

## Package 'measlesCFR'

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**Version 1.0.0**

**Description** A system for estimating measles case fatality ratios (CFRs) at the country, year, and age level for low- and middle-income countries. Users can inform covariate predictors in both/either the historic or future time periods, and the package will provide the resulting measles CFR estimates.

### createHistoricDF()

*Create a historic data frame.*

#### Description

User provides inputs of measles incidence, measles-containing vaccine first-dose (MCV1) coverage, or other covariates for the historic period. The function will standardize the provided covariates, rely on default values for any covariates that are not user-specified, and return a data frame that is long by year and wide by covariates.

#### Usage

```
createHistoricDF(country, df_incidence, df_mcv1, df_maternal_education, df_u5mr,  
                 df_prop_urban, df_vitA, ...)
```

#### Arguments

country	The three-digit ISO3 code for the country in which to estimate measles CFRs. See Details for how to set this up as a loop for multiple countries.
df_incidence	Optional parameter. A country-specific numeric vector of measles incidence that is long by year. Values must be non-negative.
df_mcv1	Optional parameter. A country-specific numeric vector of MCV1 coverage that is long by year. Values are bounded between 0 and 1.
df_maternal_education	Optional parameter. A country-specific numeric vector of maternal educational attainment that is long by year. Values must be bounded between 0 and 18 years.
df_u5mr	Optional parameter. A country-specific numeric vector of under-five mortality rate (per 1000) that is long by year. Values must be non-negative.
df_prop_urban	Optional parameter. A country-specific numeric vector of proportion of population living in urban settings that is long by year. Values must be between 0 and 1.

df_vitA	Optional parameter. A country-specific numeric vector of vitamin A deficiency prevalence that is long by year. Values must be between 0 and 1.
bound_sample_range	Boolean value (TRUE/FALSE). If set to FALSE (set as default), the package will provide measles CFR estimates with an accompanying warning. The sample bounds will be applied to any visualizations that display covariates in other package functions. If TRUE, the package will restrict user-specified covariate values to the sample range that the model was fit to [see Details].

### Details

First, this function transforms each covariate according to the defined model fit in Sbarra, et al. (2023):

- Untransformed: maternal education, MCV1 coverage, under-5 mortality rate, proportion living in urban setting, vitamin A deficiency prevalence
- Logit transformed: measles incidence

Second, this function standardizes the transformed covariates by subtracting the mean of the covariate and dividing by the standard deviation. Third, the function returns a data frame that is long by year and wide by transformed, standardized covariates.

Across all countries, the sample range for each untransformed, unstandardized covariate is as described below.

Covariate	Minimum value	Maximum value
Measles incidence	0.0000	0.1096
Maternal education	0.2484	13.9316
MCV1 coverage	0.0019	0.99
Under-5 mortality rate (per 1000)	3.1	341.2
Proportion living in urban setting	0.0434	0.9120
Vitamin A deficiency prevalence	0.0042	0.4820

### Value

A data frame of numeric class for the historic period (`historicDF`). The data frame is long by year and wide by covariates.

## Examples

```
# Set local working directory; revise to location of input files
setwd("E:/")
# Load and save relevant input files to working environment
eth_incidence <- read.csv("eth_incidence.csv",header=TRUE)
eth_mcv1 <- read.csv("eth_mcv1.csv",header=TRUE)
# Create historic DF with user-specified incidence and MCV1 coverage
# All other covariates rely on package defaults
eth_historicDF <- createHistoricDF(country="ETH", df_incidence=eth_incidence,
df_mcv1=eth_mcv1)
```

## createProjectionDF()

*Create a projection data frame.*

### Description

User provides inputs of measles incidence, measles-containing vaccine first-dose (MCV1) coverage, or other covariates for the projection period. The projection period can be specified for any end year through the year 2100. The function will standardize the provided covariates, rely on default values for any covariates that are not user-specified, and return a data frame that is long by year and wide by covariates.

