Power analysis and sample-size determination in survival models with the new **stpower** command

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Outline

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   - Theory and terminology
   - Introduction to **stpower** subcommands
2. Sample-size determination for survival studies
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   - Exponential survivor functions
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Terminology

- type I study
  all subjects experience an event (fail) by the end of the study

- type II study
  a study terminates after a fixed time T resulting in censored subjects

Terminology

- type I study
  all subjects experience an event (fail) by the end of the study
- type II study
  a study terminates after a fixed time T resulting in censored subjects
- administrative censoring
  the right censoring occuring when the study observation period ends
- loss to follow-up (withdrawal), $L(t)$
  occurs when subjects fail to complete the course of the study for reasons unrelated to the event of interest

Terminology, cont.

- accrual period, R
  period during which subjects are being enrolled into a study
- follow-up period, f
  period during which subjects are under observation and no new subjects enter a study

Terminology, cont.

- accrual period, R
  period during which subjects are being enrolled into a study
- follow-up period, f
  period during which subjects are under observation and no new subjects enter a study
- exponential (parametric) test
  test on difference or log ratio of (two) exponential hazard rates

Main components of sample-size computation

Choose:

- method of analysis

  log-rank test, Cox PH model, parametric test
- probability of a type I error (significance level), α

  usually 0.05, 0.01
- power, $1-\beta$ (or probability of a type II error, β)

  usually 80%, 90% (or 20%, 10%)
- effect size, ψ, usually expressed as

  the hazard ratio, $\Delta = h_2(t)/h_1(t), \forall t$ (PH assumption), or

  the log of the hazard ratio, $\ln \Delta$, or

  the coefficient in a Cox regression model,

  $\beta_1 = \ln\{h(t, x_1+1|x_2,\ldots,x_p)/h(t, x_1|x_2,\ldots,x_p)\}$

General formula

The general formula for the required number of subjects in a survival study may be expressed as

$$N = \frac{E(\alpha, \beta, \psi)}{p_E\{S(t), L(t), R, T\}}$$

where

$E()$ is the number of events required to be observed in a study, and
$p_E()$ is the probability of observing an event in a study.

Note:

- power, $1 - \beta$, is directly related to the number of events
- duration of a study T, accrual and loss to follow up patterns affect the probability of a subject to experience an event in a study.

stpower command

Three subcommands:

- `stpower logrank`
- `stpower cox`
- `stpower exponential`

All subcommands:

- share main common options `alpha()`, `power()`, `beta()`, `n()`, `hratio()`, `onesided`, ...
- accept multiple values (*numlist*) in main options
- facilitate customizable tables of results
- save results in a dataset

stpower logrank

- Type of test

  two-sample log-rank test

- Computation

  sample size (given power and hazard ratio)
  power (given sample size and hazard ratio)
  (log) hazard ratio (given power and sample size)

- Capabilities

  unequal group allocation
  uniform accrual
  conservative adjustment for withdrawal

- Methodology

  Freedman (1982) (default)
  Schoenfeld (1981) (option `schoenfeld`)

Sample-size determination for the log-rank test

Objective. Obtain the required sample size to ensure prespecified power of a two-sided log-rank test at level α to detect a $\Delta_a \times 100\%$ reduction in hazard of the experimental group relative to the control group.

Hypothesis. H_o: $S_1(t) = S_2(t)$ vs H_a: $S_1(t) \neq S_2(t)$

Assumptions. Proportional hazards, $S_2(t) = \{S_1(t)\}^{\Delta}$; large-sample approximation to the test statistic holds

Equivalent hypothesis. H_o: $\Delta = 1$ vs H_a: $\Delta \neq 1$ (default)
H_o: $\ln(\Delta) = 0$ vs H_a: $\ln(\Delta) \neq 0$ (`schoenfeld`)

Two-sample comparison of survivor curves

Example

- Estimate required sample size to achieve 80% power to detect 50% reduction in a hazard of the experimental group by using a two-sided 0.05-level log-rank test under 4 different study designs (A, B, C, and D below).
- All of these study designs assume $\alpha = 0.05$, $1 - \beta = 0.8$, and $\Delta_a = 0.5$.

Design A: type I study (unlimited follow up); 1:1 randomization.

```
. stpower logrank, power(0.8) hratio(0.5) nratio(1)

Estimated sample sizes for two-sample comparison of survivor functions
Log-rank test, Freedman method
Ho: S1(t) = S2(t)

Input parameters:

      alpha =    0.0500  (two sided)
     hratio =    0.5000
      power =    0.8000
         p1 =    0.5000

Estimated number of events and sample sizes:

          E =        72
          N =        72
         N1 =        36
         N2 =        36
```

Design B: type II study (40% of subjects in the control group survive by the end of the study); 1:1 randomization; no withdrawal.

```
. stpower logrank 0.4

Estimated sample sizes for two-sample comparison of survivor functions
Log-rank test, Freedman method
Ho: S1(t) = S2(t)

Input parameters:

      alpha =    0.0500  (two sided)
         s1 =    0.4000
         s2 =    0.6325
     hratio =    0.5000
      power =    0.8000
         p1 =    0.5000

Estimated number of events and sample sizes:

          E =        72
          N =       148
         N1 =        74
         N2 =        74
```

Design C: type II study (40% of subjects in the control group survive by the end of the study); 1:2 randomization; no withdrawal.

```
. stpower logrank 0.4, nratio(2)

Estimated sample sizes for two-sample comparison of survivor functions
Log-rank test, Freedman method
Ho: S1(t) = S2(t)

Input parameters:

      alpha =     0.0500  (two sided)
         s1 =     0.4000
         s2 =     0.6325
     hratio =     0.5000
      power =     0.8000
         p1 =     0.3333

Estimated number of events and sample sizes:

          E =         63
          N =        142
         N1 =         47
         N2 =         95
```

Design D: type II study (40% of subjects in the control group survive by the end of the study); 1:2 randomization; 10% withdrawal.

```
. stpower logrank 0.4, nratio(2) wdprob(0.1)
Estimated sample sizes for two-sample comparison of survivor functions
Log-rank test, Freedman method
Ho: S1(t) = S2(t)
Input parameters:
      alpha =     0.0500  (two sided)
         s1 =     0.4000
         s2 =     0.6325
     hratio =     0.5000
      power =     0.8000
         p1 =     0.3333
 withdrawal =     10.00%
Estimated number of events and sample sizes:
          E =         63
          N =        157
         N1 =         52
         N2 =        105
```

stpower cox

- Type of test

  Wald test of a covariate in a Cox PH model
- Computation

  sample size (given power and coefficient)
  power (given sample size and coefficient)
  coefficient (hazard ratio) (given power and sample size)
- Capabilities

  binary or continuous covariate
  adjustment for other covariates in a model
  conservative adjustment for withdrawal
- Methodology

  Schoenfeld (1983), Hsieh and Lavori (2000)

Sample-size determination for the Cox PH regression

Objective. Obtain the required sample size to ensure prespecified power of a two-sided α-level Wald test to detect a change of $\beta_{1a} = \ln(\Delta_a)$ in log hazards for a one-unit change in a covariate of interest x_1 adjusted for other factors $x_2, \ldots, x_p$.

