

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

2018-08-22

Welcome to the data analysis code of the corresponding article.

This Document

This is an R Markdown document combining R analysis code with comments.

To execute this file, save it as a text file with the extension “.Rmd” and open the file in R Studio <https://www.rstudio.com/>.

Before executing the code, install the necessary packages and place the file *hbmass_development_data.xlsx* in the same directory as this file.

Now press *Run All* or *Cmd/Ctrl + Alt + R*. You can also *knit* this document to an HTML report.

Loading Packages

```
knitr:::opts_chunk$set(message = FALSE, warning = FALSE)
library(tidyverse) # to use modern R code, see www.tidyverse.org
library(readxl) # to read Excel data file
library(lme4) # perform linear mixed modeling
library(modelr) # working with model objects
```

Loading Data

```
data <- read_excel("hbmass_development_data.xlsx", range = "A1:BP155",
                    col_names = TRUE) %>%
  mutate(ID = factor(ID),
         A_K = factor(A_K),
         age_16 = age_y - 16, # so modelled intercepts = values at age 16
         VO2_per_Hb = VO2max_abs / HbM_g,
         VO2_per_BV = VO2max_abs / BV,
         VO2_per_PV = VO2max_abs / PV)
```

Adjust Plotting Style

```
theme_custom <- function (base_size = 8, base_family = "") {
  theme_grey(base_size = base_size, base_family = base_family) %+replace%
    theme(
      axis.ticks.length = unit(-0.1, "cm"),
      axis.ticks = element_line(colour = "black", size = 0.5),
      axis.text.x = element_text(margin = unit(c(0.2, 0.2, 0.0, 0.0), "cm"),
                                 colour = "black"),
```

```

axis.text.y = element_text(margin = unit(c(0.2, 0.2, 0.0, 0.0), "cm"),
                           colour = "black"),

panel.background = element_rect(fill = "white", colour = NA),
panel.border = element_blank(),
axis.line = element_line(colour = "black", size = 0.5),

panel.grid.major.y = element_line(linetype = "dotted", size = 0.5,
                                   colour = "darkgrey"),
panel.grid.major.x = element_blank(),
panel.grid.minor = element_blank(),

strip.background = element_rect(fill = "white", colour = "black"),

legend.key = element_rect(fill = "white", colour = NA),
legend.margin = margin(c(0, 0, 0.1, 0), unit = "cm"),
legend.box.spacing = unit(0.0, "cm"),
legend.position = "top",
complete = TRUE)
}

```

Defining Functions

Next we define important functions for later use. E.g. to quickly plot the individual development of a variable or to sequentially fit a mixed model for a variable.

```

# function to plot the individual development of a variable colored by group
plot_develop_indiv <- function(var){
  ggplot(data) +
    aes_string(x = "age_y", y = var, color = "A_K", group = "ID") +
    geom_line(alpha = 0.5) +
    theme_custom()
}

# function to find the right linear mixed model for a variable
get_lmer <- function(variable){

  # build all models (from baseline to full model)
  # all models use the same random effects: (age_16|ID)
  baseline <- lmer(as.formula(paste(variable, "~ 1 + (age_16|ID)")), data = data)
  lmem_age <- lmer(as.formula(paste(variable, "~ age_16 + (age_16|ID)")),
                   data = data)
  lmem_tr <- lmer(as.formula(paste(variable, "~ A_K + (age_16|ID)")),
                  data = data)
  lmem_age_tr <- lmer(as.formula(paste(variable, "~ age_16 + A_K + (age_16|ID)")),
                      data = data)
  lmem_age_tr_i <- lmer(as.formula(paste(variable, "~ age_16 * A_K + (age_16|ID)")),
                         data = data)

  # choose the right model with likelihood ratio tests (proceed if p < 0.05)
  print(paste("baseline to lmem_age:",
             anova(baseline, lmem_age)$`Pr(>Chisq)`[2]))
}

```

```

print(paste("baseline to lmem_tr:",
            anova(baseline, lmem_tr)$`Pr(>Chisq)`[2]))
print(paste("baseline to lmem_age_tr_i:",
            anova(baseline, lmem_age_tr_i)$`Pr(>Chisq)`[2]))
if(anova(baseline, lmem_age)$`Pr(>Chisq)`[2] < 0.05) {
  model <- lmem_age
  print(paste("lmem_age to lmem_age_tr:",
              anova(lmem_age, lmem_age_tr)$`Pr(>Chisq)`[2]))
  if(anova(lmem_age, lmem_age_tr)$`Pr(>Chisq)`[2] < 0.05) {
    model <- lmem_age_tr
    print(paste("lmem_age_tr to lmem_age_tr_i:",
                anova(lmem_age_tr, lmem_age_tr_i)$`Pr(>Chisq)`[2]))
    if(anova(lmem_age_tr, lmem_age_tr_i)$`Pr(>Chisq)`[2] < 0.05) {
      model <- lmem_age_tr_i
    }
  } else {
    print(paste("lmem_age to lmem_age_tr_i:",
                anova(lmem_age, lmem_age_tr_i)$`Pr(>Chisq)`[2]))
    if(anova(lmem_age, lmem_age_tr_i)$`Pr(>Chisq)`[2] < 0.05) {
      model <- lmem_age_tr_i
    }
  }
} else if(anova(baseline, lmem_tr)$`Pr(>Chisq)`[2] < 0.05) {
  model <- lmem_tr
  print(paste("lmem_tr to lmem_age_tr:",
              anova(lmem_tr, lmem_age_tr)$`Pr(>Chisq)`[2]))
  if(anova(lmem_tr, lmem_age_tr)$`Pr(>Chisq)`[2] < 0.05) {
    model <- lmem_age_tr
    print(paste("lmem_age_tr to lmem_age_tr_i:",
                anova(lmem_age_tr, lmem_age_tr_i)$`Pr(>Chisq)`[2]))
    if(anova(lmem_age_tr, lmem_age_tr_i)$`Pr(>Chisq)`[2] < 0.05) {
      model <- lmem_age_tr_i
    }
  } else {
    print(paste("lmem_tr to lmem_age_tr_i:",
                anova(lmem_tr, lmem_age_tr_i)$`Pr(>Chisq)`[2]))
    if(anova(lmem_tr, lmem_age_tr_i)$`Pr(>Chisq)`[2] < 0.05) {
      model <- lmem_age_tr_i
    }
  }
} else {
  model <- baseline
  if(anova(baseline, lmem_age_tr_i)$`Pr(>Chisq)`[2] < 0.05){
    model <- lmem_age_tr_i
  }
}
# at the end, return the right model
return(model)
}

# function to get confidence limits for the fixed effects with bootstrapping
get_boot_cls <- function(model, variable, n = 1000){

```

```

b <- bootMer(model, nsim = n, FUN = function(x) predict(x, re.form = NA))
cls <- apply(b$�, 2, function(x) quantile(x, probs = c(0.05, 0.95)))
cls_data <- tibble(low = cls[1,], high = cls[2,],
                     age_16 = data$age_16, A_K = data$A_K) %>%
  gather(key = "cl", value = "Var", low, high)
names(cls_data)[names(cls_data) == "Var"] <- variable

return(cls_data)
}

# function to plot the fixed effects of the mixed model with CLS and data
plot_lmer <- function(model, variable, cls_data, no_AK = FALSE){

  p <- ggplot(data) +
    aes_string(x = "age_16+16", y = variable, color = "A_K") +
    geom_point(size = 1) +
    geom_line(aes(group = ID), size = 0.3) +
    scale_color_discrete(labels = c("Athletes", "Controls"), name = "Group") +
    labs(x = "Age (y)") +
    theme_custom()

  # and add confidence limits (overall, or separate for athletes and controls)
  if(no_AK == FALSE){
    p +
      geom_line(aes(y = predict(model, re.form=NA), group = ID),
                size = 0.75, color = "black") +
      geom_line(data = cls_data, aes(group = interaction(cl, A_K)),
                size = 0.5, linetype = "dashed", color = "black")
  } else {
    p +
      geom_line(aes(y = predict(model, re.form=NA)),
                size = 0.75, color = "black") +
      geom_line(data = cls_data %>% filter(A_K == "A"),
                aes(group = interaction(cl)),
                size = 0.5, linetype = "dashed", color = "black")
  }
}

```

Data preparation

When checking the raw data, some outliers were detected for sTfR and EPO. They were adjusted as follows:

sTfR

Delete values with a distance > 3 sd from the mean

```

cutoff <- data$sTfR %>% mean() + 3 * data$sTfR %>% sd()
data$sTfR[data$sTfR > cutoff] <- NA

```

EPO

Delete values > 20

```
data$epo[data$epo > 20] <- NA
```

Main Plots

We use the previously defined functions to find the right model, calculate confidence limits for the fixed effects and plot the model together with the raw data.

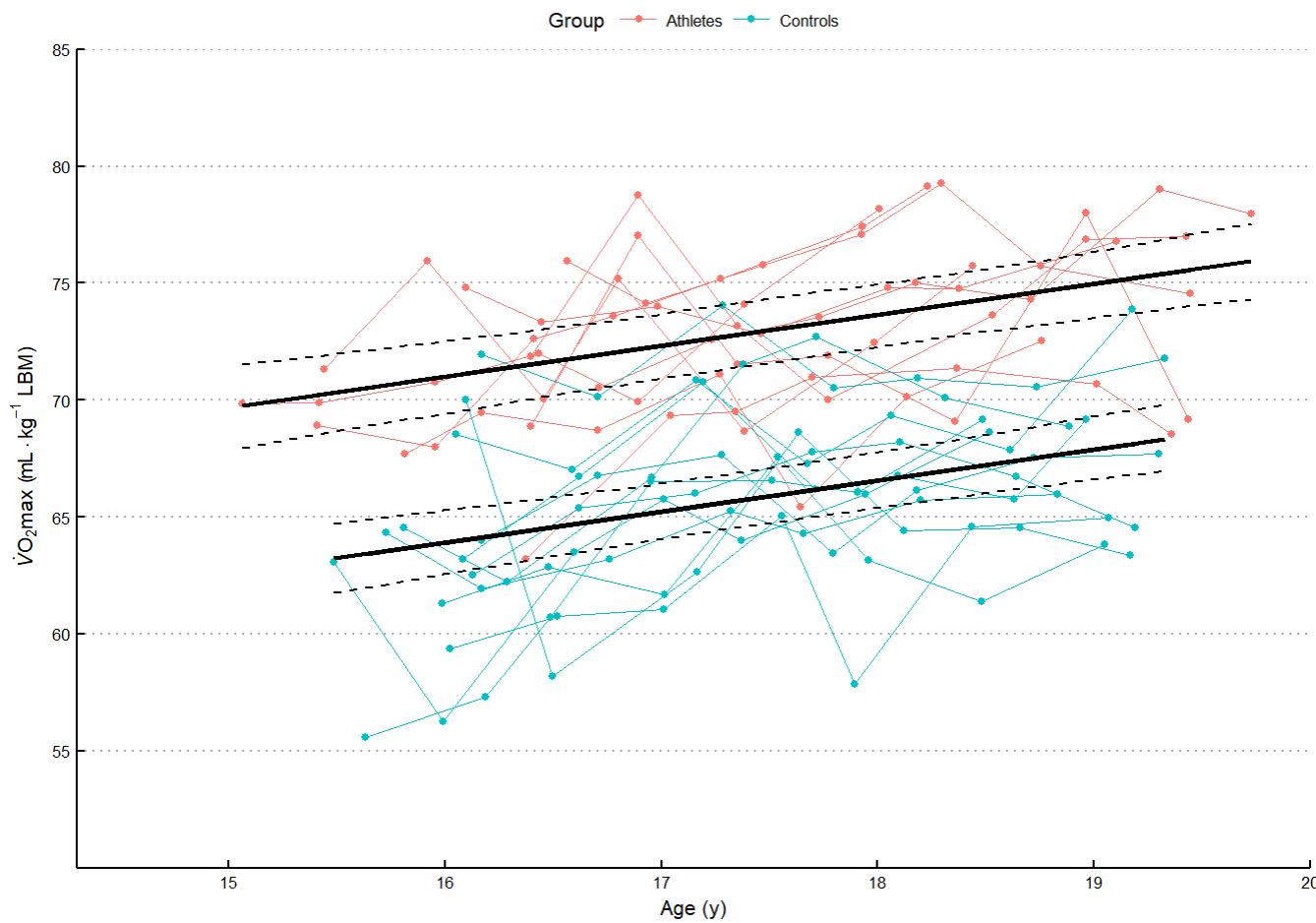
VO2max

```
model <- get_lmer("VO2max_LBM")
```

```
## [1] "baseline to lmem_age: 3.95690095457991e-05"
## [1] "baseline to lmem_tr: 5.90362390665932e-07"
## [1] "baseline to lmem_age_tr_i: 3.13790752784746e-09"
## [1] "lmem_age to lmem_age_tr: 4.18237467831728e-07"
## [1] "lmem_age_tr to lmem_age_tr_i: 0.958873195031813"
```

```
cls_data <- get_boot_cls(model, "VO2max_LBM")
p <- plot_lmer(model, "VO2max_LBM", cls_data)

# To finish we adjust some labels and scales and save the plot
p +
  labs(y = expression(paste(dot(italic(V)), O[2], "max ( ", mL%.%kg^-1, " LBM) "))) +
  scale_y_continuous(breaks = seq(55, 85, 5)) +
  coord_cartesian(ylim = c(50, 85), xlim = c(14.3, 20), expand = FALSE)
```



```
ggsave(filename = "plots/plot_vo2max.svg", width = 8, height = 8, units = "cm")
```

