P8108 Final Project

Group 6

2025-11-16

Data Import

```
lung_df <- survival::lung %>%
  janitor::clean_names() %>%
  mutate(
    inst = as.factor(inst),
    time = as.numeric(time),
    status = as.factor(status),
    event = status == 2,
    age = as.numeric(age),
    sex = factor(sex, levels = c(1, 2), labels = c("Male", "Female")),
    ph_ecog = factor(ph_ecog, ordered = TRUE),
    ph_karno = as.numeric(ph_karno),
    pat_karno = as.numeric(pat_karno),
    meal_cal = as.numeric(meal_cal),
    wt_loss = as.numeric(wt_loss)
  )
```

We create a new variable called `event` to indicate survival status, where 1 represents death and 0 represents censoring.

The variable `ph_ecog` (ECOG performance score, 0–3) is treated as an ordinal variable. For descriptive and Kaplan–Meier analyses, it is handled as a categorical factor to visualize group differences. It might be modeled as an ordinal numeric variable in Cox model.

Check NAs

```
summary(lung_df)
```

```
##       inst          time          status        age             sex         ph_ecog
##  1      : 36   Min.   :   5.0   1: 63   Min.   :39.00   Male  :138   0   : 63
##  12     : 23   1st Qu.: 166.8   2:165   1st Qu.:56.00   Female: 90   1   :113
##  13     : 20   Median : 255.5           Median :63.00                2   : 50
##  3      : 19   Mean   : 305.2           Mean   :62.45                3   :  1
##  11     : 18   3rd Qu.: 396.5           3rd Qu.:69.00                NA's:  1
##  (Other):111   Max.   :1022.0           Max.   :82.00
##  NA's   :  1
##     ph_karno        pat_karno         meal_cal          wt_loss
```

```
## Min.   : 50.00   Min.   : 30.00   Min.   :  96.0   Min.   :-24.000
## 1st Qu.: 75.00   1st Qu.: 70.00   1st Qu.: 635.0   1st Qu.:  0.000
## Median : 80.00   Median : 80.00   Median : 975.0   Median :  7.000
## Mean   : 81.94   Mean   : 79.96   Mean   : 928.8   Mean   :  9.832
## 3rd Qu.: 90.00   3rd Qu.: 90.00   3rd Qu.:1150.0   3rd Qu.: 15.750
## Max.   :100.00   Max.   :100.00   Max.   :2600.0   Max.   : 68.000
## NA's   :1        NA's   :3        NA's   :47       NA's   :14
##   event
## Mode :logical
## FALSE:63
## TRUE :165
##
##
##
##
```

```
lung_cc <- lung_df %>%
  filter(complete.cases(time, event, age, sex, ph_ecog,
                        ph_karno, pat_karno, meal_cal, wt_loss, inst))
summary(lung_cc)
```

```
##      inst          time         status       age            sex       ph_ecog
## 1      :28   Min.   :   5.0   1: 47   Min.   :39.00   Male  :103   0:47
## 12     :16   1st Qu.: 174.5   2:120   1st Qu.:57.00   Female: 64   1:81
## 11     :13   Median : 268.0           Median :64.00                2:38
## 13     :13   Mean   : 309.9           Mean   :62.57                3: 1
## 22     :13   3rd Qu.: 419.5           3rd Qu.:70.00
## 3      :12   Max.   :1022.0           Max.   :82.00
## (Other):72
##    ph_karno        pat_karno         meal_cal         wt_loss
## Min.   : 50.00   Min.   : 30.00   Min.   :  96.0   Min.   :-24.000
## 1st Qu.: 70.00   1st Qu.: 70.00   1st Qu.: 619.0   1st Qu.:  0.000
## Median : 80.00   Median : 80.00   Median : 975.0   Median :  7.000
## Mean   : 82.04   Mean   : 79.58   Mean   : 929.1   Mean   :  9.719
## 3rd Qu.: 90.00   3rd Qu.: 90.00   3rd Qu.:1162.5   3rd Qu.: 15.000
## Max.   :100.00   Max.   :100.00   Max.   :2600.0   Max.   : 68.000
##
##   event
## Mode :logical
## FALSE:47
## TRUE :120
##
##
##
##
```

There are NAs in this data, so we will also create another dataset that observations with missing values will be excluded to ensure that all variables used in the analysis had complete information.

Both the original dataset and the complete-case dataset were retained for further analyses to allow comparisons and sensitivity checks.

EDA

Descriptive Table

```
lung_cc %>%
  select(time, event, age, sex, ph_ecog, ph_karno, pat_karno, meal_cal, wt_loss) %>%
  tbl_summary(
    by = sex,
    missing = "no",
    statistic = list(all_continuous() ~ "{mean} ({sd})", all_categorical() ~ "{n} ({p}%)"),
    label = list(
      time ~ "Survival time (days)",
      event ~ "Death indicator",
      age ~ "Age (years)",
      ph_ecog ~ "ECOG performance status",
      ph_karno ~ "Physician Karnofsky score",
      pat_karno ~ "Patient Karnofsky score",
      meal_cal ~ "Meal calories",
      wt_loss ~ "Weight loss (kg)"
    )
  ) %>%
  add_overall() %>%
  add_p(test = everything() ~ "wilcox.test") %>%
  bold_labels()
```

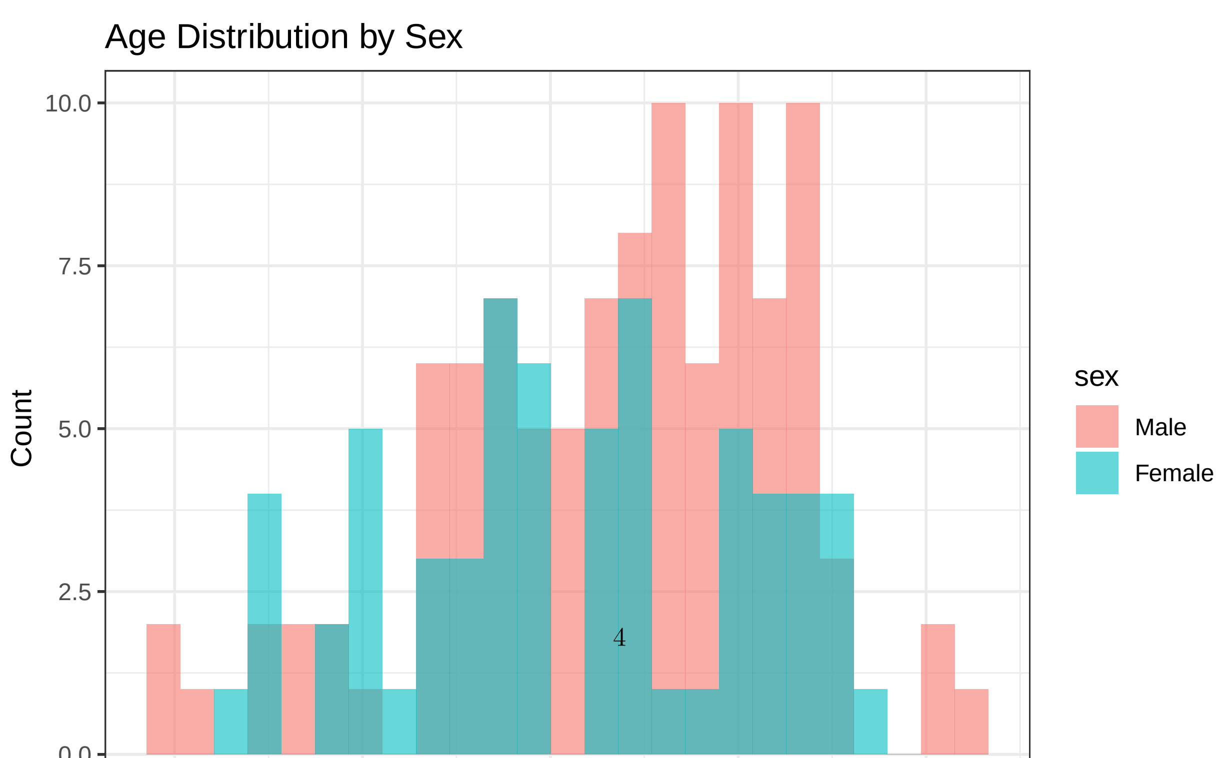
```
## The following errors were returned during `add_p()`:
## x For variable `age` (`sex`) and "p.value" statistic: The package "broom" (>=
##   1.0.8) is required.
## x For variable `event` (`sex`) and "p.value" statistic: The package "broom" (>=
##   1.0.8) is required.
## x For variable `meal_cal` (`sex`) and "p.value" statistic: The package "broom"
##   (>= 1.0.8) is required.
## x For variable `pat_karno` (`sex`) and "p.value" statistic: The package "broom"
##   (>= 1.0.8) is required.
## x For variable `ph_ecog` (`sex`) and "p.value" statistic: The package "broom"
##   (>= 1.0.8) is required.
## x For variable `ph_karno` (`sex`) and "p.value" statistic: The package "broom"
##   (>= 1.0.8) is required.
## x For variable `time` (`sex`) and "p.value" statistic: The package "broom" (>=
##   1.0.8) is required.
## x For variable `wt_loss` (`sex`) and "p.value" statistic: The package "broom"
##   (>= 1.0.8) is required.
```

