

# Personal recommendation of potassium and phosphorous intakes for end-stage renal patients

## Supplementary Materials

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### Abstract

This notebook is a supplementary material for the article

This notebook repeats fully the analysis of personal diet recommendations described in the main article. The notebook starts from the collected raw data, prepares it for analysis and estimates personal reaction models with these data. The personal reaction models are combined with the estimation of the current personal diets for constructing personal graphical models. These personal models generate the levels of blood concentrations when a diet is given, they are used in simulating recommended personal diets for reaching predefined normal concentrations. Finally, these personal diet recommendations are compared for showing the divergence among the studied patients.

The notebook execution generates all the figures and tables that are included in the article, and produces also the referenced supplementary figures. The article is accompanied with a PDF rendition of the notebook that shows all the supplementary figures and important parts of the program code so that the analysis can be followed in detail. The executable RMarkdown notebook with data can be found in a public Github repository of the corresponding author.

## Dialysis patient data

The analyzed dataset consists of food records and laboratory measurements from end-stage renal patients in dialysis. Following nutrients are possible considered as predictors of concentrations. Note that we use energy-% of fats and protein as unit in our analysis. This is referred as Table 1 in the main article.

Supplementary Table S 1: Nutrient predictors of the model.

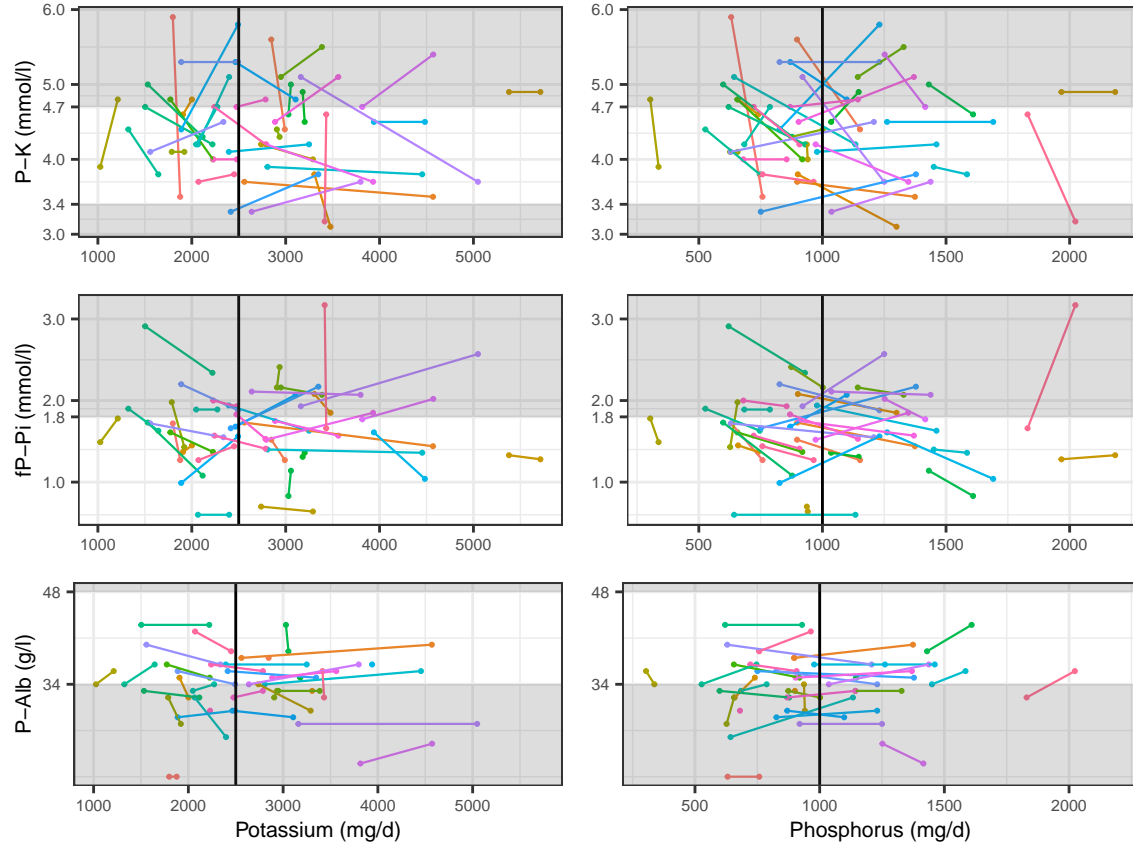
Nutrient	Sample avg. (min-max)
Carbonhydrates, E%	43.6 (27.1 - 63.6) E%
Fat E%	38.9 (23.4 - 54.1) E%
Monounsaturated Fatty Acids, E%	14.7 (5.6 - 25.1) E%
Polyunsaturated Fatty Acids, E%	7.1 (2.2 - 15.8) E%
Protein, E%	15.1 (9.2 - 22.4) E%
Saturated Fatty Acids, E%	13.7 (5.9 - 24.5) E%
Fiber	17 (5 - 42) g/d
Protein, g/kg	0.8 (0.2 - 2.1) g/kg/d
Energy, kcal/kg	21.8 (5.6 - 58.6) kcal/kg
Calsium	570 (123 - 1741) mg/d
Natrium	2588 (813 - 5487) mg/d
<b>Phosphorous</b>	<b>1042 (304 - 2184) mg/d</b>
<b>Potassium</b>	<b>2785 (1026 - 5713) mg/d</b>
Salt	6560 (201 - 13863) mg/d
Water	1804 (601 - 3613) ml/d
Vitamin D	8 (0 - 31) ug/d

and also following personal details and medication are considered as predictors. This is referenced as Table 2 in the article.

