

Package ‘BE’

September 27, 2020

Version 0.1.2

Title Bioequivalence Study Data Analysis

Description Analyze bioequivalence study data with industrial strength. Sample size could be determined for various crossover designs, such as 2x2 design, 2x4 design, 4x4 design, Balaam design, Two-sequence dual design, and William design.

Reference: Chow SC, Liu JP. Design and Analysis of Bioavailability and Bioequivalence Studies. 3rd ed. (2009, ISBN:978-1-58488-668-6).

Depends rtf

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NeedsCompilation no

LazyLoad yes

Repository CRAN

URL <https://cran.r-project.org/package=BE>

Date/Publication 2020-09-27 04:20:06 UTC

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BE-package	<i>Bioequivalence Study Data Analysis</i>
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Description

Analyze bioequivalence study data with industrial strength. Sample size could be determined for various crossover designs, such as 2x2 design, 2x4 design, 4x4 design, Balaam design, Two-sequence dual design, and William design. Basic assumption is that the variable is distributed as a log-normal distribution. This is SAS PROC GLM style. If you want PROC MIXED style, use `n1me::lme`.

Details

It performs bioequivalency tests for several variables of a 2x2 study in a data file.

Author(s)

Kyun-Seop Bae `k@acr.kr`

References

1. Chow SC, Liu JP. Design and Analysis of Bioavailability and Bioequivalence Studies. 3rd ed. (2009, ISBN:978-1-58488-668-6)
2. Hauschke D, Steinijans V, Pigeot I. Bioequivalence Studies in Drug Development. (2007, ISBN:978-0-470-09475-4)
3. Diletti E, Hauschke D, Steinijans VW. Sample size determination for bioequivalence assessment by means of confidence intervals. *Int J Clinical Pharmacol Ther Tox.* 1991;29(1):1-8

Examples

```
# write.csv(NCAResult4BE, "temp.csv", quote=FALSE, row.names=FALSE)
# be2x2("temp.csv", c("AUClast", "Cmax", "Tmax"))

## 'n1me' or SAS PROC MIXED is preferred for the confidence interval

## SAS PROC MIXED equivalent
# require(n1me)
# r2 = lme(log(Cmax) ~ GRP + PRD + TRT, random=~1|SUBJ, data=BEdata)
# summary(r2)
# VarCorr(r2)
```

```

# ci = intervals(r2, 0.90) ; ci
# exp(ci$fixed["TRTT",])

## SAS PROC GLM equivalent
# require(sasLM) # includes 'BEdata' which is a real dataset
# BEdata = af(BEdata, c("SEQ", "SUBJ", "PRD", "TRT")) # Columns as factor
# formula1 = log(CMAX) ~ SEQ/SUBJ + PRD + TRT # Model
# GLM(formula1, BEdata) # ANOVA tables of Type I, II, III SS
# T3MS(formula1, BEdata) # EMS table
# T3test(formula1, BEdata, Error="SEQ:SUBJ") # Hypothesis test

```

be2x2

Bioequivalence test of a 2x2 study

Description

It performs conventional bioequivalence test for 2x2 study. Input is a file. Basic assumption is that the variable is distributed as a log-normal distribution. This is SAS PROC GLM style. If you want PROC MIXED style, use `n1me::lme`.

Usage

```
be2x2(Data, Columns = c("AUClast", "Cmax", "Tmax"), rtfName="")
```

Arguments

Data	A data.frame or a file name. This should have at least the following columns and variable column(s) to be tested. AUC and Cmax should be all positive values. GRP : Group or Sequence, 'RT' or 'TR' PRD : Period, 1 or 2 SUBJ : Subject ID TRT : Treatment or Drug, 'R' or 'T'
Columns	Column names of variables to be tested. This is usually <code>c("AUClast", "Cmax", "Tmax")</code> or <code>c("AUClast", "AUCinf", "Cmax", "Tmax")</code>
rtfName	Output filename of rich text format(rtf)

Details

It performs bioequivalency tests for several variables of a 2x2 study in a data file. If you specify output filename in `rtfName`, the output will be saved in the file.

Value

Returns text output of equivalence test result.