Age Distribution by Sex

```
ggplot(lung_cc, aes(x = age, fill = sex)) +
  geom_histogram(bins = 25, position = "identity", alpha = 0.6) +
  theme_bw() +
  labs(title = "Age Distribution by Sex", x = "Age (years)", y = "Count")
```

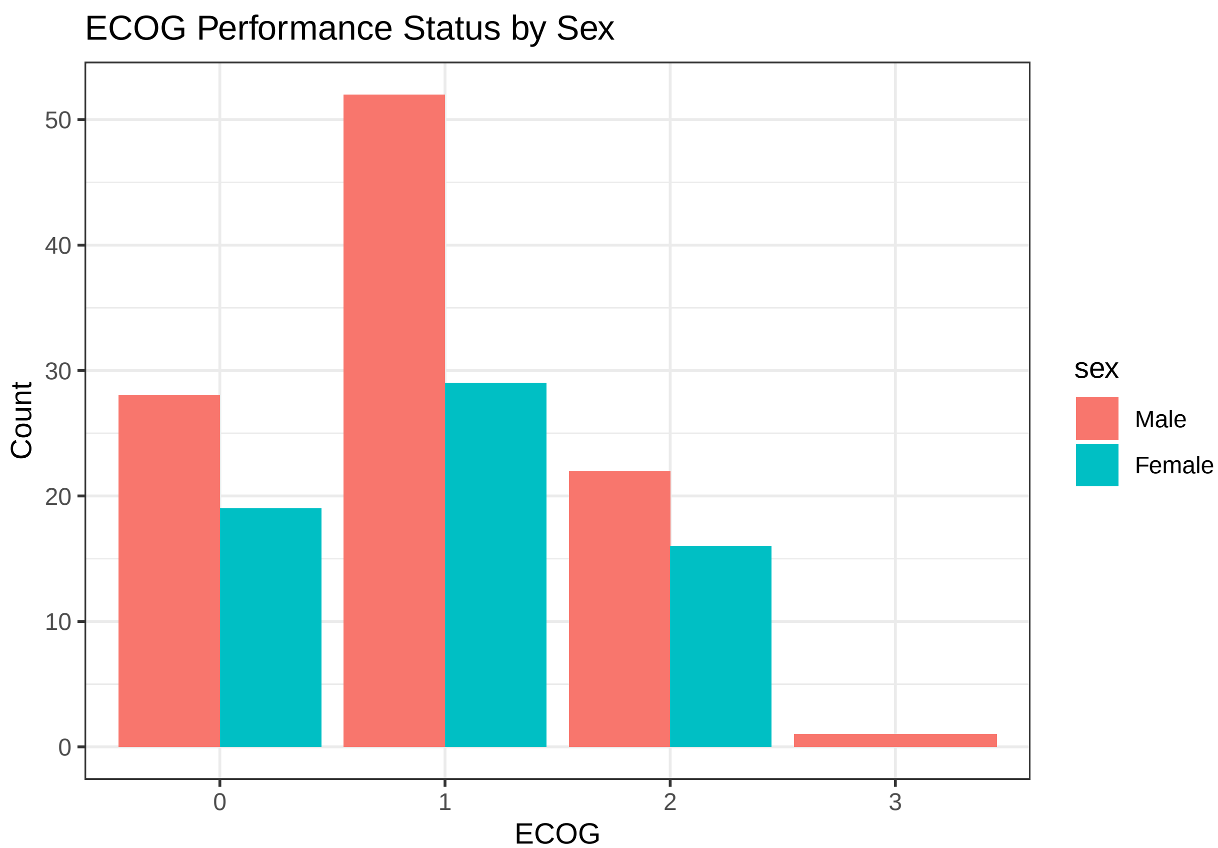
Characteristic	Overall N = 167[1]	Male N = 103[1]	Female N = 64[1]	p-value
Survival time (days)	310 (209)	291 (208)	340 (209)	
Death indicator	120 (72%)	82 (80%)	38 (59%)	
Age (years)	63 (9)	63 (9)	61 (9)	
ECOG performance status				
0	47 (28%)	28 (27%)	19 (30%)	
1	81 (49%)	52 (50%)	29 (45%)	
2	38 (23%)	22 (21%)	16 (25%)	
3	1 (0.6%)	1 (1.0%)	0 (0%)	
Physician Karnofsky score				
50	4 (2.4%)	3 (2.9%)	1 (1.6%)	
60	16 (9.6%)	8 (7.8%)	8 (13%)	
70	24 (14%)	16 (16%)	8 (13%)	
80	47 (28%)	28 (27%)	19 (30%)	
90	50 (30%)	32 (31%)	18 (28%)	
100	26 (16%)	16 (16%)	10 (16%)	
Patient Karnofsky score				
30	2 (1.2%)	1 (1.0%)	1 (1.6%)	
40	2 (1.2%)	1 (1.0%)	1 (1.6%)	
50	3 (1.8%)	2 (1.9%)	1 (1.6%)	
60	23 (14%)	15 (15%)	8 (13%)	
70	30 (18%)	24 (23%)	6 (9.4%)	
80	37 (22%)	20 (19%)	17 (27%)	
90	44 (26%)	24 (23%)	20 (31%)	
100	26 (16%)	16 (16%)	10 (16%)	
Meal calories	929 (413)	985 (428)	840 (374)	
Weight loss (kg)	10 (13)	12 (13)	7 (13)	

[1] Mean (SD); n (%)



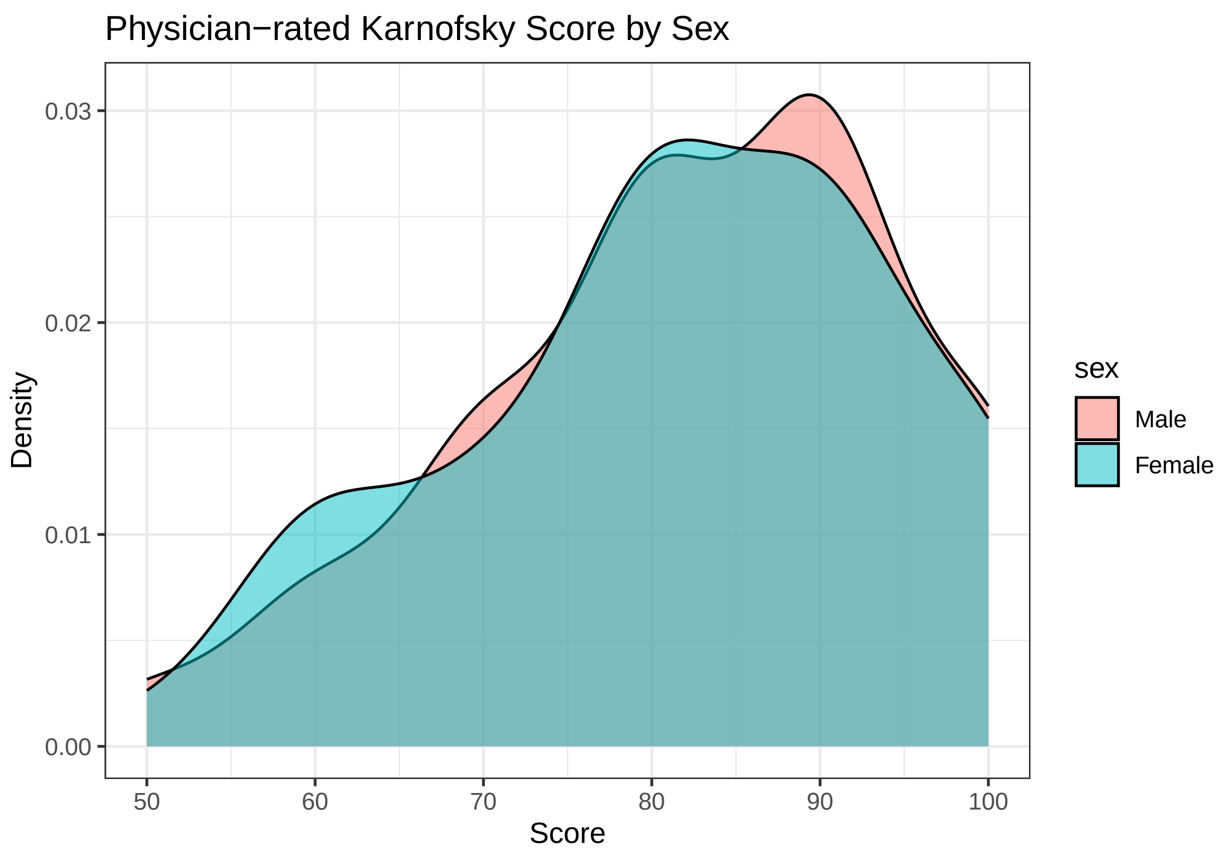
ECOG Performance Status by Sex

```r
ggplot(lung_cc, aes(x = ph_ecog, fill = sex)) +
  geom_bar(position = "dodge") +
  theme_bw() +
  labs(title = "ECOG Performance Status by Sex", x = "ECOG", y = "Count")
```