Supplementary Table S 2: Personal details that are used as predictors.

Personal detail	Percentage of patients
Blood fat medication	68%
Diabetes medication	51%
Hydroxycholecalciferol	43%
Phosphate binder med.	22%
Renavit	97%
Gender	41% female
Home hemodialysis	24%
Hospital hemodialysis	57%
Peritoneal dialysis	19%

Let us explore then how the intake of dietary potassium and phosphorus corresponds in data to plasma concentrations of potassium, phosphate and albumin



Supplementary Figure S 1: Figure shows the progress between two observations of plasma potassium (P-K), fasting plasma phosphate (fP-Pi) and plasma albumin (P-Alb) concentrations of the studied patients. White regions in the panels show the recommended concentration levels, P-K 3.4 - 4.7 mmol/l, fP-Pi < 1.8 mmol/l and P-Alb 34 - 48 g/l. Vertical black lines denote the commonly recommended maximum intakes of these nutrients. The goal is to find personal intake levels that keep the concentrations in recommended levels, if possible. The figure is plotted with ggplot2 package for R language (v 3.3.5, <https://ggplot2.tidyverse.org>).

Aim of this analysis is to find such personal levels of potassium and phosphorous intakes that keep all these concentrations in their normal levels marked with white regions, if possible.

## Development of nutrition reaction model

In this work we construct personal generative models for concentrations that allow conditioning personal diet recommendations. Essential part of these models is the personal reactions to nutrients and other predictors.

Simultaneous reactions on all considered concentrations are modeled as multivariate model that has all the concentrations are response variables.

For comparison, we estimate multivariate systems with and without cross-model covariance. With cross-model covariance estimated, the model corresponds to seemingly unrelated model system, and without the model is Bayesian network with separated local distributions. This simpler model is estimated first with only potassium and phosphorous concentrations as responses.

```
initial_graph <- mebn.fully_connected_bipartite_graph(datadesc_fat_epros)

pk_fppi_targets <- datadesc_fat_epros[datadesc_fat_epros$Name %in% c('pk','fppi'),]

dialdiet_gamma <- mebn.bipartite_model(reaction_graph = initial_graph,
                                     inputdata = dialysis,
                                     predictor_columns = assumedpredictors_fat_epros,
                                     assumed_targets = pk_fppi_targets,
                                     group_column = "potilas",
                                     local_estimation = mebn.sampling,
                                     local_model_cache = "models/BLMM_gamma_separate",
                                     stan_model_file = "mebn/v2/BLMM_gamma.stan",
                                     normalize_values = TRUE)

# Write the generated graph in a GraphML file
write.graph(dialdiet_gamma, "graphs/dialysis_gamma_separate.graphml", "graphml")
```

In Bayesian network both responses were estimated separately. Next, we estimate a multivariate model where both distribution are estimated during single sampling. It does not factorize into separate distributions, but allows using more data.

```
##
## Attaching package: 'igraph'

## The following object is masked from 'package:tidyr':
##
##   crossing

## The following objects are masked from 'package:dplyr':
##
##   as_data_frame, groups, union

## The following objects are masked from 'package:lubridate':
##
##   %--%, union

## The following objects are masked from 'package:stats':
##
##   decompose, spectrum

## The following object is masked from 'package:base':
##
##   union
```

```
dialdiet_gamma_mv2_epros <- mebn.bipartite_multivariate(reaction_graph = initial_graph,
  inputdata = dialysis,
  predictor_columns = assumedpredictors_fat_epros,
  assumed_targets = pk_fppi_targets,
  group_column = "potilas",
  local_estimation = mebn.multivariate_sampling,
  local_model_cache =
    "models/BLMM_gamma_qr_multivariate2/fat_epros",
  stan_model_file = "mebn/v2/BLMM_gamma_qr_mv.stan",
  normalize_values = TRUE)

write.graph(dialdiet_gamma_mv2_epros,
  "graphs/dialysis_gamma_multivariate2_epros.graphml", "graphml")
```

Next we like to add plasma albumin concentration as a third constraint in the model, but unfortunately 8 of 37 patients have missing albumin measurements. From such a small dataset we don't want to remove any patients and so we predict the missing albumin levels and impute them to dataset.

For prediction, estimate the model without missing values in P-Alb. The rows with missing values are held out from the density estimation, but patients are kept in the model for estimating their parameters.

```
pk_fppi_palb_targets <-
  datadesc_fat_epros[datadesc_fat_epros$Name %in% c('pk','fppi','palb'),]

# 0/1-index for palb = NA
holdout_index <- as.vector(as.numeric(is.na(dialysis$palb)))

# Stan does not support NA in data (in Y), so let's change NA to magic number
if (anyNA(dialysis$palb)) dialysis[is.na(dialysis$palb),]$palb <- -1

initial_graph <- mebn.fully_connected_bipartite_graph(datadesc_fat_epros)

dialdiet_gamma_mv3_missing_palb <- mebn.bipartite_multivariate(
  reaction_graph = initial_graph,
  inputdata = dialysis,
  targetdata = holdout_index,
  predictor_columns = assumedpredictors_fat_epros,
  assumed_targets = pk_fppi_palb_targets,
  group_column = "potilas",
  local_estimation = mebn.multivariate_sampling,
  local_model_cache =
    "models/BLMM_gamma_qr_multivariate3/fat_epros_missing_palb",
  stan_model_file = "mebn/v2/BLMM_gamma_qr_mv_cv.stan",
  normalize_values = TRUE)
```

