Package 'bw'

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Title Dynamic Body Weight Models for Children and Adults

Description
Implementation of the dynamic weight change models for adults from ``The Dynamics of Human Body Weight Change'' by CC. Chow and KD. Hall (2008) <doi:10.1371/journal.pcbi.1000045>. As well as the children weight change model from ``Dynamics of childhood growth and obesity: development and validation of a quantitative mathematical model'' by KD. Hall, NF. Butte, BA. Swinburn, and CC. Chow (2013) <doi:10.1016/S2213-8587(13)70051-2>. These model the physiological processes related to weight change in each individual by considering each of the biological processes involved. This package was developed under funding by Bloomberg Philanthropies.

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R topics documented:

`adult_bmi` *Get BMI prevalence results from Adult Weight Change Model*

Description

Gets survey proportions `svytable`, standard error and confidence interval estimates of BMI from `adult_weight`.

Usage

```
adult_bmi(weight, days = seq(0, length(weight[["Time"]]) - 1, length.out =
  25), group = rep(1, nrow(weight[["BMI_Category"]])),
  design = svydesign(ids = ~1, weights = rep(1,
  nrow(weight[["BMI_Category"]])), data =
  as.data.frame(weight[["BMI_Category"]])), confidence = 0.95)
```

Arguments

`weight`	(list) List from `adult_weight`
	Optional
`days`	(vector) Vector of days in which to compute the estimates
`group`	(vector) Variable in which to group the results.
`design`	A `survey.design` object. See `svydesign` for additional information on design objects.
`confidence`	(numeric) Confidence level (`default = 0.95`)

Details

The default `design` is that of simple random sampling.

Author(s)

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Examples

```
#EXAMPLE 1: RANDOM SAMPLE MODELLING
#-------------------------------------------------------

#Antropometric data
weights <- c(45, 67, 58, 67, 81)
heights <- c(1.30, 1.73, 1.77, 1.92, 1.73)
ages    <- c(45, 23, 66, 44, 23)
sexes   <- c("male", "female", "female", "male", "male")

#Matrix of energy consumption reduction:
EIchange <- rbind(rep(-100, 365), rep(-200, 365), rep(-200, 365),
                  rep(-123, 365), rep(-50, 365))
```

```
#Create weight change model
model_weight <- adult_weight(weights, heights, ages, sexes,
                             EIchange)

#Calculate proportions
adult_bmi(model_weight)

#EXAMPLE 2: Survey data
#-----------------------------------------------------
set.seed(7423)

#Data frame for use in survey
probs   <- runif(10, 20, 60)
datasvy <- data.frame(
  id    = 1:10,
  bw    = runif(10,60,90),
  ht    = runif(10, 1.5, 2),
  age   = runif(10, 18, 80),
  sex   = sample(c("male","female"),10, replace = TRUE),
  kcal  = runif(10, 2000, 3000),
  group = sample(c(0,1), 10, replace = TRUE),
  svyw  = probs/sum(probs))

#Days to model
days <- 365

#Energy intake matrix
EIchange <- matrix(NA, ncol = days, nrow = 0)
for(i in 1:nrow(datasvy)){
    EIchange <- rbind(EIchange, rep(datasvy$kcal[i], days))
}

#Calculate weight change
weight <- adult_weight(datasvy$bw, datasvy$ht, datasvy$age,
                         datasvy$sex, EIchange)


#Create survey design using survey package
design <- survey::svydesign(id = ~id, weights = datasvy$svyw,
data = datasvy)

#' #Group to calculate means
group  <- datasvy$group

#Calculate survey mean and variance for 25 days
adult_bmi(weight, design = design, group = group)
```

`adult_weight` *Dynamic Adult Weight Change Model*

Description

Estimates weight change given energy and sodium intake changes at individual level.