Physician-rated Karnofsky Score by Sex

```r
ggplot(lung_cc, aes(x = ph_karno, fill = sex)) +
  geom_density(alpha = 0.5) +
  theme_bw() +
  labs(title = "Physician-rated Karnofsky Score by Sex", x = "Score", y = "Density")
```

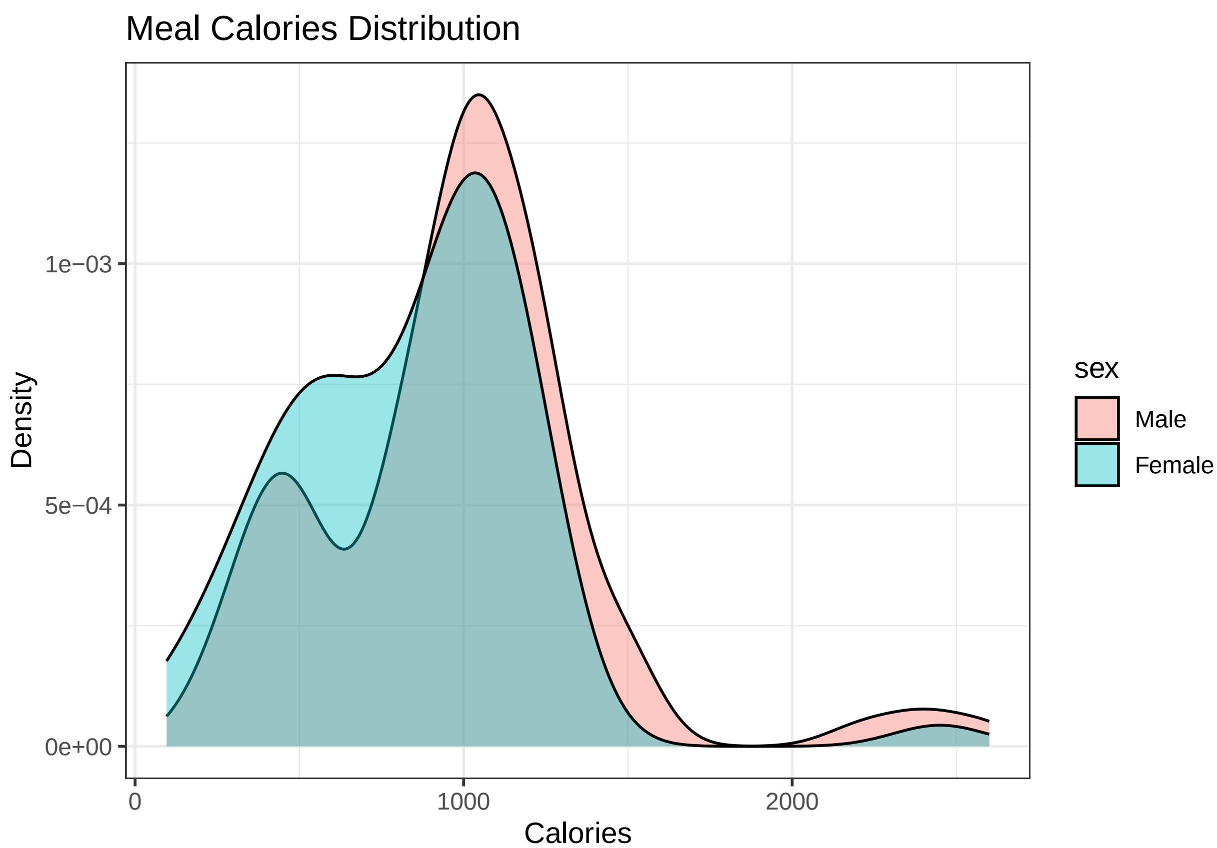


Meal Calories and Weight Loss Distributions

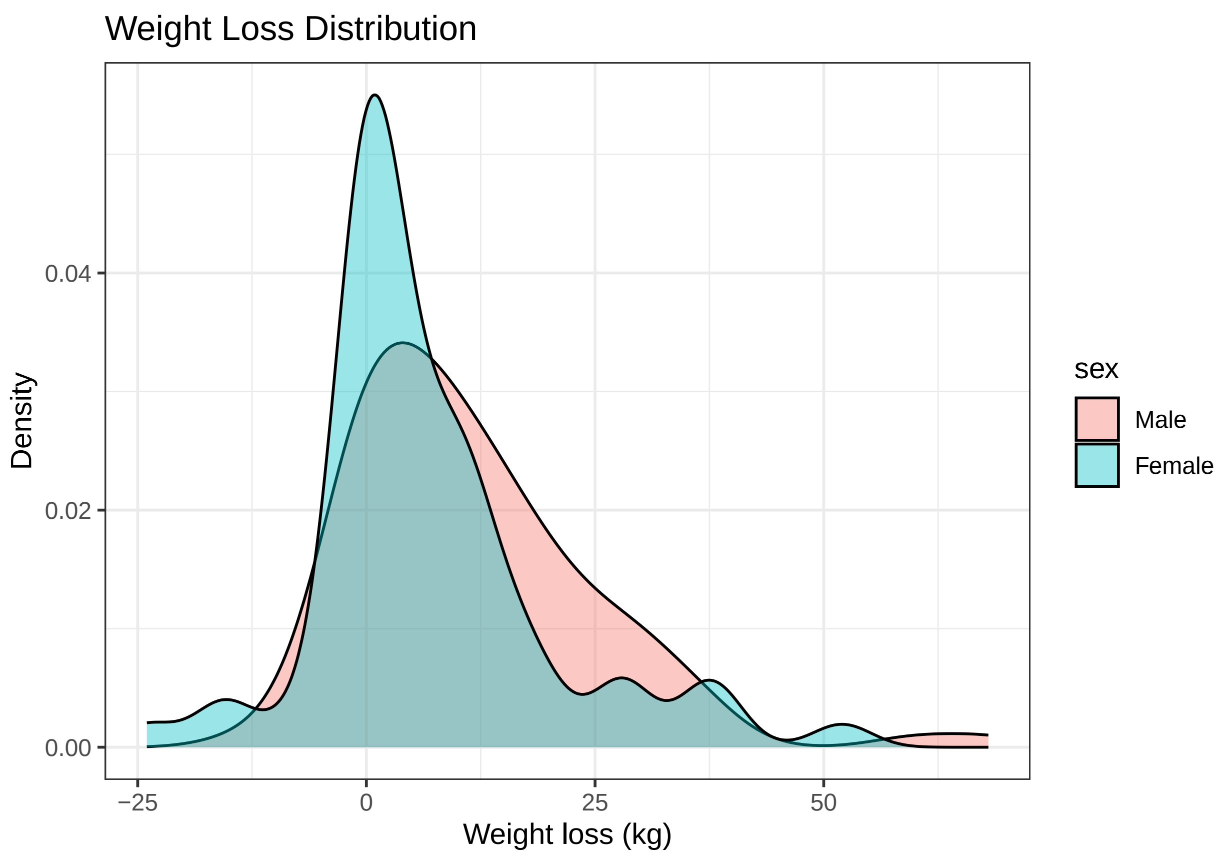
```
p1 <- ggplot(lung_cc, aes(x = meal_cal, fill = sex)) +
  geom_density(alpha = 0.4) +
  labs(title = "Meal Calories Distribution", x = "Calories", y = "Density") +
  theme_bw()

p2 <- ggplot(lung_cc, aes(x = wt_loss, fill = sex)) +
  geom_density(alpha = 0.4) +
  labs(title = "Weight Loss Distribution", x = "Weight loss (kg)", y = "Density") +
  theme_bw()

p1; p2
```