### Usage

```
createProjectionDF(country, df_incidence, df_mcv1, df_maternal_education, df_u5mr,
df_prop_urban, df_vitA, ...)
```

### Arguments

country	The three-digit ISO3 code for the country in which to estimate measles CFRs. See Details for how to set this up as a loop for multiple countries.
df_incidence	Optional parameter. A country-specific numeric vector of measles incidence that is long by year. Values must be non-negative.
df_mcv1	Optional parameter. A country-specific numeric vector of MCV1 coverage that is long by year. Values are bounded between 0 and 1.
df_maternal_education	Optional parameter. A country-specific numeric vector of maternal educational attainment that is long by year. Values must be bounded between 0 and 18 years.
df_u5mr	Optional parameter. A country-specific numeric vector of under-five mortality rate (per 1000) that is long by year. Values must be non-negative.
df_prop_urban	Optional parameter. A country-specific numeric vector of proportion of population living in urban settings that is long by year. Values must be between 0 and 1.

df_vitA	Optional parameter. A country-specific numeric vector of vitamin A deficiency prevalence that is long by year. Values must be between 0 and 1.
bound_sample_range	Boolean value (TRUE/FALSE). If set to FALSE (set as default), the package will provide measles CFR estimates with an accompanying warning. The sample bounds will be applied to any visualizations that display covariates in other package functions. If TRUE, the package will restrict user-specified covariate values to the sample range that the model was fit to [see Details].

## Details

First, this function transforms each covariate according to the defined model fit in Sbarra, et al. (2023). Second, this function standardizes the transformed covariates by subtracting the mean of the covariate and dividing by the standard deviation. Third, the function returns a data frame that is long by year and wide by transformed, standardized covariates.

Each covariate is held constant at its 2019 estimated value across the projected time period. Across all countries, the sample range of each untransformed, unstandardized covariate value is as described below.

Covariate	Minimum value	Maximum value
Measles incidence	0.0000	0.0549
Maternal education	1.5164	13.9316
MCV1 coverage	0.37	0.99
Under-5 mortality rate (per 1000)	3.1	118.3
Proportion living in urban setting	0.1325	0.9120
Vitamin A deficiency prevalence	0.0042	0.2644

## Value

A data frame of numeric class for the projection (i.e., future) period (`projectionDF`). The data frame is long by year and wide by covariates.

## Examples

```
# Set local working directory; revise to location of input files
setwd("E:/")
# Load and save relevant input files to working environment
eth_incidence_proj <- read.csv("eth_incidence.csv",header=TRUE)
eth_mcv1_proj <- read.csv("eth_mcv1.csv",header=TRUE)
# Create projection DF with user-specified incidence and MCV1 coverage
# All other covariates rely on package defaults
eth_projectionDF <- createProjectionDF(country="ETH",
df_incidence=eth_incidence_proj, df_mcv1=eth_mcv1_proj)
```

## createInputDF()

*Create a combined input data frame.*

### Description

If historic and/or projection data frames are created by the user, the function will combine user-specified values with default values for the specified time period. If no user-specified data frames are created, the function will rely on default values for the specified time period.

### Usage

```
createInputDF(country, historicDF, projectionDF, historic_include, projection_include, ...)
```

### Arguments

country	The three-digit ISO3 code for the country in which to estimate measles CFRs. See Details for how to set this up as a loop for multiple countries.
historicDF	Optional parameter. Output data frame created by <code>createHistoricDF()</code> .
projectionDF	Optional parameter. Output data frame created by <code>createProjectionDF()</code> .
historic_include	Boolean value (TRUE/FALSE). If set to TRUE, will include default historic Default set to TRUE.
projection_include	Boolean value (TRUE/FALSE). Default set to TRUE.
vaccination_scenario	An indicator to specify whether to estimate CFRs given vaccination (i.e. baseline) or no-vaccination scenario (options: baseline, no_vaccination). Default set to baseline.
start_year	The start year to begin measles CFR estimation. An integer class value that is bounded between 1980 and 2100. <code>start_year</code> cannot be greater than <code>end_year</code> . Default set to 1990.
end_year	The end year through which to estimate measles CFR. An integer class value that is bounded between 1980 and 2100. <code>end_year</code> cannot be less than <code>start_year</code> .

