Package 'nephro'

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Title Utilities for Nephrology

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Description Set of functions to estimate kidney function and other phenotypes of interest in nephrology based on different biomechimal traits. MDRD, CKD-EPI, and Virga equations are compared in Pattaro (2013) <doi:10.1159/000351043>, where the respective references are given. In addition, the software includes Stevens (2008) <doi:10.1053/j.ajkd.2007.11.018> and Cockroft (1976) <doi:10.1159/000180580> formulas. The race-free CKD-EPI equations (2021) <doi:10.1056/NEJMoa2102953> are also implemented from ver.1.3.

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nephro-package   *Biostatistics utilities for nephrology*

Description

This package contains a set of tools for the estimation of kidney function. Kidney function is assessed by means of the Glomerular Filtration Rate (GFR), which can be estimated using different biomarkers. The most commonly used ones are serum or plasma creatinine and cystatin C. Included in this package are the following GFR estimating functions: the Modification of Diet in Renal Disease (MDRD) study equation based on four (MDRD4) or six (MDRD6) parameters (see Levey 1999, 2006); the CKD-Epi equations for creatinine (CKDEpi.creat, CKDEpi.creat.rf), cystatin C (CKDEpi.cys), and a combination of creatinine and cystatin C (CKDEpi.creat.cys, CKDEpi.creat.cys.rf) (see Inker 2012 & Inker 2021); the three equations proposed by Stevens 2008 based on cystatin C only (Stevens.cys1), age- and sex-weighted cystatin C (Stevens.cys2), and a combination of cystatin C and creatinine (Stevens.creat.cys); the classic Cockroft and Gault 1976 equation for creatinine clearance estimation (CG); and the recent equation by Virga (2007) (Virga). A comparative description of several functions included in the package can be found in Pattaro (2013). An extensive literature does exist that compares the methods described.

Details

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Author(s)

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References

Citing this package:
- Pattaro C, Riegler P, Stifter G, Modenese M, Minelli C, Pramstaller PP. Estimating the glomerular filtration rate in the general population using different equations: effects on classification and association. *Nephron Clin Pract* 2013; **123**(1-2):102-11.

Formulas:
- Cockroft DW, Gault MH. Prediction of creatinine clearance from serum creatinine. *Nephron* 1976;

16: 31-41.

- Inker LA, *et al*. Estimating glomerular filtration rate from serum creatinine and cystatin C. *N Engl J Med* 2012; **367**: 20-9.
- Inker LA, *et al*. New Creatinine- and Cystatin C-based Equations to Estimate GFR without Race. *N Engl J Med* 2021; **385**: 1737-1749.
- Levey AS, *et al*. A more accurate method to estimate glomerular filtration rate from serum creatinine: a new prediction equation. Modification of Diet in Renal Disease Study Group. *Ann Intern Med*. 1999; **130**(6): 461-70.
- Levey AS, *et al*. Using standardized serum creatinine values in the modification of diet in renal disease study equation for estimating glomerular filtration rate. *Ann Intern Med*. 2006; **145**: 247-54.
- Stevens LA, *et al*. Estimating GFR using serum cystatin C alone and in combination with serum creatinine: a pooled analysis of 3,418 individuals with CKD. *Am J Kidney Dis* 2008; **51**: 395-406.
- Virga G, *et al*. A new equation for estimating renal function using age, body weight and serum creatinine. *Nephron Clin Pract* 2007; **105**: c43-53.

On IDMS calibration:

- Levey AS, *et al*. Expressing the Modification of Diet in Renal Disease Study equation for estimating glomerular filtration rate with standardized serum creatinine values. *Clin Chem* 2007; **53**:766-72.
- Matsushita K, *et al*. Comparison of risk prediction using the CKD-EPI equation and the MDRD study equation for estimated glomerular filtration rate. *J Am Med Assoc* 2012; **307**:1941-51.
- Skali H, *et al*. Prognostic assessment of estimated glomerular filtration rate by the new Chronic Kidney Disease Epidemiology Collaboration equation in comparison with the Modification of Diet in Renal Disease Study equation. *Am Heart J* 2011; **162**:548-54.