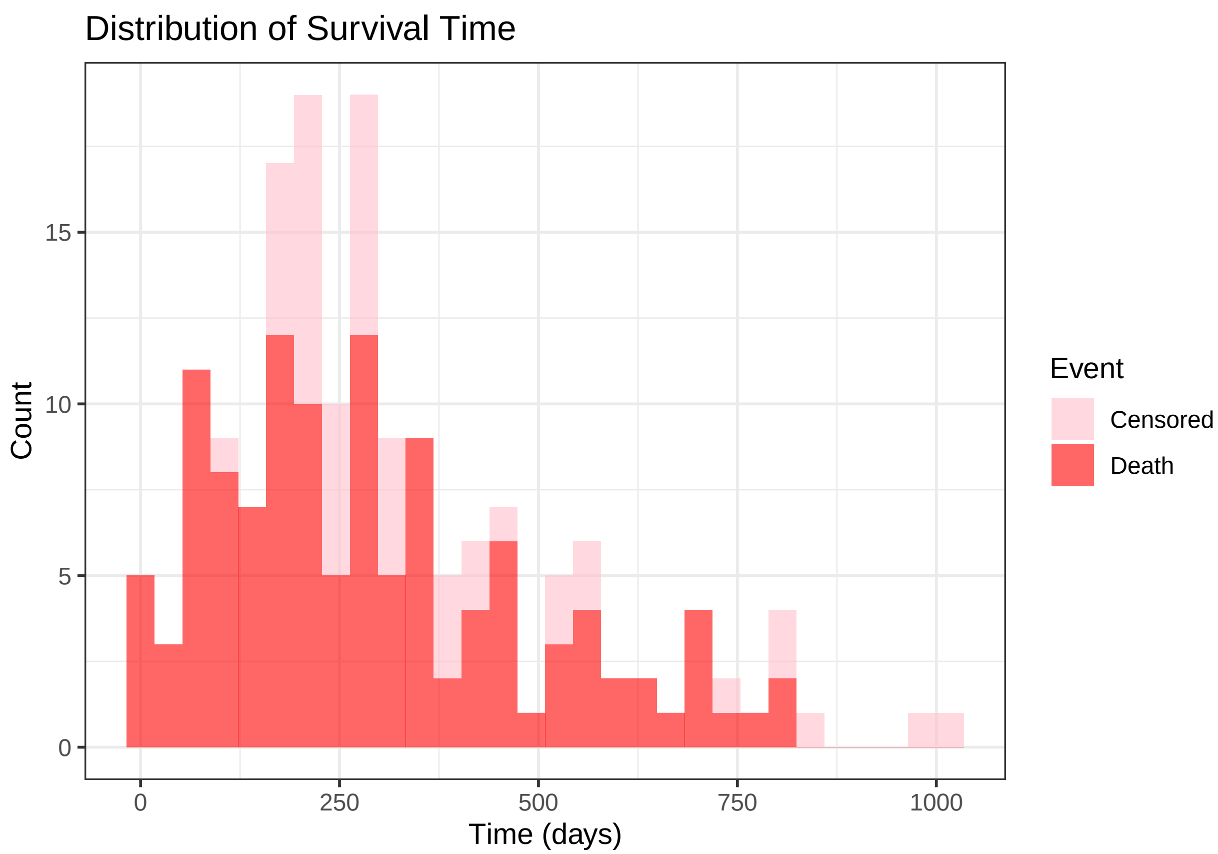


Meal Calories Distribution
Density
1e−03
5e−04
0e+00
0
1000
2000
Calories
sex
Male
Female



Distribution of Survival Time

```
ggplot(lung_cc, aes(x = time, fill = event)) +
  geom_histogram(bins = 30, alpha = 0.6) +
  theme_bw() +
  labs(title = "Distribution of Survival Time", x = "Time (days)", y = "Count") +
  scale_fill_manual(values = c("PINK", "RED"), name = "Event", labels = c("Censored", "Death"))
```



Comparison of Survival Curves

```r
# Create a survival object, which bundles the time and event data
surv_object <- Surv(time = lung_cc$time, event = lung_cc$event)
```

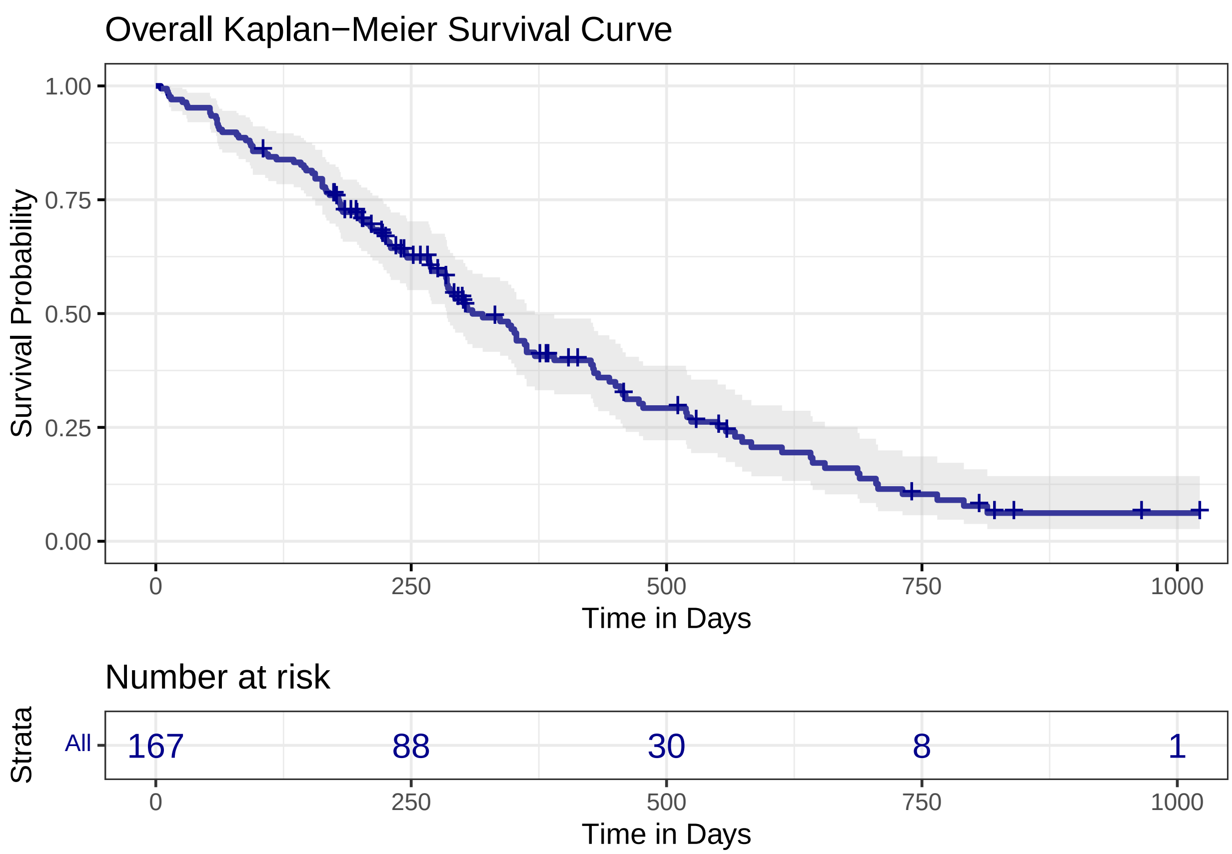
```r
# Fit the Overall Kaplan-Meier Model
km_overall_fit <- survfit(surv_object ~ 1, data = lung_cc)

print(km_overall_fit)
```

```
## Call: survfit(formula = surv_object ~ 1, data = lung_cc)
##
##         n events median 0.95LCL 0.95UCL
## [1,] 167    120    310     285     371
```

```r
ggsurvplot(
  km_overall_fit,
  data = lung_cc,
  conf.int = TRUE,
  risk.table = TRUE,
  risk.table.col = "strata",
  title = "Overall Kaplan-Meier Survival Curve",
  xlab = "Time in Days",
```

```r
  ylab = "Survival Probability",
  ggtheme = theme_bw(),
  palette = "darkblue",
  legend = "none"
)
```