HbMass

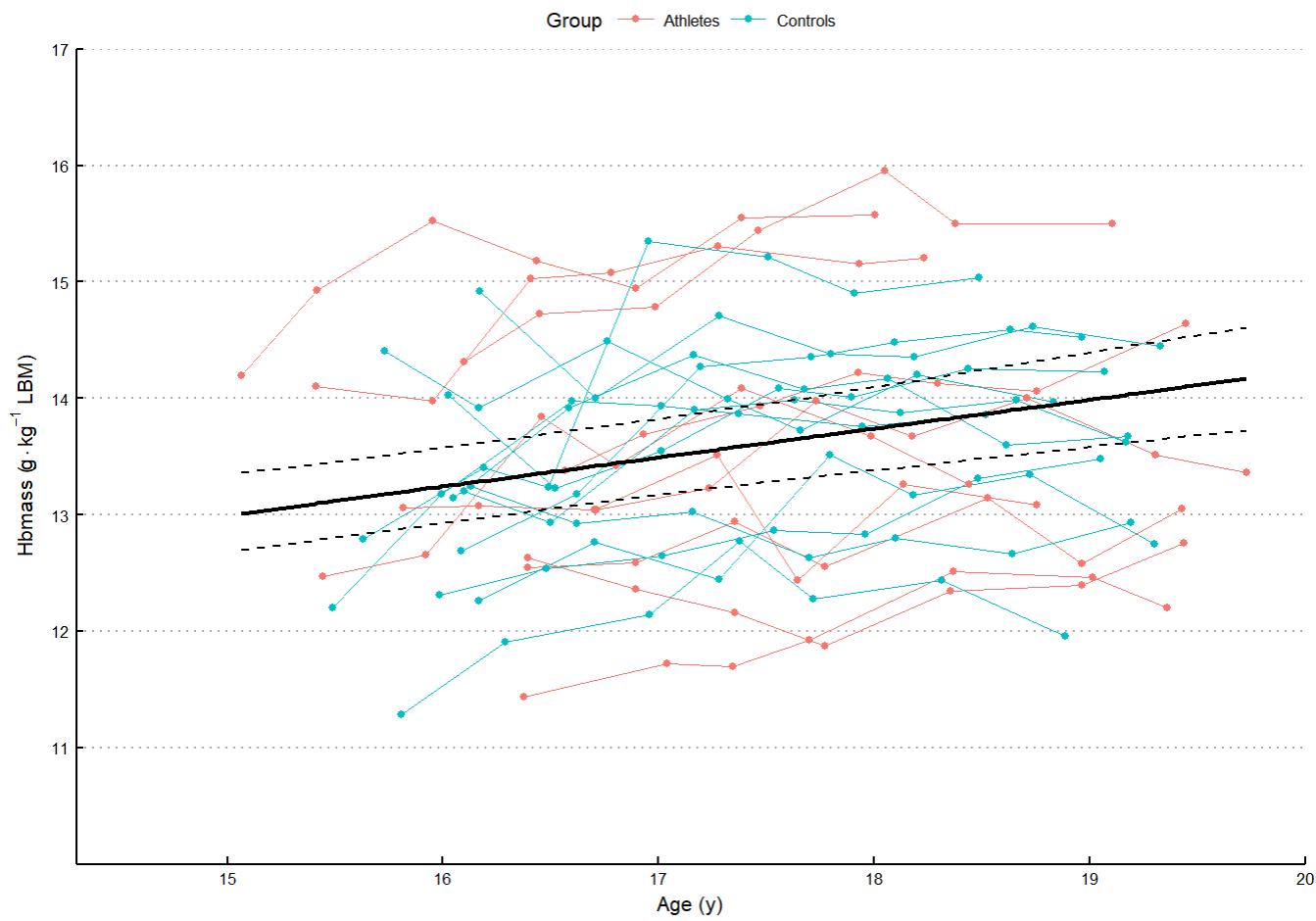
```
model <- get_lmer("HbM_LBM")
```

```
## [1] "baseline to lmem_age: 4.40893341816593e-05"
## [1] "baseline to lmem_tr: 0.796690717779254"
## [1] "baseline to lmem_age_tr_i: 0.000792829111660387"
## [1] "lmem_age to lmem_age_tr: 0.803351532692963"
## [1] "lmem_age to lmem_age_tr_i: 0.965361650660179"
```

```
cls_data <- get_boot_cls(model, "HbM_LBM")
p <- plot_lmer(model, "HbM_LBM", cls_data, no_AK = TRUE)

# To finish we adjust some labels and scales and save the plot
p +
  labs(y = expression(paste("Hbmass (", g%, %kg^-1, " LBM)")))) +
  scale_y_continuous(breaks = seq(11, 17, 1)) +
  coord_cartesian(ylim = c(10, 17), xlim = c(14.3, 20), expand = FALSE)
```

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```
ggsave(filename = "plots/plot_hbm.svg", width = 8, height = 8, units = "cm")
```

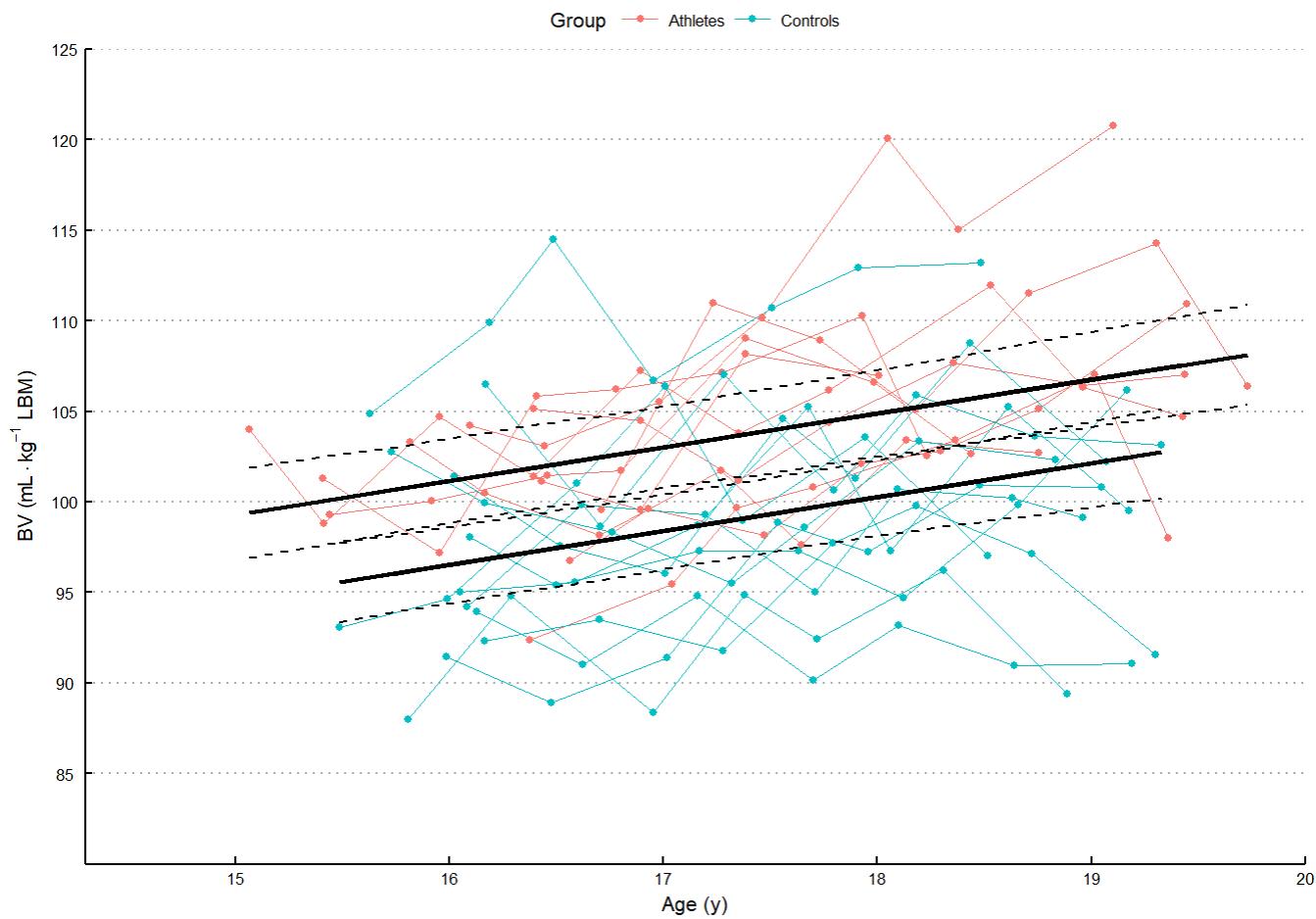
BV

```
model <- get_lmer("BV_LBM")
```

```
## [1] "baseline to lmem_age: 8.21284254715656e-06"
## [1] "baseline to lmem_tr: 0.0255462801053532"
## [1] "baseline to lmem_age_tr_i: 3.84612230795517e-06"
## [1] "lmem_age to lmem_age_tr: 0.0239636299700087"
## [1] "lmem_age_tr to lmem_age_tr_i: 0.0887688223002285"
```

```
cls_data <- get_boot_cls(model, "BV_LBM")
p <- plot_lmer(model, "BV_LBM", cls_data)

# To finish we adjust some labels and scales and save the plot
p +
  labs(y = expression(paste("BV ( ", mL % . % kg^-1, " LBM) "))) +
  scale_y_continuous(breaks = seq(85, 125, 5)) +
  coord_cartesian(ylim = c(80, 125), xlim = c(14.3, 20), expand = FALSE)
```



```
ggsave(filename = "plots/plot_bv.svg", width = 8, height = 8, units = "cm")
```

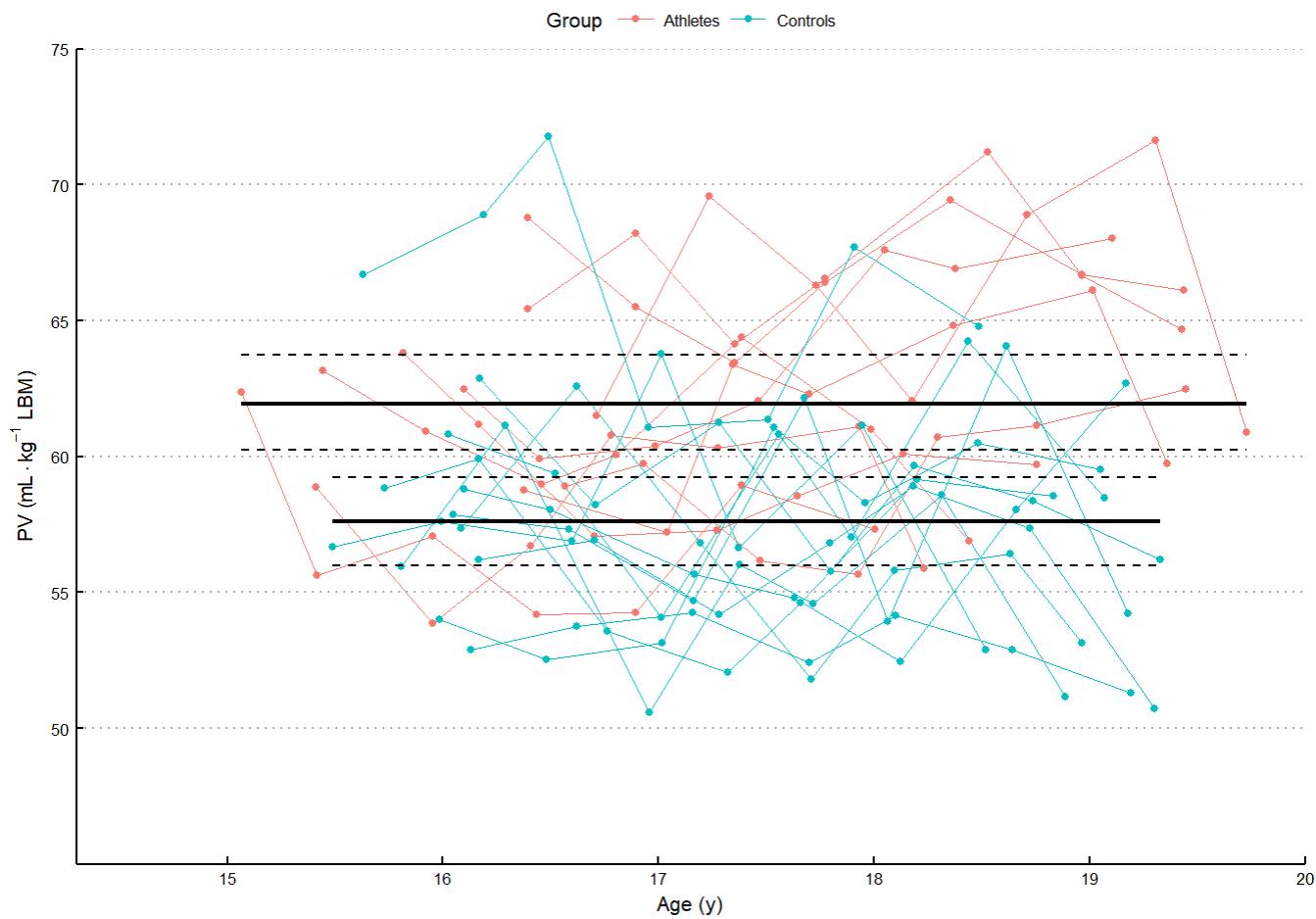
PV

```
model <- get_lmer("PV_LBM")
```

```
## [1] "baseline to lmem_age: 0.851395615526362"
## [1] "baseline to lmem_tr: 0.00826051719414878"
## [1] "baseline to lmem_age_tr_i: 0.0122235746075533"
## [1] "lmem_tr to lmem_age_tr: 0.777149918852902"
## [1] "lmem_tr to lmem_age_tr_i: 0.139894989312945"
```

```
cls_data <- get_boot_cls(model, "PV_LBM")
p <- plot_lmer(model, "PV_LBM", cls_data)

# To finish we adjust some labels and scales and save the plot
p +
  labs(y = expression(paste("PV ( ", mL%.%kg^-1, " LBM) "))) +
  scale_y_continuous(breaks = seq(50, 75, 5)) +
  coord_cartesian(ylim = c(45, 75), xlim = c(14.3, 20), expand = FALSE)
```



```
ggsave(filename = "plots/plot_pv.svg", width = 8, height = 8, units = "cm")
```

Numeric Summaries

Main Tables

Now we calculate the tables summarising the raw data by group and testnumber and export a CSV.

```
important_vars <- c("LBM_kg", "fat_kg", "fat_perc",
                    "weight_kg", "height_cm", "biolage_y", "vmax_kmh",
                    "PV_LBM", "BV_LBM", "EV_LBM",
                    "HbM_LBM", "HbM_g", "HbM_gkg",
                    "VO2max_LBM", "VO2max_abs", "VO2max_rel",
                    "VO2_per_BV", "VO2_per_Hb", "VO2_per_PV",
                    "hb", "hkt", "reti_proz", "epo", "sTfR", "ferritin")

# function to return a nicely formatted mean ± SD summary
mean_sd <- function(x){
  if (mean(x, na.rm = TRUE) < 120)
    sprintf("%.1f ± %.1f", mean(x, na.rm = TRUE), sd(x, na.rm = TRUE))
  else
    sprintf("%.0f ± %.0f", mean(x, na.rm = TRUE), sd(x, na.rm = TRUE))
}
```

```
# take data, select variables, group by A/C and testnumber and calculate summary
overview_table <- data %>%
  select(A_K, testnumber, age_y, important_vars, train_h_ausd) %>%
  group_by(A_K, testnumber) %>%
  summarise_all(mean_sd) %>%
  arrange(A_K, testnumber)

write_csv(overview_table, "overview_table.csv")
```

Values by group

Summaries of variables by group.