Examples

```
# Comparison between different equations

creat <- c(0.8, 0.9, 1.0, 1.1, 1.2, 1.3)
cyst  <- c(1.1, 0.95, 1.1, 1.0, 1.3, 1.2)
sex <- c(1, 1, 1, 0, 0, 0)
age <- c(60, 65, 43, 82, 71, 55)
ethn <- round(runif(6))
wt <- c(70, 80, 60, 55, 87, 71)

eGFR <- data.frame(creat, cyst)
eGFR$MDRD4 <- MDRD4(creat, sex, age, ethn, 'IDMS')
eGFR$CKDEpi.creat <- CKDEpi.creat(creat, sex, age, ethn)
eGFR$CKDEpi.creat.rf <- CKDEpi.creat.rf(creat, sex, age)
eGFR$CKDEpi.cys <- CKDEpi.cys(cyst, sex, age)
eGFR$CKDEpi.creat.cys <- CKDEpi.creat.cys(creat, cyst, sex, age, ethn)
eGFR$CKDEpi.creat.cys.rf <- CKDEpi.creat.cys.rf(creat, cyst, sex, age)
eGFR$Stevens.cys1 <- Stevens.cys1(cyst)
eGFR$Stevens.cys2 <- Stevens.cys2(cyst, sex, age, ethn)
eGFR$Stevens.creat.cys <- Stevens.creat.cys(creat, cyst, sex, age, ethn)
eGFR$cg <- CG(creat, sex, age, wt)
eGFR$virga <- Virga(creat, sex, age, wt)
```

```
pairs(eGFR[,3:13])

# For use with non-IDMS calibrated creatinine
# several authors (see references) suggested
# a 5% creatinine adjustment

creat <- c(0.8, 0.9, 1.0, 1.1, 1.2, 1.3)
sex <- c(1, 1, 1, 0, 0, 0)
age <- c(60, 65, 43, 82, 71, 55)
ethn <- round(runif(6))
gfr <- CKDEpi.creat(0.95*creat, sex, age, ethn)
```

CG *Cockroft and Gault equation*

Description

Creatinine clearance is estimated with the Cockroft and Gault formula.

Usage

```
CG(creatinine, sex, age, wt)
```

Arguments

creatinine	Numeric vector with serum or plasma creatinine values in mg/dl
sex	Numeric vector with 0 for females and 1 for males
age	Numeric vector with age in years
wt	Numeric vector with weight in kg

Value

A numeric vector with eGFR values in ml/min/1.73 m^2.

Author(s)

Cristian Pattaro

References

Cockroft DW, Gault MH. Prediction of creatinine clearance from serum creatinine. *Nephron* 1976; **16**: 31-41.

See Also

CKDEpi.creat, MDRD4, Virga

CKDEpi.creat	*CKD-EPI equation for serum creatinine*

Description

GFR is estimated with the CKD-EPI Study equation based on IDMS serum or plasma creatinine.

Usage

```
CKDEpi.creat(creatinine, sex, age, ethnicity)
```

Arguments

creatinine	Numeric vector with serum or plasma creatinine values in mg/dl
sex	Numeric vector with 0 for females and 1 for males
age	Numeric vector with age in years
ethnicity	Numeric vector with 0 for non-Black and 1 for Black individuals

Value

A numeric vector with eGFR values in ml/min/1.73 m^2.

Author(s)

Cristian Pattaro

References

Inker LA, *et al*. Estimating glomerular filtration rate from serum creatinine and cystatin C. *N Engl J Med* 2012; **367**: 20-29.

See Also

CKDEpi.creat.cys, CKDEpi.cys, CKDEpi.creat.rf, CKDEpi.creat.cys.rf

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CKDEpi.creat.cys   *CKD-EPI equation for creatinine and cystatin C*

Description

CKD-EPI equation to estimate GFR based on a combination of creatinine and cystatin C

Usage

```
CKDEpi.creat.cys(creatinine, cystatin, sex, age, ethnicity)
```

Arguments

creatinine	Numeric vector with serum or plasma creatinine values in mg/dl
cystatin	Numeric vector with serum or plasma cystatin C values in mg/dl
sex	Numeric vector with 0 for females and 1 for males
age	Numeric vector with age in years
ethnicity	Numeric vector with 0 for non-Black and 1 for Black individuals

Value

A numeric vector with eGFR values in ml/min/1.73 m^2.

Author(s)

Cristian Pattaro

References

Inker LA, *et al*. Estimating glomerular filtration rate from serum creatinine and cystatin C. *N Engl J Med* 2012; **367**: 20-29.