Sex

```r
# Fit the Kaplan-Meier model to estimate survival curves for each group ('sex')
km_sex_fit <- survfit(surv_object ~ sex, data = lung_cc)

summary(km_sex_fit)
```

```
## Call: survfit(formula = surv_object ~ sex, data = lung_cc)
##
##                 sex=Male
##  time n.risk n.event survival std.err lower 95% CI upper 95% CI
##    11    103       1   0.9903 0.00966       0.9715        1.000
##    12    102       1   0.9806 0.01360       0.9543        1.000
##    13    101       1   0.9709 0.01657       0.9389        1.000
##    15    100       1   0.9612 0.01904       0.9246        0.999
##    26     99       1   0.9515 0.02118       0.9108        0.994
##    30     98       1   0.9417 0.02308       0.8976        0.988
```

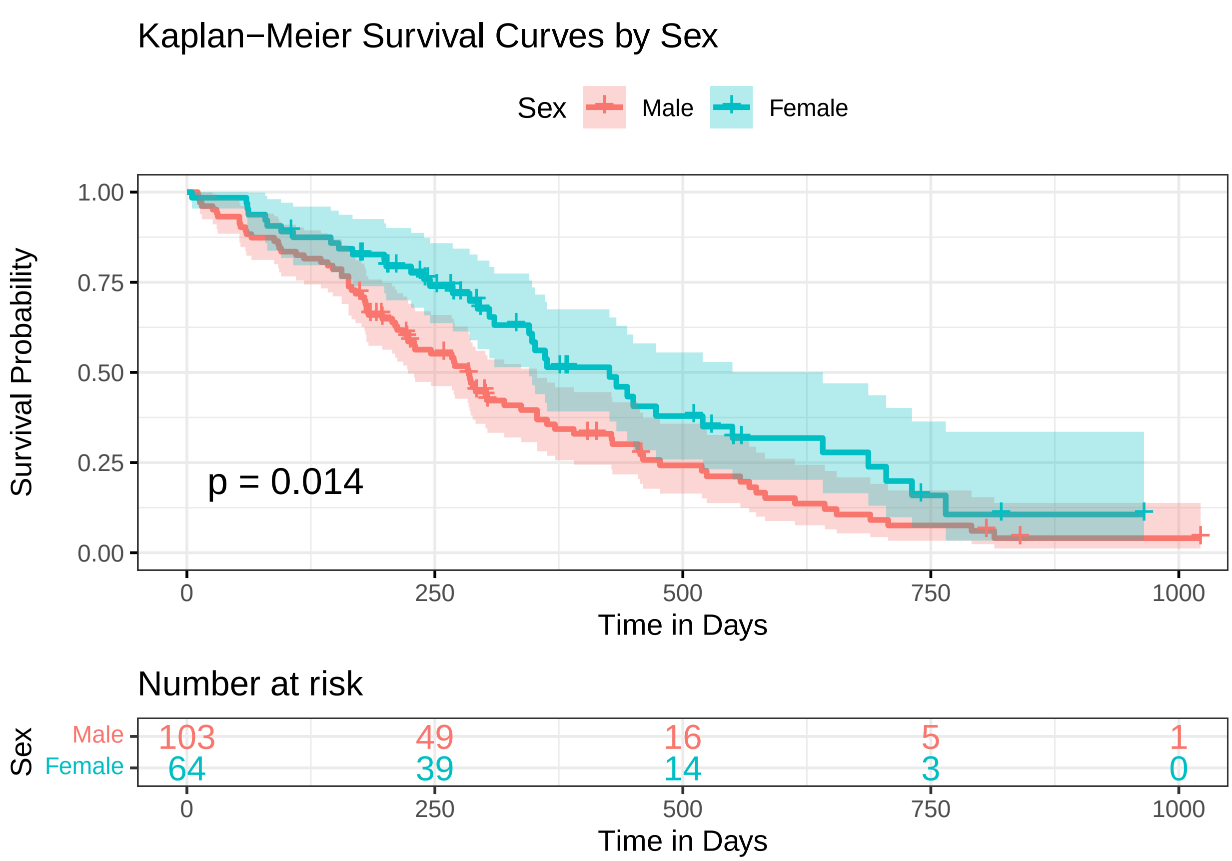
```
##    31      97        1   0.9320 0.02480        0.8847          0.982
##    53      96        2   0.9126 0.02782        0.8597          0.969
##    54      94        1   0.9029 0.02917        0.8475          0.962
##    59      93        1   0.8932 0.03043        0.8355          0.955
##    60      92        1   0.8835 0.03161        0.8237          0.948
##    65      91        1   0.8738 0.03272        0.8119          0.940
##    88      90        1   0.8641 0.03377        0.8004          0.933
##    92      89        1   0.8544 0.03476        0.7889          0.925
##    93      88        1   0.8447 0.03569        0.7775          0.918
##    95      87        1   0.8350 0.03658        0.7663          0.910
##   110      86        1   0.8252 0.03742        0.7551          0.902
##   118      85        1   0.8155 0.03822        0.7440          0.894
##   135      84        1   0.8058 0.03898        0.7329          0.886
##   142      83        1   0.7961 0.03970        0.7220          0.878
##   147      82        1   0.7864 0.04038        0.7111          0.870
##   156      81        2   0.7670 0.04165        0.6895          0.853
##   163      79        3   0.7379 0.04333        0.6576          0.828
##   166      76        1   0.7282 0.04384        0.6471          0.819
##   170      75        1   0.7184 0.04432        0.6366          0.811
##   176      73        1   0.7086 0.04479        0.6260          0.802
##   179      72        1   0.6988 0.04523        0.6155          0.793
##   180      71        1   0.6889 0.04566        0.6050          0.784
##   181      70        2   0.6692 0.04642        0.5842          0.767
##   183      68        1   0.6594 0.04677        0.5738          0.758
##   197      64        1   0.6491 0.04716        0.5629          0.748
##   207      62        1   0.6386 0.04755        0.5519          0.739
##   210      61        1   0.6282 0.04791        0.5409          0.729
##   212      60        1   0.6177 0.04824        0.5300          0.720
##   218      59        1   0.6072 0.04855        0.5191          0.710
##   222      57        1   0.5966 0.04885        0.5081          0.700
##   223      55        1   0.5857 0.04915        0.4969          0.690
##   229      52        1   0.5745 0.04948        0.4852          0.680
##   230      51        1   0.5632 0.04977        0.4736          0.670
##   246      50        1   0.5519 0.05004        0.4621          0.659
##   267      48        1   0.5404 0.05030        0.4503          0.649
##   269      47        1   0.5289 0.05053        0.4386          0.638
##   270      46        1   0.5174 0.05072        0.4270          0.627
##   283      45        1   0.5059 0.05088        0.4154          0.616
##   284      44        1   0.4944 0.05101        0.4039          0.605
##   285      42        1   0.4827 0.05113        0.3922          0.594
##   286      41        1   0.4709 0.05122        0.3805          0.583
##   288      40        1   0.4591 0.05128        0.3689          0.571
##   291      39        1   0.4473 0.05129        0.3573          0.560
##   301      36        1   0.4349 0.05135        0.3451          0.548
##   303      34        1   0.4221 0.05141        0.3325          0.536
##   320      32        1   0.4089 0.05147        0.3195          0.523
##   337      31        1   0.3957 0.05147        0.3067          0.511
##   353      30        2   0.3694 0.05131        0.2813          0.485
##   363      28        1   0.3562 0.05114        0.2688          0.472
##   371      27        1   0.3430 0.05092        0.2564          0.459
##   390      26        1   0.3298 0.05064        0.2441          0.446
##   428      23        1   0.3154 0.05043        0.2306          0.432
##   429      22        1   0.3011 0.05014        0.2173          0.417
##   455      21        1   0.2868 0.04976        0.2041          0.403
```

```
##   457     20        1   0.2724 0.04929       0.1911        0.388
##   460     18        1   0.2573 0.04882       0.1774        0.373
##   477     17        1   0.2422 0.04824       0.1639        0.358
##   519     16        1   0.2270 0.04754       0.1506        0.342
##   524     15        1   0.2119 0.04672       0.1375        0.326
##   558     14        1   0.1968 0.04577       0.1247        0.310
##   567     13        1   0.1816 0.04468       0.1121        0.294
##   574     12        1   0.1665 0.04344       0.0998        0.278
##   583     11        1   0.1514 0.04205       0.0878        0.261
##   613     10        1   0.1362 0.04048       0.0761        0.244
##   643      9        1   0.1211 0.03870       0.0647        0.227
##   655      8        1   0.1059 0.03671       0.0537        0.209
##   689      7        1   0.0908 0.03444       0.0432        0.191
##   707      6        1   0.0757 0.03185       0.0332        0.173
##   791      5        1   0.0605 0.02886       0.0238        0.154
##   814      3        1   0.0404 0.02533       0.0118        0.138
##
##                 sex=Female
##  time n.risk n.event survival std.err lower 95% CI upper 95% CI
##     5     64       1    0.984  0.0155       0.9545        1.000
##    60     63       1    0.969  0.0217       0.9270        1.000
##    61     62       1    0.953  0.0264       0.9027        1.000
##    62     61       1    0.938  0.0303       0.8800        0.999
##    79     60       1    0.922  0.0335       0.8584        0.990
##    81     59       1    0.906  0.0364       0.8376        0.981
##    95     58       1    0.891  0.0390       0.8174        0.970
##   107     56       1    0.875  0.0414       0.7972        0.960
##   145     55       1    0.859  0.0436       0.7774        0.949
##   153     54       1    0.843  0.0456       0.7581        0.937
##   167     53       1    0.827  0.0475       0.7390        0.925
##   199     50       1    0.810  0.0493       0.7194        0.913
##   201     49       1    0.794  0.0510       0.7000        0.900
##   226     45       1    0.776  0.0528       0.6794        0.887
##   239     43       1    0.758  0.0546       0.6584        0.873
##   245     40       1    0.739  0.0564       0.6366        0.859
##   268     37       1    0.719  0.0583       0.6136        0.843
##   285     34       1    0.698  0.0603       0.5894        0.827
##   293     32       1    0.676  0.0623       0.5647        0.810
##   305     30       1    0.654  0.0641       0.5394        0.792
##   310     29       1    0.631  0.0658       0.5146        0.774
##   345     27       1    0.608  0.0674       0.4892        0.755
##   348     26       1    0.584  0.0687       0.4642        0.736
##   351     25       1    0.561  0.0698       0.4397        0.716
##   361     24       1    0.538  0.0707       0.4155        0.696
##   363     23       1    0.514  0.0714       0.3918        0.675
##   426     19       1    0.487  0.0726       0.3639        0.653
##   433     18       1    0.460  0.0734       0.3366        0.629
##   444     17       1    0.433  0.0739       0.3100        0.605
##   450     16       1    0.406  0.0741       0.2839        0.581
##   473     15       1    0.379  0.0739       0.2585        0.556
##   520     13       1    0.350  0.0738       0.2314        0.529
##   550     11       1    0.318  0.0736       0.2020        0.501
##   641      8       1    0.278  0.0744       0.1648        0.470
##   687      7       1    0.239  0.0736       0.1303        0.437
```

```
##    705       6        1     0.199  0.0713        0.0984        0.401
##    731       5        1     0.159  0.0672        0.0695        0.364
##    765       3        1     0.106  0.0623        0.0335        0.335
```

```r
# --- Visualize the Estimated Survival Probabilities ---

# Generate the Kaplan-Meier plot using ggsurvplot
ggsurvplot(
  km_sex_fit,
  data = lung_cc,
  pval = TRUE,                  # The p-value from the log-rank test will be displayed
  conf.int = TRUE,              # Display confidence intervals for the curves
  risk.table = TRUE,            # Add a table showing the number of subjects at risk
  risk.table.col = "strata",    # Color the risk table to match the curves
  legend.labs = c("Male", "Female"),
  legend.title = "Sex",
  xlab = "Time in Days",
  ylab = "Survival Probability",
  title = "Kaplan-Meier Survival Curves by Sex",
  ggtheme = theme_bw()          # Apply a clean theme
)
```




```r
# With rho = 0 this is the log-rank or Mantel-Haenszel test, and with rho = 1 it is equivalent to the P
log_rank_sex <- survdiff(surv_object ~ sex, data = lung_cc, rho = 0)
print(log_rank_sex)
```

```
## Call:
## survdiff(formula = surv_object ~ sex, data = lung_cc, rho = 0)
##
##              N Observed Expected (O-E)^2/E (O-E)^2/V
## sex=Male   103       82     68.7      2.57      6.05
## sex=Female  64       38     51.3      3.44      6.05
##
##  Chisq= 6  on 1 degrees of freedom, p= 0.01
```

```
wilcoxon_sex <- survdiff(surv_object ~ sex, data = lung_cc, rho = 1)
print(wilcoxon_sex)
```

```
## Call:
## survdiff(formula = surv_object ~ sex, data = lung_cc, rho = 1)
##
##              N Observed Expected (O-E)^2/E (O-E)^2/V
## sex=Male   103     51.0     41.8      2.01      6.76
## sex=Female  64     21.1     30.3      2.77      6.76
##
##  Chisq= 6.8  on 1 degrees of freedom, p= 0.009
```

