BS852 HOMEWORK 2

Jiayuan Shi

Feb.4, 2016

1

a. Test whether there is interaction between smoking and coffee use using both Breslow day test and the Woolf's method.

```r
library(epiR)
```

```
## Loading required package: survival
## Package epiR 0.9-69 is loaded
## Type help(epi.about) for summary information
```

```r
palmer.data <- c(30, 33, 207, 327, 117, 25, 216, 114)
dim(palmer.data) <- c(2,2,2)
dimnames(palmer.data)[[1]] <- c("MI", "No MI")
dimnames(palmer.data)[[2]] <- c("Coffee 5+", "Coffee 0-4")
dimnames(palmer.data)[[3]] <- c("Never/Former", "Current")
palmer.data
```

```
## , , Never/Former
##
##       Coffee 5+ Coffee 0-4
## MI           30        207
## No MI        33        327
##
## , , Current
##
##       Coffee 5+ Coffee 0-4
## MI          117        216
## No MI        25        114
```

```r
# Testing interaction, Breslow Day test
res.BD <- epi.2by2(dat=palmer.data, method="case.control", homogeneity="breslow.day", conf.level=0.95)
summary(res.BD)
```

```
## $OR.strata.wald
##      est    lower    upper
## 1 1.4361 0.850232 2.425672
## 2 2.4700 1.516483 4.023060
##
## $OR.strata.cfield
##      est     lower    upper
## 1 1.4361 0.8450472 2.431476
## 2 2.4700 1.5266741 4.075971
##
```

```
## $OR.strata.score
##        est    lower     upper
## 1 1.436100 0.479798 0.8537075
## 2 7.393043 2.470000 1.5205967
##
## $OR.strata.mle
##        est     lower    upper
## 1 1.435168 0.8186412 2.508328
## 2 2.465616 1.4890439 4.200426
##
## $OR.crude.wald
##        est    lower    upper
## 1 2.642333 1.896033 3.682386
##
## $OR.crude.cfield
##        est    lower    upper
## 1 2.642333 1.900479 3.698384
##
## $OR.crude.score
##        est    lower    upper
## 1 4.003748 1.337644 1.897372
##
## $OR.crude.mle
##        est    lower    upper
## 1 2.640006 1.876796 3.749981
##
## $OR.mh
##        est        se    lower    upper
## 1 1.953015 0.1796099 1.373477 2.777089
##
## $ARe.strata.wald
##         est     lower     upper
## 1  3.491561 -1.685798  8.668921
## 2 17.149524  8.960713 25.338334
##
## $ARe.strata.score
##         est     lower     upper
## 1  3.491561 -1.510606  8.993886
## 2 17.149524  8.474642 24.904993
##
## $ARe.crude.wald
##        est     lower    upper
## 1 3.491561 -1.685798 8.668921
##
## $ARe.crude.score
##        est     lower    upper
## 1 3.491561 -1.510606 8.993886
##
## $AR.mh
##        est       se   lower    upper
## 1 9.049599 2.659543 3.83699 14.26221
##
## $ARp.strata.wald
##         est     lower     upper
```

```
## 1  1.386097 -2.481535  5.253729
## 2 12.099134  4.490939 19.707329
##
## $ARp.strata.piri
##         est      lower     upper
## 1  1.386097 -0.6737997  3.445994
## 2 12.099134  6.2789773 17.919291
##
## $ARp.crude.wald
##        est    lower    upper
## 1 7.553554 3.882371 11.22474
##
## $ARp.crude.piri
##        est    lower    upper
## 1 7.553554 5.084768 10.02234
##
## $AFest.strata
##         est      lower     upper
## 1 0.3032173 -0.2215364 0.6013281
## 2 0.5944219  0.3284281 0.7619289
##
## $AFpest.strata
##         est       lower     upper
## 1 0.1446046 -0.09278468 0.3304251
## 2 0.4903632  0.25060559 0.6534140
##
## $chisq.strata
##   test.statistic df      p.value
## 1       1.845792  1 0.1742736411
## 2      13.712065  1 0.0002130812
##
## $chisq.crude
##   test.statistic df      p.value
## 1       34.45037  1 4.372593e-09
##
## $chisq.mh
##   test.statistic df      p.value
## 1       13.28192  1 0.0002679783
##
## $OR.homog
##   test.statistic df   p.value
## 1       2.221734  1 0.1360801
```