## Personal data imputation models

Now we can create personal models for patients that have missing plasma albumin measurements. These models are then used for making personal predictions for replacing missing values.

```

# Extract personal generative models for patients who have missing P-Alb values

patients_with_missing_palb <- unique(as.vector(dialysis[is.na(dialysis$palb),]$potilas))

# - initial graph structure
initial_graph <- mebn.fully_connected_bipartite_graph(datadesc_fat_epros)

# - previously estimated graphical model with all the persons
local_distributions <- pk_fppi_palb_targets
local_distributions$modelcache <-
  "models/BLMM_gamma_qr_multivariate3/fat_epros_missing_palb"

# - get personal data, normalized and original

# - statistics for vertex levels are calculated from normalized data
predictors <- nrow(assumedpredictors_fat_epros)
normalized_input <- sapply(1:predictors, mebn.scale_gaussians,
  data = dialysis, datadesc = assumedpredictors_fat_epros)
normalized_input_df <- as.data.frame(normalized_input)

datadesc <- datadesc_fat_epros

```

Then we predict missing values with these data imputing models

```

for (i in 1:nrow(rows_with_missing_palb)) {

  datarow <- rows_with_missing_palb[i,]

  # get model for patient in this datarow

  personal_model_dir <- paste0("data_imputation_models/", datarow$potilas)
  print(paste0("Reading personal data imputation model '", personal_model_dir,
    "/personal_graph.graphml'"))

  personal_graph <- read.graph(paste0(personal_model_dir, "/personal_graph.graphml"), "graphml")

  # and use the data in this row to predict palb
  evidence <- rows_with_missing_palb[i, assumedpredictors_fat_epros$Name]

  posterior_prediction <- mebn.personal_prediction(reaction_graph = personal_graph,
    graph_dir = personal_model_dir,
    evidence = evidence,
    stan_model_file = "diet/posterior_prediction.stan")

  # personal_predictions contains predictions multivariate predictions
  # P-K and fP-Pi are known, but P-Alb is missing

  posterior <- rstan::extract(posterior_prediction, par= "posterior[3]")

  # use predicted posterior mean for missing P-Alb value
  # - this is i:th NA value in dialysis
  predicted_palb <- mean(posterior$posterior[3])
}

```

```

# rows in 'rows_with_missing_palb' and 'original_palb' are in same order
# so we can imput in the NA values at 'original_palb'

for (m in 1:imput_length)
{
  if (is.na(original_palb[m]))
  {
    original_palb[m] <- predicted_palb
    break;
  }
}
}

dialysis2 <- dialysis
dialysis2$palb <- original_palb
saveRDS(dialysis2, "data/DIALYSIS_imputed_palb.rds")

```

With this data imputation we can estimate a cross-covariance model with three responses

```

pk_fppi_palb_targets <- datadesc_fat_epros[datadesc_fat_epros$Name %in% c('pk','fppi','palb'),]

initial_graph <- mebn.fully_connected_bipartite_graph(datadesc_fat_epros)

```

```

dialysis_imputed <- readRDS("data/DIALYSIS_imputed_palb.rds")
no_holdout <- rep(0, nrow(dialysis_imputed))

dialdiet_gamma_mv3 <- mebn.bipartite_multivariate(reaction_graph = initial_graph,
  inputdata = dialysis_imputed,
  targetdata = no_holdout,
  predictor_columns = assumedpredictors_fat_epros,
  assumed_targets = pk_fppi_palb_targets,
  group_column = "potilas",
  local_estimation = mebn.multivariate_sampling,
  local_model_cache =
    "models/BLMM_gamma_qr_multivariate3/imputed_palb",
  stan_model_file = "mebn/v2/BLMM_gamma_qr_mv_cv.stan",
  normalize_values = TRUE)

write.graph(dialdiet_gamma_mv3,
  "graphs/dialysis_gamma_multivariate3_imputed.graphml", "graphml")

```

Finally, we consider also the effect of dialysis treatment type as new level of grouping in data. This allows us to estimate average effects of nutrition for each treatment type and then also personal effects within those treatments.

```

dialysis_imputed <- readRDS("data/DIALYSIS_imputed_palb.rds")

# add the dialysis treatment type as a grouping factor
dialysis_imputed$hoitoryhma <- as.factor(dialysis_imputed$hoitomuoto)

# and sort the data by treatment/patient/observation
dialysis_imputed <- dialysis_imputed[order(dialysis_imputed$hoitoryhma,

```

```

dialysis_imputed$potilas, dialysis_imputed$havainto),]

dialdiet_gamma_mv3_two_level <- mebn.bipartite_two_level_multivariate(
  reaction_graph = initial_graph,
  inputdata = dialysis_imputed,
  targetdata = no_holdout,
  predictor_columns = assumedpredictors_fat_epros,
  assumed_targets = pk_fppi_palb_targets,
  group_column = "hoitoryhma",
  subject_column = "potilas",
  local_estimation = mebn.two_level_multivariate_sampling,
  local_model_cache =
    "models/BLMM_gamma_mv_cross/two_levels",
  stan_model_file =
    "mebn/v2/BLMM_gamma_two_level_grouping.stan",
  normalize_values = TRUE)

write.graph(dialdiet_gamma_mv3_two_level,
  "graphs/dialysis_gamma_two_level_grouping.graphml", "graphml")

```

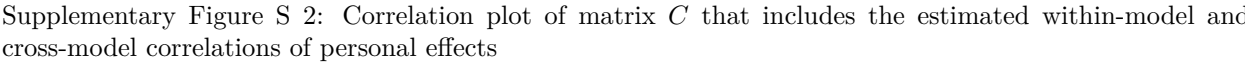
## Model analysis

```

## Scale for 'fill' is already present. Adding another scale for 'fill', which
## will replace the existing scale.