```
data %>% group_by(A_K) %>% summarise_at(
  vars(VO2_per_Hb, vmax_kmh, hb, reti_proz, epo, sTfR, ferritin), mean_sd)
```

```
## # A tibble: 2 x 8
##   A_K    VO2_per_Hb  vmax_kmh    hb      reti_proz  epo      sTfR  ferritin
##   <fct>  <chr>     <chr>     <chr>    <chr>     <chr>    <chr>  <chr>
## 1 A      5.4 ± 0.4 15.6 ± 0.5 14.4 ± 1.1 0.8 ± 0.3 10.9 ± ~ 7.6 ± ~ 60.0 ± ~
## 2 K      4.9 ± 0.4 13.0 ± 0.8 15.1 ± 0.7 0.8 ± 0.3 10.6 ± ~ 7.4 ± ~ 47.1 ± ~
```

Mixed Models

Data Preparation

Log-transformation for fat, percent fat and ferritin.

```
data$fat_kg <- log(data$fat_kg)
data$fat_perc <- log(data$fat_perc)
data$ferritin <- log(data$ferritin)
```

Detailed Model Outputs

The following loop will for each variable: Plot the individual lines, fit the appropriate mixed model, print the model summary and the residual plot.

```
# change the order of factor levels (intercept = controls)
data$A_K <- data$A_K %>% fct_relevel("K", "A")

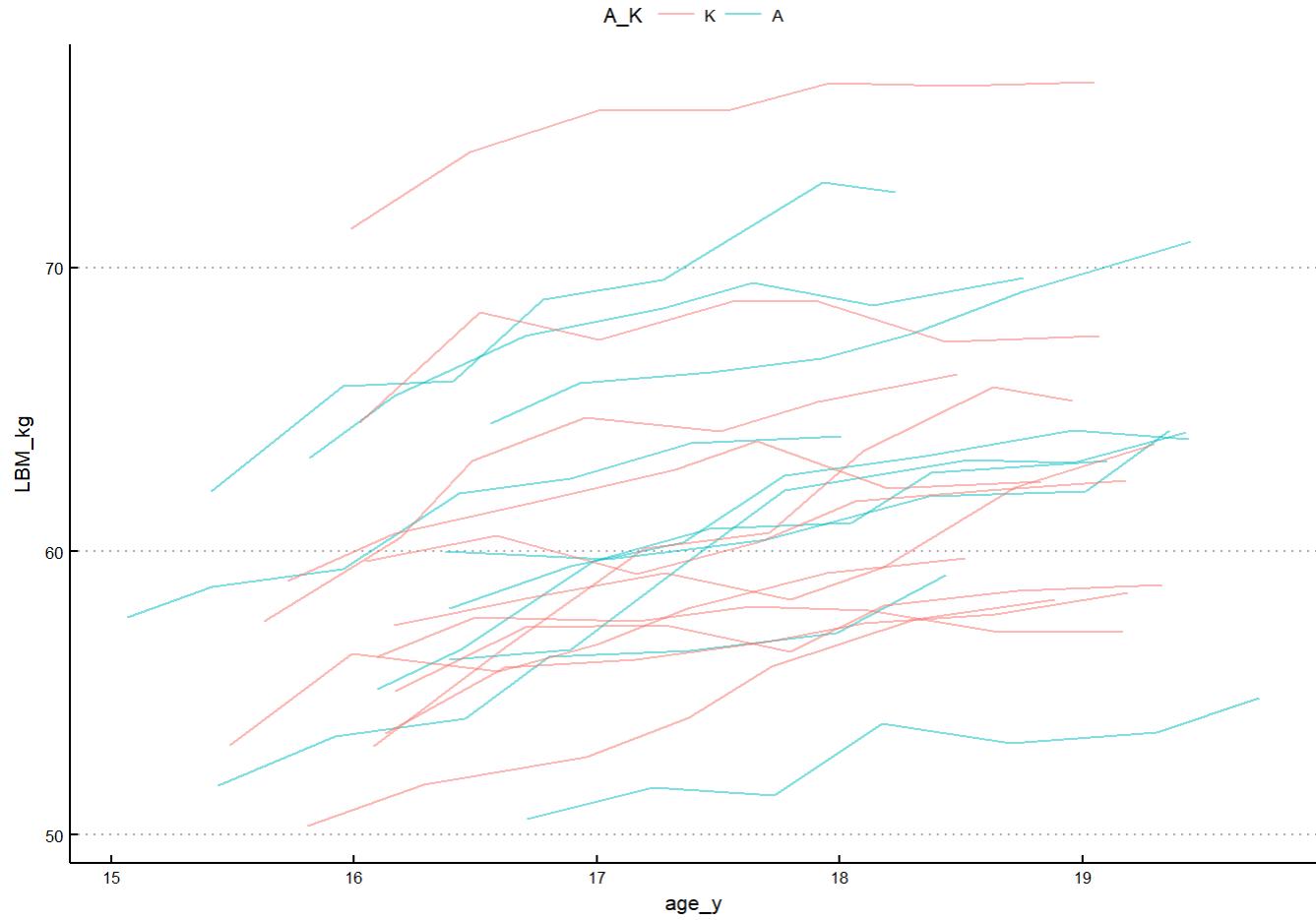
# define function
print_lmer <- function(variable){
  print("-----")
  print(variable)
  print("-----")

  plot_develop_indiv(variable) %>% print()
  model <- get_lmer(variable)
  model %>% summary() %>% print()
```

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```
model %>% plot() %>% print()  
}  
  
# applies function to every important variable  
walk(important_vars, print_lmer)
```

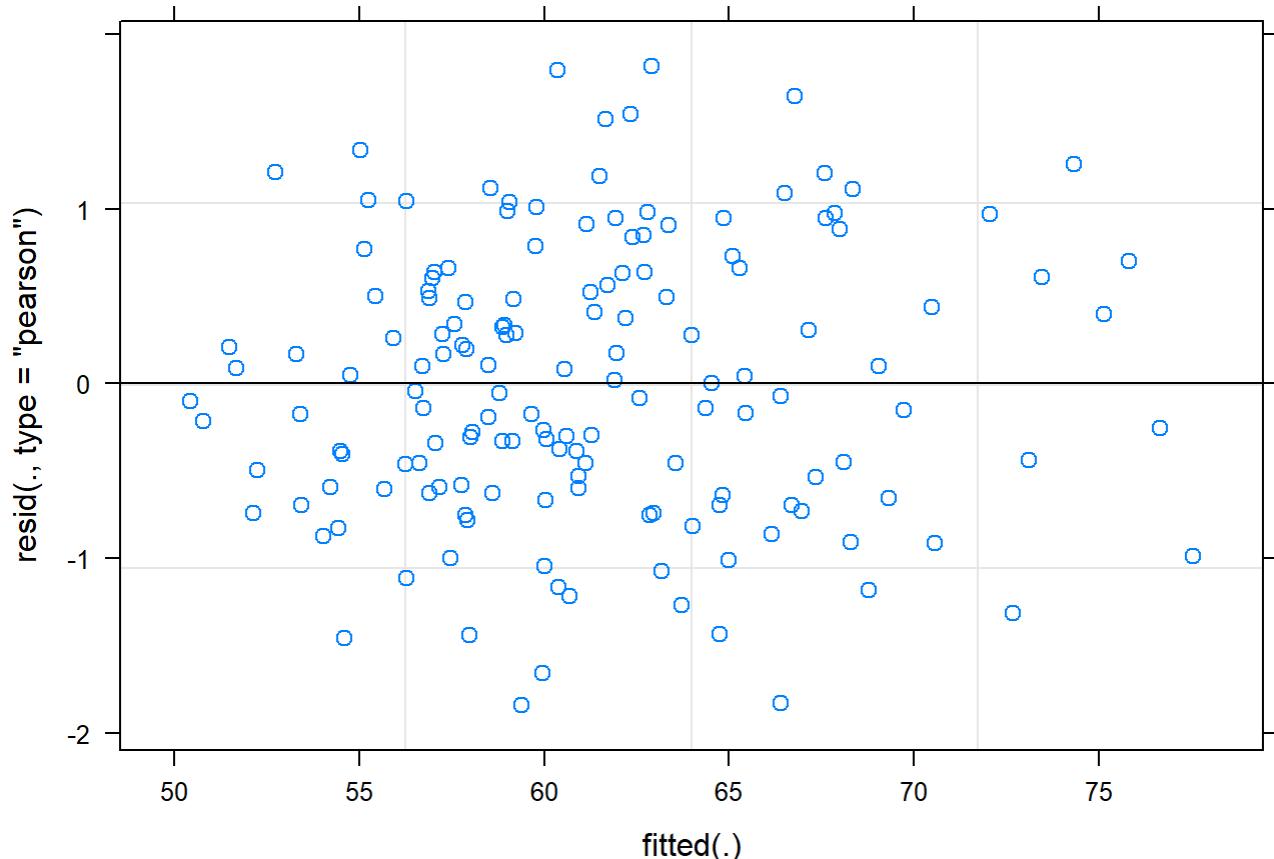
```
## [1] "-----"  
## [1] "LBM_kg"  
## [1] "-----"
```



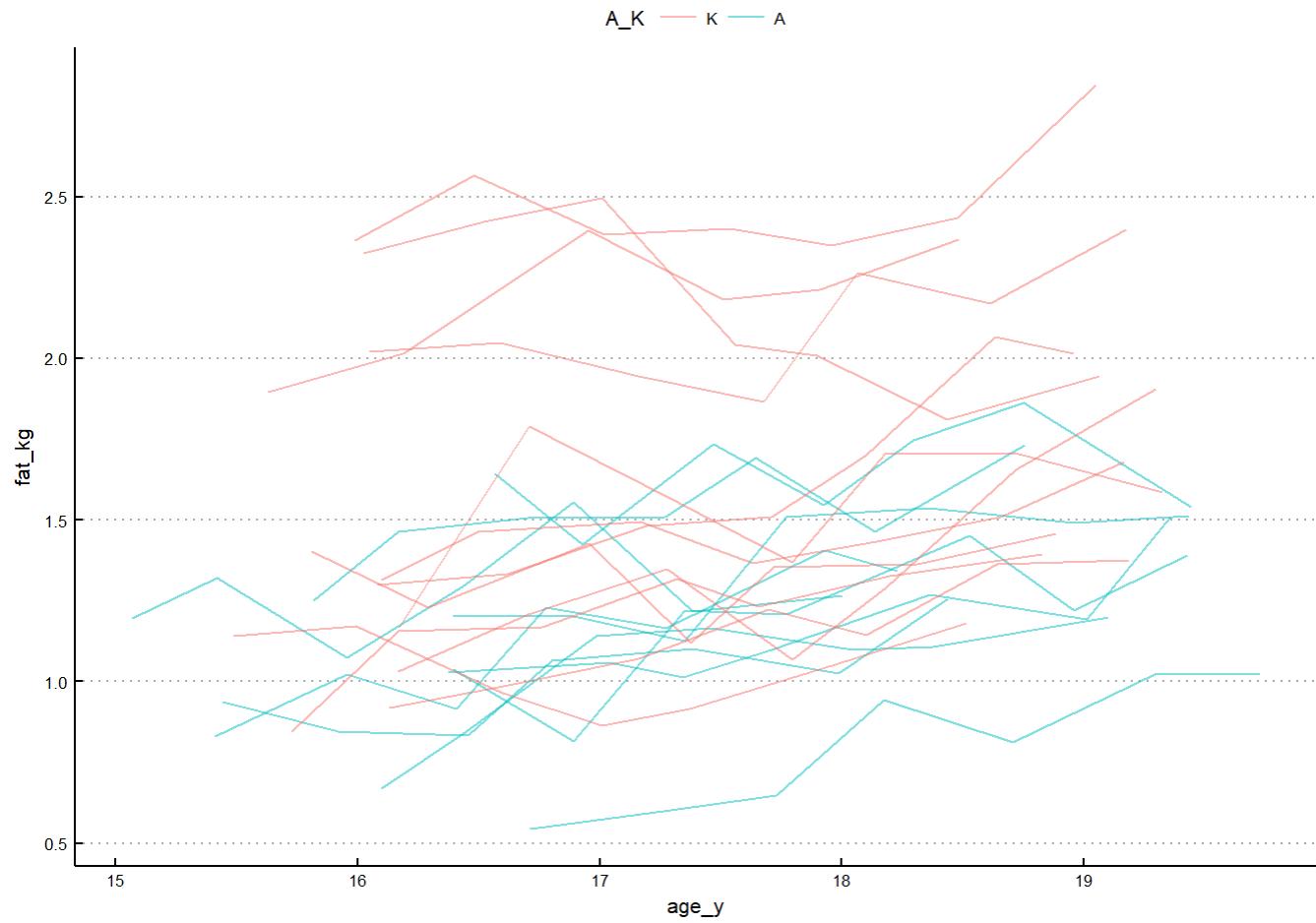
```
## [1] "baseline to lmem_age: 2.34944726424691e-09"  
## [1] "baseline to lmem_tr: 0.877808818743114"  
## [1] "baseline to lmem_age_tr_i: 3.41186287966931e-08"  
## [1] "lmem_age to lmem_age_tr: 0.88556380362213"  
## [1] "lmem_age to lmem_age_tr_i: 0.37646121700274"  
## Linear mixed model fit by REML ['lmerMod']  
## Formula: LBM_kg ~ age_16 + (age_16 | ID)  
## Data: data  
##  
## REML criterion at convergence: 576.2  
##  
## Scaled residuals:  
##      Min       1Q   Median       3Q      Max  
## -2.00078 -0.64913 -0.05592  0.65768  1.97456  
##
```