Hypothesis. H_o: $(\beta_1, \beta_2, \ldots, \beta_p) = (0, \beta_2, \ldots, \beta_p)$ vs
H_a: $(\beta_1, \beta_2, \ldots, \beta_p) = (\beta_{1a}, \beta_2, \ldots, \beta_p)$

Assumptions. Proportional hazards; large-sample approximation to the test statistic holds.

Wald test of a covariate of interest

Example

- Hsieh and Lavori (2000) estimate required sample size for a study of multiple-myeloma patients investigating the effect of the log of the blood urea nitrogen, lBUN, on patients' survival.
- The significance of the effect is to be determined via a one-sided Wald test on the coefficient of lBUN, β_1, estimated from the Cox model in the presence of other covariates.
- Main study parameters: $\alpha = 0.05$, $1 - \beta = 0.8$, $\beta_{1a} = 1$, $\sigma = 0.3126$.
- We'll consider several study designs.

Assumptions: IBUN is independent of other covariates ($R^2 = 0$);
no censoring ($p_E = 1$).

```
. stpower cox 1, sd(0.3126) onesided

Estimated sample size for Cox PH regression
Wald test, log-hazard metric
Ho: [b1, b2, ..., bp] = [0, b2, ..., bp]

Input parameters:

         alpha =    0.0500  (one sided)
            b1 =    1.0000
            sd =    0.3126
         power =    0.8000

Estimated number of events and sample size:

             E =        64
             N =        64
```

Assumptions: IBUN is not independent of other covariates ($R^2 = 0.1837$); no censoring ($p_E = 1$).

```
. stpower cox 1, sd(0.3126) onesided r2(0.1837)

Estimated sample size for Cox PH regression
Wald test, log-hazard metric
Ho: [b1, b2, ..., bp] = [0, b2, ..., bp]

Input parameters:

         alpha =    0.0500  (one sided)
            b1 =    1.0000
            sd =    0.3126
         power =    0.8000
            R2 =    0.1837

Estimated number of events and sample size:

             E =        78
             N =        78
```

Assumptions: IBUN is not independent of other covariates ($R^2 = 0.1837$); the overall death rate is $p_E = 0.738$.

```
. stpower cox 1, sd(0.3126) onesided r2(0.1837) failprob(0.738)

Estimated sample size for Cox PH regression
Wald test, log-hazard metric
Ho: [b1, b2, ..., bp] = [0, b2, ..., bp]

Input parameters:

         alpha =    0.0500  (one sided)
            b1 =    1.0000
            sd =    0.3126
         power =    0.8000
     Pr(event) =    0.7380
            R2 =    0.1837

Estimated number of events and sample size:

             E =        78
             N =       106
```

stpower exponential

- Type of test

  two-sample exponential test on difference of hazards or log hazards (option `loghazard`)

- Computation

  sample size (given power and difference (or ratio) of hazards)
  power (given sample size and difference (or ratio) of hazards)

- Capabilities

  unequal group allocation
  uniform or truncated exponential accrual
  group-specific exponential loss to follow up hazard rates
  conditional or unconditional approaches

- Methodology

  Lachin (1981), Lachin and Foulkes (1986) (default)
  Rubinstein, Gail and Santner (1981) (options `loghazard` and `unconditional`)

Sample-size determination for the exponential test

Objective. Obtain the required sample size to ensure prespecified power of a test of disparity in two exponential survivor functions with hazard rates λ_1 and λ_2.

The disparity may be expressed as a difference between the hazard or log hazard rates, $\delta = \lambda_2 - \lambda_1$ or $\ln(\Delta) = \ln(\lambda_2) - \ln(\lambda_1)$, resp.

Assumptions. Exponential survivor functions, $S_i(t) = \exp\{-\lambda_i t\}, i = 1, 2$; large-sample approximation to the test statistic holds

Equivalent hypothesis. H_o: $\delta = 0$ vs H_a: $\delta \neq 0$ (default)
H_o: $\ln(\Delta) = 0$ vs H_a: $\ln(\Delta) \neq 0$ (`loghazard`)

Two-sample comparison of exponential survivor curves

Example

- Lachin (2000, 412) demonstrates sample-size determination for a study comparing two therapies for lupus nephritis.
- From previous studies control-group survivor function was found to be log-linear with constant yearly hazard rate $\lambda_1 = 0.3$ ($t_{50} \approx 2.31$).
- Study parameters: $\alpha = 0.05$ (one sided), $1 - \beta = 0.9$, $\delta = \lambda_2 - \lambda_1 = -0.15$

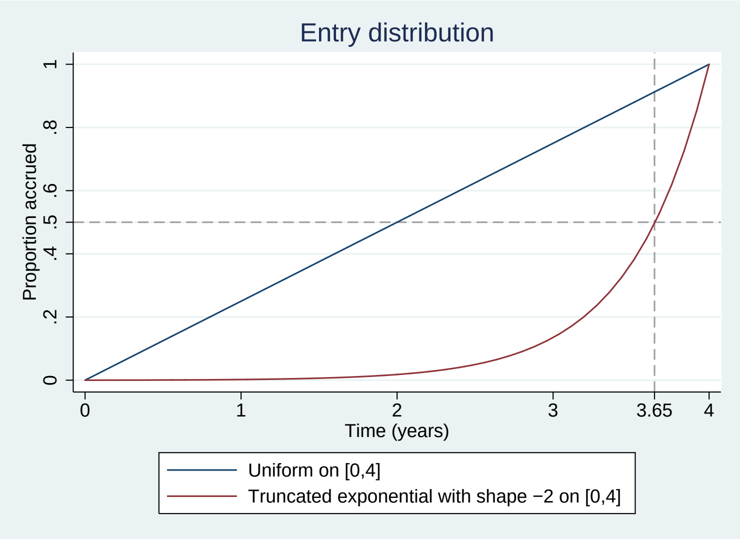
Design A: no right censoring (unlimited follow up).

```
. stpower exponential 0.3 0.15, onesided power(0.9)
Note: input parameters are hazard rates.

Estimated sample sizes for two-sample comparison of survivor functions
Exponential test, hazard difference, conditional
Ho: h2-h1 = 0

Input parameters:

      alpha =    0.0500  (one sided)
         h1 =    0.3000
         h2 =    0.1500
      h2-h1 =   -0.1500
      power =    0.9000
         p1 =    0.5000

Estimated sample sizes:

          N =        82
         N1 =        41
         N2 =        41
```