```





Supplementary Table S 3: Table shows 30 highest positive or negative correlations between personal effects of nutrients or other considered predictors. This structure of correlations is used in estimating the personal effects based on personal intake and matching concentrations.

Personal effects of nutrients		
Effect 1	Effect 2	Correlation
Diabetes medication -> P-K	Carbonhydrates, E% -> fP-Pi	0.136
Fiber -> P-K	Hydroxycholecalciferol -> fP-Pi	0.116
Fat E% -> P-K	Natrium -> P-K	0.105
Fat E% -> P-K	Calsium -> fP-Pi	0.102
Diabetes medication -> P-K	fP-Pi level	0.100
Fiber -> fP-Pi	Natrium -> fP-Pi	0.097
Natrium -> fP-Pi	Fiber -> fP-Pi	0.097
Blood fat medication -> P-Alb	Hydroxycholecalciferol-> P-Alb	0.096
Protein, g/kg -> fP-Pi	Blood fat medication-> P-Alb	0.095
Phosphate binder med. -> P-K	Potassium -> fP-Pi	0.094
Carbonhydrates, E% -> P-K	Phosphate binder med. -> fP-Pi	0.093
Phosphate binder med. -> fP-Pi	Carbonhydrates, E% -> P-K	0.093
Blood fat medication -> P-K	Protein, g/kg -> fP-Pi	0.092
Energy, kcal/kg -> P-K	Calsium-> P-Alb	0.092
Gender -> P-Alb	Protein, E% -> P-K	0.092
Energy, kcal/kg -> P-K	Gender -> fP-Pi	-0.092
Gender -> fP-Pi	Energy, kcal/kg -> P-K	-0.092
Blood fat medication -> P-K	Salt -> fP-Pi	-0.094
Natrium -> P-K	Polyunsaturated Fatty Acids, E% -> P-K	-0.094
Phosphate binder med. -> P-K	Phosphate binder med. -> fP-Pi	-0.095
Carbonhydrates, E% -> fP-Pi	Fiber-> P-Alb	-0.100
Saturated Fatty Acids, E% -> P-Alb	Hydroxycholecalciferol-> P-Alb	-0.100
Monounsaturated Fatty Acids, E% -> P-K	Calsium -> fP-Pi	-0.102
Renavit -> fP-Pi	Saturated Fatty Acids, E% -> fP-Pi	-0.103
Potassium -> fP-Pi	Vitamin D -> fP-Pi	-0.104
Diabetes medication -> fP-Pi	Renavit -> fP-Pi	-0.105
Renavit -> P-K	Potassium -> fP-Pi	-0.108
Carbonhydrates, E% -> fP-Pi	Protein, E% -> P-K	-0.108
Protein, g/kg -> P-K	Vitamin D -> fP-Pi	-0.120
Natrium -> P-K	fP-Pi level	-0.133

## Effects of nutrition in both treatment and personal levels

First, we create personal models that include also information of personal treatment

Supplementary Table S 4: Personal graphical models with different reaction model candidates are evaluated with NRMSE for each modelled concentration and average model error.

Reaction model	NRMSE			
	P-K	fP-Pi	P-Alb	average error
mv3_cross_two_levels	0.004	0.007	0.002	0.004
mv3_cross_single_level	0.036	0.13	0.059	0.036

Then, we make a summary from effects of treatment and personal variations within the treatment

## Two level effect summary

This large table in includes all estimated nutrition effects

Table 1: Estimated effects of nutrition in general and dialysis treatment levels, and in personal level within the same treatment.