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```
## Random effects:  
## Groups Name Variance Std.Dev. Corr  
## ID (Intercept) 30.0138 5.4785  
## age_16 0.8638 0.9294 -0.12  
## Residual 0.8498 0.9218  
## Number of obs: 154, groups: ID, 22  
##  
## Fixed effects:  
## Estimate Std. Error t value  
## (Intercept) 58.5152 1.1758 49.767  
## age_16 1.9522 0.2117 9.222  
##  
## Correlation of Fixed Effects:  
## (Intr)  
## age_16 -0.140
```



```
## [1] "-----"  
## [1] "fat_kg"  
## [1] "-----"
```



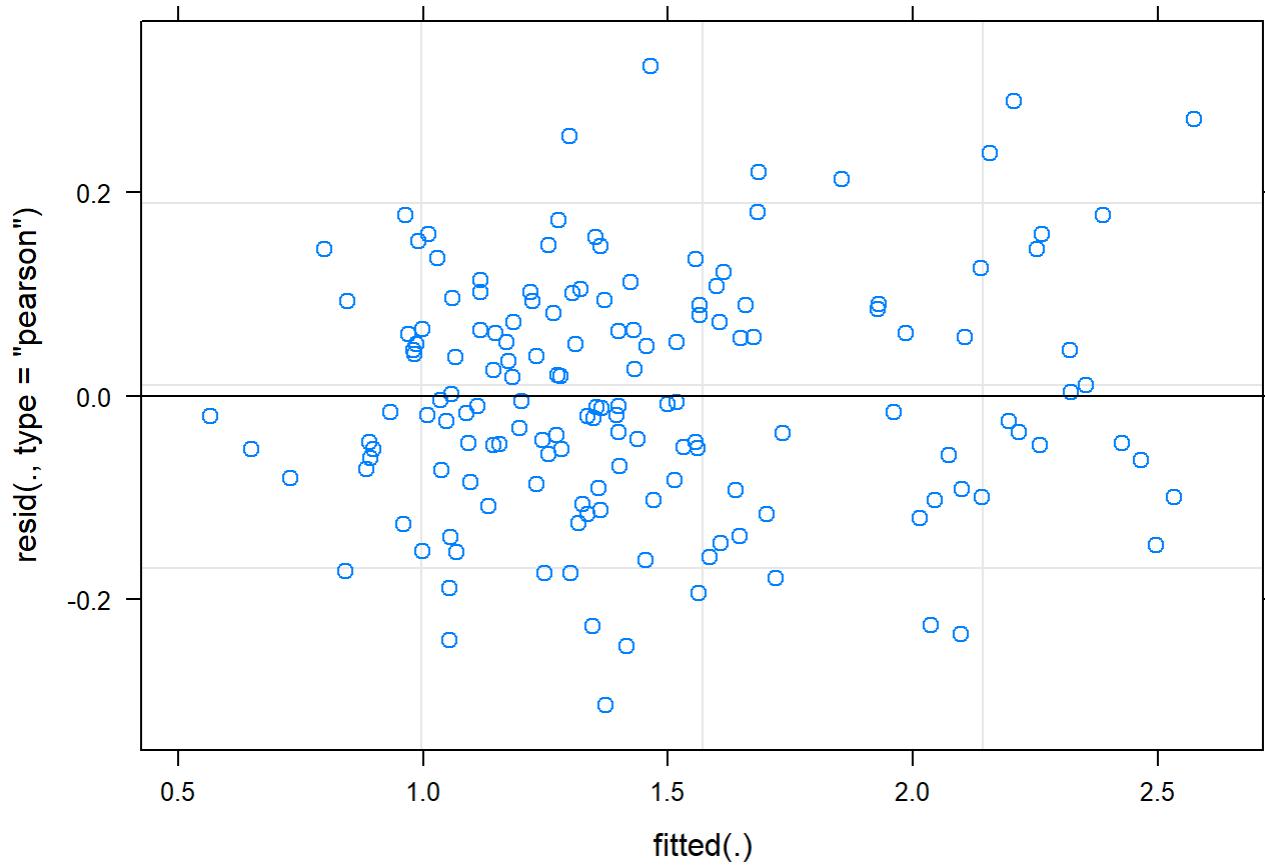
```

## [1] "baseline to lmem_age: 1.93048282469141e-05"
## [1] "baseline to lmem_tr: 0.0196999078663384"
## [1] "baseline to lmem_age_tr_i: 2.22526351168085e-05"
## [1] "lmem_age to lmem_age_tr: 0.0193847702018757"
## [1] "lmem_age_tr to lmem_age_tr_i: 0.471988563139435"
## Linear mixed model fit by REML ['lmerMod']
## Formula: fat_kg ~ age_16 + A_K + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: -57
##
## Scaled residuals:
##      Min     1Q Median     3Q    Max 
## -2.2660 -0.5881 -0.0789  0.6027  2.4161 
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 0.203018  0.45058
##          age_16       0.006596  0.08121 -0.57
##   Residual            0.018019  0.13424
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 1.46024   0.12283 11.889
## age_16      0.10664   0.02042  5.223

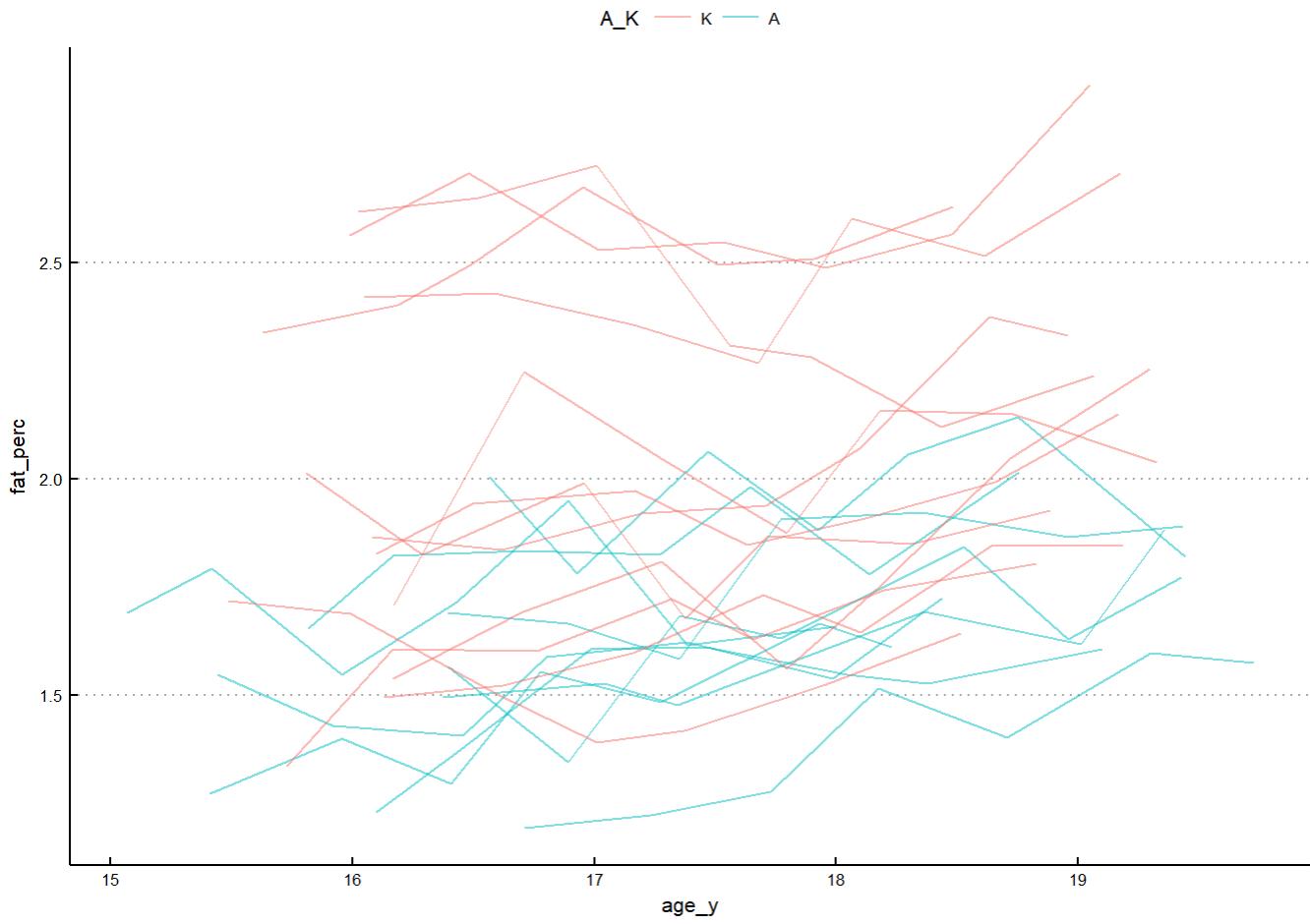
```

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```
## A_KA      -0.39157    0.16301   -2.402
##
## Correlation of Fixed Effects:
##          (Intr) age_16
## age_16   -0.448
## A_KA     -0.602  0.000
```



```
## [1] "-----"
## [1] "fat_perc"
## [1] "-----"
```



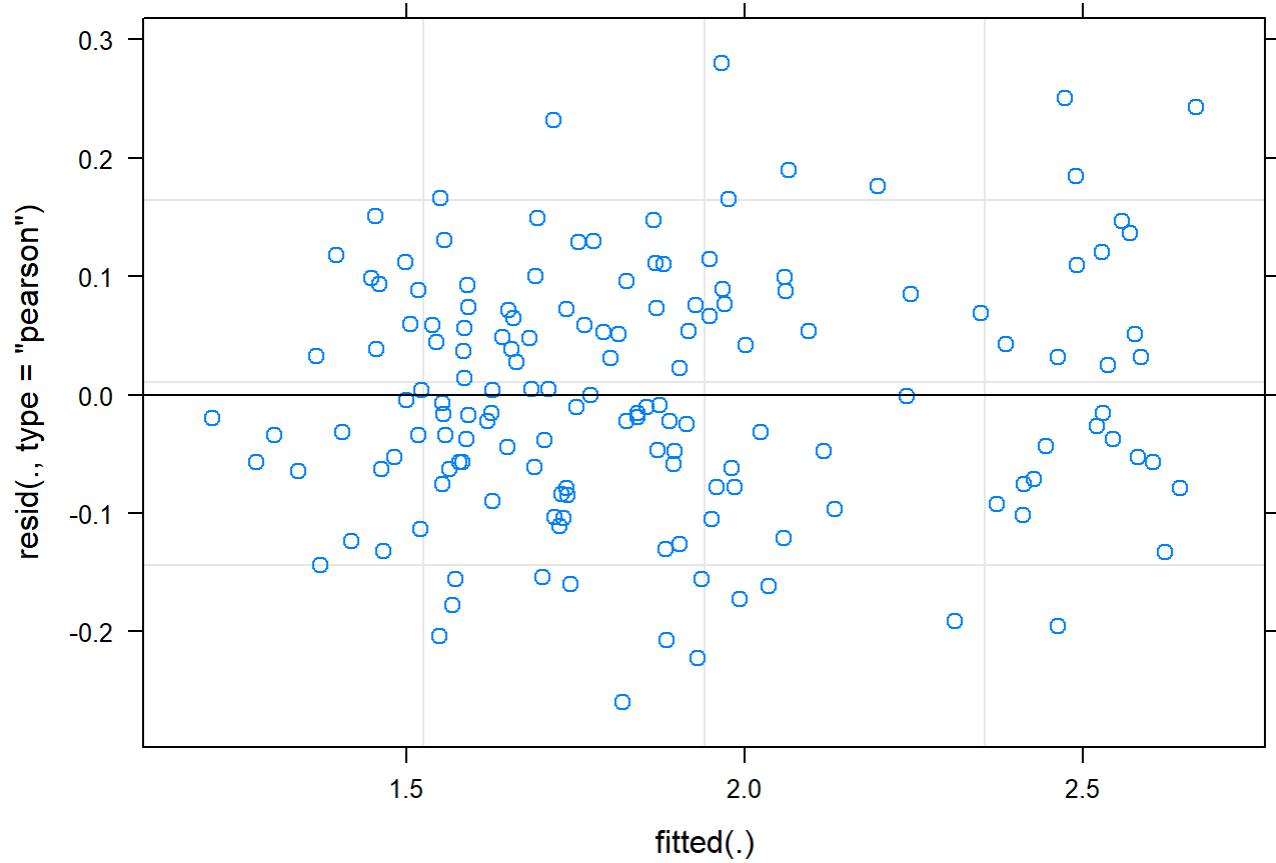
```

## [1] "baseline to lmem_age: 0.000436534762697919"
## [1] "baseline to lmem_tr: 0.00400583770097151"
## [1] "baseline to lmem_age_tr_i: 0.000101167777608284"
## [1] "lmem_age to lmem_age_tr: 0.00389217919377166"
## [1] "lmem_age_tr to lmem_age_tr_i: 0.537147822051965"
## Linear mixed model fit by REML ['lmerMod']
## Formula: fat_perc ~ age_16 + A_K + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: -102.4
##
## Scaled residuals:
##      Min       1Q     Median       3Q      Max
## -2.20113 -0.54550 -0.08097  0.61028  2.37438
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 0.124754  0.35321
##          age_16       0.004797  0.06926 -0.62
##   Residual            0.013951  0.11811
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 1.92870    0.09553 20.189
## age_16      0.07019    0.01757  3.995

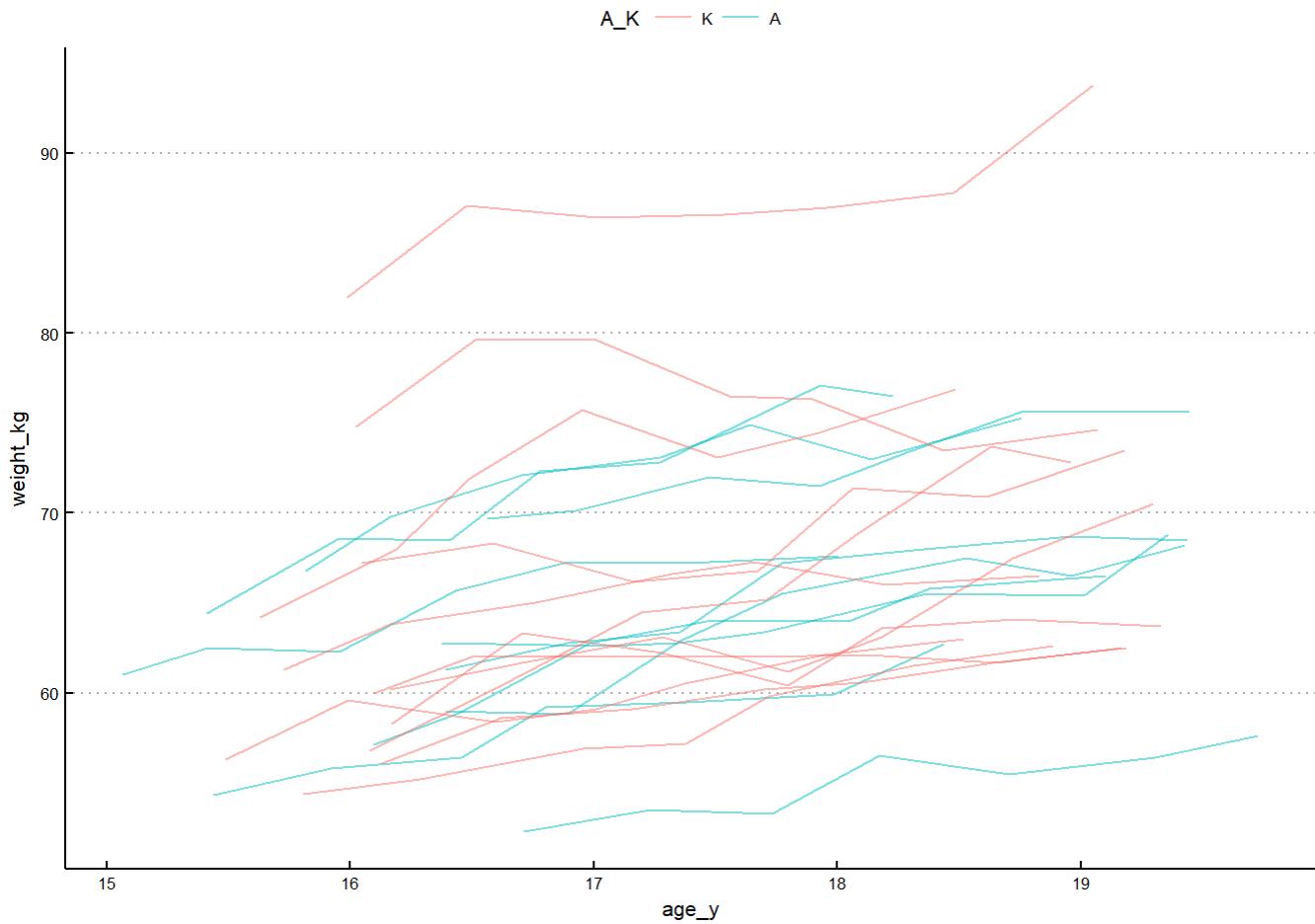
```