Author(s)

Kyun-Seop Bae k@acr.kr

See Also

[test2x2](#), [plot2x2](#)

Examples

```
be2x2(NCARResult4BE, c("AUClast", "Cmax", "Tmax"))
```

ci2cv

Coefficient of variation (CV) from a confidence interval of previous 2x2 study

Description

It calculates coefficient of variation (CV) from a confidence interval of previous 2x2 study.

Usage

```
ci2cv(n1, n2, LL, UL, Alpha = 0.1)
```

Arguments

n1	Subject count of group 1
n2	Subject count of group 2
LL	Lower limit of the confidence interval of geometric mean ratio (Test/Reference)
UL	Upper limit of the confidence interval of geometric mean ratio (Test/Reference)
Alpha	Alpha level. This means $(1 - \alpha/2) \times 100$ % confidence interval is given

Details

It calculates coefficient of variation (CV) from a confidence interval of 2x2 bioequivalence study.

Value

Returns coefficient of variation (CV) in percent (%).

Author(s)

Kyun-Seop Bae k@acr.kr

Examples

```
ci2cv(12, 13, 0.85, 1.11)
```

ci2mse	<i>Mean squared error (MSE) from a confidence interval of previous 2x2 study</i>
--------	--

Description

It calculates mean squared error (MSE) from a confidence interval of previous 2x2 study.

Usage

```
ci2mse(n1, n2, LL, UL, Alpha = 0.1)
```

Arguments

n1	Subject count of group 1
n2	Subject count of group 2
LL	Lower limit of the confidence interval of geometric mean ratio (Test/Reference)
UL	Upper limit of the confidence interval of geometric mean ratio (Test/Reference)
Alpha	Alpha level. This means $(1 - \alpha/2) \times 100$ % confidence interval is given

Details

It calculates coefficient of variation (CV) from a confidence interval of 2x2 bioequivalence study.

Value

Returns mean squared error (MSE).

Author(s)

Kyun-Seop Bae k@acr.kr

Examples

```
ci2mse(12, 13, 0.85, 1.11)
```

cv2mse

Mean squared error (MSE) from coefficient of variation (CV)

Description

It calculates mean squared error (MSE) from coefficient of variation (CV).

Usage

```
cv2mse(cv)
```

Arguments

cv Coefficient of variation (%) in the original scale

Details

Coefficient of variation (CV) is percent in original scale and mean squared error (MSE) is log scale.

Value

Returns mean squared error (MSE) in log scale.

Author(s)

Kyun-Seop Bae k@acr.kr

Examples

```
cv2mse(25)
```

hodges*Hodges-Lehmann estimation for a variable of a 2x2 study*

Description

It performs Hodges-Lehmann estimation for 2x2 study. This is usually for Tmax variable.

Usage

```
hodges(bedata, Var)
```

Arguments

bedata	Data table name. This should have at least the following columns and a variable column to be tested. GRP : Group or Sequence, 'RT' or 'TR' PRD : Period, 1 or 2 SUBJ : Subject ID TRT : Treatment or Drug, 'R' or 'T'
Var	Variable to be estimated. This should be one of the column names in bedata table. Usually 'Tmax'

Details

It nonparametrically tests Var variable equivalency from a 2x2 study. This is done for a variable which we cannot assume log-normal distribution.

Value

Wilcoxon Signed-Rank Test	A kind of nonparametric test
Hodges-Lehmann Estimate	90% confidence interval in the original scale and the percent scale

Author(s)

Kyun-Seop Bae k@acr.kr

Examples

```
hodges(NCAResult4BE, "Tmax")
```

mse2cv

Coefficient of variation (CV) from mean squared error (MSE)

Description

It calculates coefficient of variation (CV) from mean squared error (MSE).

Usage

```
mse2cv(mse)
```

Arguments

mse	Mean square error (MSE) in log scale
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Details

Coefficient of variation (CV) is percent in the original scale and mean squared error (MSE) is the log scale.

Value

Returns coefficient of variation (CV) in percent (%).

Author(s)

Kyun-Seop Bae k@acr.kr

Examples

```
mse2cv(0.06062462)
```

NCAResult4BE

An Example of Noncompartmental Analysis Result for Bioequivalence Test

Description

Contains a noncompartmental analysis result table from a concentration simulated bioequivalence study.

Usage

```
NCAResult4BE
```

Format

A data frame with 48 observations on the following 10 variables.