### Details

The function returns the default historic (if `historic_include` is set to `TRUE`) and/or projection (if `projection_include` is set to `TRUE`) data frames as a combined data frame. If the user supplies an historic data frame created by `createHistoricDF()` and/or projection data frame created by `createProjectionDF()`, the function returns the combined data frame of the user-specified data frame objects.

### Value

A data frame of numeric class for the user-specified start to end years. The data frame is long by year and wide by covariates.

### Examples

```
# Create input DF with package defaults for years 2000 to 2030
eth_inputDF_default <- createInputDF(country="ETH", start_year=2000,
end_year=2030)

# Create input DF with user-created historic DF and projection DF
eth_inputDF <- createInputDF(country="ETH", historicDF=eth_historicDF,
projectionDF=eth_projectionDF, historic_include=FALSE,
projection_include=FALSE, vaccination_scenario="baseline", start_year=1980,
end_year=2100)
```

## displayCovariates()

*Visually display covariates in individual plots.*

### Description

In a multi-panel plot object, each set of covariate values is visually displayed over time (i.e., by calendar year) from the start year to end year specified. Covariate values can be user-specified through the use of the `createHistoricDF`, `createProjectionDF`, and `createInputDF` functions, or can rely on default covariate values.

### Usage

```
displayCovariates(country, inputDF = NULL, ...)
```

### Arguments

country	The three-digit ISO3 code for the country in which to estimate measles CFRs. See Details for how to set this up as a loop for multiple countries.
inputDF	Optional parameter. If supplied, the function will display the combination of user-specified and default covariate values by year. Each covariate will be displayed in its own plot (i.e., six plots). If no <code>inputDF</code> is supplied, the function will rely on default covariate values.

## Details

The function returns the default (untransformed, unstandardized?) covariate values over time (in calendar years) as a multi-panel plot object. If the user supplies an input data frame created by `createInputDF()`, the function returns the user-specified covariate values over time (in calendar years) as a multi-panel plot object.

## Value

A multi-panel plot of each set of covariate values. The plots are graphed over time (i.e., by calendar year).

## Examples

```
# Examine default covariates
displayCovariates(country="ETH")

# Examine user-specified covariates
displayCovariates(country="ETH", inputDF=eth_inputDF)
```

## predictCFR()

*Predict measles case fatality ratios.*

## Description

For specified years, age, and covariates, the function will provide estimated measles case fatality ratios (CFRs) assuming vaccination or no-vaccination, in community or hospital settings, with specified uncertainty bounds, with or without sampled draws.

## Usage

```
predictCFR(country, inputDF=NULL, ...)
```

## Arguments

country	The three-digit ISO3 code for the country in which to estimate measles CFRs. See Details for how to set this up as a loop for multiple countries.
inputDF	Data frame of input covariates from the <code>createInputDF</code> function that is long by calendar year and single year of age.
vaccination_scenario	An indicator to specify whether to estimate CFRs given vaccination (i.e. baseline) or no-vaccination scenario (options: "baseline", "no_vaccination"). Default set to "baseline".
age_start	The youngest single year of age at which to estimate measles CFR. An integer value that is bounded between 0 and 100. <code>age_start</code> cannot be greater than <code>age_end</code> .
age_end	The oldest single year of age at which to estimate measles CFR. An integer value that is bounded between 0 and 100. <code>age_end</code> cannot be less than <code>age_start</code> .