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```
## A_KA      -0.37912    0.12389   -3.060
##
## Correlation of Fixed Effects:
##          (Intr) age_16
## age_16   -0.487
## A_KA     -0.588  0.000
```



```
## [1] "-----"
## [1] "weight_kg"
## [1] "-----"
```



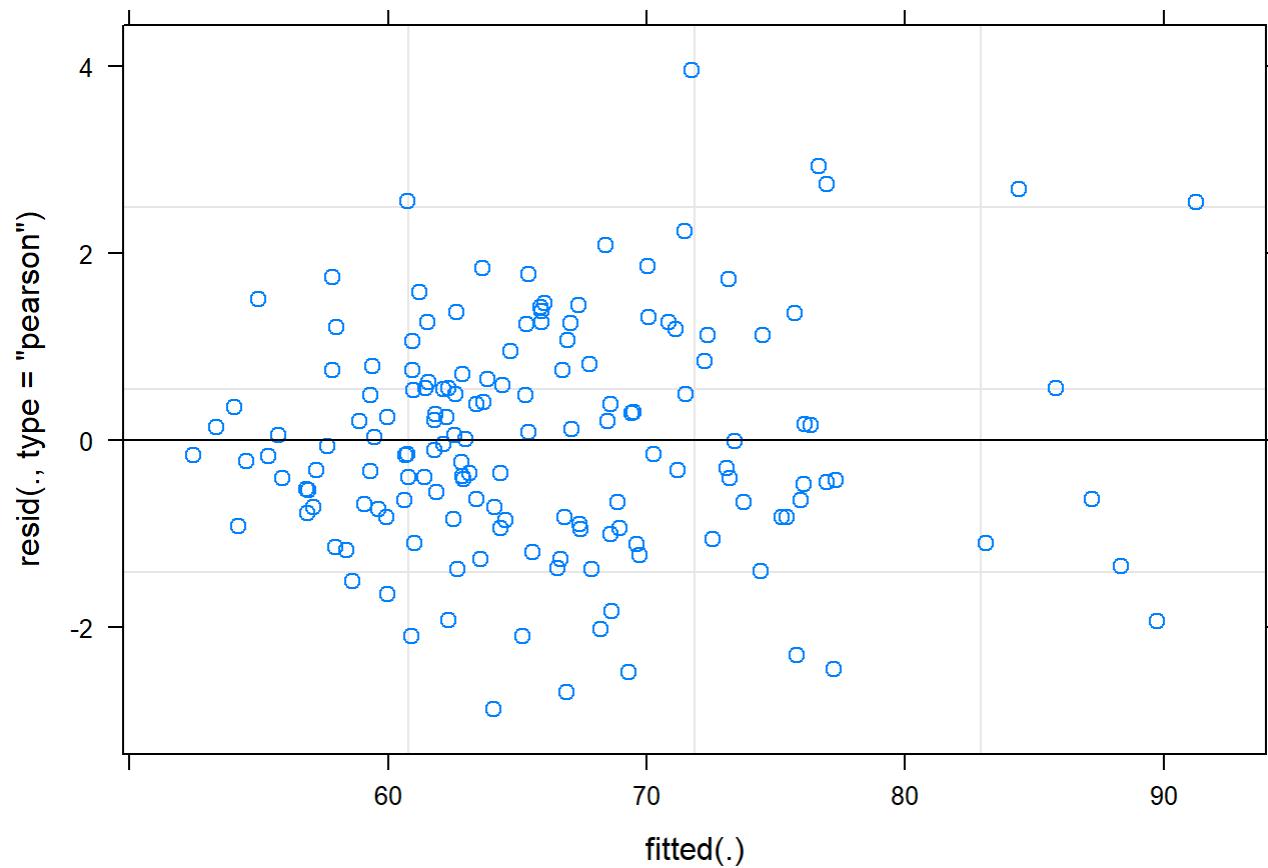
```

## [1] "baseline to lmem_age: 1.81518186660196e-08"
## [1] "baseline to lmem_tr: 0.570706662747848"
## [1] "baseline to lmem_age_tr_i: 3.68525120101223e-07"
## [1] "lmem_age to lmem_age_tr: 0.565034634210204"
## [1] "lmem_age to lmem_age_tr_i: 0.594614819368363"
## Linear mixed model fit by REML ['lmerMod']
## Formula: weight_kg ~ age_16 + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: 695.6
##
## Scaled residuals:
##      Min     1Q Median     3Q    Max 
## -2.0507 -0.5863 -0.0621  0.5325  2.8154 
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 56.790   7.536    
##          age_16       1.585   1.259   -0.20  
##   Residual           1.982   1.408    
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 62.6177    1.6198 38.658
## age_16       2.3971    0.2915  8.224

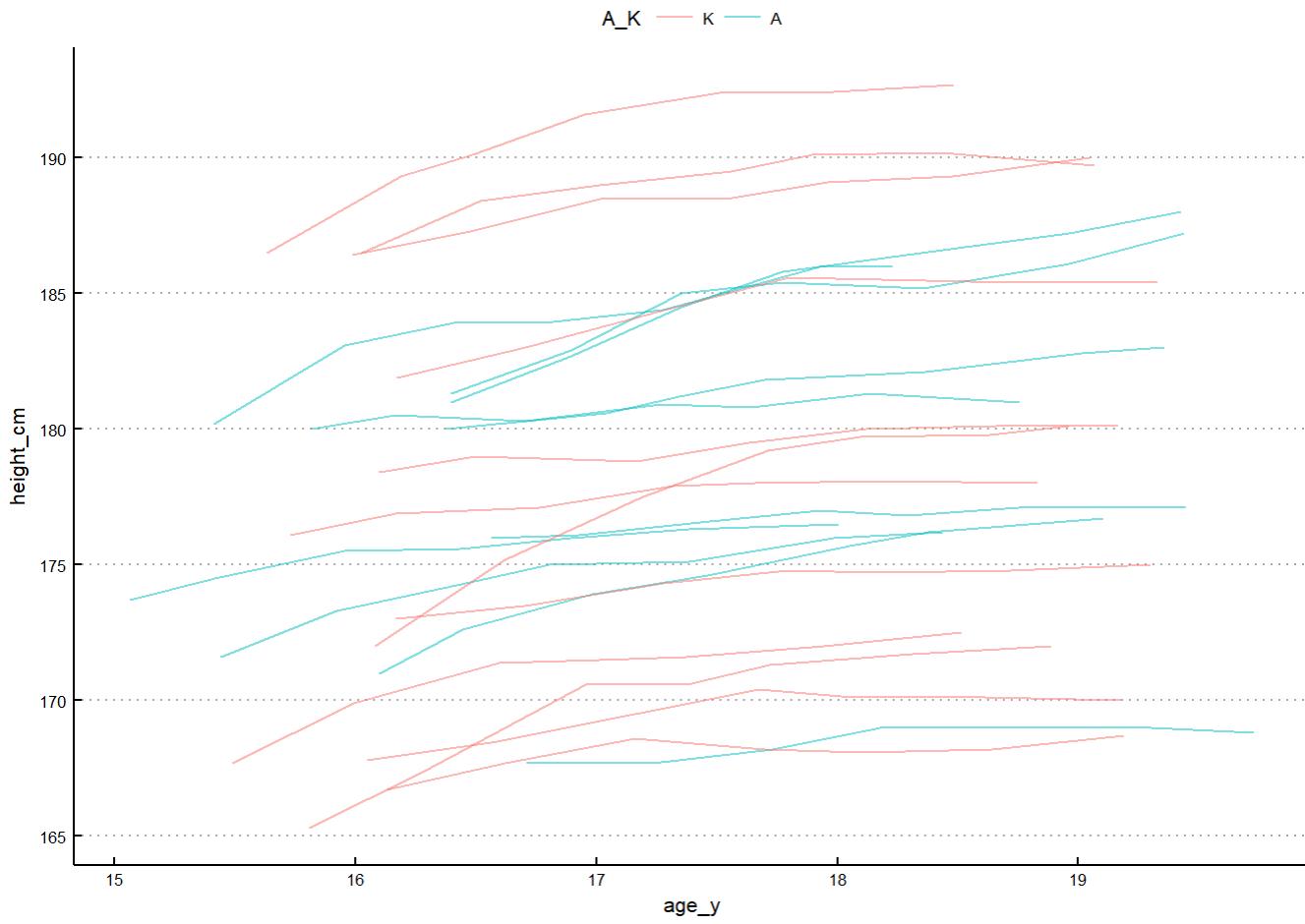
```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
##  
## Correlation of Fixed Effects:  
##          (Intr)  
## age_16 -0.219
```



```
## [1] "-----"  
## [1] "height_cm"  
## [1] "-----"
```