Usage

```
adult_weight(bw, ht, age, sex, EIchange = matrix(0, ncol =
  abs(ceiling(days/dt)), nrow = length(bw)), NAchange = matrix(0, ncol =
  abs(ceiling(days/dt)), nrow = length(bw)), EI = NA, fat = rep(NA,
  length(bw)), PAL = rep(1.5, length(bw)), pcarb_base = rep(0.5,
  length(bw)), pcarb = pcarb_base, days = 365, dt = 1,
  checkValues = TRUE)
```

Arguments

bw	(vector) Body weight for model (kg)
ht	(vector) Height for model (m)
age	(vector) Age of individual (yrs)
sex	(vector) Sex either "female" or "male"
EIchange	(matrix) Matrix of caloric intake change (kcals)
NAchange	(matrix) Vector of sodium intake change (mg)
	Optional
EI	(vector) Energy Intake at Baseline.
fat	(vector) Vector containing fat mass. Recall that
PAL	(vector) Physical activity level.
pcarb_base	(vector) Percent carbohydrates at baseline.
pcarb	(vector) Percent carbohydrates after intake change.
days	(double) Days to run the model.
dt	(double) Time step for model; default 1 day (dt = 1)
checkValues	(boolean) Check whether the values from the model are biologically feasible.

Details

EIchange and NAchange must be consumption change matrices. Each row should represent consumption at each day. That is, each row of EIchange and NAchange represents a day in consumption change since baseline. Consumption change is non-cummulative and it's all from baseline. As an example, EIchange <- rep(-100, 50) represents that each day -100 kcals are reduced from consumption.

Author(s)

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References

Chow, Carson C, and Kevin D Hall. 2008. *The Dynamics of Human Body Weight Change.* PLoS Comput Biol 4 (3):e1000045.

Hall, Kevin D. 2010. *Predicting Metabolic Adaptation, Body Weight Change, and Energy Intake in Humans.* American Journal of Physiology-Endocrinology and Metabolism 298 (3). Am Physiological Soc: E449–E466.

Hall, Kevin D, and Peter N Jordan. 2008. *Modeling Weight-Loss Maintenance to Help Prevent Body Weight Regain.* The American Journal of Clinical Nutrition 88 (6). Am Soc Nutrition: 1495–1503.

Hall, Kevin D, Gary Sacks, Dhruva Chandramohan, Carson C Chow, Y Claire Wang, Steven L Gortmaker, and Boyd A Swinburn. 2011. *Quantification of the Effect of Energy Imbalance on Bodyweight.* The Lancet 378 (9793). Elsevier: 826–37. *A New Predictive Equation for Resting Energy Expenditure in Healthy Individuals.* The American Journal of Clinical Nutrition 51 (2). Am Soc Nutrition: 241–47.

See Also

model_plot for plotting the results and model_mean for aggregate data estimation. child_weight implements a similar model for children.

Examples

```
#EXAMPLE 1: INDIVIDUAL MODELLING
#-------------------------------------------------------
#For one female in a diet of 100 kcal reduction.
adult_weight(80, 1.8, 40, "female", rep(-100, 365))

#Same female also reducing sodium in -25mg
adult_weight(80, 1.8, 40, "female", rep(-100, 365), rep(-25, 365))

#Same female modelled for 400 days
adult_weight(80, 1.8, 40, "female", rep(-100, 400), rep(-25, 400), days = 400)

#Same female reducing -50 kcals per 100 days and not reducing sodium
kcalvec <-c(rep(-50, 100), rep(-100, 100), rep(-150, 100), rep(-200, 100))
adult_weight(80, 1.8, 40, "female", kcalvec, days = 400)

#Same female with known energy intake
adult_weight(80, 1.8, 40, "female", rep(-100, 365), rep(-25, 365), EI = 2000)

#Same female with known fat mass
adult_weight(80, 1.8, 40, "female", rep(-100, 365), rep(-25, 365), fat = 32)

#Same female with known fat mass and known energy consumption
adult_weight(80, 1.8, 40, "female", rep(-100, 365), rep(-25, 365), EI = 2000, fat = 32)

#EXAMPLE 2: DATASET MODELLING
#-------------------------------------------------------

#Antropometric data
weights <- c(45, 67, 58, 92, 81)
heights <- c(1.30, 1.73, 1.77, 1.92, 1.73)
ages    <- c(45, 23, 66, 44, 23)
sexes   <- c("male", "female", "female", "male", "male")

#Matrix of energy consumption reduction:
EIchange <- rbind(rep(-100, 365), rep(-200, 365), rep(-200, 365),
                  rep(-123, 365), rep(-50, 365))

#Returns a weight change matrix and other matrices
model_weight <- adult_weight(weights, heights, ages, sexes,
                             EIchange)["Body_Weight"][[1]]
```