The p-value is even smaller than the log-rank p-value. This not only confirms the result of the log-rank test but also suggests that the survival advantage for females is particularly pronounced at the beginning and middle of the follow-up period.

```
# Fleming-Harrington test statistic
fit_sex <- ten(surv_object ~ sex, data = lung_cc)
comp(fit_sex)
```

```
##                      Q         Var       Z pNorm
## 1             -13.2826     29.2085 -2.4577     5
## n           -1424.0000 303810.1223 -2.5835     4
## sqrtN        -133.2089   2591.7008 -2.6166     1
## S1             -9.0659     12.2163 -2.5938     2
## S2             -8.9740     11.9825 -2.5925     3
## FH_p=1_q=1     -2.1759      1.0197 -2.1548     6
##               maxAbsZ        Var      Q pSupBr
## 1          1.3806e+01 2.9209e+01 2.5545      5
## n          1.4410e+03 3.0381e+05 2.6143      4
## sqrtN      1.3534e+02 2.5917e+03 2.6585      1
## S1         9.1529e+00 1.2216e+01 2.6187      2
## S2         9.0560e+00 1.1982e+01 2.6162      3
## FH_p=1_q=1 2.2505e+00 1.0197e+00 2.2287      6
```

```
lrt_mat <- attr(fit_sex, "lrt")
data.frame(
test = c("Log-Rank", "Wilcoxon", "Tarone", "Peto", "Modified-Peto", "FH(1, 1)"),
Z_squared = lrt_mat[, "Z"]^2
)
```

```
##             test        Z
## 1       Log-Rank 6.040270
```

```
## 2      Wilcoxon 6.674485
## 3        Tarone 6.846710
## 4          Peto 6.727883
## 5 Modified-Peto 6.720914
## 6      FH(1, 1) 4.643096
```

The final summary table (Z_squared) shows that regardless of the specific test used, the result is always highly significant (all Z^2 values correspond to p-values well below 0.05).

