# The Games-Howell Test in R

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# Multiple comparisons – the tests?

**Fisher LSD:** too liberal, correction necessary

**Tukey HSD:** less liberal, only with equal sample size

**Duncan's test:** only with equal sample size

**Games-Howell:** no equal sample size needed, works even with heteroscedastic data

**Problem: Not implemented in** 

# How to perform the Games-Howell test?

## Original publication:

Paul A. Games and John F. Howell

Pairwise Multiple Comparison Procedures with Unequal N's and / or Variances: A Monte Carlo Study

*Journal of Educational Statistics*, Vol.1, No. 2, 1976, pp. 113-125

**Extension of the Tukey-Kramer test for unequal variances**

**Error term**

$$\sqrt{\frac{\frac{s_i^2}{n_i} + \frac{s_j^2}{n_j}}{2}}$$

**Degrees of freedom**

$$df' = \frac{\left(\frac{s_i^2}{n_i} + \frac{s_j^2}{n_j}\right)^2}{\frac{\left(\frac{s_i^2}{n_i}\right)^2}{n_i - 1} + \frac{\left(\frac{s_j^2}{n_j}\right)^2}{n_j - 1}}$$

Source: uvm.edu/~dhowell/StatPages/More_Stuff/MultComp

# How to perform the Games-Howell test?

## There‘s no R-Package, but:

**http://aoki2.si.gunma-u.ac.jp/R/src/tukey.R**

## ...an R-script!

テューキーの方法による多重比較　Last modified: Aug 03, 2009

目的

テューキーの方法による多重比較を行う。
Games-Howell 法も選択できる。

R の TukeyHSD や pairwise.t.test 関数も参照するとよい。

使用法

```
tukey(data, group, method=c("Tukey", "Games-Howell"))
```

引数

| | |
|---|---|
| data | 観察値ベクトル |
| group | 群変数ベクトル |
| method | "Tukey" のとき Tukey 法（デフォルト） |
| | "Games-Howell" のとき Games-Howell 法 |

ソース

インストールは，以下の 1 行をコピーし，R コンソールにペーストする

```
source("http://aoki2.si.gunma-u.ac.jp/R/src/tukey.R", encoding="euc-jp")

# Tukey の方法による多重比較
# Games-Howell の方法も選択できるように拡張 2009/08/03
tukey <- function(      data,                           # 観察値ベクトル
                        group,                          # 群変数ベクトル
                        method=c("Tukey", "Games-Howell"))      # 手法の選択
```

tukey(data, group, method=c("Tukey", "Games-Howell"))

# The function itself!

```
tukey <- function(data, group, method=c("Tukey", "Games-Howell"))
 {
          OK <- complete.cases(data, group)
          data <- data[OK]
          group <- factor(group[OK])
          n <- tapply(data, group, length)
          a <- length(n)
          phi.e <- sum(n)-a
          Mean <- tapply(data, group, mean)
          Variance <- tapply(data, group, var)
          result1 <- cbind(n, Mean, Variance)
          rownames(result1) <- paste("Group", 1:a, sep="")
          method <- match.arg(method)
          if (method == "Tukey") { ## Here comes the syntax for the Tukey test

                    v.e <- sum((n-1)*Variance)/phi.e
                    t <- combn(a, 2, function(ij) abs(diff(Mean[ij]))/sqrt(v.e*sum(1/n[ij])) )
                    p <- ptukey(t*sqrt(2), a, phi.e, lower.tail=FALSE)
                    Tukey <- cbind(t, p)
                    rownames(Tukey) <- combn(a, 2, paste, collapse=":")
                    return(list(result1=result1, Tukey=Tukey, phi=phi.e, v=v.e))
          }
          else {    ## Here comes the syntax for the Games-Howell test
                    t.df <- combn(a, 2, function(ij) {
                    t <- abs(diff(Mean[ij]))/sqrt(sum(Variance[ij]/n[ij]))
                    df <- sum(Variance[ij]/n[ij])^2/sum((Variance[ij]/n[ij])^2/(n[ij]-1))
                    return(c(t, df))
                    } )
                    t <- t.df[1,]
                    df <- t.df[2,]
                    p <- ptukey(t*sqrt(2), a, df, lower.tail=FALSE)
                    Games.Howell <- cbind(t, df, p)
                    rownames(Games.Howell) <- combn(a, 2, paste, collapse=":")
                    return(list(result1=result1, Games.Howell=Games.Howell))}}
```