`child_weight` *Dynamic Children Weight Change Model*

Description

Estimates weight given age, sex, fat mass, and fat free mass,

Usage

```
child_weight(age, sex, FM = child_reference_FFMandFM(age, sex)$FM,
  FFM = child_reference_FFMandFM(age, sex)$FFM, EI = NA,
  richardsonparams = list(K = NA, Q = NA, B = NA, A = NA, nu = NA, C = NA),
  days = 365, dt = 1, checkValues = TRUE)
```

Arguments

`age`	(vector) Age of individual (yrs)
`sex`	(vector) Sex either `"female"` or `"male"`
`FM`	(vector) Fat Mass at Baseline
`FFM`	(vector) Fat Free Mass at Baseline
`EI`	(matrix) Numeric Matrix with energy intake
`richardsonparams`	(list) List of parameters for Richardson's curve for energy. See details.
	Optional
`days`	(numeric) Days to run the model.
`dt`	(double) Time step for Rungue-Kutta method
`checkValues`	(boolean) Checks whether values of fat mass and free fat mass are possible

Details

`richardsonparams` is a named list of parameters: `K`, `A`, `Q`, `C`, `B`, `nu` which result in Richardon's curve:

$$A + \frac{K - A}{(C + Qexp(-B * t))^{1/nu}}$$

The Richardson's curve is another option for modelling the energy intake for a child: by specifying the parameters no energy input is needed; instead Energy is assumed to follow the equation:

$$EI(t) = A + \frac{K - A}{(C + Qexp(-B * t))^{1/nu}}$$

Author(s)

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References

Hall, K. D., Butte, N. F., Swinburn, B. A., & Chow, C. C. (2013). *Dynamics of childhood growth and obesity: development and validation of a quantitative mathematical model*. The Lancet Diabetes & Endocrinology, 1(2), 97-105.

Haschke, F. (1989). *Body Composition During Adolescence.* Body Composition Measurements in Infants and Children. Ross Laboratories Columbus, OH, 76–83.

Fomon, Samuel J, Ferdinand Haschke, Ekhard E Ziegler, and Steven E Nelson. 1982. *Body Composition of Reference Children from Birth to Age 10 Years.* The American Journal of Clinical Nutrition 35 (5). Am Soc Nutrition: 1169–75.

Ellis, Kenneth J, Roman J Shypailo, Steven A Abrams, and William W Wong. 2000. *The Reference Child and Adolescent Models of Body Composition: A Contemporary Comparison.* Annals of the New York Academy of Sciences 904 (1). Wiley Online Library: 374–82.

Deurenberg, Paul, Jan A Weststrate, and Jaap C Seidell. 1991. *Body Mass Index as a Measure of Body Fatness: Age-and Sex-Specific Prediction Formulas.* British Journal of Nutrition 65 (2). Cambridge University Press: 105–14.

Katan, Martijn B, Janne C De Ruyter, Lothar DJ Kuijper, Carson C Chow, Kevin D Hall, and Margreet R Olthof. 2016. *Impact of Masked Replacement of Sugar-Sweetened with Sugar-Free Beverages on Body Weight Increases with Initial Bmi: Secondary Analysis of Data from an 18 Month Double–Blind Trial in Children.* PloS One 11 (7). Public Library of Science: e0159771.

See Also

@adult_weight for the weight change model for adults; model_plot for plotting the results and model_mean for aggregate data estimation.