Nutrient	Conc.	General effect	Home hemodialysis			Hospital hemodialysis			Peritoneal dialysis		
			avg	min	max	avg	min	max	avg	min	max
Water	P-Alb	-0.94 [-1.03; 2.79]	<b>-1.33</b> [-3.96; 2.19]	-2.09 [-5.21; 2.75]	-0.99 [-4.14; 2.37]	<b>-0.43</b> [-2.51; 1.46]	-0.77 [-2.17; 1.47]	0.36 [-3.68; 3.52]	<b>-1.53</b> [-5.03; 3.24]	-2.08 [-5.59; 3.46]	-0.97 [-5.15; 3.14]
Natrium	P-Alb	-2.60 [-0.24; 7.58]	<b>-0.02</b> [-9.95; 7.96]	2.78 [-16.47; 7.74]	0.21 [-6.29; 8.56]	<b>-0.27</b> [-7.82; 7.72]	-1.87 [-13.40; 7.77]	1.34 [-4.12; 8.06]	<b>-6.70</b> [-30.75; 7.59]	-7.97 [-36.19; 8.14]	-5.36 [-24.93; 7.70]
Energy, kcal/kg	P-Alb	3.46 [1.76; 15.59]	<b>2.63</b> [-5.85; 12.96]	1.07 [-6.48; 11.89]	3.59 [-5.90; 14.48]	<b>3.42</b> [-5.54; 14.49]	1.76 [-7.86; 12.96]	4.16 [-4.11; 15.21]	<b>3.49</b> [-5.50; 15.16]	2.91 [-5.71; 15.90]	4.13 [-4.85; 17.20]
Phosphorous	P-Alb	0.24 [0.30; 9.18]	<b>0.83</b> [-0.93; 7.38]	-0.40 [-8.26; 7.29]	1.45 [-6.89; 8.04]	<b>-0.87</b> [-5.55; 6.58]	-2.26 [-8.24; 6.32]	0.61 [-5.61; 7.50]	<b>0.85</b> [-5.63; 9.97]	-0.06 [-6.80; 9.46]	1.79 [-5.14; 11.47]
Diabetes medication	P-Alb	0.98 [2.55; 5.86]	<b>-2.22</b> [-8.21; 7.17]	-2.99 [-9.13; 6.95]	-1.75 [-9.01; 8.29]	<b>0.99</b> [-5.89; 4.66]	0.01 [-7.55; 4.72]	1.73 [-6.02; 6.63]	<b>0.99</b> [-7.53; 10.12]	-0.28 [-10.08; 9.25]	1.26 [-8.79; 10.17]
Renavit	P-Alb	7.67 [10.56; 23.52]	<b>8.89</b> [-11.49; 22.52]	8.78 [-12.02; 22.63]	9.72 [-11.07; 23.87]	<b>5.50</b> [-10.54; 22.08]	4.28 [-10.88; 22.95]	6.86 [-10.28; 22.56]	<b>6.41</b> [-11.66; 22.37]	6.07 [-12.09; 22.46]	7.41 [-11.94; 23.58]
Hydroxycholecalciferol	P-Alb	3.73 [4.17; 10.25]	<b>2.74</b> [-7.13; 9.43]	0.88 [-9.11; 9.33]	2.86 [-9.90; 11.57]	<b>3.01</b> [-4.00; 9.51]	1.68 [-6.12; 7.45]	4.57 [-4.02; 12.35]	<b>2.26</b> [-9.21; 9.34]	1.19 [-10.08; 9.84]	3.46 [-11.16; 14.06]
Potassium	P-Alb	-0.33 [-0.22; 3.86]	<b>-0.97</b> [-0.09; 3.72]	-2.20 [-6.85; 3.35]	0.45 [-7.04; 7.24]	<b>0.22</b> [-2.90; 3.23]	-1.41 [-4.22; 2.72]	1.48 [-1.88; 5.78]	<b>0.90</b> [-3.16; 5.94]	0.12 [-4.47; 5.37]	1.85 [-4.13; 7.86]
Phosphate binder med.	P-Alb	-1.28 [-2.86; 14.60]	<b>-0.19</b> [-9.29; 10.80]	-2.12 [-9.90; 9.54]	1.38 [-10.25; 9.85]	<b>-1.18</b> [-9.01; 6.76]	-4.28 [-12.97; 7.67]	0.51 [-9.86; 8.53]	<b>-0.40</b> [-7.38; 8.54]	-0.58 [-9.27; 10.76]	1.29 [-7.68; 10.11]
Carbonhydrates, E	P-Alb	0.67 [1.37; 4.02]	<b>0.74</b> [-3.17; 3.45]	0.62 [-3.62; 3.69]	0.96 [-3.23; 4.63]	<b>0.89</b> [-2.88; 3.37]	0.63 [-3.18; 3.47]	1.25 [-3.14; 4.96]	<b>0.54</b> [-5.02; 5.33]	0.49 [-4.98; 5.52]	0.66 [-5.10; 5.86]
Fiber											
Gender	P-Alb	-1.11 [0.04; 7.33]	<b>-0.82</b> [-13.78; 6.85]	-2.29 [-17.44; 6.89]	-0.30 [-15.40; 8.63]	<b>2.62</b> [-5.38; 9.55]	1.14 [-7.53; 9.67]	4.31 [-4.49; 16.23]	<b>-1.74</b> [-13.81; 9.41]	-3.39 [-15.65; 7.52]	-0.90 [-13.88; 14.29]
Blood fat medication	P-Alb	-1.17 [-0.48; 9.57]	<b>0.65</b> [-6.05; 13.04]	1.68 [-7.70; 13.61]	1.08 [-6.12; 15.32]	<b>-1.66</b> [-5.63; 4.27]	-2.85 [-9.07; 4.49]	-0.36 [-5.07; 5.04]	<b>1.96</b> [-6.75; 11.86]	2.29 [-8.54; 11.88]	2.29 [-7.17; 11.72]
Blood fat medication	P-K	-1.42 [-1.74; 2.05]	<b>-0.22</b> [-3.30; 3.06]	-0.30 [-3.64; 3.11]	0.02 [-2.97; 3.25]	<b>-0.41</b> [-1.33; 0.90]	-0.53 [-1.69; 0.94]	-0.25 [-1.41; 1.35]	<b>-0.42</b> [-4.45; 1.92]	-0.58 [-5.03; 1.82]	-0.27 [-4.20; 1.92]
