.9          50    191,510.2         140    398,567.1
2001              88    226,264.5          73    208,364.3         161    434,628.7
2002             103    246,932.1          87    226,507.1         190    473,439.2
2003             112    266,494.1          81    244,572.0         193    511,066.1
2004             127    285,837.8          86    262,096.8         213    547,934.7
2005             142    306,749.1          97    280,423.9         239    587,173.0
2006             160    327,017.7         126    297,280.1         286    624,297.8
2007             134    348,717.7         118    314,814.7         252    663,532.4
2008             148    373,177.9         155    333,565.5         303    706,743.4
2009             168    395,625.0         125    351,061.2         293    746,686.2
2010             204    416,259.6         148    366,239.3         352    782,498.9
2011             194    438,395.4         187    381,920.9         381    820,316.3
Sum            1,844  4,340,931.9       1,480  3,922,669.3       3,324  8,263,601.2

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.993 0.981 1.005
Women     0.999 0.986 1.012
null device
          1
```

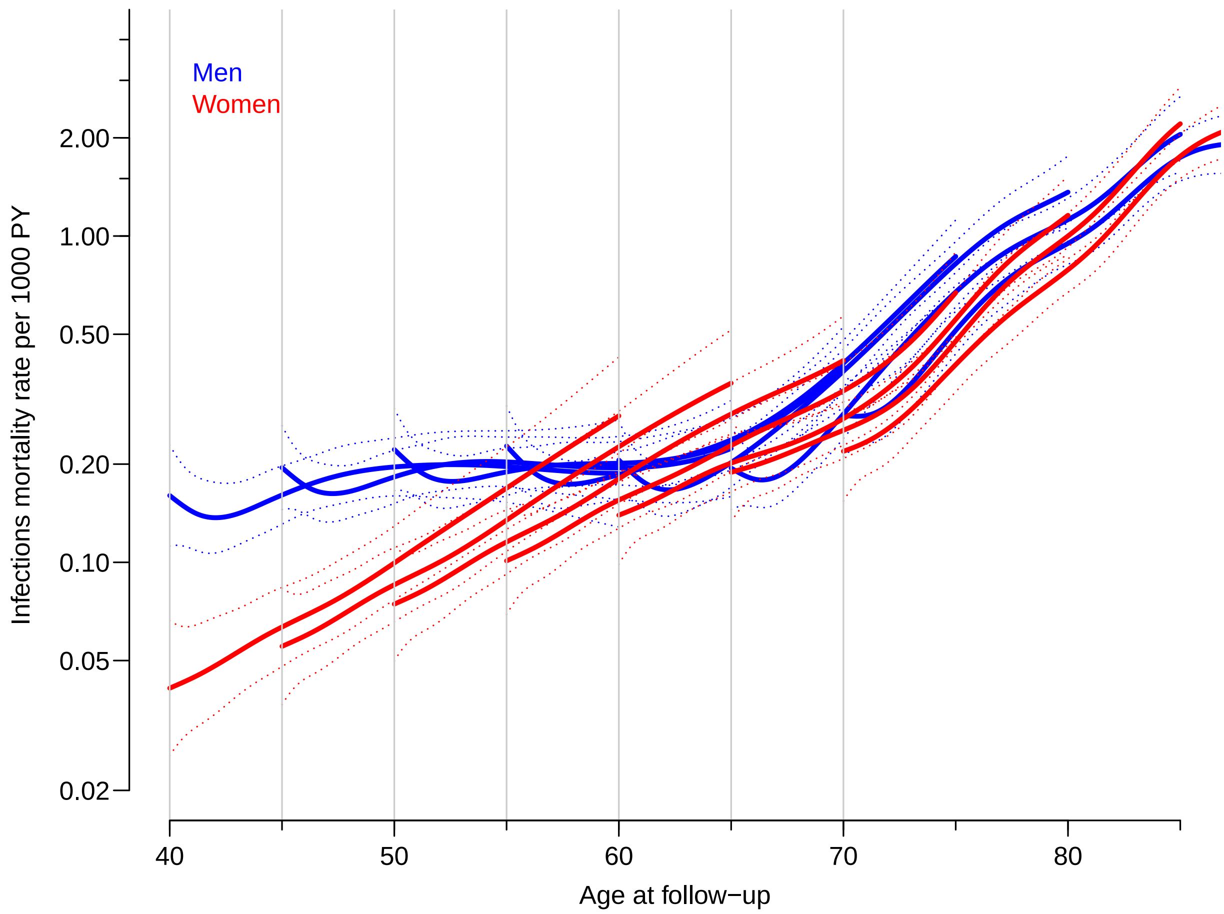

Figure 5.21: *Mortality rates from infections in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women...*`../graph/iInfc-prM`

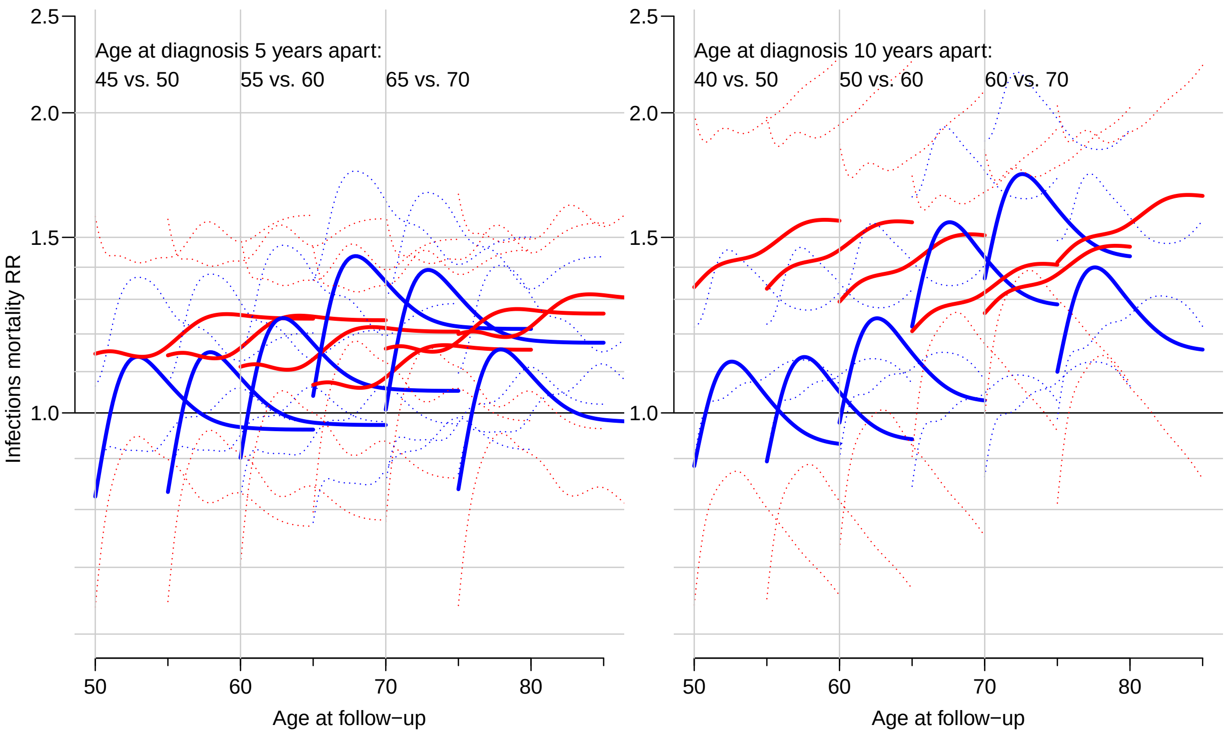

Figure 5.22: *Infections mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* `../graph/iInfc-RReqd`

5.3.8 Other causes (excluding infections)

```
> cod( Agi, "i", "Othr", "Other causes (eicl. inf.)", Rmin=0.5, RRmin=0.8 )
Analysis of Othr Other causes (eicl. inf.) :
     sex         Men                     Women                      Sum
                   D           Y             D           Y            D           Y
Year
1997           1,424   147,860.8         1,187   135,650.4        2,611   283,511.2
1998           1,485   167,287.3         1,262   154,893.8        2,747   322,181.1