Design B: fixed-duration study ($R = 4$, $f = 2$); uniform accrual.

```
. stpower exponential 0.3 0.15, onesided power(0.9) aperiod(4) fperiod(2)
Note: input parameters are hazard rates.
Estimated sample sizes for two-sample comparison of survivor functions
Exponential test, hazard difference, conditional
Ho: h2-h1 = 0
Input parameters:
       alpha =    0.0500  (one sided)
          h1 =    0.3000
          h2 =    0.1500
       h2-h1 =   -0.1500
       power =    0.9000
          p1 =    0.5000
 Accrual and follow-up information:
    duration =    6.0000
   follow-up =    2.0000
     accrual =    4.0000  (uniform)
Estimated sample sizes:
           N =       136
          N1 =        68
          N2 =        68
```

Design C: fixed-duration study ($R = 4$, $f = 2$); truncated exponential accrual with shape -2.



```
. stpower exponential 0.3 0.15, onesided power(0.9) aperiod(4) fperiod(2)
> ashape(-2)
Note: input parameters are hazard rates.

Estimated sample sizes for two-sample comparison of survivor functions
Exponential test, hazard difference, conditional
Ho: h2-h1 = 0

Input parameters:

        (omitted)

 Accrual and follow-up information:

    duration =    6.0000
   follow-up =    2.0000
     accrual =    4.0000  (exponential)
  accrued(%) =     50.00  (by time t*)
          t* =    3.6536  (91.34% of accrual)

Estimated sample sizes:

           N =       184
          N1 =        92
          N2 =        92
```

Design D: fixed-duration study ($R = 4$, $f = 2$); truncated exponential accrual with shape -2; exponential yearly loss hazard rates of 0.05.

```
. stpower exponential 0.3 0.15, onesided power(0.9) aperiod(4) fperiod(2)
> ashape(-2) losshaz(0.05 0.05)
Note: input parameters are hazard rates.

Estimated sample sizes for two-sample comparison of survivor functions
Exponential test, hazard difference, conditional
Ho: h2-h1 = 0

Input parameters:

        (omitted)

 Accrual and follow-up information:

    duration =    6.0000
   follow-up =    2.0000
     accrual =    4.0000  (exponential)
  accrued(%) =     50.00  (by time t*)
          t* =    3.6536  (91.34% of accrual)
         lh1 =    0.0500
         lh2 =    0.0500

Estimated sample sizes:

           N =       194
          N1 =        97
          N2 =        97
```

Obtaining estimates of power or effect size

- Power determination:

  specify sample size in `n()`

- Effect-size determination:

  specify both sample size in `n()` and power in `power()` or,
  specify both `n()` and prob. of a type II error in `beta()`;
  not available with `stpower exponential`

Note that the value of the estimated effect size corresponding to the reduction in a hazard of the experimental group ($\Delta < 1$, $\ln(\Delta) < 0$, $\beta < 0$) is reported.

Power determination

Example

Recall design B of a study comparing survivor functions using the log-rank test. Compute power for a fixed sample size of 148.

```
. stpower logrank 0.4, n(148)
Estimated power for two-sample comparison of survivor functions
Log-rank test, Freedman method
Ho: S1(t) = S2(t)
Input parameters:
      alpha =    0.0500  (two sided)
         s1 =    0.4000
         s2 =    0.6325
     hratio =    0.5000
          N =       148
         p1 =    0.5000
Estimated number of events and power:
          E =        72
      power =    0.8053
```

Effect-size determination

Example

Compute a minimal detectable value of the hazard ratio given 80% power and a sample size of 148.

```
. stpower logrank 0.4, n(148) power(0.8)
Estimated hazard ratio for two-sample comparison of survivor functions
Log-rank test, Freedman method
Ho: S1(t) = S2(t)
Input parameters:
      alpha =    0.0500  (two sided)
         s1 =    0.4000
         s2 =    0.6308
          N =       148
      power =    0.8000
         p1 =    0.5000
Estimated number of events and hazard ratio:
          E =        72
     hratio =    0.5028
```

Using *numlist*

- stpower allows obtaining results for multiple values of survival probabilities, hazard rates, and coefficients (must be enclosed in parentheses)
- stpower allows obtaining results for multiple values specified in alpha(), power() or beta(), n(), and hratio()
- stpower logrank and stpower exponential also allow obtaining results for multiple values specified in p1() or nratio()
- multiple values may be directly enumerated or specified as *numlist*
- results for multiple values of other options may be obtained by using forvalues; see example 5 in [ST] **stpower exponential**

Table production

- option `table` displays results in a table with default columns
- option `columns(`*colnames*`)` displays results in a table with *colnames* columns (see help files for the description of *colnames*)
- if multiple values per option are specified results are displayed in a table automatically
- use `table saving()` to save table data and use `list` to display results or `graph` to produce plots of results

Example

Display results from example of `stpower exponential` (design A) in a table

```
. stpower exponential 0.3 0.15, onesided power(0.9) table
Note: input parameters are hazard rates.

Estimated sample sizes for two-sample comparison of survivor functions
Exponential test, hazard difference, conditional
Ho: h2-h1 = 0
```

Power	N	N1	N2	H1	H2	H2-H1	Alpha*
.9	82	41	41	.3	.15	-.15	.05

```
* one sided
```

Example

Compute sample sizes for $\lambda_2 = 0.15$ and $\lambda_2 = 0.18$ from example of `stpower exponential` (design B)

```
. stpower exponential 0.3 (0.15 0.18), onesided power(0.9) aperiod(4) fperiod(2)
Note: input parameters are hazard rates.
Estimated sample sizes for two-sample comparison of survivor functions
Exponential test, hazard difference, conditional
Ho: h2-h1 = 0
```

Power	N	N1	N2	H1	H2	H2-H1	Alpha*
.9	136	68	68	.3	.15	-.15	.05
.9	232	116	116	.3	.18	-.12	.05

FP	AP+
2	4
2	4

```
* one sided
+ uniform accrual; 50.00% accrued by 50.00% of AP
```

Example

Control column width by using option colwidth()

```
. stpower exponential 0.3 (0.15 0.18), onesided power(0.7(0.05)0.9) aperiod(4)
> fperiod(2) colwidth(7)
Note: input parameters are hazard rates.
Estimated sample sizes for two-sample comparison of survivor functions
Exponential test, hazard difference, conditional
Ho: h2-h1 = 0
```