SUBJ Subject ID

GRP Group or Sequence character code: 'RT' or 'TR'

PRD Period numeric value: 1 or 2

TRT Treatment or Drug code: 'R' or 'T'

AUClast AUClast positive numeric value

Cmax Cmax positive numeric value

Tmax Tmax positive numeric value

Details

This contains a simulated data for 2x2 bioequivalence study data analysis. Noncompartmental analysis results are from the NonCompartment package.

`plot2x2`*Plot bioequivalence variable of a 2x2 study*

Description

It plots two 2x2 plots for a variable.

Usage

```
plot2x2(bedata, Var)
```

Arguments

<code>bedata</code>	Data table name. This should have at least the following columns and a variable column to be plotted. GRP : Group or Sequence, 'RT' or 'TR' PRD : Period, 1 or 2 SUBJ : Subject ID TRT : Treatment or Drug, 'R' or 'T'
<code>Var</code>	Variable to be plotted. This should be one of the column names in bedata table.

Details

It plots Var column values according to GRP, PRD, TRT.

Value

It just draws two 2x2 plots for equivalence exploration.

Author(s)

Kyun-Seop Bae k@acr.kr

Examples

```
plot2x2(NCAResult4BE, "AUClast")  
plot2x2(NCAResult4BE, "Cmax")  
plot2x2(NCAResult4BE, "Tmax")
```

`pow2x2ci`*Power using a confidence interval of previous 2x2 study*

Description

It calculates power for the bioequivalence test on ratio using a confidence interval of previous 2x2 study.

Usage

```
pow2x2ci(n1, n2, LL, UL, Alpha = 0.1)
```

Arguments

n1	Subject count of group 1
n2	Subject count of group 2
LL	Lower limit of the confidence interval of geometric mean ratio (Test/Reference)
UL	Upper limit of the confidence interval of geometric mean ratio (Test/Reference)
Alpha	Alpha level. This means $(1 - \alpha/2) \times 100$ % confidence interval is given

Details

It calculates power of sample size (n per group) with CV.

Value

Returns power [0, 1)

Author(s)

Kyun-Seop Bae k@acr.kr

Examples

```
pow2x2ci(12, 13, 0.85, 1.11)
```

pow2x2mse

Power using mean squared error (MSE) of previous 2x2 study

Description

It calculates power for the bioequivalence test on ratio using mean squared error (MSE of previous 2x2 study).

Usage

```
pow2x2mse(n1, n2, mse, True.R = 1, Alpha = 0.1, ThetaL = 0.8, ThetaU = 1.25)
```

Arguments

n1	Subject count of group 1
n2	Subject count of group 2
mse	Mean squared error
True.R	True ratio of test/reference
Alpha	Alpha level. This means $(1 - \alpha/2)*100$ % confidence interval is given
ThetaL	Lower limit of equivalence criteria
ThetaU	Upper limit of equivalence criteria

Details

It calculates power of sample size (n per group) with CV.

Value

Returns power [0, 1)

Author(s)

Kyun-Seop Bae k@acr.kr

Examples

```
pow2x2mse(12, 13, 0.0756530)
```

powcv

*Power using coefficient of variation (CV)***Description**

It calculates power for the bioequivalence test on ratio using coefficient of variation (CV).

Usage

```
powcv(n, CV, DesignNo = 1, True.R = 1, Alpha = 0.1, ThetaL = 0.8, ThetaU = 1.25)
```

Arguments

n	Sample size, n per group
CV	Coefficient of Variation (%)
DesignNo	Crossover design number. Design Number (treatment x sequence x period) 1 2x2x2 : RT TR (no carry-over) 2 2x4x2 (Balaam Design) : TT RR RT TR (no carry-over) 3 2x2x3 (Two-sequence Dual Design): TRR RTT (no carry-over) 4 2x3x3 : TRR RTR RRT - carry-over effect 5 2x2x4c : TRRT RTTR + carry-over effect 6 2x2x4 : TRRT RTTR - carry-over effect 7 2x4x4 : TTRR RRTT TRRT RTTR 8 3x6x3c (William Design for 3 treatments) + carry-over effect : RBA ARB BAR ABR BRA RAB 9 3x6x3 (William Design for 3 treatments) - carry-over effect : RBA ARB BAR ABR BRA RAB 10 4x4x4c (William Design for 4 treatments) + carry-over effect : RCAB ARBC BACR CBRA 11 4x4x4 (William Design for 4 treatments) - carry-over effect : RCAB ARBC BACR CBRA
True.R	True ratio of test/reference
Alpha	Alpha error level
ThetaL	Lower limit of equivalence criteria
ThetaU	Upper limit of equivalence criteria

Details

It calculates power of sample size (n per group) with CV.