```
# Testing interaction, Woolf's method
res.W <- epi.2by2(dat=palmer.data, method="case.control", homogeneity="woolf", conf.level=0.95)
summary(res.W)
```

```
## $OR.strata.wald
##      est    lower    upper
## 1 1.4361 0.850232 2.425672
## 2 2.4700 1.516483 4.023060
##
## $OR.strata.cfield
##      est     lower    upper
```

```
## 1 1.4361 0.8450472 2.431476
## 2 2.4700 1.5266741 4.075971
##
## $OR.strata.score
##        est    lower     upper
## 1 1.436100 0.479798 0.8537075
## 2 7.393043 2.470000 1.5205967
##
## $OR.strata.mle
##        est     lower    upper
## 1 1.435168 0.8186412 2.508328
## 2 2.465616 1.4890439 4.200426
##
## $OR.crude.wald
##        est    lower    upper
## 1 2.642333 1.896033 3.682386
##
## $OR.crude.cfield
##        est    lower    upper
## 1 2.642333 1.900479 3.698384
##
## $OR.crude.score
##        est    lower    upper
## 1 4.003748 1.337644 1.897372
##
## $OR.crude.mle
##        est    lower    upper
## 1 2.640006 1.876796 3.749981
##
## $OR.mh
##        est        se    lower    upper
## 1 1.953015 0.1796099 1.373477 2.777089
##
## $ARe.strata.wald
##         est     lower     upper
## 1  3.491561 -1.685798  8.668921
## 2 17.149524  8.960713 25.338334
##
## $ARe.strata.score
##         est     lower     upper
## 1  3.491561 -1.510606  8.993886
## 2 17.149524  8.474642 24.904993
##
## $ARe.crude.wald
##        est     lower    upper
## 1 3.491561 -1.685798 8.668921
##
## $ARe.crude.score
##        est     lower    upper
## 1 3.491561 -1.510606 8.993886
##
## $AR.mh
##        est       se   lower    upper
## 1 9.049599 2.659543 3.83699 14.26221
```

```
##
## $ARp.strata.wald
##         est     lower     upper
## 1  1.386097 -2.481535  5.253729
## 2 12.099134  4.490939 19.707329
##
## $ARp.strata.piri
##         est      lower     upper
## 1  1.386097 -0.6737997  3.445994
## 2 12.099134  6.2789773 17.919291
##
## $ARp.crude.wald
##        est    lower    upper
## 1 7.553554 3.882371 11.22474
##
## $ARp.crude.piri
##        est    lower    upper
## 1 7.553554 5.084768 10.02234
##
## $AFest.strata
##         est      lower     upper
## 1 0.3032173 -0.2215364 0.6013281
## 2 0.5944219  0.3284281 0.7619289
##
## $AFpest.strata
##         est       lower     upper
## 1 0.1446046 -0.09278468 0.3304251
## 2 0.4903632  0.25060559 0.6534140
##
## $chisq.strata
##   test.statistic df      p.value
## 1       1.845792  1 0.1742736411
## 2      13.712065  1 0.0002130812
##
## $chisq.crude
##   test.statistic df      p.value
## 1       34.45037  1 4.372593e-09
##
## $chisq.mh
##   test.statistic df      p.value
## 1       13.28192  1 0.0002679783
##
## $OR.homog
##   test.statistic df  p.value
## 1       2.120248  1 0.145363
```

Breslow Day test:
H0: OR1 and OR2 is equal; H1: OR1 and OR2 is not equal.
From the $OR.homog results, we can get the test statistic chi-square is 2.22, with df=1, and the p-value is 0.136. The p-value is larger than 0.05, so with 95% confidence, we can not reject the null hypothesis. Hence, OR1 and OR2 is similar, and there is no interaction between smoking and coffee use using Breslow Day test.