<code>year_start</code>	The start year to begin measles CFR estimation. An integer class value that is bounded between 1980 and 2100. <code>year_start</code> cannot be greater than <code>year_end</code> .
<code>year_end</code>	The end year through which to estimate measles CFR. An integer class value that is bounded between 1980 and 2100. <code>year_end</code> cannot be less than <code>year_start</code> .
<code>community_indicator</code>	An indicator to specify whether to estimate CFRs given a community or hospital setting (options: 1 for community, 0 for hospital). Default set to 1.
<code>get_draws</code>	Boolean value (TRUE/FALSE). If set to TRUE, the function will output the 1000 draws used to estimate measles CFR uncertainty. If set to FALSE, the function will output the mean, upper bound, and lower bound measles CFR for the specified ages and years. Default set to FALSE.
<code>upper_bound</code>	The upper bound percentile to return for the measles CFR uncertainty interval. A numeric value bounded between 0 and 1. <code>upper_bound</code> cannot be less than <code>lower_bound</code> . Default set to 0.975.
<code>lower_bound</code>	The lower bound percentile to return for the measles CFR uncertainty interval. A numeric value bounded between 0 and 1. <code>lower_bound</code> cannot be greater than <code>upper_bound</code> . Default set to 0.025.

## Details

The function returns estimated measles CFRs over time (by calendar year) from `start_year` to `end_year` according to the supplied input data frame created by `createInputDF()`. The `start_age` must be defined as an integer value between 0 and 100. The `end_age` must be defined as an integer value between 0 and 100. If `vaccination_scenario` is set to “vaccination” (default), the estimated measles CFRs include the measles-containing-vaccine-first-dose (MCV1) coverage covariate, which approximates vaccine coverage at the country level. If `vaccination_scenario` is set to “no-vaccination,” the estimated measles CFRs assume the MCV1 coverage covariate is set to 0% for all countries, which approximates a counterfactual in which no vaccine program has been implemented. If `community_indicator` is set to “community” (default), the estimated measles CFRs are returned for the community-based setting (i.e., CFRs among cases that do not require hospitalization). If `community_indicator` is set to “hospital,” the estimated measles CFRs are returned for the hospital-based setting (i.e., CFRs among cases that require hospitalization).

If `get_draws` is set to “TRUE,” the function will output the 1000 draws used to estimate measles CFR uncertainty. If `get_draws` is set to “FALSE” (default), the function will output the mean, upper bound, and lower bound measles CFR for the specified ages and years. The `upper_bound` percentile must be supplied as a numeric value bounded between 0 and 1 (default set to 0.975).



The lower bound percentile must be supplied as a numeric value bounded between 0 and 1 (default set to 0.025).

The function will return estimated measles CFRs for a single country, defined by the supplied three-digit ISO3 code for the country in which to estimate measles CFRs. In order to set up a loop to return estimates across multiple countries, you must first save a vector of ISO3 codes for your countries of interest as a .CSV file, see Table A.

**Table A. ISO3 codes for running a country loop for selected Southeast Asian countries.**

iso3
BGD
BTN
IDN
IND
LKA
MDV
MMR
NPL
THA
TLS

From your working directory, load your data frame as a .CSV file into your R environment:

```
countries <- read.csv("LMIC_codes.csv", header=TRUE)
```

Run the measlesCFR package as a loop per the following code, revising your inputs and arguments accordingly. This example loops through the above countries for children ages 0 to 4 from years 2000 to 2030, assuming community-based cases given a vaccination program, returning only the mean, upper bound (0.975 percentile), and lower bound (0.025 percentile) estimates.

```
directory <- "C:\" ## your file path
setwd(directory)
covariates <- inputDF() ## your inputDF object

for (i0 in 1:length(countries){
```

```

i <- countries[i0]

output <- predictCFR(country = i, inputDF = covariates,
vaccination_scenario = "baseline", start_age = 0, end_age = 4, year_start =
2000, year_end = 2030, community_indicator=1, get_draws = FALSE, upper_bound =
0.975, lower_bound = 0.025)

write.csv(output,paste0(directory,"output_",i,".csv"), row.names = FALSE)
}

```

## Value

A data frame of numeric class that is long by year and single year of age.