Diabetes medication	P-K	-0.77 [-0.09; 1.45]	<b>-1.04</b> [-3.70; 0.93]	-1.17 [-4.67; 1.07]	-0.62 [-3.47; 1.17]	<b>-0.40</b> [-1.97; 0.73]	-0.75 [-3.32; 0.61]	-0.16 [-1.99; 1.31]	<b>-1.64</b> [-3.86; 1.49]	-1.85 [-4.07; 1.40]	-1.39 [-3.59; 1.52]
Gender	P-K	-0.37 [-0.33; 2.45]	<b>0.35</b> [-1.18; 2.54]	-0.32 [-3.71; 2.80]	0.81 [-1.06; 3.10]	<b>0.20</b> [-1.35; 1.39]	-0.35 [-1.89; 1.65]	0.60 [-1.34; 2.32]	<b>0.97</b> [-1.19; 2.77]	0.79 [-1.51; 3.33]	1.34 [-1.38; 3.52]
Carbonhydrates, EFat EWater	P-K	0.03 [0.23; 2.11]	<b>-0.04</b> [-2.09; 0.97]	-0.12 [-2.39; 1.00]	0.07 [-2.23; 1.14]	<b>0.12</b> [-0.44; 0.71]	0.07 [-0.53; 0.63]	0.20 [-0.58; 0.96]	<b>-0.16</b> [-2.92; 1.43]	-0.24 [-3.02; 1.37]	-0.08 [-2.75; 1.61]
Renavit	P-K	2.46 [2.45; 6.63]	<b>2.52</b> [-4.12; 8.39]	2.46 [-4.28; 8.64]	2.77 [-4.03; 9.24]	<b>2.74</b> [-2.38; 6.89]	2.52 [-2.23; 6.82]	3.06 [-2.34; 7.19]	<b>3.20</b> [-2.46; 8.22]	2.88 [-3.27; 7.77]	3.39 [-2.35; 8.18]
Protein, g/kg	P-Alb	-3.36 [-1.96; 4.65]	<b>-6.42</b> [-15.03; 4.12]	-7.96 [-15.10; 4.31]	-4.16 [-13.91; 5.61]	<b>-3.61</b> [-13.13; 4.26]	-6.61 [-13.09; 3.76]	-1.58 [-12.52; 6.91]	<b>-2.80</b> [-17.04; 5.18]	-4.29 [-17.36; 5.47]	-1.43 [-18.18; 10.29]
Monounsaturated Fatty Acids, ECalsium	P-Alb	1.71 [2.37; 7.24]	<b>1.20</b> [-2.27; 6.36]	0.47 [-4.00; 5.89]	1.62 [-2.66; 8.20]	<b>-0.01</b> [-4.83; 3.66]	-0.41 [-5.41; 3.16]	0.71 [-3.47; 4.53]	<b>0.96</b> [-4.96; 6.27]	0.57 [-6.78; 6.68]	1.18 [-5.96; 7.21]
Fat EVitamin D	P-Alb	1.02 [1.80; 4.83]	<b>1.38</b> [-1.70; 3.73]	0.97 [-3.84; 4.93]	2.03 [-1.37; 5.05]	<b>1.26</b> [-0.58; 2.48]	0.99 [-1.99; 3.09]	1.66 [-0.63; 4.42]	<b>1.19</b> [-2.02; 5.15]	0.89 [-3.11; 5.20]	1.40 [-2.86; 6.39]
Phosphorous	P-K	0.18 [0.06; 1.91]	<b>-0.16</b> [-1.65; 1.54]	-0.37 [-2.92; 1.57]	0.08 [-1.29; 2.18]	<b>0.24</b> [-1.20; 1.60]	0.02 [-2.11; 1.51]	0.60 [-0.57; 2.58]	<b>-0.15</b> [-2.42; 1.70]	-0.51 [-3.66; 1.78]	0.09 [-2.12; 2.07]
Hydroxycholecalciferol	P-K	-2.20 [-0.70; 3.33]	<b>-1.44</b> [-5.94; 3.29]	-1.63 [-6.11; 3.32]	-0.23 [-6.09; 4.08]	<b>-0.23</b> [-1.55; 1.43]	-0.56 [-2.90; 1.45]	0.27 [-1.65; 3.95]	<b>-1.41</b> [-5.15; 3.91]	-1.79 [-5.03; 3.53]	-1.29 [-4.99; 4.80]
Polyunsaturated Fatty Acids, ESalt	P-Alb	7.19 [-1.91; 37.18]	<b>1.87</b> [-8.54; 14.87]	1.48 [-9.11; 14.84]	2.14 [-8.25; 14.92]	<b>1.30</b> [-5.87; 7.79]	0.76 [-9.44; 7.59]	1.99 [-3.85; 7.92]	<b>3.87</b> [-9.82; 27.21]	3.68 [-10.66; 27.11]	4.37 [-9.20; 27.28]
Energy, kcal/kg	P-K	-0.23 [-1.01; 5.76]	<b>1.00</b> [-2.34; 5.98]	0.80 [-2.42; 4.79]	1.17 [-2.42; 5.21]	<b>-0.53</b> [-2.72; 4.53]	-0.89 [-3.12; 2.80]	-0.35 [-2.86; 6.97]	<b>-0.75</b> [-4.05; 5.44]	-0.96 [-4.03; 4.68]	-0.56 [-3.88; 6.43]
Natrium	P-K	-1.94 [-0.62; 1.53]	<b>-1.36</b> [-8.97; 1.74]	-1.67 [-9.14; 1.61]	-0.90 [-8.39; 1.95]	<b>-0.57</b> [-1.57; 0.71]	-0.96 [-1.88; 0.66]	-0.23 [-1.57; 0.96]	<b>-1.74</b> [-5.59; 1.06]	-2.18 [-6.16; 1.14]	-1.68 [-5.51; 1.15]
Saturated Fatty Acids, EHydroxycholecalciferol	P-Pi	0.27 [0.27; 2.94]	<b>-0.16</b> [-1.67; 2.17]	-0.33 [-2.38; 2.31]	0.09 [-1.58; 3.70]	<b>0.50</b> [-0.58; 1.66]	0.13 [-1.72; 1.81]	0.77 [-0.44; 1.84]	<b>0.10</b> [-2.28; 1.77]	-0.17 [-3.07; 2.03]	0.28 [-2.39; 2.21]