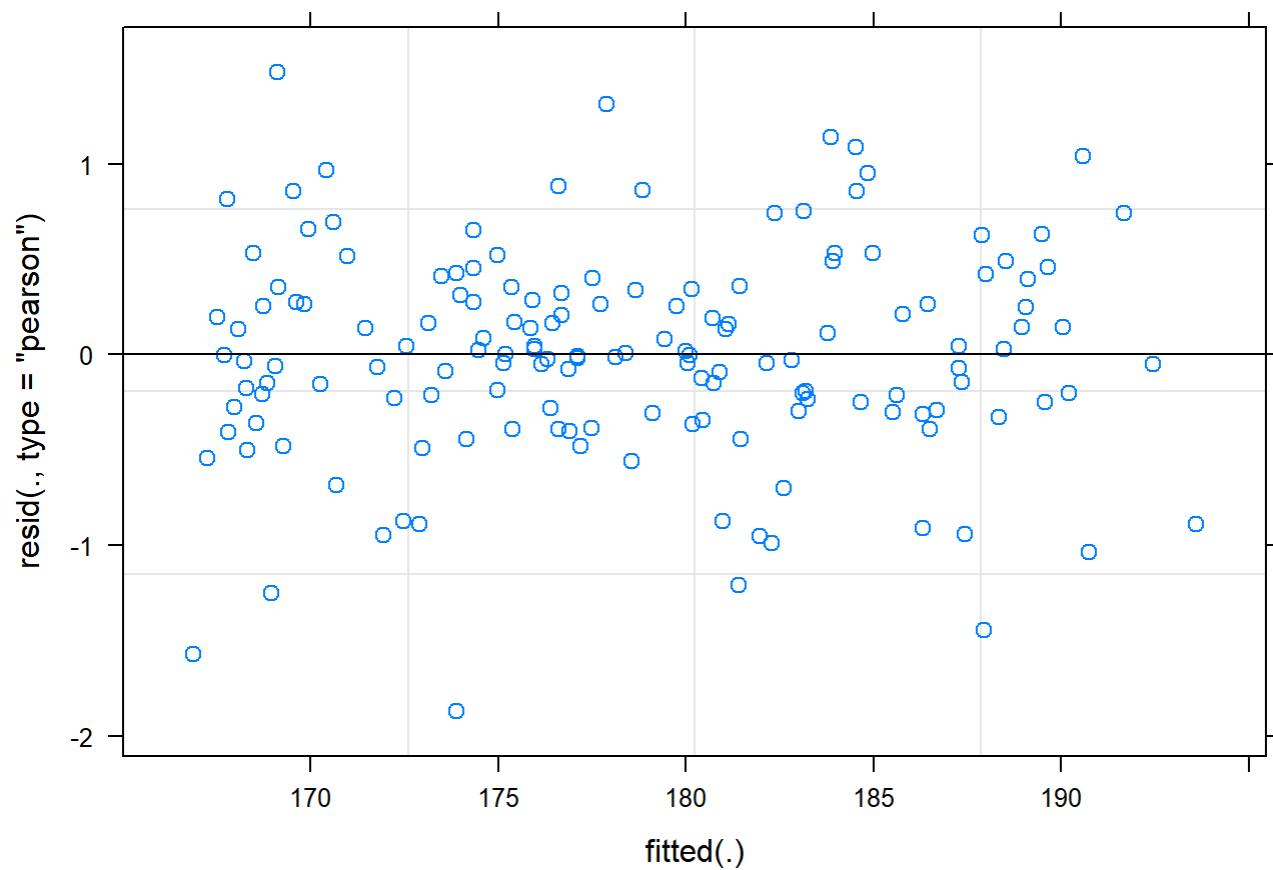
```

## [1] "baseline to lmem_age: 1.38894428913354e-08"
## [1] "baseline to lmem_tr: 0.94280698828231"
## [1] "baseline to lmem_age_tr_i: 4.73140135469937e-07"
## [1] "lmem_age to lmem_age_tr: 0.946649973985829"
## [1] "lmem_age to lmem_age_tr_i: 0.997471404694807"
## Linear mixed model fit by REML ['lmerMod']
## Formula: height_cm ~ age_16 + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: 490.6
##
## Scaled residuals:
##      Min       1Q     Median       3Q      Max
## -2.89615 -0.45978 -0.00515  0.51653  2.29413
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 45.0247  6.7100
##          age_16       0.4015  0.6336  0.18
##   Residual            0.4183  0.6468
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 176.6888    1.4337 123.239
## age_16       1.2099    0.1448   8.353

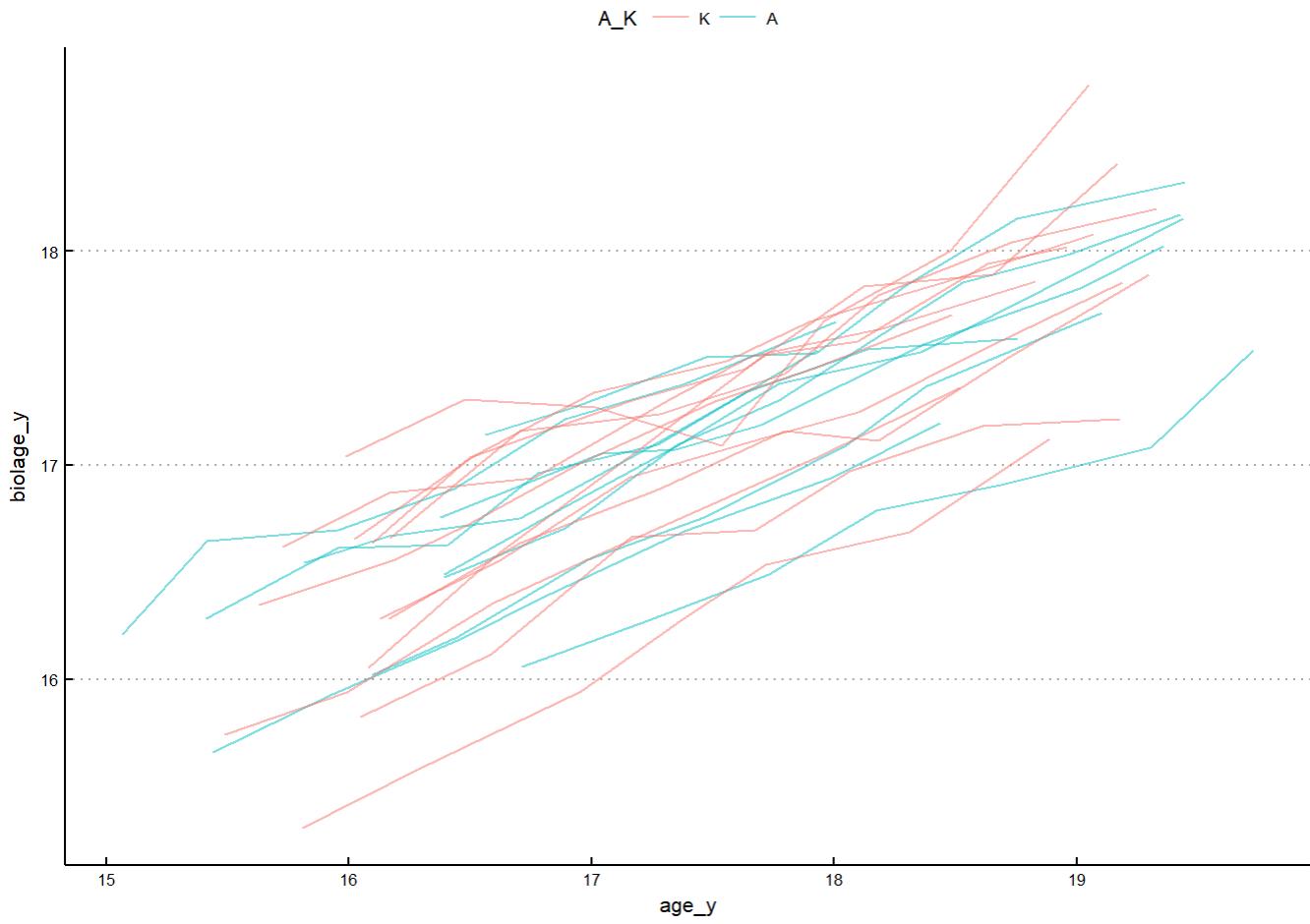
```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
##  
## Correlation of Fixed Effects:  
##          (Intr)  
## age_16  0.144
```



```
## [1] "-----"  
## [1] "biolage_y"  
## [1] "-----"
```



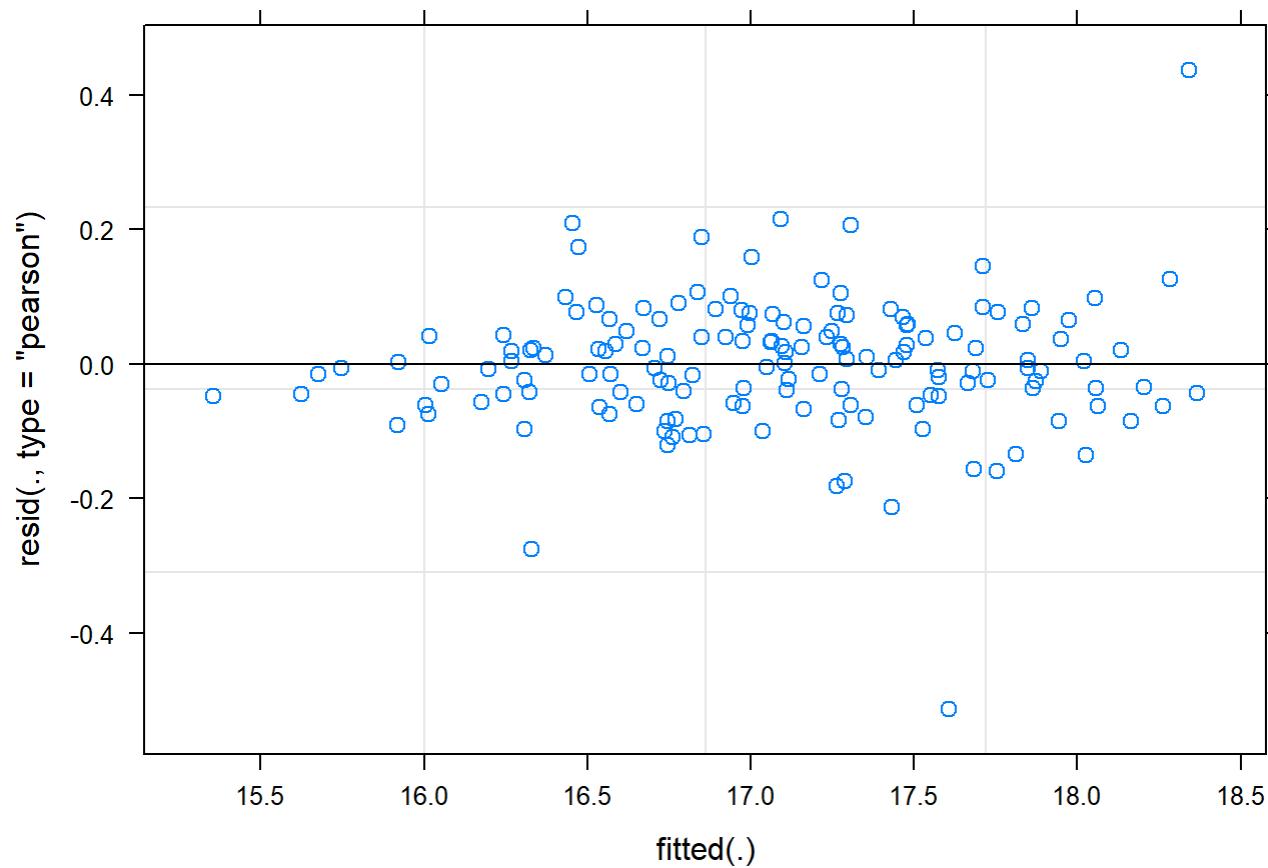
```

## [1] "baseline to lmem_age: 3.97065180591532e-21"
## [1] "baseline to lmem_tr: 0.625869499041139"
## [1] "baseline to lmem_age_tr_i: 2.29743140671939e-19"
## [1] "lmem_age to lmem_age_tr: 0.656249912278727"
## [1] "lmem_age to lmem_age_tr_i: 0.632880389143895"
## Linear mixed model fit by REML ['lmerMod']
## Formula: biolage_y ~ age_16 + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: -118
##
## Scaled residuals:
##      Min       1Q   Median      3Q     Max
## -4.6564 -0.4343  0.0273  0.5093  3.9639
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 0.152608  0.39065
##          age_16       0.002802  0.05293 -0.50
##   Residual            0.012186  0.11039
## Number of obs: 153, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 16.35416    0.08482 192.81
## age_16       0.49601    0.01442  34.39

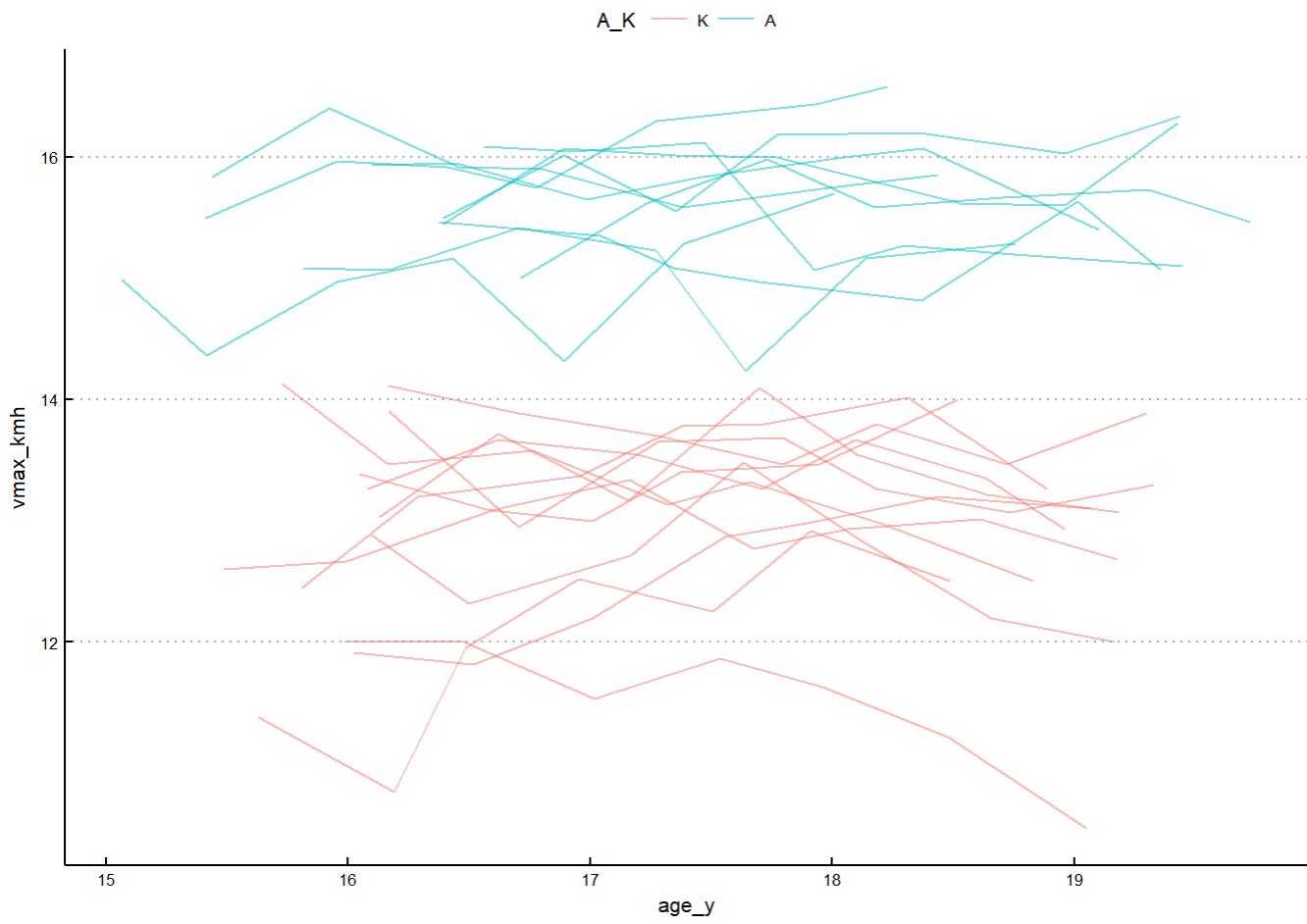
```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
##  
## Correlation of Fixed Effects:  
##          (Intr)  
## age_16 -0.480
```



```
## [1] "--"  
## [1] "vmax_kmh"  
## [1] "--"
```