Power	N	N1	N2	H1	H2	H2-H1	Alpha*	FP	AP+
.7	74	37	37	.3	.15	-.15	.05	2	4
.75	86	43	43	.3	.15	-.15	.05	2	4
.8	98	49	49	.3	.15	-.15	.05	2	4
.85	114	57	57	.3	.15	-.15	.05	2	4
.9	136	68	68	.3	.15	-.15	.05	2	4
.7	126	63	63	.3	.18	-.12	.05	2	4
.75	146	73	73	.3	.18	-.12	.05	2	4
.8	166	83	83	.3	.18	-.12	.05	2	4
.85	194	97	97	.3	.18	-.12	.05	2	4
.9	232	116	116	.3	.18	-.12	.05	2	4

```
* one sided
+ uniform accrual; 50.00% accrued by 50.00% of AP
```

Example

Use option `columns()` to select specific columns to be displayed in a table.

```
. local columns power n ea eo la lo h1 h2 aperiod fperiod alpha
. stpower exponential 0.3 (0.15 0.18), onesided power(0.8 0.9) aperiod(4) fperiod(2)
> losshaz(0.05 0.05) colw(7 6 6 6 6 7) columns(`columns')
Note: input parameters are hazard rates.
Estimated sample sizes for two-sample comparison of survivor functions
Exponential test, hazard difference, conditional
Ho: h2-h1 = 0
```

Power	N	E|Ha	E|Ho	L|Ha	L|Ho	H1	H2	AP+	FP	Alpha*
.8	108	56	58	13	12	.3	.15	4	2	.05
.9	148	76	78	18	18	.3	.15	4	2	.05
.8	182	99	100	22	20	.3	.18	4	2	.05
.9	252	137	140	29	30	.3	.18	4	2	.05

```
* one sided
+ uniform accrual; 50.00% accrued by 50.00% of AP
```

Example

Use option `parallel` to request results to be computed for pairs of values rather than for all possible combinations of values

```
. stpower exponential 0.3 (0.15 0.18), onesided power(0.8 0.9) aperiod(4) fperiod(2)
> losshaz(0.05 0.05) colw(7 6 6 6 6 6 7) columns(`columns') parallel
Note: input parameters are hazard rates.

Estimated sample sizes for two-sample comparison of survivor functions
Exponential test, hazard difference, conditional
Ho: h2-h1 = 0
```

Power	N	E|Ha	E|Ho	L|Ha	L|Ho	H1	H2	AP+	FP	Alpha*
.8	108	56	58	13	12	.3	.15	4	2	.05
.9	252	137	140	29	30	.3	.18	4	2	.05

```
* one sided
+ uniform accrual; 50.00% accrued by 50.00% of AP
```

Note: options with multiple values must contain the same numbers of values if `parallel` is specified

Example

Display results sorted on values of power first and then on values of the experimental group hazard rate h2

```
. qui stpower exponential 0.3 (0.15 0.18), onesided power(0.7(0.05)0.9) aperiod(4)
> fperiod(2) colwidth(7) saving(mydata, replace)
. use mydata
. sort power h2
. list
```

	power	n	n1	n2	h1	h2	diff	alpha	fperiod	aperiod
1.	.7	74	37	37	.3	.15	-.15	.05	2	4
2.	.7	126	63	63	.3	.18	-.12	.05	2	4
3.	.75	86	43	43	.3	.15	-.15	.05	2	4
4.	.75	146	73	73	.3	.18	-.12	.05	2	4
5.	.8	98	49	49	.3	.15	-.15	.05	2	4
6.	.8	166	83	83	.3	.18	-.12	.05	2	4
7.	.85	114	57	57	.3	.15	-.15	.05	2	4
8.	.85	194	97	97	.3	.18	-.12	.05	2	4
9.	.9	136	68	68	.3	.15	-.15	.05	2	4
10.	.9	232	116	116	.3	.18	-.12	.05	2	4

Building a table using stpower exponential dialog box

- Recall the following example:

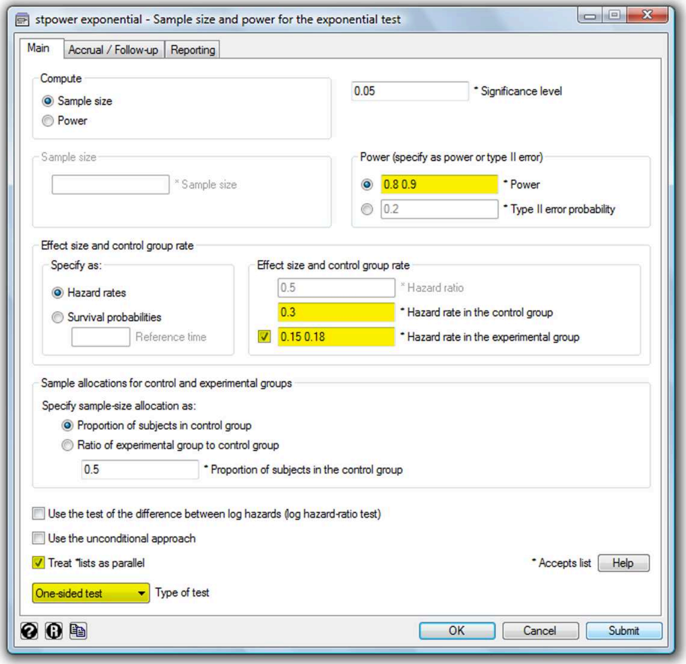
```
. stpower exponential 0.3 (0.15 0.18), onesided power(0.8 0.9) aperiod(4)
> fperiod(2) losshaz(0.05 0.05) colw(7 6 6 6 6 6 7)
> columns(power n ea eo la lo h1 h2 aperiod fperiod alpha) parallel
```