Woolf's method:
H0: OR1 and OR2 is equal; H1: OR1 and OR2 is not equal.
From the $OR.homog results, we can get the test statistic chi-square is 2.12, with df=1, and the p-value is

0.145. The p-value is larger than 0.05, so with 95% confidence, we can not reject the null hypothesis. Hence, OR1 and OR2 is similar, and there is no interaction between smoking and coffee use using Woolf's method.

b. Show whether there is confounding.

```r
epi.2by2(dat=palmer.data, method="case.control", conf.level=0.95)
```

```
##              Outcome +    Outcome -      Total        Prevalence *
## Exposed +          147          423        570                25.8
## Exposed -           58          441        499                11.6
## Total              205          864       1069                19.2
##                   Odds
## Exposed +        0.348
## Exposed -        0.132
## Total            0.237
##
## Point estimates and 95 % CIs:
## ---------------------------------------------------------
## Odds ratio (W) (crude)                      2.64 (1.90, 3.68)
## Odds ratio (M-H)                            1.95 (0.18, 1.37)
## Odds ratio (crude:M-H)                      1.35
## Attrib prevalence (W) (crude) *             3.49 (-1.69, 8.67)
## Attrib prevalence (M-H) *                   9.05 (2.66, 3.84)
## Attrib prevalence (crude:M-H)               0.39
## ---------------------------------------------------------
##  Test of homogeneity of  OR: X2 test statistic: 2.222 p-value: 0.136
##  W: Wald confidence limits
##  M-H: Mantel-Haenszel
##  * Cases per 100 population units
```

The adjusted odds ratio is 1.95, while the crude odds ratio is 2.64. The ratio $\frac{OR_{adjusted}}{OR_{crude}} = \frac{1.95}{2.64.} = 0.74$. 0.74 is not in the (0.9,1.1) interval, which means the two measures differ by more than 10%, so we conclude that there is confounding, and we summarize the results of the adjusted analysis.

c. Produce the Mantel-Haenszel chi-square test statistic to test whether there is an association between coffee consumption and MI using the continuity correction and without using the continuity corrections.

```r
# using the continuity correction
mantelhaen.test(palmer.data)
```

```
##
##  Mantel-Haenszel chi-squared test with continuity correction
##
## data:  palmer.data
## Mantel-Haenszel X-squared = 13.282, df = 1, p-value = 0.000268
## alternative hypothesis: true common odds ratio is not equal to 1
## 95 percent confidence interval:
##  1.373477 2.777089
```

```
## sample estimates:
## common odds ratio
##          1.953015
```

Mantel-Haenszel chi-square test(using the continuity correction):
H0: there is no association between coffee consumption and MI after adjusting for smoking; H1: there is an association between coffee consumption and MI after adjusting for smoking.
From the above output, we can see that the Mantel-Haenszel X-squared is 13.282 with 1 df, and the p-value is 0.00027, less than 0.001, so we can reject the null hypothesis. Hence, there is an significant association between coffee consumption and MI using the continuity correction.