Table 1: Estimated effects of nutrition in general and dialysis treatment levels, and in personal level within the same treatment (table continues).

Nutrient	Conc.	General effect	Home hemodialysis			Hospital hemodialysis			Peritoneal dialysis		
			avg	min	max	avg	min	max	avg	min	max
Protein, EFiber	IP-Pi	0.49 [0.10; 2.28]	<b>0.12</b> [-0.61; 0.82]	0.04 [-0.75; 0.61]	0.16 [-0.66; 0.78]	<b>-0.15</b> [-0.69; 0.51]	-0.26 [-0.86; 0.49]	-0.09 [-0.60; 0.55]	<b>-0.11</b> [-0.73; 0.99]	-0.16 [-0.80; 0.85]	-0.07 [-0.80; 0.99]
Polyunsaturated Fatty Acids, EMonounsaturated Fatty Acids, ECarbohydrates, E	P-K	1.89 [1.25; 6.13]	<b>1.01</b> [-2.11; 2.99]	-0.60 [-4.01; 3.17]	2.01 [-1.78; 5.02]	<b>0.58</b> [-2.20; 2.63]	-0.34 [-4.75; 2.67]	2.14 [-2.67; 6.54]	<b>0.85</b> [-1.18; 3.46]	-0.61 [-5.61; 4.33]	1.70 [-1.33; 4.36]
Phosphate binder med.	IP-Pi	-0.49 [-0.10; 0.73]	<b>-0.16</b> [-2.09; 1.28]	-0.26 [-2.12; 1.30]	-0.07 [-2.08; 1.55]	<b>-0.23</b> [-1.13; 0.54]	-0.44 [-1.27; 0.51]	-0.09 [-1.22; 0.67]	<b>0.18</b> [-1.65; 1.80]	0.11 [-1.74; 1.82]	0.22 [-1.67; 1.98]
Blood fat medication	P-K	0.04 [0.18; 2.18]	<b>-0.17</b> [-1.88; 2.04]	-0.48 [-2.60; 2.34]	0.24 [-1.00; 2.30]	<b>0.50</b> [-0.69; 1.75]	-0.16 [-1.44; 1.22]	0.84 [-0.63; 2.88]	<b>0.26</b> [-0.83; 2.27]	-0.22 [-1.53; 1.82]	0.63 [-1.01; 2.61]
Phosphate binder med.	IP-Pi	-0.05 [-0.23; 1.67]	<b>-0.18</b> [-1.40; 1.40]	-0.53 [-2.78; 1.76]	0.56 [-1.48; 1.86]	<b>0.10</b> [-1.26; 1.40]	-0.35 [-1.78; 1.72]	0.58 [-1.56; 2.12]	<b>-0.21</b> [-1.34; 1.04]	-0.36 [-1.53; 1.18]	0.04 [-1.88; 1.24]
Protein, g/kg	P-K	0.43 [-0.26; 4.73]	<b>-0.93</b> [-5.97; 2.43]	-1.03 [-6.08; 2.43]	-0.85 [-5.87; 2.44]	<b>-0.01</b> [-5.03; 2.51]	-0.18 [-5.04; 2.62]	0.14 [-4.87; 2.60]	<b>0.42</b> [-2.78; 3.61]	0.29 [-2.77; 3.55]	0.54 [-2.82; 3.50]
Fat EMonounsaturated Fatty Acids, ESaturated Fatty Acids, ECalsium	IP-Pi	-0.01 [-0.39; 2.45]	<b>-0.18</b> [-0.94; 0.74]	-0.26 [-0.91; 0.99]	0.00 [-0.94; 0.88]	<b>-0.20</b> [-0.64; 0.20]	-0.41 [-0.98; 0.18]	0.01 [-0.63; 0.50]	<b>-0.01</b> [-0.98; 1.08]	-0.04 [-1.09; 1.13]	0.18 [-0.95; 1.32]
Phosphorous	IP-Pi	0.02 [0.03; 2.03]	<b>0.00</b> [-1.12; 1.54]	-0.12 [-1.35; 1.40]	0.09 [-1.01; 1.56]	<b>0.03</b> [-1.00; 0.78]	-0.05 [-1.15; 0.81]	0.13 [-0.88; 0.97]	<b>-0.12</b> [-1.66; 1.44]	-0.16 [-1.49; 1.37]	-0.09 [-1.56; 1.47]
Diabetes medication	IP-Pi	-0.24 [-0.31; 1.53]	<b>-0.45</b> [-2.01; 1.01]	-0.66 [-2.46; 1.09]	-0.14 [-1.85; 1.16]	<b>0.09</b> [-0.73; 1.09]	-0.17 [-1.06; 1.14]	0.22 [-0.87; 1.09]	<b>0.64</b> [-1.26; 2.88]	0.60 [-1.32; 2.86]	0.85 [-1.13; 3.00]
Renavit	IP-Pi	-3.72 [-1.64; 2.92]	<b>-1.90</b> [-10.81; 3.65]	-2.01 [-11.83; 3.68]	-1.70 [-9.90; 3.83]	<b>-0.54</b> [-2.69; 2.10]	-0.66 [-2.90; 2.11]	-0.43 [-2.12; 2.23]	<b>-2.77</b> [-14.84; 3.19]	-2.88 [-15.22; 3.15]	-2.71 [-14.52; 3.19]
Potassium	IP-Pi	-0.05 [-0.22; 0.72]	<b>0.13</b> [-0.65; 1.08]	0.01 [-0.81; 1.01]	0.25 [-0.66; 1.58]	<b>-0.07</b> [-0.58; 0.48]	-0.18 [-0.81; 0.47]	0.15 [-0.45; 1.47]	<b>0.17</b> [-0.46; 0.90]	0.15 [-0.63; 1.06]	0.27 [-0.39; 1.37]