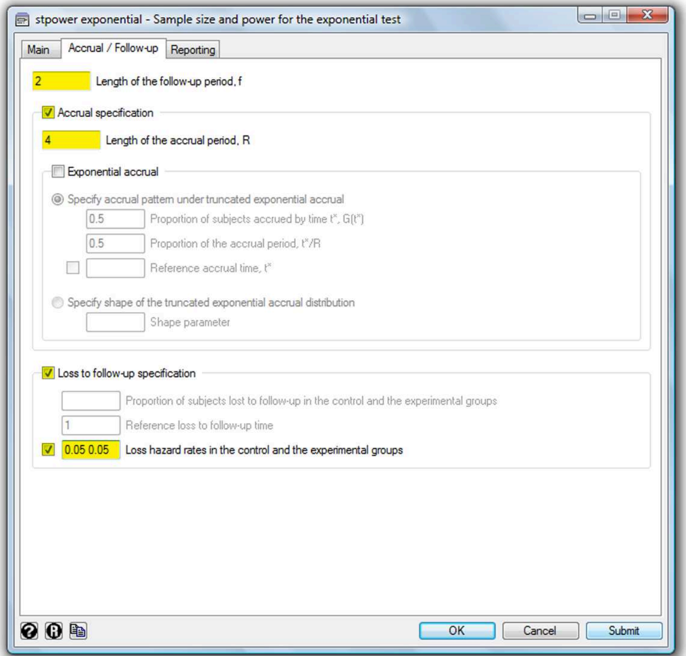
Building a table using stpower exponential dialog box

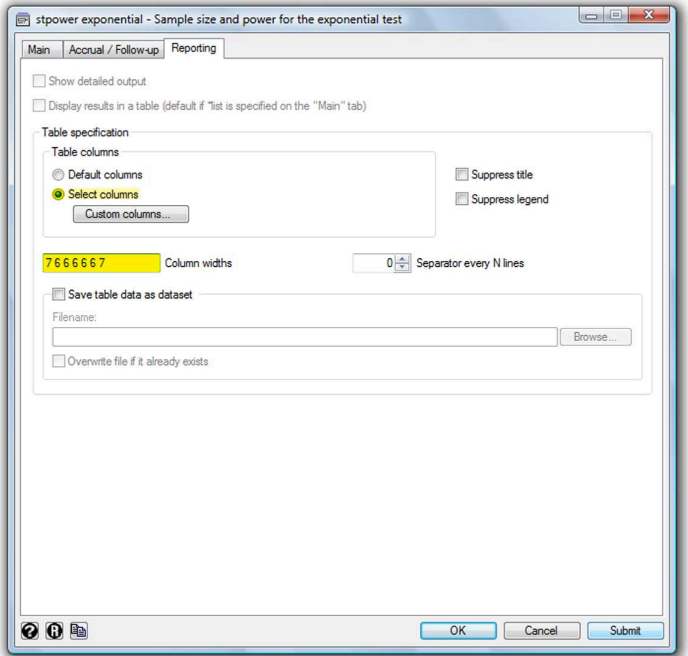
- Recall the following example:

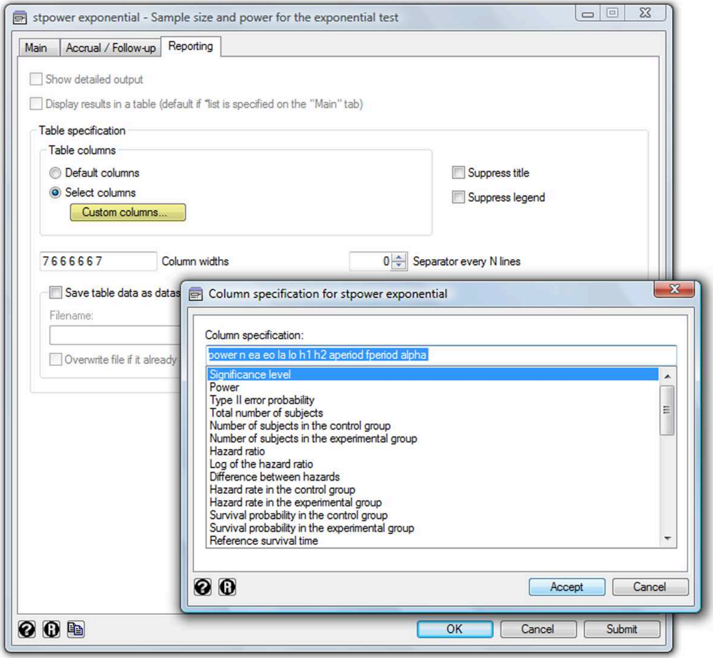
```
. stpower exponential 0.3 (0.15 0.18), onesided power(0.8 0.9) aperiod(4)
> fperiod(2) losshaz(0.05 0.05) colw(7 6 6 6 6 6 7)
> columns(power n ea eo la lo h1 h2 aperiod fperiod alpha) parallel
```

- Go to **Statistics** > **Power and sample size** > **Exponential test**
- Main tab: fill in values for power and hazard rates, check "Treat *list as parallel" box and choose type of test to be one sided
- Accrual/Follow-up tab: fill in values for accrual and follow-up periods, and for loss to follow-up hazard rates
- Reporting tab: select columns to be displayed in the table and optionally fill in values for column widths
- Click **Submit** or **OK**


stpower exponential - Sample size and power for the exponential test
Main
Accrual / Follow-up
Reporting
Compute
Sample size
Power
0.05
* Significance level
Sample size
* Sample size
Power (specify as power or type II error)
0.8 0.9
* Power
0.2
* Type II error probability
Effect size and control group rate
Specify as:
Hazard rates
Survival probabilities
Reference time
Effect size and control group rate
0.5
* Hazard ratio
0.3
* Hazard rate in the control group
0.15 0.18
* Hazard rate in the experimental group
Sample allocations for control and experimental groups
Specify sample-size allocation as:
Proportion of subjects in control group
Ratio of experimental group to control group
0.5
* Proportion of subjects in the control group
Use the test of the difference between log hazards (log hazard-ratio test)
Use the unconditional approach
Treat *lists as parallel
* Accepts list
Help
One-sided test
Type of test
OK
Cancel
Submit


stpower exponential - Sample size and power for the exponential test
Main
Accrual / Follow-up
Reporting
2
Length of the follow-up period, f
Accrual specification
4
Length of the accrual period, R
Exponential accrual
Specify accrual pattern under truncated exponential accrual
0.5
Proportion of subjects accrued by time t*, G(t*)
0.5
Proportion of the accrual period, t*/R
Reference accrual time, t*
Specify shape of the truncated exponential accrual distribution
Shape parameter
Loss to follow-up specification
Proportion of subjects lost to follow-up in the control and the experimental groups
1
Reference loss to follow-up time
0.05 0.05
Loss hazard rates in the control and the experimental groups
OK
Cancel
Submit


stpower exponential - Sample size and power for the exponential test
Main
Accrual / Follow-up
Reporting
Show detailed output
Display results in a table (default if *list is specified on the "Main" tab)
Table specification
Table columns
Default columns
Select columns
Custom columns...
Suppress title
Suppress legend
7 6 6 6 6 6 7
Column widths
0
Separator every N lines
Save table data as dataset
Filename:
Browse...
Overwrite file if it already exists
OK
Cancel
Submit


stpower exponential - Sample size and power for the exponential test
Main
Accrual / Follow-up
Reporting
Show detailed output
Display results in a table (default if "list is specified on the "Main" tab)
Table specification
Table columns
Default columns
Select columns
Custom columns...
Suppress title
Suppress legend
7 6 6 6 6 6 7
Column widths
0
Separator every N lines
Save table data as datas
Filename:
Overwrite file if it already
OK
Cancel
Submit
Column specification for stpower exponential
Column specification:
power n ea eo la lo h1 h2 aperiod fperiod alpha
Significance level
Power
Type II error probability
Total number of subjects
Number of subjects in the control group
Number of subjects in the experimental group
Hazard ratio
Log of the hazard ratio
Difference between hazards
Hazard rate in the control group
Hazard rate in the experimental group
Survival probability in the control group
Survival probability in the experimental group
Reference survival time
Accept
Cancel