Based on the adjusted analysis, the odds ratio is 1.95, so after adjusting for smoking, those who have consumed 5+ cups coffee are at 1.95 times the odds of an MI compared to those who have consumed 0-4 cups coffee.

```r
# without using the continuity correction
mantelhaen.test(palmer.data, correct = F)
```

```
##
##  Mantel-Haenszel chi-squared test without continuity correction
##
## data:  palmer.data
## Mantel-Haenszel X-squared = 13.913, df = 1, p-value = 0.0001915
## alternative hypothesis: true common odds ratio is not equal to 1
## 95 percent confidence interval:
##  1.373477 2.777089
## sample estimates:
## common odds ratio
##          1.953015
```

Mantel-Haenszel chi-square test(without using the continuity correction):
H0: there is no association between coffee consumption and MI after adjusting for smoking; H1: there is an association between coffee consumption and MI after adjusting for smoking.
From the above output, we can see that the Mantel-Haenszel X-squared is 13.913 with 1 df, and the p-value is 0.00019, less than 0.001, so we can reject the null hypothesis. Hence, there is an significant association between coffee consumption and MI without using the continuity correction.

Based on the adjusted analysis, the odds ratio for is 1.95, so after adjusting for smoking, those who have consumed 5+ cups coffee are at 1.95 times the odds of an MI compared to those who have consumed 0-4 cups coffee.

d. Write down the conclusions of your study.

Conclusions:
1. There is no evidence of interaction between smoking and coffee use using both Breslow Day test and Woolf's method.
2. There is confounding because crude OR and adjusted OR differ by less than 10%, and we summarize the results of the adjusted analysis.
3. Based on the adjusted analysis, the odds ratio is 1.95, so after adjusting for smoking, those who have consumed 5+ cups coffee are at 1.95 times the odds of an MI compared to those who have consumed 0-4 cups coffee. The association is statistically significant (MH statistic = 13.282, p-value = 0.00027 with continuity correction, and MH statistic = 13.913, p-value = 0.00019 without continuity correction).

2

a. a crude odds ratio

```
framdat2 <- read.table("framdat2.txt", header = T, sep = "", na.strings = c("."))
framdat2[1:5,]
```

```
##   SEX CHD DTH CAU AGE CSM GLI X5FVC MRW SPF
## 1   2   0  13   6  35   0   0    NA 131 110
## 2   2   0   8   5  47   0   0   254 181 124
## 3   2   0   0   0  63   0   0   355 118 138
## 4   2   0   0   0  44   0   0   492 116 105
## 5   1   0   0   0  47  30   0   409 124 126
```

```
framdat2 <- framdat2[which(framdat2$SEX==2 & (framdat2$CHD==0 | framdat2$CHD>4)),]
attach(framdat2)
agef <- AGE
agef[which(AGE>=35 & AGE<45)] <- 1
agef[which(AGE>=45 & AGE<55)] <- 2
agef[which(AGE>=55 & AGE<65)] <- 3
agef[which(AGE>=65 & AGE<75)] <- 4
chd_sw = CHD<4
gli4 = GLI==0
fhd.data <- table(gli4, chd_sw, agef)
fhd.data
```

```
## , , agef = 1
##
##        chd_sw
## gli4    FALSE TRUE
##   FALSE     3    7
##   TRUE     57  452
##
## , , agef = 2
##
##        chd_sw
## gli4    FALSE TRUE
##   FALSE     6    9
##   TRUE     91  427
##
## , , agef = 3
##
##        chd_sw
## gli4    FALSE TRUE
##   FALSE    13   10
##   TRUE    113  291
##
## , , agef = 4
##
##        chd_sw
## gli4    FALSE TRUE
##   FALSE     0    4
##   TRUE     12   28
```

```r
res <- epi.2by2(dat = fhd.data, method = "cohort.count", conf.level = 0.95)
res
```

```
##              Outcome +    Outcome -      Total        Inc risk *
## Exposed +           22           30         52              42.3
## Exposed -          273         1198       1471              18.6
## Total              295         1228       1523              19.4
##                   Odds
## Exposed +        0.733
## Exposed -        0.228
## Total            0.240
##
##
## Point estimates and 95 % CIs:
## ---------------------------------------------------------
## Inc risk ratio (W) (crude)                 2.28 (1.63, 3.19)
## Inc risk ratio (M-H)                       1.94 (1.40, 2.68)
## Inc risk ratio (crude:M-H)                 1.18
## Odds ratio (W) (crude)                     3.22 (1.83, 5.67)
## Odds ratio (M-H)                           2.69 (1.52, 4.76)
## Odds ratio (crude:M-H)                     1.20
## Attrib risk (W) (crude) *                  18.80 (-9.73, 47.34)
## Attrib risk (M-H) *                        20.58 (-63.79, 104.96)
## Attrib risk (crude:M-H)                    0.91
## ---------------------------------------------------------
##  Test of homogeneity of IRR: X2 test statistic: 6.123 p-value: 0.106
##  Test of homogeneity of  OR: X2 test statistic: 4.557 p-value: 0.207
##  W: Wald confidence limits
##  M-H: Mantel-Haenszel
##  * Cases per 100 population units
```