## Examples

```

# Predict CFRs with default covariates
eth_cfr_default <- predictCFR(country="ETH")

# Predict CFRs in the no-vaccination scenario with default covariates
eth_cfr_default_novax <- predictCFR(country="ETH", vaccination_scenario =
"no_vaccination")

# Predict CFRs in a hospital setting with default covariates
eth_cfr_default <- predictCFR(country="ETH", community_indicator=0)

# Predict CFRs for years 2000 to 2030 with default covariates
eth_cfr_default <- predictCFR(country="ETH", year_start=2000, year_end=2030)

# Predict CFRs with user-specified covariates
eth_cfr <- predictCFR(country="ETH", inputDF=eth_inputDF)

# Predict CFRs with user-specified covariates for ages 0 to 14
eth_cfr <- predictCFR(country="ETH", inputDF=eth_inputDF, age_start=0,
age_end=14)

# Predict CFRs with user-specified covariates including all parameter set draws
eth_cfr <- predictCFR(country="ETH", inputDF=eth_inputDF, get_draws=TRUE)

```

## displayAgeCFR()

*Display plots of measles case fatality rate by age.*

## Description

In a multi-panel plot, each single year of age estimated with `predictDF` is visually displayed by calendar year.

## Usage

```
displayAgeCFR(predictDF, ...)
```

## Arguments

predictDF	Data frame object created by <code>predictDF</code> function.
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list_of_years	A list of years obtained with unique values from <code>predictDF</code> function, or a list specified by the user in order to display a subset of years.
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### Details

The function returns a multi-panel plot in which each year of age from `start_age` to `end_age` included in the `predictDF()` object is graphed over calendar year. If no `year_list` is supplied, the function will return plots with `start_year` and `end_year` defined according to the `predictDF()` object; otherwise, a list of years can be passed to the function in order to display the relevant calendar years. If `plot_uncertainty` is set to "TRUE" (default), the multi-panel plots will incorporate uncertainty intervals based on the defined `upper_bound` and `lower_bound` percentiles in the `predictDF()` object. If `plot_uncertainty` is set to "FALSE," the multi-panel plots will only include estimated mean CFRs over time.

### Value

A multi-panel plot of estimated measles CFR by single year of age. The plots are graphed over time (i.e., by calendar year) for the specified time period.

### Examples

```
# Examine predicted CFRs using predictions based on default covariates
# Rely on list of years generated through unique values in dataframe
displayAgeCFR(predictDF=eth_cfr_default)

# Examine predicted CFRs for years 2000 to 2030
displayAgeCFR(predictDF=eth_cfr, list_of_years=c(seq(2000,2030,1)))
```

## displayTimeCFR()

*Display plots of measles case fatality rate over time (i.e., by calendar year).*

### Description

In a multi-panel plot, each calendar estimated with `predictDF` is visually displayed by single year of age.

### Usage

```
displayTimeCFR(predictDF, ...)
```

### Arguments

predictDF	Data frame object created by <code>predictDF</code> function.
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<code>list_of_ages</code>	A list of single-year ages obtained with unique values from <code>predictDF</code> function, or a list specified by the user in order to display a subset of ages.
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### Details

The function returns a multi-panel plot in which each calendar year from `start_year` to `end_year` included in the `predictDF()` object is graphed for single-year age groups. If no `age_list` is supplied, the function will return plots with `start_age` and `end_age` defined according to the `predictDF()` object; otherwise, a list of single-year ages can be passed to the function in order to display the relevant age groups. If `plot_uncertainty` is set to "TRUE" (default), the multi-panel plots will incorporate uncertainty intervals based on the defined `upper_bound` and `lower_bound` percentiles in the `predictDF()` object. If `plot_uncertainty` is set to "FALSE," the multi-panel plots will only include estimated mean CFRs by age.

### Value

A multi-panel plot of estimated measles CFR by calendar year. The plots are graphed by single year of age for the specified ages.

### Examples

```
# Examine predicted CFRs using predictions based on default covariates
# Rely on list of ages generated through unique values in dataframe
displayTimeCFR(predictDF=eth_cfr_default)

# Examine predicted CFRs for ages 0 to 14
displayAgeCFR(predictDF=eth_cfr, list_of_ages=c(seq(0,14,1)))
```