Examples

```
#EXAMPLE 1: INDIVIDUAL MODELLING
#---------------------------------------------------------
#For one child with default energy intake
child_weight(6,"male")

#For a child with specific energy intake
child_weight(6,"male",2.5, 16, as.matrix(rep(2000, 365)), days = 365)

#Using Richardson's energy
girl <- child_weight(6,"female", days=365, dt = 5,
                     richardsonparams = list(K = 2700, Q = 10,
                     B = 12, A = 3, nu = 4, C = 1))
plot(girl$Body_Weight[1,])

#EXAMPLE 2: DATASET MODELLING
#---------------------------------------------------------
#Antropometric data
FatFree <- c(32, 17.2, 18.8, 20, 24.1)
Fat     <- c(4.30, 2.02, 3.07, 1.12, 2.93)
ages    <- c(10, 6.2, 5.4, 4, 4.1)
sexes   <- c("male", "female", "female", "male", "male")

#With specific energy intake
eintake <- matrix(rep(2000, 365*5), ncol = 5)

#Returns a weight change matrix and other matrices
```

```
model_weight <- child_weight(ages, sexes, Fat, FatFree, eintake)

model_weight_2 <- child_weight(ages, sexes, Fat, FatFree,
                    richardsonparams = list(K = 2700, Q = 10,
                    B = 12, A = 3, nu = 4, C = 1))
```

`energy_build` *Energy Matrix Interpolating Function*

Description

Creates a matrix interpolating energy consumption from measurements at specific moments in time.

Usage

```
energy_build(energy, time, interpolation = "Brownian")
```

Arguments

`energy`	(matrix) Matrix with each row representing an individual and each column a moment in time in which energy was measured. Energy is assumed to be measured at time 0 initially.
`time`	(vector) Vector of times at which the measurements (columns of energy) were made. **Note** that first element of time most always be `0`.
	Optional
`interpolation`	(string) Way to interpolate the values between measurements. Currently supporting `"Linear"`, `"Exponential"`, `"Stepwise_R"`, `"Stepwise_L"`, `"Logarithmic"` and `"Brownian"`.

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See Also

`adult_weight` for weight change in adults and `child_weight` for children weight change.

Examples

```
#EXAMPLE 1: INDIVIDUAL MODELLING
#-------------------------------------------------------

#Get energy consumption
myconsumption <- energy_build(c(0, 200, -500), c(0, 365*2, 365*4), "Linear")
plot(1:(365*4), myconsumption, type = "l")

#Change interpolation to exponential
myexponential <- energy_build(c(0, 200, -500), c(0, 365*2, 365*4), "Exponential")
lines(1:(365*4), myexponential, type = "l", col = "red")
```

```
mystepwise    <- energy_build(c(0, 200, -500), c(0, 365*2, 365*4), "Stepwise_R")
lines(1:(365*4), mystepwise, type = "l", col = "blue")

mystepwise2    <- energy_build(c(0, 200, -500), c(0, 365*2, 365*4), "Stepwise_L")
lines(1:(365*4), mystepwise2, type = "l", col = "green")

mylogarithmic <- energy_build(c(0, 200, -500), c(0, 365*2, 365*4), "Logarithmic")
lines(1:(365*4), mylogarithmic, type = "l", col = "purple")

mybrownian    <- energy_build(c(0, 200, -500), c(0, 365*2, 365*4), "Brownian")
lines(1:(365*4), mybrownian, type = "l", col = "forestgreen")

#EXAMPLE 2: GROUP MODELLING
#-----------------------------------------------------

#Get energy consumption
multiple <- energy_build(cbind(runif(10,1000,2000),
                               runif(10,1000,2000),
                               runif(10,1000,2000)), c(0, 142, 365),
                               "Brownian")
matplot(1:365, t(multiple), type = "l")
```

`model_mean` *Get Mean results from Adult model Change Model*

Description

Gets survey means `svymean`, standard error and confidence interval estimates of `adult_weight` or `child_weight`.

Usage

```
model_mean(model, meanvars = names(model)[-which(names(model) %in% c("Time",
  "BMI_Category", "Correct_Values", "Model_Type"))], days = seq(0,
  length(model[["Time"]]) - 1, length.out = 25), group = rep(1,
  nrow(model[[meanvars[1]]])), design = NA, confidence = 0.95)
```

Arguments

`model`	(list) List from `adult_weight` or `adult_weight`.
	Optional
`meanvars`	(vector) Strings indicating which variables are required to estimate the mean.
`days`	(vector) Vector of days in which to compute the estimates
`group`	(vector) Variable in which to group the results.
`design`	A `survey.design` object. See `svydesign` for additional information on design objects.
`confidence`	(numeric) Confidence level (`default = 0.95`)

Details

The default `design` is that of simple random sampling.