As we can see in the R ourput for res,

```r
# Odds ratio (W) (crude)                      3.22 (1.83, 5.67)
```

The crude odds ratio is 3.22, with 95% CI (1.83, 5.67).

b. stratum-specific odds ratios

```r
summary(res)
```

```
## $RR.strata.wald
##        est    lower    upper
## 1 2.678947 1.007604 7.122596
## 2 2.276923 1.191921 4.349599
## 3 2.020777 1.366669 2.987951
## 4 0.000000 0.000000      NaN
##
## $RR.srata.score
##        est     lower    upper
```

```
## 1 2.678947 0.9400094 5.723068
## 2 2.276923 1.1046517 3.837111
## 3 2.020777 1.2846588 2.803963
## 4 0.000000 0.0000000 1.805830
##
## $RR.crude.wald
##        est    lower    upper
## 1 2.279656 1.630792 3.186692
##
## $RR.crude.score
##        est   lower    upper
## 1 2.279656 1.58565 3.077421
##
## $RR.mh
##        est        se    lower    upper
## 1 1.937826 0.1654046 1.401271 2.679831
##
## $OR.strata.wald
##        est     lower     upper
## 1 3.398496 0.8547537 13.512403
## 2 3.128205 1.0865101  9.006513
## 3 3.347788 1.4272525  7.852627
## 4 0.000000 0.0000000       NaN
##
## $OR.strata.cfield
##        est     lower     upper
## 1 3.398496 0.6944381 13.273069
## 2 3.128205 1.0103391  9.089372
## 3 3.347788 1.4100008  8.079579
## 4 0.000000 0.0000000  2.959314
##
## $OR.strata.score
##        est    lower    upper
## 1 3.398496 2.497076 1.531579
## 2 4.257457 3.128205 1.918681
## 3 7.428571 5.458210 3.347788
## 4 0.000000 0.000000 0.000000
##
## $OR.strata.mle
##        est     lower     upper
## 1 3.386693 0.5498855 15.359424
## 2 3.119289 0.8904396 10.097487
## 3 3.336579 1.3093643  8.765674
## 4 0.000000 0.0000000  4.079503
##
## $OR.crude.wald
##        est   lower  upper
## 1 3.218071 1.82787 5.6656
##
## $OR.crude.cfield
##        est   lower    upper
## 1 3.218071 1.80488 5.662252
##
## $OR.crude.score
```

```
##        est    lower    upper
## 1 5.203558 3.823362 2.345055
##
## $OR.crude.mle
##        est    lower    upper
## 1 3.214837 1.737895 5.863823
##
## $OR.mh
##        est        se    lower    upper
## 1 2.686623 0.2921564 1.515384 4.763112
##
## $ARe.strata.wald
##         est      lower     upper
## 1  18.80157  -9.732819  47.33596
## 2  22.43243  -2.575021  47.43989
## 3  28.55144   7.824580  49.27830
## 4 -30.00000 -44.201288 -15.79871
##
## $ARe.strata.score
##         est       lower    upper
## 1  18.80157  -0.7051233 49.25876
## 2  22.43243   1.9137813 46.92933
## 3  28.55144   8.3051227 47.00167
## 4 -30.00000 -45.4300177 20.78610
##
## $ARe.crude.wald
##        est     lower    upper
## 1 18.80157 -9.732819 47.33596
##
## $ARe.crude.score
##        est      lower    upper
## 1 18.80157 -0.7051233 49.25876
##
## $AR.mh
##        est       se    lower   upper
## 1 20.58021 43.04917 -63.7946 104.955
##
## $ARp.strata.wald
##          est      lower     upper
## 1  0.3622654  -3.520091  4.244622
## 2  0.6313067  -4.002120  5.264733
## 3  1.5378997  -4.615968  7.691768
## 4 -2.2269353 -21.406938 16.953067
##
## $ARp.strata.piri
##          est      lower     upper
## 1  0.3622654 -0.2307925 0.9553232
## 2  0.6313067 -0.1397271 1.4023406
## 3  1.5378997  0.2650389 2.8107605
## 4 -2.2269353 -5.9567382 1.5028675
##
## $AFe.strata
##         est       lower     upper
## 1 0.6267191 0.007547002 0.8596018
```

```
## 2 0.5608108 0.161018267 0.7700938
## 3 0.5051409 0.268294138 0.6653224
## 4      -Inf        -Inf       NaN
##
## $AFp.strata
##           est        lower      upper
## 1  0.03133595 -0.020917946 0.08091533
## 2  0.03468933 -0.008346230 0.07588816
## 3  0.05211771  0.008131716 0.09415308
## 4 -0.07879925 -0.218341635 0.04476069
##
## $chisq.strata
##   test.statistic df     p.value
## 1      3.3908573  1 0.065558853
## 2      4.9276828  1 0.026429736
## 3      8.5281756  1 0.003496901
## 4      0.9226676  1 0.336775527
##
## $chisq.crude
##   test.statistic df      p.value
## 1        18.1377  1 2.054928e-05
##
## $chisq.mh
##   test.statistic df      p.value
## 1         11.213  1 0.0008122648
##
## $RR.homog
##   test.statistic df   p.value
## 1       6.123124  3 0.1057712
##
## $OR.homog
##   test.statistic df   p.value
## 1       4.556624  3 0.2072948
```