See Also

CKDEpi.creat, CKDEpi.cys, CKDEpi.creat.rf, CKDEpi.creat.cys.rf

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CKDEpi.creat.cys.rf *CKD-EPI equation for serum creatinine and cystatin C without race coefficient*

Description

CKD-EPI equation to estimate GFR based on a combination of creatinine and cystatin C without race coefficient

Usage

```
CKDEpi.creat.cys.rf(creatinine, cystatin, sex, age)
```

Arguments

creatinine   Numeric vector with serum or plasma creatinine values in mg/dl

cystatin   Numeric vector with serum or plasma cystatin C values in mg/l

sex   Numeric vector with 0 for females and 1 for males

age   Numeric vector with age in years

Value

A numeric vector with eGFR values in ml/min/1.73 m^2.

Author(s)

Ryosuke Fujii

References

Inker LA, *et al.* New creatinine- and cystatin C-based equations to estimate GFR without race. *N Engl J Med* 2021; **385**: 1737-1749.

See Also

CKDEpi.creat, CKDEpi.creat.cys, CKDEpi.cys, CKDEpi.creat.rf

CKDEpi.creat.rf   *CKD-EPI equation for serum creatinine without race coefficient*

Description

GFR is estimated with the CKD-EPI Study equation based on serum creatinine without race coefficient.

Usage

```
CKDEpi.creat.rf(creatinine, sex, age)
```

Arguments

creatinine	Numeric vector with serum or plasma creatinine values in mg/dl
sex	Numeric vector with 0 for females and 1 for males
age	Numeric vector with age in years

Value

A numeric vector with eGFR values in ml/min/1.73 m^2.

Author(s)

Ryosuke Fujii

References

Inker LA, *et al.* New creatinine- and cystatin C-based equations to estimate GFR without race. *N Engl J Med* 2021; **385**: 1737-1749.

See Also

CKDEpi.creat, CKDEpi.creat.cys, CKDEpi.cys, CKDEpi.creat.cys.rf

---

CKDEpi.cys   *CKD-EPI equation for cystatin C*

Description

GFR is estimated with the CKD-EPI equation for cystatin C proposed by Inker et al., N Engl J Med 2012

Usage

```
CKDEpi.cys(cystatin, sex, age)
```

Arguments

cystatin	Numeric vector with serum or plasma cystatin C values in mg/l
sex	Numeric vector with 0 for females and 1 for males
age	Numeric vector with age in years

Value

The function returns a numeric vector with eGFR values in ml/min/1.73 m^2.

Author(s)

Cristian Pattaro

References

Inker LA, *et al*. Estimating glomerular filtration rate from serum creatinine and cystatin C. *N Engl J Med* 2012; **367**: 20-29.

See Also

CKDEpi.creat, CKDEpi.creat.cys, CKDEpi.creat.rf, CKDEpi.creat.cys.rf

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MDRD4	*Four-parameter MDRD study equation*

Description

GFR is estimated with the 4-parameter Modification of Diet in Renal Disease (MDRD) study equation.

Usage

```
MDRD4(creatinine, sex, age, ethnicity, method = "IDMS")
```

Arguments

creatinine	Numeric vector with serum or plasma creatinine values in mg/dl
sex	Numeric vector with 0 for females and 1 for males
age	Numeric vector with age in years
ethnicity	Numeric vector with 0 for non-Black and 1 for Black individuals
method	Defaults is 'IDMS' for IDMS-traceable creatinine; write 'other' if not IDMS

Value

A numeric vector with eGFR values in ml/min/1.73 m^2.

Author(s)

Cristian Pattaro

References

Levey AS, *et al*. A more accurate method to estimate glomerular filtration rate from serum creatinine: a new prediction equation. Modification of Diet in Renal Disease Study Group. *Ann Intern Med*. 1999; **130**(6): 461-70.

Levey AS, *et al*. Using standardized serum creatinine values in the modification of diet in renal disease study equation for estimating glomerular filtration rate. *Ann Intern Med.* 2006; **145**: 247-254.

See Also

CKDEpi.creat, MDRD6, CG

MDRD6   *Six-parameter MDRD study equation*

Description

GFR is estimated with the 6-parameter Modification of Diet in Renal Disease (MDRD) study equation.

Usage

```
MDRD6(creatinine, sex, age, albumin, BUN, ethnicity, method = 'IDMS')
```

Arguments

creatinine	Numeric vector with serum or plasma creatinine values in mg/dl
sex	Numeric vector with 0 for females and 1 for males
age	Numeric vector with age in years
albumin	Numeric vector with serum or plasma albumin in g/dl
BUN	Numeric vector with blood urea nitrogen levels in mg/dl
ethnicity	Numeric vector with 0 for non-Black and 1 for Black individuals
method	Defaults is 'IDMS' for IDMS-traceable creatinine; write 'other' if not IDMS

Value

A numeric vector with eGFR values in ml/min/1.73 m^2.