Value

Returns power [0, 1)

Author(s)

Kyun-Seop Bae k@acr.kr

Examples

powcv(12, 25)

powmse *Power using mean squared error (MSE)*

Description

It calculates power for the bioequivalence test on ratio using mean squared error (MSE).

Usage

```
powmse(n, mse, DesignNo = 1, True.R = 1, Alpha = 0.1, ThetaL = 0.8, ThetaU = 1.25)
```

Arguments

n	Sample size, n per group
mse	Mean squared error
DesignNo	Crossover design number. Design Number (treatment x sequence x period) 1 2x2x2 : RT TR (no carry-over) 2 2x4x2 (Balaam Design) : TT RR RT TR (no carry-over) 3 2x2x3 (Two-sequence Dual Design): TRR RTT (no carry-over) 4 2x3x3 : TRR RTR RRT - carry-over effect 5 2x2x4c : TRRT RTTR + carry-over effect 6 2x2x4 : TRRT RTTR - carry-over effect 7 2x4x4 : TTRR RRRT TRRT RTTR 8 3x6x3c (William Design for 3 treatments) + carry-over effect : RBA ARB BAR ABR BRA RAB 9 3x6x3 (William Design for 3 treatments) - carry-over effect : RBA ARB BAR ABR BRA RAB 10 4x4x4c (William Design for 4 treatments) + carry-over effect : RCAB ARBC BACR CBRA 11 4x4x4 (William Design for 4 treatments) - carry-over effect : RCAB ARBC BACR CBRA
True.R	True ratio of test/reference
Alpha	Alpha error level
ThetaL	Lower limit of equivalence criteria
ThetaU	Upper limit of equivalence criteria

Details

It calculates power of sample size (n per group) with mse.

Value

Returns power [0, 1))

Author(s)

Kyun-Seop Bae k@acr.kr

Examples

```
pwmse(12, 0.06)
```

 ss2x2ci

Sample size using a confidence interval of previous 2x2 study

Description

It calculates sample size for the bioequivalence test on ratio using a confidence interval of previous 2x2 study.

Usage

```
ss2x2ci(n1, n2, LL, UL, Alpha = 0.1)
```

Arguments

n1	Subject count of group 1
n2	Subject count of group 2
LL	Lower limit of the confidence interval of geometric mean ratio (Test/Reference)
UL	Upper limit of the confidence interval of geometric mean ratio (Test/Reference)
Alpha	Alpha level. This means $(1 - \alpha/2) \times 100$ % confidence interval is given

Details

It calculates sample size (n per group) with CV, Alpha, and Beta for bioequivalence test.

Value

Returns sample size (n per group) for bioequivalence test with ratio criteria.

Author(s)

Kyun-Seop Bae k@acr.kr

Examples

```
ss2x2ci(12, 13, 0.85, 1.11)
```

sscv

*Sample size using coefficient of variation (CV)***Description**

It calculates sample size for the bioequivalence test on ratio using coefficient of variation (CV).

Usage

```
sscv(CV, DesignNo = 1, True.R = 1, Alpha = 0.1, Beta = 0.2,
      ThetaL = 0.8, ThetaU = 1.25, nMax = 999999)
```