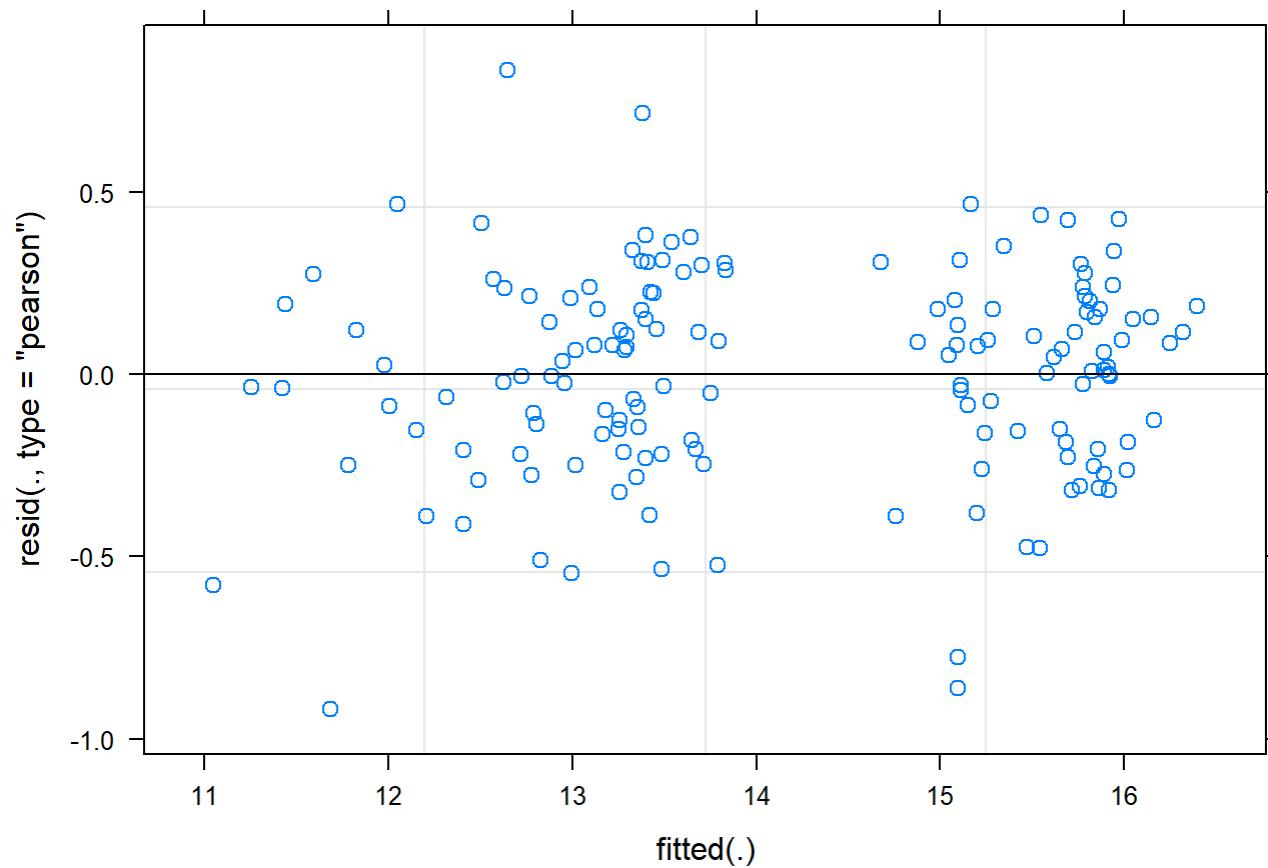
```

## [1] "baseline to lmem_age: 0.682562268243043"
## [1] "baseline to lmem_tr: 2.81556367613805e-11"
## [1] "baseline to lmem_age_tr_i: 1.18478030487875e-09"
## [1] "lmem_tr to lmem_age_tr: 0.669179910229647"
## [1] "lmem_tr to lmem_age_tr_i: 0.907729720545447"
## Linear mixed model fit by REML ['lmerMod']
## Formula: vmax_kmh ~ A_K + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: 195.2
##
## Scaled residuals:
##      Min       1Q     Median       3Q      Max
## -2.82273 -0.57320  0.09308  0.58563  2.56108
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 0.39777  0.6307
##          age_16       0.06697  0.2588  -0.56
##   Residual           0.10612  0.3258
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 13.0068    0.1550  83.94
## A_KA         2.6245    0.2305  11.39

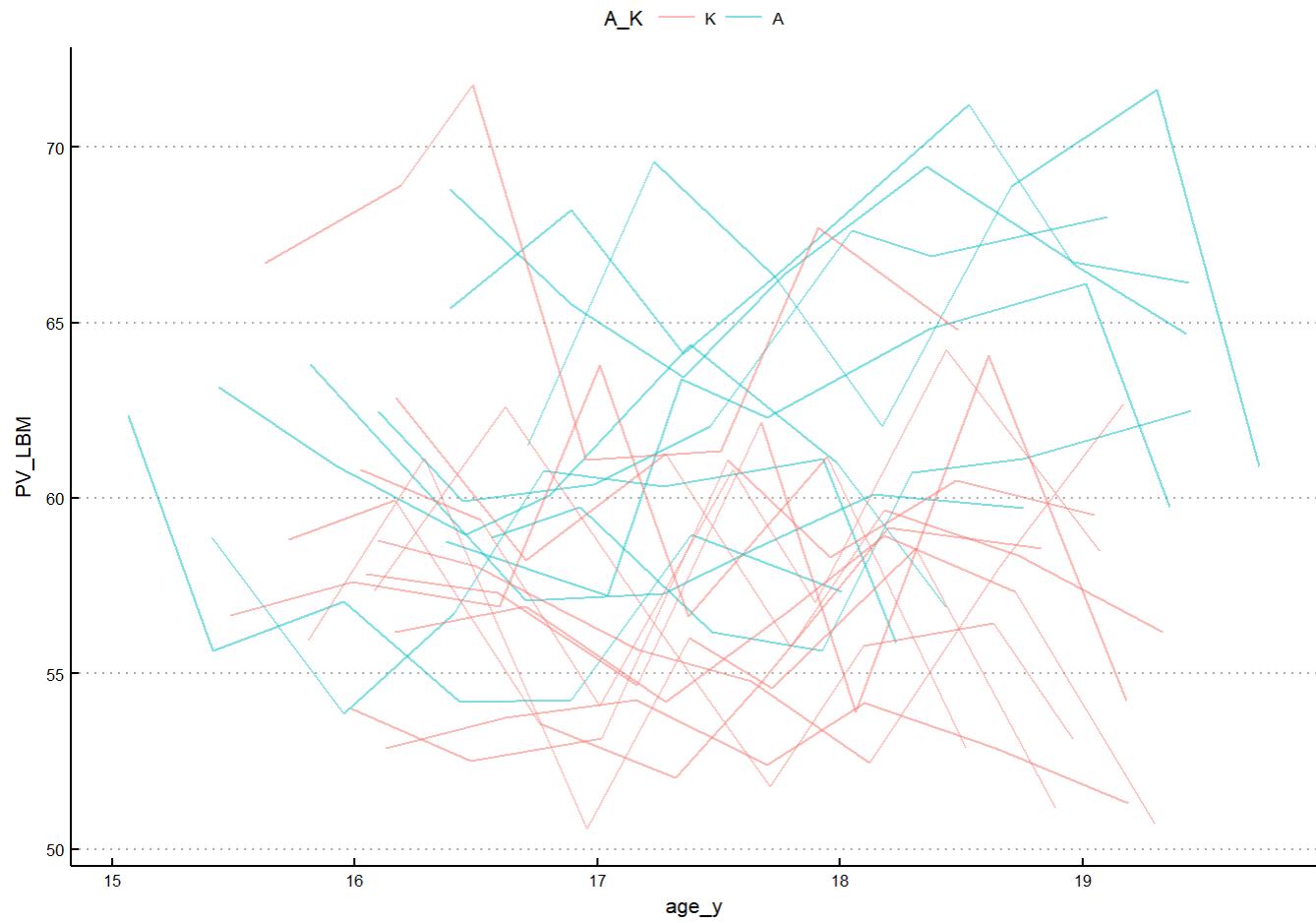
```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
##  
## Correlation of Fixed Effects:  
##      (Intr)  
## A_KA -0.672
```



```
## [1] "--"  
## [1] "PV_LBM"  
## [1] "--"
```



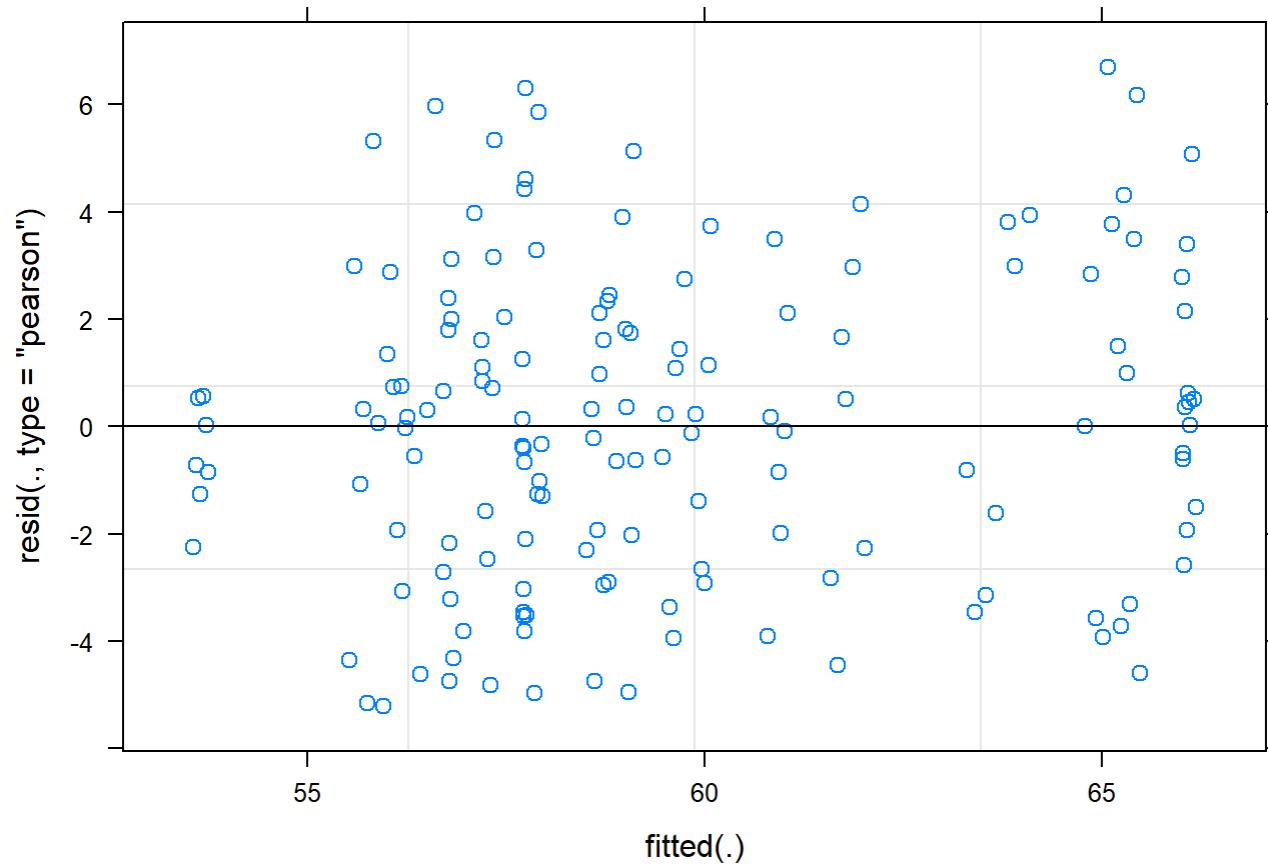
```

## [1] "baseline to lmem_age: 0.851395615526362"
## [1] "baseline to lmem_tr: 0.00826051719414931"
## [1] "baseline to lmem_age_tr_i: 0.0122235746075533"
## [1] "lmem_tr to lmem_age_tr: 0.777149918852594"
## [1] "lmem_tr to lmem_age_tr_i: 0.139894989312937"
## Linear mixed model fit by REML ['lmerMod']
## Formula: PV_LBM ~ A_K + (age_16 | ID)
## Data: data
##
## REML criterion at convergence: 828.4
##
## Scaled residuals:
##      Min       1Q   Median      3Q     Max 
## -1.68121 -0.72851  0.01516  0.65179  2.15842
##
## Random effects:
## Groups   Name        Variance Std.Dev. Corr
## ID       (Intercept) 9.8806   3.1433
##          age_16      0.1431   0.3782  -0.16
## Residual            9.6513   3.1067
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 57.6255    0.9582  60.142
## A_K         4.3290    1.4223   3.044

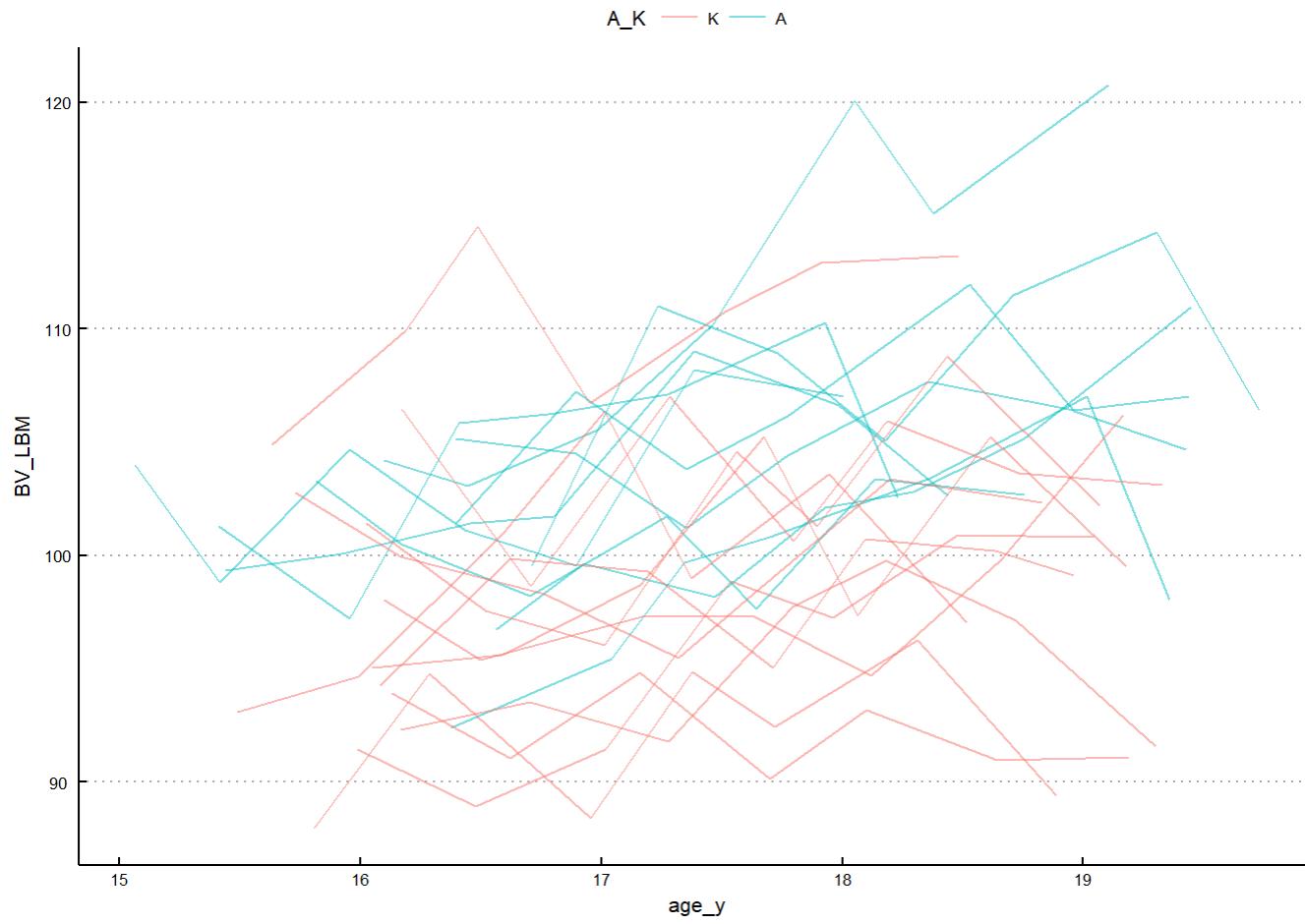
```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
##  
## Correlation of Fixed Effects:  
##      (Intr)  
## A_KA -0.674
```



```
## [1] "--"  
## [1] "BV_LBM"  
## [1] "--"
```