Author(s)

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Examples

```
#EXAMPLE 1A: RANDOM SAMPLE MODELLING FOR ADULTS
#-------------------------------------------------------

#Antropometric data
models <- c(45, 67, 58, 92, 81)
heights <- c(1.30, 1.73, 1.77, 1.92, 1.73)
ages    <- c(45, 23, 66, 44, 23)
sexes   <- c("male", "female", "female", "male", "male")

#Matrix of energy consumption reduction:
EIchange <- rbind(rep(-100, 365), rep(-200, 365), rep(-200, 365),
                  rep(-123, 365), rep(-50, 365))

#Create model change model
model_model <- adult_weight(models, heights, ages, sexes,
                            EIchange)

#Calculate survey mean and variance for 25 days

aggregate_data <- model_mean(model_model)

#You can plot the mean with ci
if(require(ggplot2)){
ggplot(subset(aggregate_data, variable == "Body_Weight")) +
    geom_line(aes(x = time, y = mean)) +
    geom_line(aes(x = time, y = Lower_CI_mean), linetype = "dashed") +
    geom_line(aes(x = time, y = Upper_CI_mean), linetype = "dashed") +
    theme_classic() + xlab("Days") + ylab("Mean Body model (kg)")
}


#EXAMPLE 1C: RANDOM SAMPLE MODELLING FOR CHILDREN
#-------------------------------------------------------
#Antropometric data
FatFree <- c(32, 17.2, 18.8, 20, 24.1)
Fat     <- c(4.30, 2.02, 3.07, 1.12, 2.93)
ages    <- c(10, 6.2, 5.4, 4, 4.1)
sexes   <- c("male", "female", "female", "male", "male")

#Returns a model change matrix and other matrices
model_model <- child_weight(ages, sexes, Fat, FatFree)

#Calculate survey mean and variance for 25 days

aggregate_data <- model_mean(model_model)

#You can plot the mean with ci
if(require(ggplot2)){
ggplot(subset(aggregate_data, variable == "Body_Weight")) +
    geom_line(aes(x = time, y = mean)) +
```

```
    geom_line(aes(x = time, y = Lower_CI_mean), linetype = "dashed") +
    geom_line(aes(x = time, y = Upper_CI_mean), linetype = "dashed") +
    theme_classic() + xlab("Days") + ylab("Mean Body model (kg)")
}


#EXAMPLE 2A: SURVEY DATA FOR ADULTS
#------------------------------------------------------

#Data frame for use in survey
probs   <- runif(10, 20, 60)
datasvy <- data.frame(
  id    = 1:10,
  bw    = runif(10,60,90),
  ht    = runif(10, 1.5, 2),
  age   = runif(10, 18, 80),
  sex   = sample(c("male","female"),10, replace = TRUE),
  kcal  = runif(10, 2000, 3000),
  group = sample(c(0,1), 10, replace = TRUE),
  svyw  = probs/sum(probs))

#Days
days <- 365

#Energy intake matrix
EIchange <- matrix(NA, nrow = 0, ncol = days)
for(i in 1:nrow(datasvy)){
    EIchange <- rbind(EIchange, rep(datasvy$kcal[i], days))
}

#Calculate model change
svymodel <- adult_weight(datasvy$bw, datasvy$ht, datasvy$age,
                         datasvy$sex, EIchange)

#Create survey design using survey package
design <- survey::svydesign(id = ~id, models = datasvy$svyw,
data = datasvy)

#Group to calculate means
group  <- datasvy$group

#Calculate survey mean and variance for 25 days
aggregate_data <- model_mean(svymodel, design = design, group = group)

#You can plot the mean with ci
if(require(ggplot2)){
ggplot(subset(aggregate_data, variable == "Body_Weight")) +
    geom_ribbon(aes(x = time, ymin = Lower_CI_mean, ymax = Upper_CI_mean,
    fill = factor(group)), alpha = 0.25) +
    geom_line(aes(x = time, y = mean, color = factor(group)), size = 2) +
    theme_classic() + xlab("Days") + ylab("Mean Body model (kg)")
}


#EXAMPLE 2A: SURVEY DATA FOR CHILDREN
#------------------------------------------------------
```

```
#Data frame for use in survey
probs   <- runif(10, 20, 60)
datasvy <- data.frame(
  id      = 1:10,
  age     = runif(10, 2, 12),
  sex     = sample(c("male","female"),10, replace = TRUE),
  fat     = runif(10, 2, 10),
  fatfree = runif(10, 8, 15),
  group   = sample(c(0,1), 10, replace = TRUE),
  svyw    = probs/sum(probs))

#Days
days <- 365

#Calculate model change
svymodel <- child_weight(datasvy$age, datasvy$sex, datasvy$fat, datasvy$fatfree)

#Create survey design using survey package
design <- survey::svydesign(id = ~id, models = datasvy$svyw,
data = datasvy)

#Group to calculate means
group  <- datasvy$group

#Calculate survey mean and variance for 25 days
aggregate_data <- model_mean(svymodel, design = design, group = group)

#You can plot the mean with ci
if(require(ggplot2)){
ggplot(subset(aggregate_data, variable == "Body_Weight")) +
    geom_ribbon(aes(x = time, ymin = Lower_CI_mean, ymax = Upper_CI_mean,
    fill = factor(group)), alpha = 0.25) +
    geom_line(aes(x = time, y = mean, color = factor(group)), size = 2) +
    theme_classic() + xlab("Days") + ylab("Mean Body Weight (kg)")
}
```