ECOG performance status (unstratified)

```r
# --- Fit the Kaplan-Meier model for ph_ecog ---
km_ecog_fit <- survfit(surv_object ~ ph_ecog, data = lung_cc)

summary(km_ecog_fit)
```

```
## Call: survfit(formula = surv_object ~ ph_ecog, data = lung_cc)
##
##                 ph_ecog=0
##  time n.risk n.event survival std.err lower 95% CI upper 95% CI
##     5     47       1    0.979  0.0210       0.9383        1.000
##    15     46       1    0.957  0.0294       0.9014        1.000
##    31     45       1    0.936  0.0357       0.8688        1.000
##    53     44       1    0.915  0.0407       0.8385        0.998
##    81     43       1    0.894  0.0450       0.8097        0.986
##   147     42       1    0.872  0.0487       0.7820        0.973
##   176     40       1    0.851  0.0521       0.7543        0.959
##   246     34       1    0.826  0.0563       0.7223        0.944
##   267     30       1    0.798  0.0607       0.6874        0.926
##   285     26       1    0.767  0.0657       0.6487        0.908
##   286     25       1    0.737  0.0699       0.6116        0.887
##   303     22       1    0.703  0.0743       0.5716        0.865
##   320     21       1    0.670  0.0779       0.5331        0.841
##   337     19       1    0.634  0.0814       0.4933        0.816
##   348     18       1    0.599  0.0842       0.4549        0.789
##   353     17       2    0.529  0.0878       0.3818        0.732
##   371     15       1    0.493  0.0887       0.3468        0.702
##   428     12       1    0.452  0.0904       0.3057        0.669
##   433     11       1    0.411  0.0910       0.2664        0.635
##   455     10       1    0.370  0.0907       0.2289        0.598
##   558      9       1    0.329  0.0895       0.1930        0.561
##   574      7       1    0.282  0.0882       0.1527        0.520
##   643      6       1    0.235  0.0851       0.1155        0.478
##   655      5       1    0.188  0.0800       0.0816        0.433
##   705      4       1    0.141  0.0725       0.0515        0.386
##   791      3       1    0.094  0.0617       0.0260        0.340
##
##                 ph_ecog=1
##  time n.risk n.event survival std.err lower 95% CI upper 95% CI
##    59     81       1   0.9877  0.0123       0.9639        1.000
##    60     80       2   0.9630  0.0210       0.9227        1.000
##    62     78       1   0.9506  0.0241       0.9046        0.999
```

```
##    79     77       1   0.9383  0.0267       0.8873        0.992
##    88     76       1   0.9259  0.0291       0.8706        0.985
##    92     75       1   0.9136  0.0312       0.8544        0.977
##    95     74       1   0.9012  0.0331       0.8385        0.969
##   110     73       1   0.8889  0.0349       0.8230        0.960
##   135     72       1   0.8765  0.0366       0.8078        0.951
##   142     71       1   0.8642  0.0381       0.7927        0.942
##   145     70       1   0.8519  0.0395       0.7779        0.933
##   156     69       1   0.8395  0.0408       0.7633        0.923
##   163     68       2   0.8148  0.0432       0.7345        0.904
##   167     66       1   0.8025  0.0442       0.7203        0.894
##   170     65       1   0.7901  0.0452       0.7062        0.884
##   179     62       1   0.7774  0.0463       0.6918        0.874
##   181     61       2   0.7519  0.0481       0.6632        0.852
##   197     57       1   0.7387  0.0491       0.6485        0.841
##   207     54       1   0.7250  0.0500       0.6333        0.830
##   210     53       1   0.7113  0.0509       0.6182        0.818
##   218     52       1   0.6977  0.0517       0.6033        0.807
##   223     49       1   0.6834  0.0526       0.5877        0.795
##   226     47       1   0.6689  0.0535       0.5719        0.782
##   229     46       1   0.6543  0.0542       0.5562        0.770
##   230     45       1   0.6398  0.0550       0.5407        0.757
##   245     43       1   0.6249  0.0557       0.5248        0.744
##   268     42       1   0.6100  0.0563       0.5091        0.731
##   269     41       1   0.5952  0.0568       0.4936        0.718
##   270     40       1   0.5803  0.0573       0.4781        0.704
##   283     39       1   0.5654  0.0578       0.4628        0.691
##   284     38       1   0.5505  0.0581       0.4476        0.677
##   293     37       1   0.5356  0.0584       0.4325        0.663
##   301     35       1   0.5203  0.0587       0.4171        0.649
##   305     32       1   0.5041  0.0591       0.4006        0.634
##   345     31       1   0.4878  0.0594       0.3843        0.619
##   363     30       2   0.4553  0.0597       0.3521        0.589
##   390     27       1   0.4384  0.0598       0.3355        0.573
##   426     24       1   0.4202  0.0601       0.3175        0.556
##   429     23       1   0.4019  0.0602       0.2997        0.539
##   450     22       1   0.3836  0.0601       0.2821        0.522
##   457     21       1   0.3654  0.0600       0.2648        0.504
##   460     19       1   0.3461  0.0598       0.2467        0.486
##   473     18       1   0.3269  0.0595       0.2288        0.467
##   477     17       1   0.3077  0.0590       0.2112        0.448
##   519     16       1   0.2884  0.0584       0.1940        0.429
##   520     15       1   0.2692  0.0576       0.1770        0.409
##   550     13       1   0.2485  0.0568       0.1588        0.389
##   567     12       1   0.2278  0.0557       0.1411        0.368
##   583     11       1   0.2071  0.0543       0.1238        0.346
##   613     10       1   0.1864  0.0527       0.1071        0.324
##   641      9       1   0.1657  0.0507       0.0909        0.302
##   687      8       1   0.1450  0.0484       0.0753        0.279
##   689      7       1   0.1243  0.0457       0.0604        0.256
##   731      6       1   0.1035  0.0425       0.0463        0.232
##   765      4       1   0.0777  0.0390       0.0290        0.208
##
##                 ph_ecog=2
```

