Package ‘dunn.test’

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Title Dunn's Test of Multiple Comparisons Using Rank Sums
Author Alexis Dinno <alexis.dinno@pdx.edu>
Maintainer Alexis Dinno <alexis.dinno@pdx.edu>
Description Computes Dunn's test (1964) for stochastic dominance and reports the results among multiple pairwise comparisons after a Kruskal-Wallis test for stochastic dominance among k groups (Kruskal and Wallis, 1952). The interpretation of stochastic dominance requires an assumption that the CDF of one group does not cross the CDF of the other. 'dunn.test' makes k(k-1)/2 multiple pairwise comparisons based on Dunn's z-test-statistic approximations to the actual rank statistics. The null hypothesis for each pairwise comparison is that the probability of observing a randomly selected value from the first group that is larger than a randomly selected value from the second group equals one half; this null hypothesis corresponds to that of the Wilcoxon-Mann-Whitney rank-sum test. Like the rank-sum test, if the data can be assumed to be continuous, and the distributions are assumed identical except for a difference in location, Dunn's test may be understood as a test for median difference. 'dunn.test' accounts for tied ranks.

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**dunn.test**

**Dunn’s Test**

**Description**

Performs Dunn’s test of multiple comparisons using rank sums

**Usage**

```r
dunn.test (x, g=NA, method=p.adjustment.methods, kw=TRUE, label=TRUE, wrap=FALSE, table=TRUE, list=FALSE, rmc=FALSE, alpha=0.05, altp=FALSE)
```

`p.adjustment.methods`

# c(“none”, “bonferroni”, “sidak”, “holm”, “hs”, “hochberg”, “bh”, “by”)

**Arguments**

- **x**: a numeric vector, or a list of numeric vectors. Missing values are ignored. If the former, then groups **must** be specified using `g`.
- **g**: a factor variable, numeric vector, or character vector indicating group. Missing values are ignored.
- **method**: adjusts the `p`-value for multiple comparisons using the Bonferroni, Šidák, Holm, Holm-Šidák, Hochberg, Benjamini-Hochberg, or Benjamini-Yekutieli adjustment (see Details). The default is no adjustment for multiple comparisons.
- **kw**: if ‘TRUE’ then the results of the Kruskal-Wallis test are reported.
- **label**: if ‘TRUE’ then the factor labels are used in the output table.
- **wrap**: does not break up tables to maintain nicely formatted output. If ‘FALSE’ then output of large tables is broken up across multiple pages.
- **table**: outputs results of Dunn’s test in a table format, as qualified by the `label` and `wrap` options.
- **list**: outputs results of Dunn’s test in a list format.
- **rmc**: if ‘TRUE’ then the reported test statistics and table are based on row minus column, rather than the default column minus row (i.e. the signs of the test statistic are flipped).
- **alpha**: the nominal level of significance used in the step-up/step-down multiple comparisons procedures (Holm, Holm-Šidák, Hochberg, Benjamini-Hochberg, and Benjamini-Yekutieli).
- **altp**: if ‘TRUE’ then express `p`-values in alternative format. The default is to express `p`-value = \( P(Z \geq |z|) \), and reject Ho if \( p \leq \alpha/2 \). When the `altp` option is used, `p`-values are instead expressed as `p`-value = \( P(Z \leq |z|) \), and reject Ho if \( p \leq \alpha \). **These two expressions give identical test results.** Use of `altp` is therefore merely a semantic choice.
Details

dunn.test computes Dunn’s test (1964) for stochastic dominance and reports the results among multiple pairwise comparisons after a Kruskal-Wallis test for stochastic dominance among \( k \) groups (Kruskal and Wallis, 1952). The interpretation of stochastic dominance requires an assumption that the CDF of one group does not cross the CDF of the other. dunn.test makes \( m = k(k-1)/2 \) multiple pairwise comparisons based on Dunn’s \( z \)-test-statistic approximations to the actual rank statistics. The null hypothesis for each pairwise comparison is that the probability of observing a randomly selected value from the first group that is larger than a randomly selected value from the second group equals one half; this null hypothesis corresponds to that of the Wilcoxon-Mann-Whitney rank-sum test. Like the rank-sum test, if the data can be assumed to be continuous, and the distributions are assumed identical except for a difference in location, Dunn’s test may be understood as a test for median difference. dunn.test accounts for tied ranks.

dunn.test outputs both \( z \)-test-statistics for each pairwise comparison and the \( p \)-value = \( P(Z \geq |z|) \) for each. Reject Ho based on \( p \leq \alpha/2 \) (and in combination with \( p \)-value ordering for stepwise method options). If you prefer to work with \( p \)-values expressed as \( p \)-value = \( P(|Z| \geq |z|) \) use the altp=true option, and reject Ho based on \( p \leq \alpha \) (and in combination with \( p \)-value ordering for stepwise method options). These are exactly equivalent rejection decisions.

Several options are available to adjust \( p \)-values for multiple comparisons, including methods to control the family-wise error rate (FWER) and methods to control the false discovery rate (FDR):

"none" no adjustment is made. Those comparisons rejected without adjustment at the \( \alpha \) level (two-sided test) are starred in the output table, and starred in the list when using the list=TRUE option.