As we can see in the R ourput, the stratum-specific odds ratios $OR.strata.wald are,
est lower upper
1 3.398496 0.8547537 13.512403
2 3.128205 1.0865101 9.006513
3 3.347788 1.4272525 7.852627
4 0.000000 0.0000000 NaN

So for Group 1, the OR is 3.40 with 95% CI (0.85,13.51); for Group 2, the OR is 3.12 with 95% CI (1.09,9.01); for Group 3, the OR is 3.35 with 95% CI (1.43,7.86); for Group 4, the OR is 0.

c. a summary odds ratio adjusting for age

```
res
```

```
##              Outcome +    Outcome -      Total        Inc risk *
## Exposed +           22           30         52              42.3
## Exposed -          273         1198       1471              18.6
## Total              295         1228       1523              19.4
```

```
##                  Odds
## Exposed +       0.733
## Exposed -       0.228
## Total           0.240
##
##
## Point estimates and 95 % CIs:
## ---------------------------------------------------------
## Inc risk ratio (W) (crude)                   2.28 (1.63, 3.19)
## Inc risk ratio (M-H)                         1.94 (1.40, 2.68)
## Inc risk ratio (crude:M-H)                   1.18
## Odds ratio (W) (crude)                       3.22 (1.83, 5.67)
## Odds ratio (M-H)                             2.69 (1.52, 4.76)
## Odds ratio (crude:M-H)                       1.20
## Attrib risk (W) (crude) *                    18.80 (-9.73, 47.34)
## Attrib risk (M-H) *                          20.58 (-63.79, 104.96)
## Attrib risk (crude:M-H)                      0.91
## ---------------------------------------------------------
##  Test of homogeneity of IRR: X2 test statistic: 6.123 p-value: 0.106
##  Test of homogeneity of  OR: X2 test statistic: 4.557 p-value: 0.207
##  W: Wald confidence limits
##  M-H: Mantel-Haenszel
##  * Cases per 100 population units
```

```
# Odds ratio (M-H)                          2.69 (1.52, 4.76)
```