Arguments

CV	Coefficient of Variation (%)
DesignNo	Crossover design number. Design Number (treatment x sequence x period) 1 2x2x2 : RT TR (no carry-over) 2 2x4x2 (Balaam Design) : TT RR RT TR (no carry-over) 3 2x2x3 (Two-sequence Dual Design): TRR RTT (no carry-over) 4 2x3x3 : TRR RTR RRT - carry-over effect 5 2x2x4c : TRRT RTTR + carry-over effect 6 2x2x4 : TRRT RTTR - carry-over effect 7 2x4x4 : TTRR RRTT TRRT RTTR 8 3x6x3c (William Design for 3 treatments) + carry-over effect : RBA ARB BAR ABR BRA RAB 9 3x6x3 (William Design for 3 treatments) - carry-over effect : RBA ARB BAR ABR BRA RAB 10 4x4x4c (William Design for 4 treatments) + carry-over effect : RCAB ARBC BACR CBRA 11 4x4x4 (William Design for 4 treatments) - carry-over effect : RCAB ARBC BACR CBRA
True.R	True ratio of test/reference
Alpha	Alpha error level
Beta	Beta error level
ThetaL	Lower limit of equivalence criteria
ThetaU	Upper limit of equivalence criteria
nMax	Maximum subject number (sample size) per group

Details

It calculates sample size (n per group) with CV, Alpha, and Beta for bioequivalence test.

Value

Returns sample size (n per group) for bioequivalence test with ratio criteria.

Author(s)

Kyun-Seop Bae k@acr.kr

Examples

```
sscv(25)
```

ssmse

Sample size using mean squared error (MSE)

Description

It calculates sample size for the bioequivalence test on ratio using mean squared error (MSE).

Usage

```
ssmse(mse, DesignNo = 1, True.R = 1, Alpha = 0.1, Beta = 0.2,
      ThetaL = 0.8, ThetaU = 1.25, nMax = 999999)
```

Arguments

mse	Mean squared error
DesignNo	Crossover design number. Design Number (treatment x sequence x period) 1 2x2x2 : RT TR (no carry-over) 2 2x4x2 (Balaam Design) : TT RR RT TR (no carry-over) 3 2x2x3 (Two-sequence Dual Design): TRR RTT (no carry-over) 4 2x3x3 : TRR RTR RRT - carry-over effect 5 2x2x4c : TRRT RTTR + carry-over effect 6 2x2x4 : TRRT RTTR - carry-over effect 7 2x4x4 : TTRR RRTT TRRT RTTR 8 3x6x3c (William Design for 3 treatments) + carry-over effect : RBA ARB BAR ABR BRA RAB 9 3x6x3 (William Design for 3 treatments) - carry-over effect : RBA ARB BAR ABR BRA RAB 10 4x4x4c (William Design for 4 treatments) + carry-over effect : RCAB ARBC BACR CBRA 11 4x4x4 (William Design for 4 treatments) - carry-over effect : RCAB ARBC BACR CBRA
True.R	True ratio of test/reference
Alpha	Alpha error level

Beta	Beta error level
ThetaL	Lower limit of equivalence criteria
ThetaU	Upper limit of equivalence criteria
nMax	Maximum subject number (sample size) per group

Details

It calculates sample size (n per group) with mse, Alpha, and Beta for bioequivalence test.

Value

Returns sample size (n per group) for bioequivalence test with ratio criteria.

Author(s)

Kyun-Seop Bae k@acr.kr

Examples

```
ssmse(0.06)
```

test2x2

Bioequivalence test for a variable of a 2x2 study

Description

It performs conventional bioequivalence test for 2x2 study. Basic assumption is that the variable is distributed as a log-normal distribution. This is SAS PROC GLM style. If you want PROC MIXED style use nlme::lme.

Usage

```
test2x2(bedata, Var)
```

Arguments

bedata	Data table name. This should have at least the following columns and a variable column to be tested. Var column values should be all positive values. GRP : Group or Sequence, 'RT' or 'TR' PRD : Period, 1 or 2 SUBJ : Subject ID TRT : Treatment or Drug, 'R' or 'T'
Var	Variable to be tested. This should be one of the column names in bedata table. Usually 'AUClast' or 'Cmax'

Details

It tests Var variable equivalency from a 2x2 study. Current regulatory requirement is that the 90% confidence interval of geometric mean ratio (Test/Reference) should be within [0.8, 1.25].

Value

Analysis of Variance (log scale)

Analysis of Variance in log scale

Between and Within Subject Variability

Variance in log scale and coefficient of variance in original scale

Least Square Means

Geometric means

90% Confidence Interval

90% confidence interval of geometric mean ratio (T/R)

Sample Size

Sample size for the replication of this study

Author(s)

Kyun-Seop Bae k@acr.kr

Examples

```
test2x2(NCAResult4BE, "AUClast")
```

```
test2x2(NCAResult4BE, "Cmax")
```

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