Energy, kcal/kg	IP-Pi	0.20 [0.39; 2.00]	<b>0.30</b> [-1.74; 1.79]	0.21 [-1.83; 1.99]	0.43 [-1.63; 2.09]	<b>0.63</b> [-1.09; 1.71]	0.53 [-1.25; 1.60]	0.77 [-0.97; 1.88]	<b>0.48</b> [-2.37; 2.65]	0.42 [-2.55; 2.62]	0.57 [-2.27; 2.65]
Protein, g/kg	IP-Pi	-0.69 [-1.19; 2.13]	<b>-0.55</b> [-1.93; 1.48]	-0.61 [-1.89; 1.52]	-0.49 [-1.84; 1.58]	<b>-0.60</b> [-1.74; 1.19]	-0.75 [-2.09; 1.13]	-0.46 [-1.68; 1.19]	<b>-0.77</b> [-2.30; 1.62]	-0.88 [-2.51; 1.56]	-0.68 [-2.41; 1.70]
Vitamin D	P-K	-0.04 [-0.15; 0.89]	<b>-0.06</b> [-1.10; 0.72]	-0.14 [-1.18; 0.49]	0.22 [-0.85; 1.15]	<b>-0.31</b> [-0.82; 0.19]	-0.49 [-1.61; 0.19]	-0.10 [-0.67; 0.57]	<b>-0.06</b> [-0.73; 0.60]	-0.16 [-1.02; 0.53]	0.12 [-0.75; 0.80]
Fiber	P-K	0.46 [0.54; 2.53]	<b>0.31</b> [-0.77; 1.04]	0.25 [-0.92; 1.07]	0.37 [-0.70; 1.08]	<b>0.17</b> [-0.72; 1.26]	0.01 [-1.36; 0.94]	0.29 [-0.52; 1.84]	<b>0.59</b> [-1.38; 1.93]	0.47 [-1.70; 1.81]	0.66 [-1.55; 2.12]
Potassium	P-K	0.02 [-0.15; 1.95]	<b>-0.03</b> [-1.40; 1.53]	-0.25 [-1.91; 1.01]	0.01 [-1.34; 1.30]	<b>0.17</b> [-0.91; 0.83]	-0.17 [-1.11; 0.55]	0.40 [-1.05; 1.45]	<b>0.00</b> [-1.09; 2.00]	-0.10 [-1.17; 1.81]	0.20 [-1.08; 1.67]
Saturated Fatty Acids, E	IP-Pi	-0.08 [0.19; 0.89]	<b>0.16</b> [-0.49; 0.81]	0.04 [-0.61; 0.85]	0.24 [-0.57; 1.22]	<b>0.16</b> [-0.15; 0.58]	-0.05 [-0.54; 0.66]	0.28 [-0.23; 0.99]	<b>0.12</b> [-1.01; 0.88]	0.04 [-1.21; 0.84]	0.26 [-1.00; 1.17]
Water	IP-Pi	-0.10 [0.08; 1.79]	<b>0.10</b> [-1.41; 1.42]	-0.05 [-1.73; 1.38]	0.19 [-1.40; 1.43]	<b>-0.30</b> [-1.13; 0.78]	-0.50 [-2.01; 0.64]	-0.19 [-1.13; 1.14]	<b>-0.58</b> [-1.89; 0.93]	-0.63 [-2.16; 1.00]	-0.51 [-2.02; 1.35]
Gender	IP-Pi	0.20 [0.58; 1.47]	<b>0.13</b> [-1.71; 1.14]	0.08 [-1.82; 1.15]	0.26 [-1.64; 1.44]	<b>0.39</b> [-0.52; 1.13]	0.30 [-0.66; 0.93]	0.50 [-0.48; 1.39]	<b>0.22</b> [-1.50; 1.89]	0.15 [-1.63; 1.74]	0.27 [-1.53; 2.08]
Polyunsaturated Fatty Acids, EProtein, ENatrium	IP-Pi	0.26 [0.58; 2.59]	<b>1.90</b> [-0.98; 8.85]	1.68 [-0.90; 8.76]	2.14 [-0.92; 9.03]	<b>0.42</b> [-0.61; 1.28]	0.19 [-0.73; 1.37]	0.72 [-0.51; 1.59]	<b>0.81</b> [-2.20; 4.45]	0.57 [-2.43; 4.29]	1.04 [-2.17; 4.50]
Salt	P-K	-0.13 [0.02; 0.36]	<b>-0.10</b> [-0.69; 0.32]	-0.17 [-0.81; 0.30]	0.08 [-0.62; 0.73]	<b>0.08</b> [-0.23; 0.38]	-0.09 [-0.57; 0.43]	0.29 [-0.18; 0.67]	<b>0.12</b> [-0.38; 0.71]	-0.03 [-0.51; 0.77]	0.22 [-0.50; 0.86]
Vitamin D	IP-Pi	-0.08 [-0.42; 1.70]	<b>-0.16</b> [-1.11; 1.58]	-0.30 [-1.15; 1.53]	-0.05 [-1.15; 1.57]	<b>-0.34</b> [-0.96; 0.47]	-0.48 [-1.27; 0.50]	-0.15 [-0.89; 0.51]	<b>-0.26</b> [-1.68; 1.38]	-0.42 [-1.70; 1.47]	-0.17 [-1.59; 1.52]

## Personal recommendations

Here we query recommendations with graphical models. In recommendation, we let potassium and phosphorous intakes have values uniformly from full generally recommended range.

## Recommendation plot

## Warning: Ignoring unknown parameters: width

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