Author(s)

Cristian Pattaro

References

Levey AS, *et al*. A more accurate method to estimate glomerular filtration rate from serum creatinine: a new prediction equation. Modification of Diet in Renal Disease Study Group. *Ann Intern Med.* 1999; **130**(6): 461-70.

Levey AS, *et al*. Using standardized serum creatinine values in the modification of diet in renal disease study equation for estimating glomerular filtration rate. *Ann Intern Med*. 2006; **145**: 247-254.

See Also

MDRD4

Stevens.creat.cys	*Stevens' formula for a combination of serum creatinine and cystatin C*

Description

GFR estimation using the 3rd formula proposed by Stevens et al. (Am J Kidney Dis 2008), which combines creatinine and cystatin C

Usage

```
Stevens.creat.cys(creatinine, cystatin, sex, age, ethnicity)
```

Arguments

creatinine	Numeric vector with serum or plasma creatinine values in mg/dl
cystatin	Numeric vector with serum or plasma cystatin C values in mg/l
sex	Numeric vector with 0 for females and 1 for males
age	Numeric vector with age in years
ethnicity	Numeric vector with 0 for non-Black and 1 for Black individuals

Value

The function returns a numeric vector with eGFR values in ml/min/1.73 m^2.

Author(s)

Cristian Pattaro

References

Stevens LA, *et al*. Estimating GFR using serum cystatin C alone and in combination with serum creatinine: a pooled analysis of 3,418 individuals with CKD. *Am J Kidney Dis* 2008; **51**: 395-406.

See Also

CKDEpi.creat.cys

Stevens.cys1   *GFR estimation using serum cystatin C*

Description

GFR is estimated with the 1st formula proposed by Stevens et al. (Am J Kidney Dis 2008), i.e.: as a simple transformation of cystatin C, without using any other information

Usage

```
Stevens.cys1(cystatin)
```

Arguments

cystatin   Numeric vector with serum or plasma cystatin C values in mg/l

Value

A numeric vector with eGFR values in ml/min/1.73 m^2.

Author(s)

Cristian Pattaro

References

Stevens LA, *et al.* Estimating GFR using serum cystatin C alone and in combination with serum creatinine: a pooled analysis of 3,418 individuals with CKD. *Am J Kidney Dis* 2008; **51**: 395-406.

See Also

Stevens.cys2, Stevens.creat.cys, CKDEpi.cys

Stevens.cys2   *Stevens' formula for serum cystatin C, age, and sex*

Description

GFR is estimated with the 2nd formula proposed by Stevens et al. (Am J Kidney Dis 2008), where cystatin C is weighted by sex and age

Usage

```
Stevens.cys2(cystatin, sex, age, ethnicity)
```

Arguments

cystatin	Numeric vector with serum or plasma cystatin C values in mg/l
sex	Numeric vector with 0 for females and 1 for males
age	Numeric vector with age in years
ethnicity	Numeric vector with 0 for non-Black and 1 for Black individuals

Value

A numeric vector with eGFR values in ml/min/1.73 m^2.

Author(s)

Cristian Pattaro

References

Stevens LA, *et al.* Estimating GFR using serum cystatin C alone and in combination with serum creatinine: a pooled analysis of 3,418 individuals with CKD. *Am J Kidney Dis* 2008; **51**: 395-406.

See Also

Stevens.cys1, Stevens.creat.cys, CKDEpi.cys

Virga	*Virga's formula*

Description

Virga's formula is based on serum creatinine, sex, age, and body weight.

Usage

```
Virga(creatinine, sex, age, wt)
```

Arguments

creatinine	Numeric vector with serum or plasma creatinine values in mg/dl
sex	Numeric 0/1 vector: 0 for females, 1 for males
age	Numeric vector with age in years
wt	Numeric vector with weight in kg

Value

A numeric vector with eGFR values in *ml/min/1.73 m^2*

Author(s)

Cristian Pattaro

References

Virga G, *et al*. A new equation for estimating renal function using age, body weight and serum creatinine. *Nephron Clin Pract* 2007; **105**: c43-53.

See Also

CG, MDRD4

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