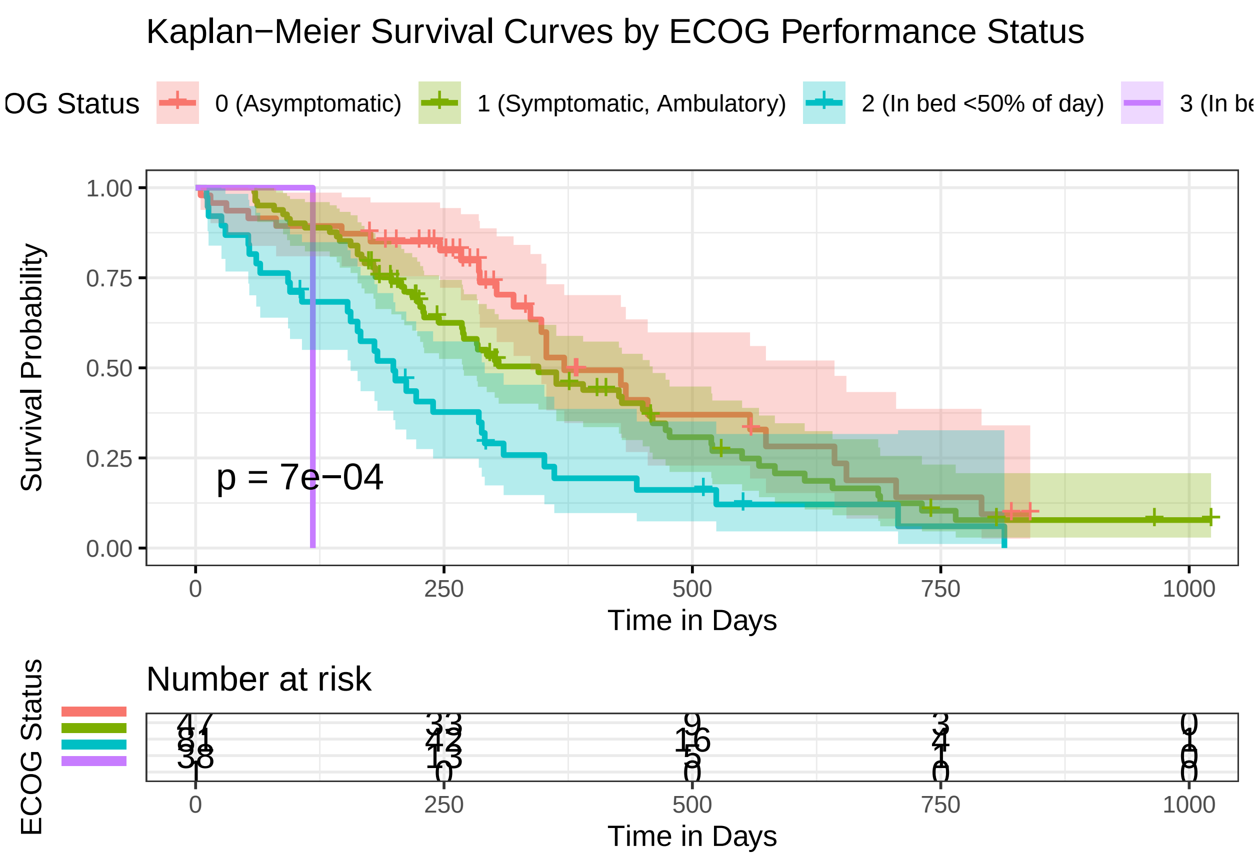
```
##   time n.risk n.event survival std.err lower 95% CI upper 95% CI
##     11     38       1   0.9737  0.0260       0.9241        1.000
##     12     37       1   0.9474  0.0362       0.8790        1.000
##     13     36       1   0.9211  0.0437       0.8392        1.000
##     26     35       1   0.8947  0.0498       0.8023        0.998
##     30     34       1   0.8684  0.0548       0.7673        0.983
##     53     33       1   0.8421  0.0592       0.7338        0.966
##     54     32       1   0.8158  0.0629       0.7014        0.949
##     61     31       1   0.7895  0.0661       0.6699        0.930
##     65     30       1   0.7632  0.0690       0.6393        0.911
##     93     29       1   0.7368  0.0714       0.6093        0.891
##     95     28       1   0.7105  0.0736       0.5800        0.870
##    107     26       1   0.6832  0.0756       0.5499        0.849
##    153     25       1   0.6559  0.0774       0.5204        0.827
##    156     24       1   0.6285  0.0789       0.4915        0.804
##    163     23       1   0.6012  0.0800       0.4632        0.780
##    166     22       1   0.5739  0.0809       0.4353        0.757
##    180     21       1   0.5466  0.0815       0.4080        0.732
##    183     20       1   0.5192  0.0819       0.3811        0.707
##    199     19       1   0.4919  0.0820       0.3547        0.682
##    201     18       1   0.4646  0.0819       0.3288        0.656
##    212     16       1   0.4355  0.0818       0.3014        0.629
##    222     15       1   0.4065  0.0813       0.2747        0.602
##    239     14       1   0.3775  0.0805       0.2485        0.573
##    285     13       1   0.3484  0.0794       0.2229        0.545
##    288     12       1   0.3194  0.0779       0.1980        0.515
##    291     11       1   0.2904  0.0760       0.1738        0.485
##    310      9       1   0.2581  0.0741       0.1470        0.453
##    351      8       1   0.2258  0.0715       0.1214        0.420
##    361      7       1   0.1936  0.0682       0.0970        0.386
##    444      6       1   0.1613  0.0640       0.0741        0.351
##    524      4       1   0.1210  0.0594       0.0462        0.317
##    707      2       1   0.0605  0.0521       0.0112        0.327
##    814      1       1   0.0000     NaN           NA           NA
##
##                 ph_ecog=3
##           time        n.risk       n.event      survival      std.err lower 95% CI
##            118             1             1             0          NaN           NA
## upper 95% CI
##           NA
```

```
ggsurvplot(
  km_ecog_fit,
  data = lung_cc,

  # --- Add Key Statistical Information ---
  pval = TRUE,                 # Display the log-rank test p-value
  conf.int = TRUE,             # Show 95% confidence intervals

  # --- Add Contextual Information ---
  risk.table = TRUE,           # Include a table showing the number of patients at risk
  risk.table.y.text.col = TRUE,# Color the risk table text to match curves
  risk.table.y.text = FALSE,   # Remove y-axis tick labels from the risk table
```

```
  # --- Customize Aesthetics and Labels ---
  title = "Kaplan-Meier Survival Curves by ECOG Performance Status",
  xlab = "Time in Days",
  ylab = "Survival Probability",
  legend.title = "ECOG Status",
  # Provide clear, descriptive labels for each group in the legend
  legend.labs = c(
    "0 (Asymptomatic)",
    "1 (Symptomatic, Ambulatory)",
    "2 (In bed <50% of day)",
    "3 (In bed >50% of day)"
  ),
  ggtheme = theme_bw()          # Use a clean black and white theme
)
```




```
# --- Perform the test ---
log_rank_ecog <- survdiff(surv_object ~ ph_ecog, data = lung_cc, rho = 0)
print(log_rank_ecog)
```

```
## Call:
## survdiff(formula = surv_object ~ ph_ecog, data = lung_cc, rho = 0)
##
##              N Observed Expected (O-E)^2/E (O-E)^2/V
## ph_ecog=0 47       27    38.054     3.211     4.737
## ph_ecog=1 81       59    62.376     0.183     0.383
```

```
## ph_ecog=2 38       33   19.394     9.546    11.483
## ph_ecog=3  1        1    0.176     3.864     3.895
##
##  Chisq= 17  on 3 degrees of freedom, p= 7e-04
```

```r
wilcoxon_ecog <- survdiff(surv_object ~ ph_ecog, data = lung_cc, rho = 1)
print(wilcoxon_ecog)
```

```
## Call:
## survdiff(formula = surv_object ~ ph_ecog, data = lung_cc, rho = 1)
##
##            N Observed Expected (O-E)^2/E (O-E)^2/V
## ph_ecog=0 47   14.231   22.518     3.050     6.299
## ph_ecog=1 81   33.801   37.054     0.286     0.826
## ph_ecog=2 38   23.250   12.392     9.513    15.668
## ph_ecog=3  1    0.844    0.162     2.878     3.144
##
##  Chisq= 20.8  on 3 degrees of freedom, p= 1e-04
```

The fact that the Wilcoxon test yields a smaller p-value than the log-rank test suggests that the survival differences between the groups are particularly pronounced early in the follow-up period.

ECOG performance status (stratified by sex)

```r
log_rank_ecog_bysex <- survdiff(surv_object ~ ph_ecog + strata(sex), data = lung_cc, rho = 0)
print(log_rank_ecog_bysex)
```

```
## Call:
## survdiff(formula = surv_object ~ ph_ecog + strata(sex), data = lung_cc,
##     rho = 0)
##
##            N Observed Expected (O-E)^2/E (O-E)^2/V
## ph_ecog=0 47       27   38.330     3.349     5.003
## ph_ecog=1 81       59   62.336     0.178     0.381
## ph_ecog=2 38       33   19.131    10.053    12.287
## ph_ecog=3  1        1    0.203     3.136     3.173
##
##  Chisq= 17.1  on 3 degrees of freedom, p= 7e-04
```

```r
wilcoxon_ecog_bysex <- survdiff(surv_object ~ ph_ecog + strata(sex), data = lung_cc, rho = 1)
print(wilcoxon_ecog_bysex)
```

```
## Call:
## survdiff(formula = surv_object ~ ph_ecog + strata(sex), data = lung_cc,
##     rho = 1)
##
##            N Observed Expected (O-E)^2/E (O-E)^2/V
## ph_ecog=0 47   13.478   22.324     3.505      7.26
## ph_ecog=1 81   34.002   37.497     0.326      0.96
## ph_ecog=2 38   23.686   11.987    11.419     18.70
```

```
## ph_ecog=3  1    0.825    0.184     2.226      2.47
##
##  Chisq= 23.4  on 3 degrees of freedom, p= 3e-05
```

Log-rank: The result is virtually identical to the unstratified test. The Chi-square statistic and the p-value have barely changed. It means that the strong predictive power of ECOG status is independent of the patient's sex. The effect is not being confounded by sex.

Wilcoxon: After stratifying by sex, the Chi-square value increased (from 20.8 to 23.4) and the p-value became even smaller. This suggests that after controlling for the baseline survival differences between sexes, the effect of ECOG status on early deaths becomes even more pronounced and clear.

Final summary for stratified analysis: ECOG is an Independent Predictor: The effect of ECOG performance status on survival is not explained away by the patient's sex. It is a strong, independent prognostic factor. Sex is not acting as a major confounder in the relationship between ECOG status and survival. Whether a patient is male or female, having a worse ECOG score (e.g., a score of 2 vs. 0) is strongly associated with a significantly poorer survival outcome. The effect holds true within both groups.