Results

```
. stpower exponential 0.3 (0.15 0.18), onesided power(0.8 0.9) aperiod(4) fperiod(2)
> losshaz(0.05 0.05) colw(7 6 6 6 6 7)
> columns(power n ea eo la lo h1 h2 aperiod fperiod alpha) parallel
Note: input parameters are hazard rates.

Estimated sample sizes for two-sample comparison of survivor functions
Exponential test, hazard difference, conditional
Ho: h2-h1 = 0
```

Power	N	E|Ha	E|Ho	L|Ha	L|Ho	H1	H2	AP+	FP	Alpha*
.8	108	56	58	13	12	.3	.15	4	2	.05
.9	252	137	140	29	30	.3	.18	4	2	.05

```
* one sided
+ uniform accrual; 50.00% accrued by 50.00% of AP
```

Producing power curves

Manually:

- specify *numlist* to compute powers for a range of values and use `saving()` to save results in a dataset
- use `graph twoway` to plot results
- use overlaid plots to produce multiple power curves

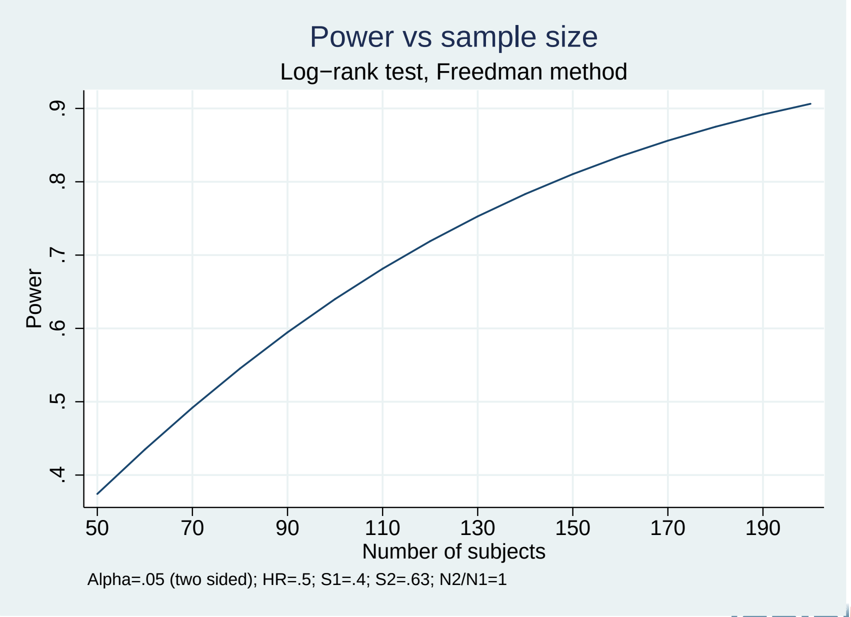
Automatic:

- use unofficial wrapper `stpowplot` to obtain simple, overlaid and separate graphs of power and other curves

Example

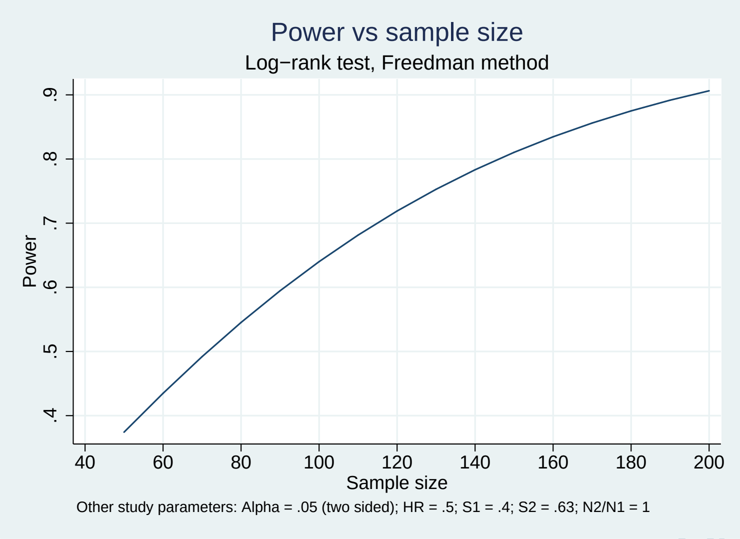
Produce a simple power curve as a function of sample size for a study from example of `stpower logrank` (design B)

```
. qui stpower logrank 0.4, n(50(10)200) saving(mypower, replace)

. use mypower

. line power n,
>       title("Power vs sample size")
>       subtitle("Log-rank test, Freedman method")
>       ytitle("Power") xtitle("Number of subjects")
>       xlabel(50(20)200, grid) ylabel(#10, grid)
>       note("Alpha=.05 (two sided); HR=.5; S1=.4; S2=.63; N2/N1=1")
```



Power vs sample size
Log−rank test, Freedman method
Power
.4
.5
.6
.7
.8
.9
50
70
90
110
130
150
170
190
Number of subjects
Alpha=.05 (two sided); HR=.5; S1=.4; S2=.63; N2/N1=1