`model_plot` *Plot Results from Weight Change Model*

Description

Generates a plot for list from `adult_weight` or `child_weight`.

Usage

```
model_plot(model, plotvars = names(model)[-which(names(model) %in% c("Time",
  "BMI_Category", "Age", "Correct_Values", "Model_Type"))], timevar = "Time",
  title = "Hall's model results", ncol = 2)
```

Arguments

`model`	(list) List from `adult_weight` or `child_weight`
	Optional

plotvars	(vector) String vector of the plots to generate (default generates all)
timevar	(string) String indicating which of the variables in model list indicates time.
title	(string) Title of plot collection
ncol	(string) Number of columns to include in plot

Details

It returns a grid object

Author(s)

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Examples

```
#EXAMPLE 1A: INDIVIDUAL MODELLING FOR ADULTS
#-------------------------------------------------------
mymodel <- adult_weight(80, 1.8, 40, "female", rep(-100, 365))

#You can plot all the variables
model_plot(mymodel)

#Or only one of them
model_plot(mymodel, "Body_Weight", ncol = 1)

#EXAMPLE 1C: INDIVIDUAL MODELLING FOR CHILDREN
#-------------------------------------------------------
mymodel <- child_weight(5, "female", 12, 4)

#You can plot all the variables
model_plot(mymodel)

#Or only one of them and specify by age
model_plot(mymodel, "Body_Weight", ncol = 1)

#EXAMPLE 2A: DATASET MODELLING FOR ADULTS
#-------------------------------------------------------

#Antropometric data
models <- c(45, 67, 58, 92, 81)
heights <- c(1.30, 1.73, 1.77, 1.92, 1.73)
ages    <- c(45, 23, 66, 44, 23)
sexes   <- c("male", "female", "female", "male", "male")

#Matrix of energy consumption reduction:
EIchange <- rbind(rep(-100, 365), rep(-200, 365), rep(-200, 365),
                  rep(-123, 365), rep(-50, 365))

#Returns a model change matrix and other matrices
model_model <- adult_weight(models, heights, ages, sexes,
                            EIchange)

#Create all plots
model_plot(model_model)
```

```
#Plot Body Mass Index
model_plot(model_model, "Body_Mass_Index")



#EXAMPLE 2C: DATASET MODELLING FOR CHILDREN
#-----------------------------------------------------------
#Antropometric data
FatFree <- c(32, 17.2, 18.8, 20, 24.1)
Fat     <- c(4.30, 2.02, 3.07, 1.12, 2.93)
ages    <- c(10, 6.2, 5.4, 4, 4.1)
sexes   <- c("male", "female", "female", "male", "male")

#Returns a model change matrix and other matrices
model_model <- child_weight(ages, sexes, Fat, FatFree)

#Create all plots
model_plot(model_model)

#Plot Body Mass Index
model_plot(model_model, "Fat_Mass")
```

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