"bonferroni" the FWER is controlled using Dunn’s (1961) Bonferroni adjustment, and adjusted \( p \)-values = \( \max(1, pm) \). Those comparisons rejected with the Bonferroni adjustment at the \( \alpha \) level (two-sided test) are starred in the output table, and starred in the list when using the list=TRUE option.

"sidak" the FWER is controlled using Šidák’s (1967) adjustment, and adjusted \( p \)-values = \( \max(1, 1 - (1 - p)^m) \). Those comparisons rejected with the Šidák adjustment at the \( \alpha \) level (two-sided test) are starred in the output table, and starred in the list when using the list=TRUE option.

"holm" the FWER controlled using Holm’s (1979) progressive step-up procedure to relax control on subsequent tests. \( p \) values are ordered from smallest to largest, and adjusted \( p \)-values = \( \max[1, (m+1-i)p] \), where \( i \) indexes the ordering. All tests after and including the first test to not be rejected are also not rejected.

"hs" the FWER is controlled using the Holm-Šidák adjustment (Holm, 1979): another progressive step-up procedure but assuming dependence between tests. \( p \) values are ordered from smallest to largest, and adjusted \( p \)-values = \( \max[1, 1 - (1 - p)^m] \), where \( i \) indexes the ordering. All tests after and including the first test not to be rejected are also not rejected.

"hochberg" the FWER is controlled using Hochberg’s (1988) progressive step-down procedure to increase control on successive tests. \( p \) values are ordered from largest smallest, and adjusted \( p \)-values = \( \max[1, p^i] \), where \( i \) indexes the ordering. All tests after and including the first to be rejected are also rejected.

"bh" the FDR is controlled using the Benjamini-Hochberg adjustment (1995), a step-down procedure appropriate to independent tests or tests that are positively dependent. \( p \)-values are ordered from largest to smallest, and adjusted \( p \)-values = \( \max[1, pm/(m+1-i)] \), where \( i \) indexes the ordering. All tests after and including the first to be rejected are also rejected.
"by" the FDR is controlled using the Benjamini-Yekutieli adjustment (2011), a step-down procedure appropriate to dependent tests. $p$-values are ordered from largest to smallest, and adjusted $p$-values $= \max[1, pmC/(m+1-i)]$, where $i$ indexes the ordering, and the constant $C = 1 + 1/2 + \ldots + 1/m$. All tests after and including the first to be rejected are also rejected.

Because the sequential step-up/step-down tests rejection decisions depend on both the $p$-values and their ordering, those tests rejected using "holm", "hs", "hochberg", "bh", or "by" at the indicated $\alpha$ level are starred in the output table, and starred in the list when using the list=TRUE option.

Value

dunn.test returns:

chi2 a scalar of the Kruskal-Wallis test statistic adjusted for ties.
Z a vector of all $m$ of Dunn $z$ test statistics.
P a vector of $p$-values corresponding to $Z$. --OR--
altp a vector of $p$-values corresponding to $Z$ when using the altp=TRUE option.
P.adjust a vector of $p$-values corresponding to $Z$, but adjusted for multiple comparisons as per method ($P = P.adjust$ if method="none"). --OR--
altp.adjust a vector of $p$-values corresponding to $Z$, but adjusted for multiple comparisons as per method ($P = P.adjust$ if method="none") when using the altp=TRUE option.
comparisons a vector of strings labeling each pairwise comparison, as qualified by the rmc option, using either the variable values, or the factor labels or (or factor values if unlabeled). These labels match the corresponding position in the $Z$, $P$, and $P.adjust$ vectors.

Author(s)

Alexis Dinno (<alexis.dinno@pdx.edu>)

References


Examples

```r
## Example cribbed and modified from the kruskal.test documentation
## Hollander & Wolfe (1973), 116.
## Mucociliary efficiency from the rate of removal of dust in normal
## subjects, subjects with obstructive airway disease, and subjects
## with asbestosis.
## x <- c(2.9, 3.0, 2.5, 2.6, 3.2)  # normal subjects
## y <- c(3.8, 2.7, 4.0, 2.4)       # with obstructive airway disease
## z <- c(2.8, 3.4, 3.7, 2.2, 2.0) # with asbestosis
## dunn.test(x=list(x,y,z))

x <- c(x, y, z)
g <- factor(rep(1:3, c(5, 4, 5)),
            labels = c("Normal",
                        "COPD",
                        "Asbestosis"))
dunn.test(x, g)

## Example based on home care data from Dunn (1964)
data(homecare)
attach(homecare)
dunn.test(occupation, eligibility, method="hs", list=TRUE)

## Air quality data set illustrates differences in different
## multiple comparisons adjustments
attach(airquality)
dunn.test(Ozone, Month, kw=FALSE, method="bonferroni")
dunn.test(Ozone, Month, kw=FALSE, method="hs")
dunn.test(Ozone, Month, kw=FALSE, method="bh")
detach(airquality)
```

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### homecare

#### Occupation and Home Care Eligibility

**Description**

Occupation and home care eligibility for 383 patients medically eligible for home care.

**Usage**

```r
homecare
```

**Format**

A data frame containing two variables, occupation and eligibility, over 383 observations.
Source
Dunn, O. J. (1964). “Multiple comparisons using rank sums.” Technometrics, 6(3):241–252. Page 244, Table 1

References
The data have been adapted from a study of a group of patients entering the Los Angeles County General Hospital during the years 1959-61.
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