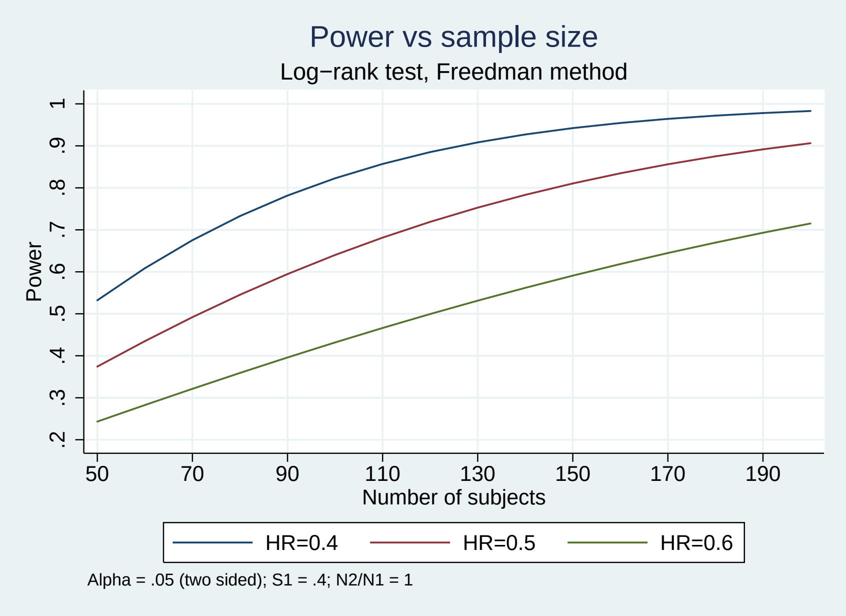
```
. stpowplot logrank 0.4, n(50(10)200) yaxis(power) xaxis(n)
Estimating power ...
```



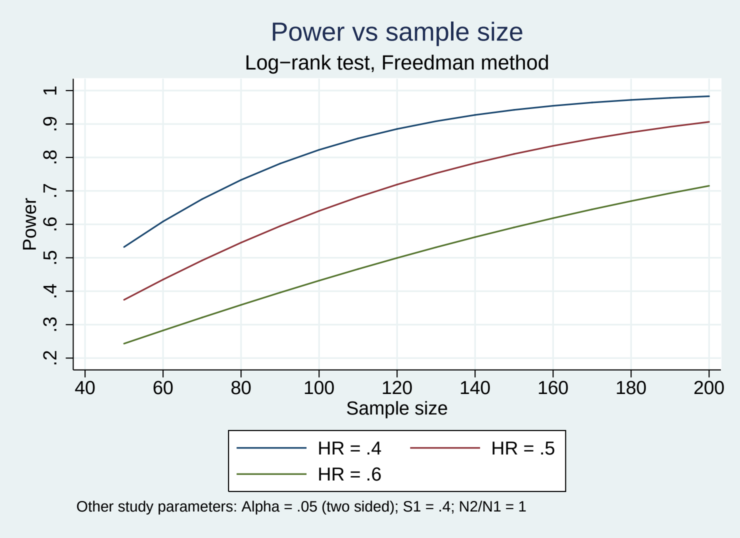
Example

Overlaid power curves as a function of sample size for the three values of hazard ratio

```
. qui stpower logrank 0.4, n(50(10)200) hratio(0.4 0.5 0.6)
> saving(mypower, replace)

. use mypower

. gr twoway line power n if hr==0.4 || line power n if hr==0.5
>                                   || line power n if hr==0.6,
>     title("Power vs sample size")
>     subtitle("Log-rank test, Freedman method")
>     ytitle("Power") xtitle("Number of subjects")
>     xlabel(50(20)200, grid) ylabel(#10, grid)
>     note("Alpha = .05 (two sided); S1 = .4; N2/N1 = 1")
>     legend(label(1 "HR=0.4") label(2 "HR=0.5") label(3 "HR=0.6") rows(1))
```


Power vs sample size
Log−rank test, Freedman method
Power
.2
.3
.4
.5
.6
.7
.8
.9
1
50
70
90
110
130
150
170
190
Number of subjects
HR=0.4
HR=0.5
HR=0.6
Alpha = .05 (two sided); S1 = .4; N2/N1 = 1

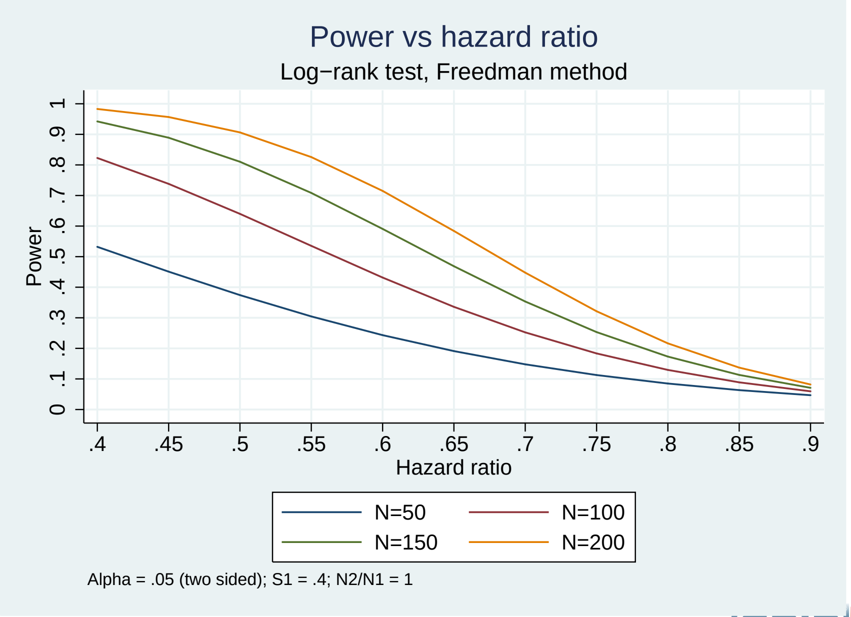
```
. stpowplot logrank 0.4, n(50(10)200) hratio(0.4 0.5 0.6) yaxis(power) xaxis(n)
>  over(hr)
Estimating power ...
```



Example

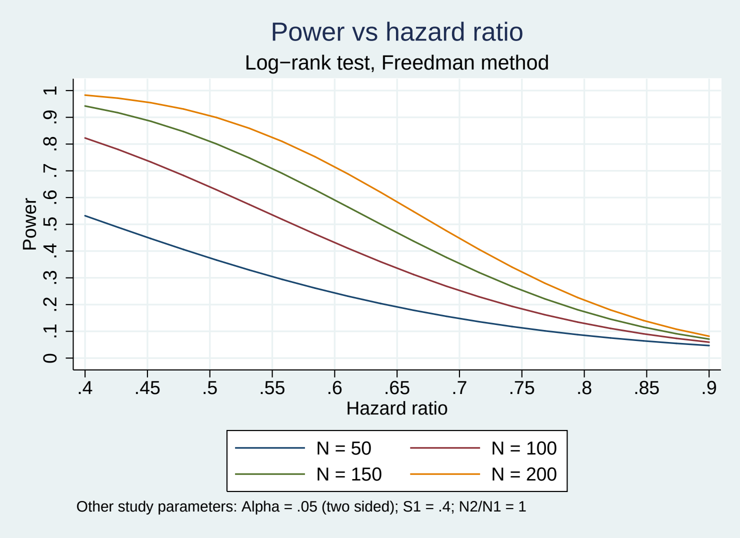
Produce power curves as a function of hazard ratio for four sample-size values

```
. qui stpower logrank 0.4, n(50(50)200) hratio(0.4(0.05)0.9) saving(mypower, replace)

. use mypower

. gr twoway line power hr if n==50 || line power hr if n==100
>        || line power hr if n==150 || line power hr if n==200,
>     title("Power vs hazard ratio")
>     subtitle("Log-rank test, Freedman method")
>     ytitle("Power") xtitle("Hazard ratio")
>     xlabel(0.4(0.05)0.9, grid) ylabel(#10, grid)
>     note("Alpha = .05 (two sided); S1 = .4; N2/N1 = 1")
>     legend(label(1 "N=50") label(2 "N=100") label(3 "N=150") label(4 "N=200"))
```