1999           1,806   187,256.1         1,471   173,769.1        3,277   361,025.2
2000           2,047   207,056.9         1,716   191,510.2        3,763   398,567.1
2001           2,215   226,264.5         1,771   208,364.3        3,986   434,628.7
2002           2,506   246,932.1         2,049   226,507.1        4,555   473,439.2
2003           2,667   266,494.1         2,230   244,572.0        4,897   511,066.1
2004           2,953   285,837.8         2,490   262,096.8        5,443   547,934.7
2005           3,147   306,749.1         2,730   280,423.9        5,877   587,173.0
2006           3,502   327,017.7         3,155   297,280.1        6,657   624,297.8
2007           3,937   348,717.7         3,509   314,814.7        7,446   663,532.4
2008           4,280   373,177.9         3,923   333,565.5        8,203   706,743.4
2009           4,470   395,625.0         3,861   351,061.2        8,331   746,686.2
2010           4,624   416,259.6         4,191   366,239.3        8,815   782,498.9
2011           4,944   438,395.4         4,158   381,920.9        9,102   820,316.3
Sum           46,007 4,340,931.9        39,703 3,922,669.3       85,710 8,263,601.2

Annual change in rates:
      exp(Est.)  2.5% 97.5%
Men       0.988 0.986 0.991
Women     0.991 0.988 0.993
null device
          1
```

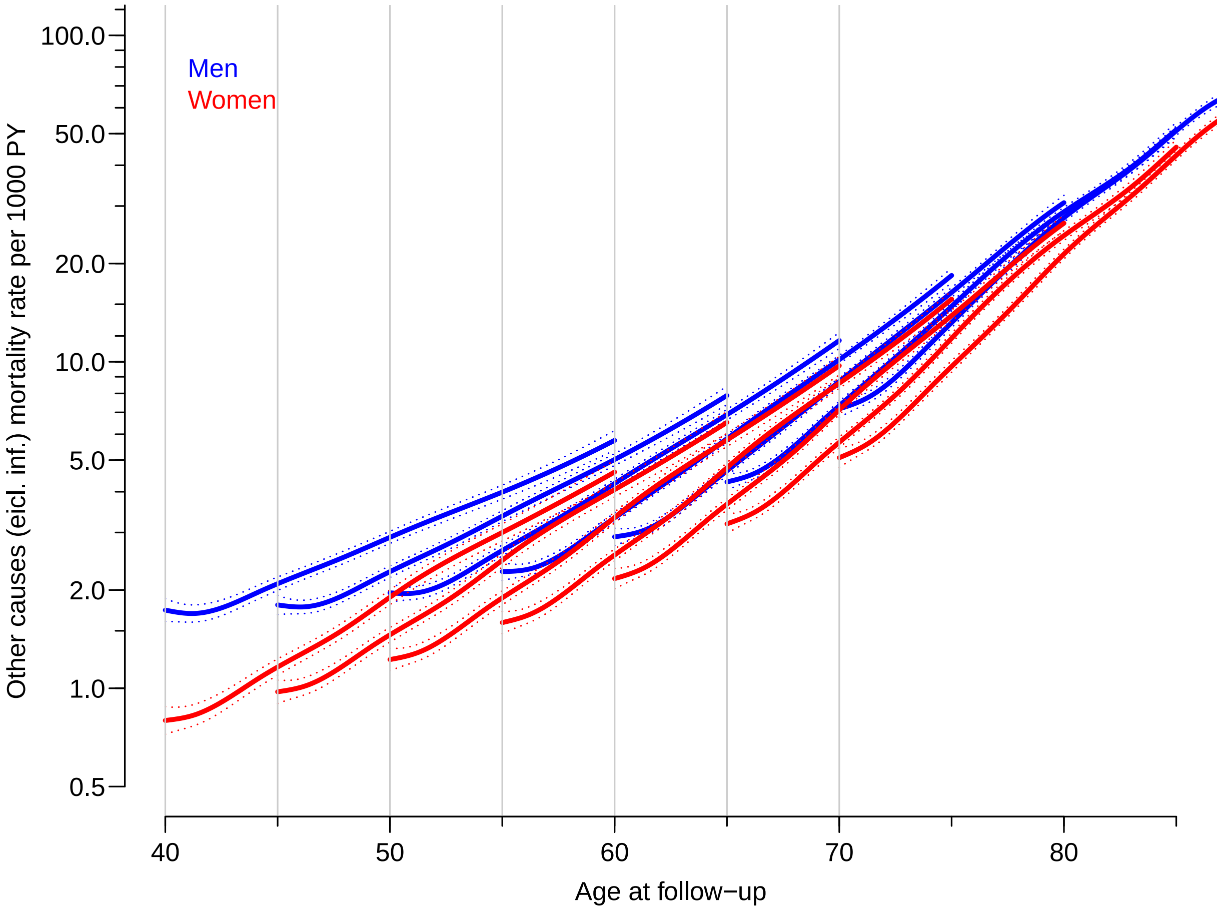

Figure 5.23: *Mortality rates from other causes (excluding infections) in Australian diabetes patients. Each curve starts at the age of diagnosis of diabetes. Blue curves are for men, red for women.* `../graph/iOthr-prM`

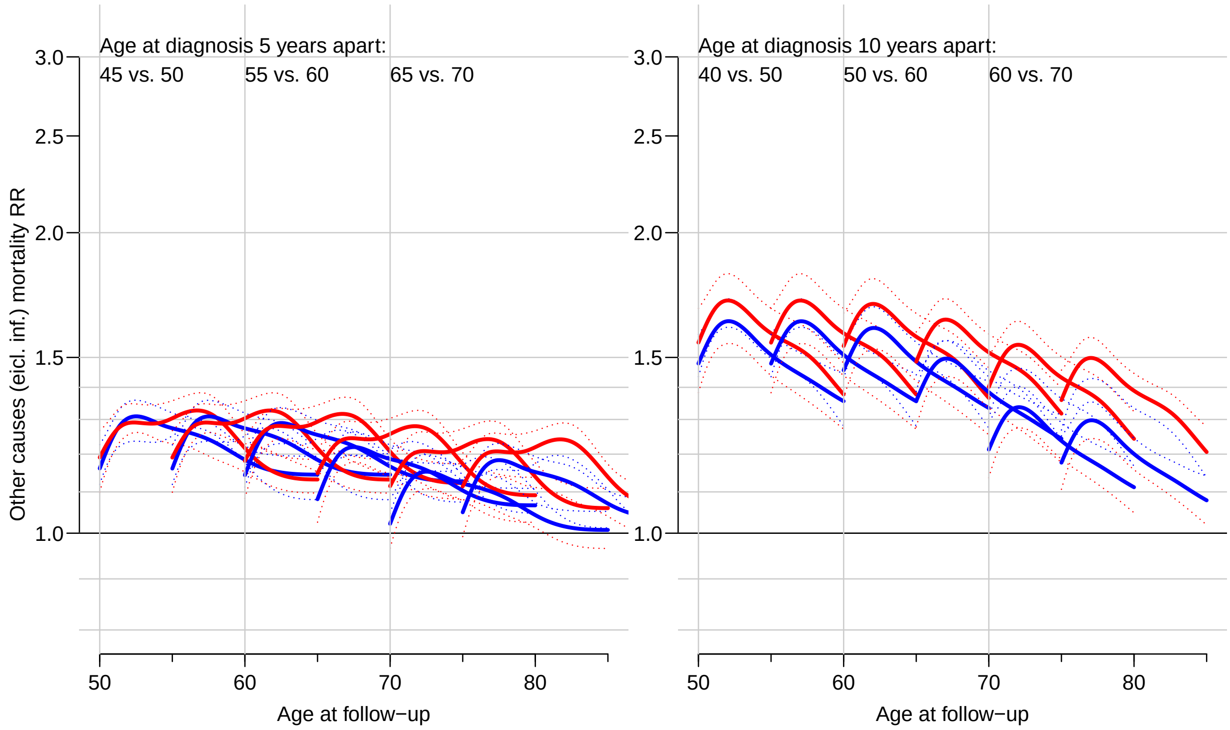

Figure 5.24: *Infections mortality RR between persons diagnosed in different ages, followed from the older person's age at diagnosis. These are thus mortality rate-ratios between person of the same age but with duration of diabetes differing 5 years (left panel) or 10 years (right panel). Blue curves are for men, red for women.* ../graph/iOthr-RReqd