The summary odds ratio adjusting for age is 2.69, with 95% CI (1.52, 4.76).

d. a Mantel-Haenszel chi-square test statistic testing the age-adjusted association between gli4 and CHD

```
mantelhaen.test(fhd.data)
```

```
##
##  Mantel-Haenszel chi-squared test with continuity correction
##
## data:  fhd.data
## Mantel-Haenszel X-squared = 11.213, df = 1, p-value = 0.0008123
## alternative hypothesis: true common odds ratio is not equal to 1
## 95 percent confidence interval:
##  1.512355 4.798929
## sample estimates:
## common odds ratio
##          2.694009
```

H0: there is no the age-adjusted association between gli4 and CHD; H1: there is an age-adjusted association between gli4 and CHD.
From the above output, we can see the Mantel-Haenszel X-squared is 11.213 with 1 df, and the p-value is 0.0008, less than 0.001, so we can reject the null hypothesis. Hence, there is a significant age-adjusted association between gli4 and CHD among women with continuity correction.

e. a 95% confidence interval for the age-adjusted association

```
mantelhaen.test(fhd.data)
```

```
##
##  Mantel-Haenszel chi-squared test with continuity correction
##
## data:  fhd.data
## Mantel-Haenszel X-squared = 11.213, df = 1, p-value = 0.0008123
## alternative hypothesis: true common odds ratio is not equal to 1
## 95 percent confidence interval:
##  1.512355 4.798929
## sample estimates:
## common odds ratio
##          2.694009
```

From the above output, the 95% confidence interval for the age-adjusted association is (1.5124, 4.7989). With 95% confidence, we estimate that the true adjusted OR for CHD lies between 1.5124 and 4.7989. This confidence interval excludes 1. There is statistically significant evidence to reject H0 and suggest an increased odds of CHD among those women who have glucose intolerance after adjusting for age.

Conclusion:

a. Confounding:
   The odds ratio for CHD, adjusted for age, is 2.69, while the unadjusted odds ratio is 3.22. The ratio $\frac{OR_{adjusted}}{OR_{crude}} = \frac{2.69}{3.22} = 0.835$. 0.835 is not in the (0.9,1.1), and the two measures differ by more than 10%, so we conclude that age confounds the association between glucose intolerance and CHD among women, and we summarize the results of the adjusted analysis.

b. Interaction:
   From the Breslow Day test, H0: OR1 and OR2 is equal; H1: OR1 and OR2 is not equal.
   As we can see in the $OR.homog from $summary(res)$ results, we can get the test statistic chi-square is 4.557 with 3 df, and the p-value is 0.207. The p-value is larger than 0.05, so with 95% confidence, we can not reject the null hypothesis. Hence, OR1 and OR2 is similar, and there is no interaction between glucose intolerance and age among women.

c. Relationship:
   Based on the adjusted analysis, the odds ratio for CHD is 2.69 (95% (1.5124, 4.7989)),so after adjusting for age, women with glucose intolerance have 2.69 times the odds for CHD compared to women without glucose intolerance. The association between glucose intolerance measured at exam 4 and development of coronary heart disease over 22 years of follow-up among women is statistically significant(MH statistic = 11.213, p-value = 0.0008 < 0.001). Also with 95% confidence, we estimate that the true adjusted OR for CHD lies between 1.5124 and 4.7989. This confidence interval excludes 1. There is statistically significant evidence to reject H0 and suggest an increased odds of CHD among those women who have glucose intolerance after adjusting for age.