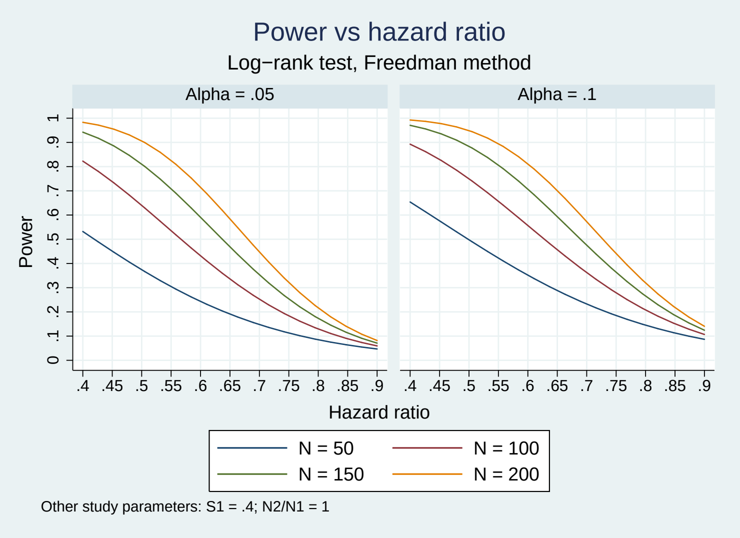


Power vs hazard ratio
Log−rank test, Freedman method
Power
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1
.4 .45 .5 .55 .6 .65 .7 .75 .8 .85 .9
Hazard ratio
N=50
N=100
N=150
N=200
Alpha = .05 (two sided); S1 = .4; N2/N1 = 1

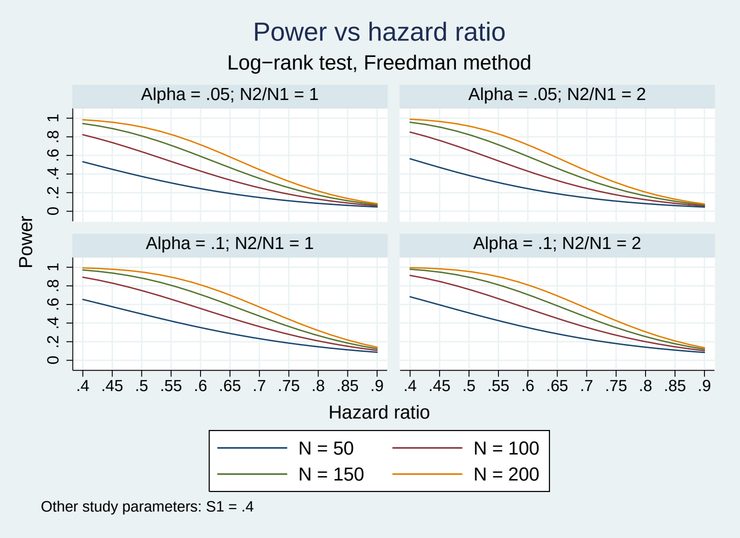
```
. stpowplot logrank 0.4, n(50(50)200) hratio(range 0.4 0.9 np 20) yaxis(power)
> xaxis(hr) over(n)
Estimating power ...
```



```
. stpowplot logrank 0.4, alpha(0.05 0.1) n(50(50)200) hratio(range 0.4 0.9)
> yaxis(power) xaxis(hr) over(n) by(alpha)
Estimating power ...
```



```
. stpowplot logrank 0.4, nratio(1 2) alpha(0.05 0.1) n(50(50)200) hratio(r 0.4 0.9)
> yaxis(power) xaxis(hr) over(n) by(alpha nratio) ylabel(#5, grid)
Estimating power ...
```



Final notes

You can use `stpower` to

- estimate sample size, power, or minimal detectable effect size
- perform power analysis for two-sample log-rank tests, parametric (exponential survival) tests, and Cox PH models
- compute results for multiple values of study parameters and display them in a table
- build your own table of results
- save results in a dataset for further production of power and other curves

Final notes, cont.

You can use stpowplot to

- automatically generate plots of power and other curves
- produce overlaid plots using over()
- produce separate plots using by()

You can obtain stpowplot by typing

```
. net from http://www.stata.com/users/ymarchenko/
. net describe stpowplot
. net install stpowplot
```

References

Collett, D. 2003. *Modelling Survival Data in Medical Research*. London: Chapman & Hall/CRC.

Freedman, L. S. 1982. Tables of the number of patients required in clinical trials using the logrank test. *Statistics in medicine* 1: 121–129.

Hsieh, F. Y., and P. W. Lavori. 2000. Sample size calculations for the Cox proportional hazards regression models with nonbinary covariates. *Controlled Clinical Trials* 21: 552–560.

Lachin, J. M. 1981. Introduction to sample size determination and power analysis for clinical trials. *Controlled Clinical Trials* 2: 93–113.

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Lachin, J. M., and M. A. Foulkes. 1986. Evaluation of sample size and power for analysis of survival with allowance for nonuniform patient entry, losses to follow-up, noncomplience, and stratification. *Biometrics* 42: 507–519.

Rubinstein, L. V., M. H. Gail, and T. J. Santner. 1981. Planning the duration of a comparative clinical trial with loss to follow-up and a period of continued observation. *Journal of Chronic Diseases* 34: 469–479.

Schoenfeld, D. 1981. The asymptotic properties of nonparametric tests for comparing survival distributions. *Biometrika* 68: 316–319.

Schoenfeld, D. 1983. Sample-size formula for the proportional-hazards regression model. *Biometrics* 39: 499–503.