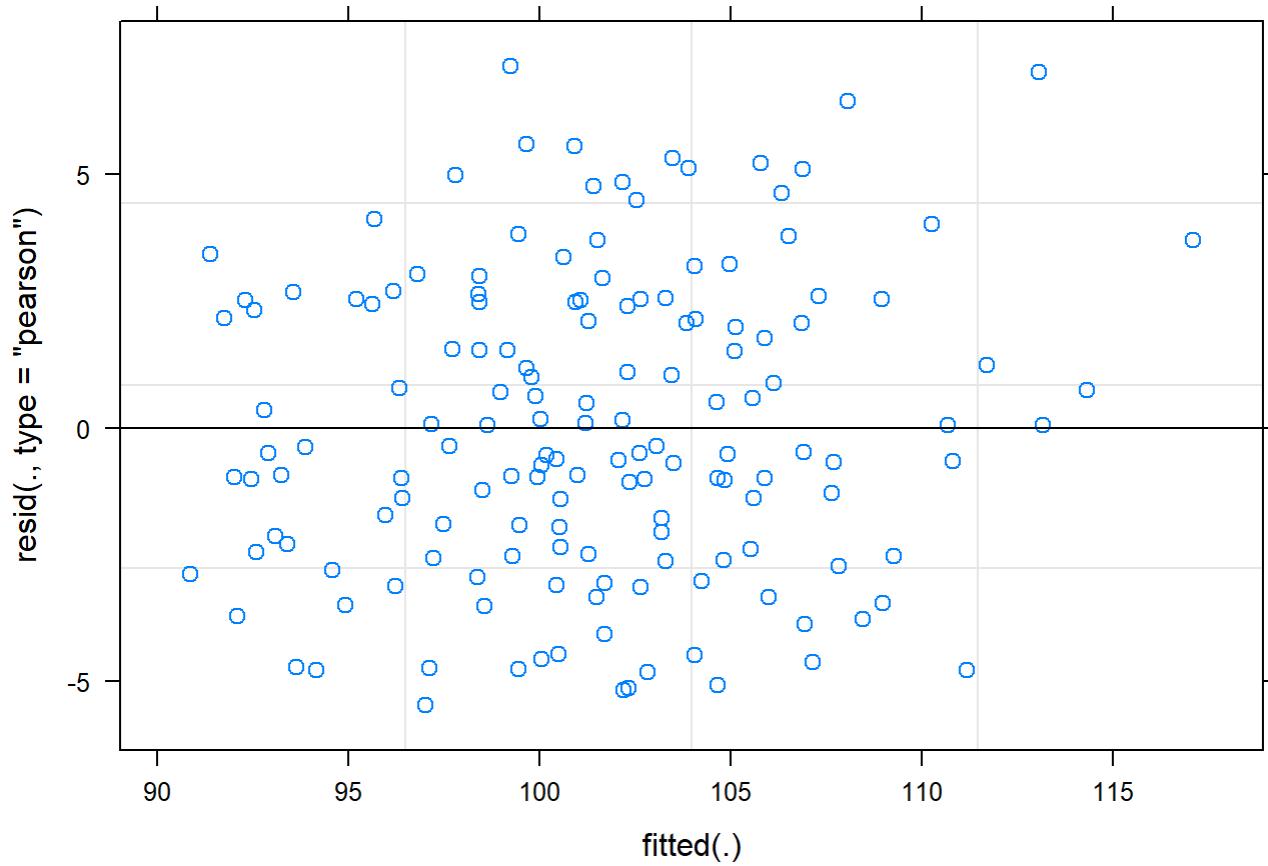
```

## [1] "baseline to lmem_age: 8.21284254715656e-06"
## [1] "baseline to lmem_tr: 0.0255462801053515"
## [1] "baseline to lmem_age_tr_i: 3.84612230795517e-06"
## [1] "lmem_age to lmem_age_tr: 0.0239636299700118"
## [1] "lmem_age_tr to lmem_age_tr_i: 0.0887688223002162"
## Linear mixed model fit by REML ['lmerMod']
## Formula: BV_LBM ~ age_16 + A_K + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: 863.4
##
## Scaled residuals:
##      Min       1Q   Median      3Q     Max
## -1.6601 -0.7416 -0.1305  0.7467  2.1637
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 16.0640  4.0080
##          age_16       0.9421  0.9706  0.13
##   Residual            10.8707  3.2971
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 96.5276    1.3027 74.097
## age_16      1.8681    0.3358  5.564

```

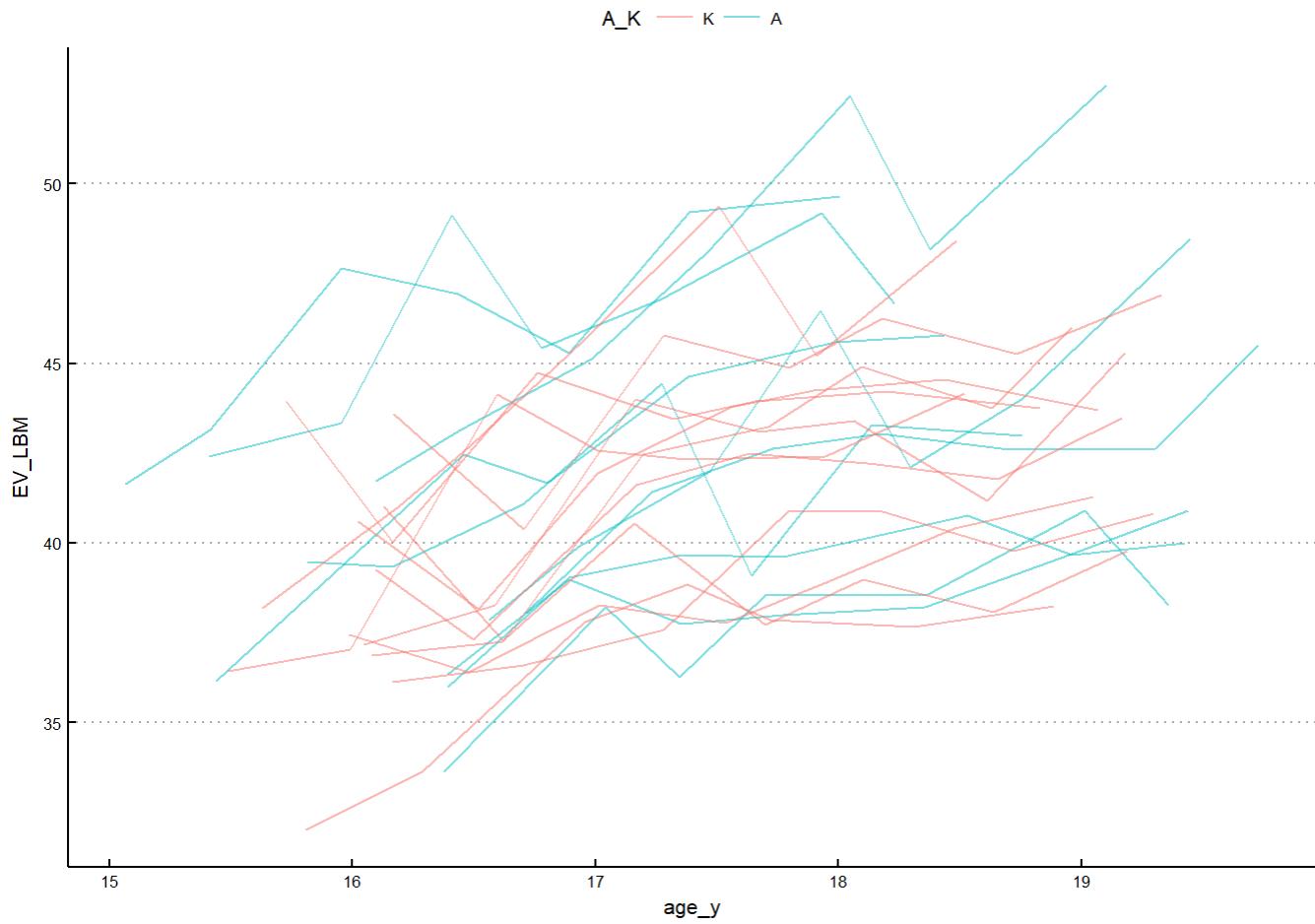
Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
## A_KA           4.6247    1.9042    2.429  
##  
## Correlation of Fixed Effects:  
##          (Intr) age_16  
## age_16 -0.180  
## A_KA   -0.662  0.000
```



```
## [1] "--"  
## [1] "EV_LBM"  
## [1] "--"
```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence



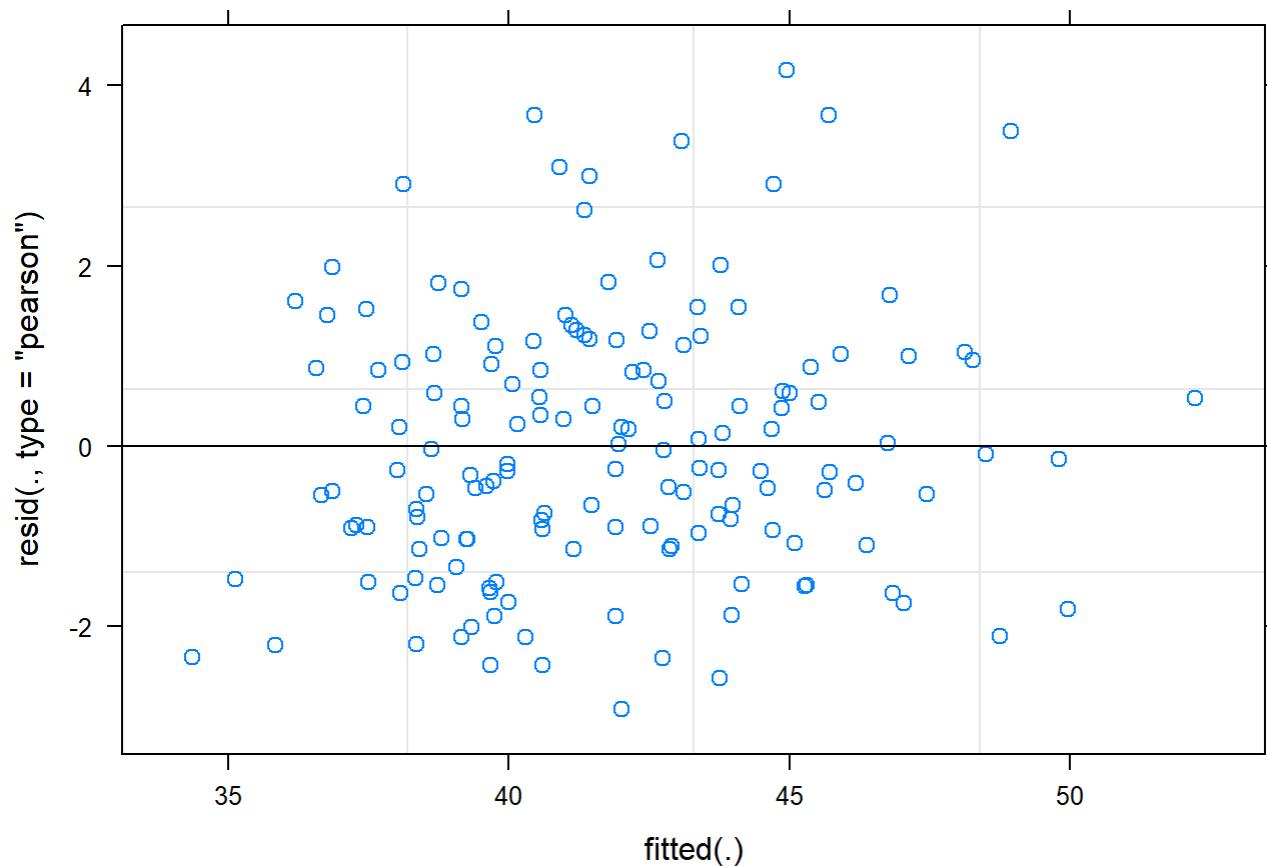
```

## [1] "baseline to lmem_age: 3.54742183717463e-09"
## [1] "baseline to lmem_tr: 0.457466908407772"
## [1] "baseline to lmem_age_tr_i: 8.31398894420757e-08"
## [1] "lmem_age to lmem_age_tr: 0.475902031632312"
## [1] "lmem_age to lmem_age_tr_i: 0.628871260584055"
## Linear mixed model fit by REML ['lmerMod']
## Formula: EV_LBM ~ age_16 + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: 675.8
##
## Scaled residuals:
##      Min       1Q   Median      3Q      Max
## -1.7949 -0.6328 -0.1044  0.5826  2.5630
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 7.9135   2.8131
##          age_16       0.5658   0.7522   0.30
##   Residual            2.6547   1.6293
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 39.1197     0.6441  60.738
## age_16       1.8662     0.2072   9.008

```

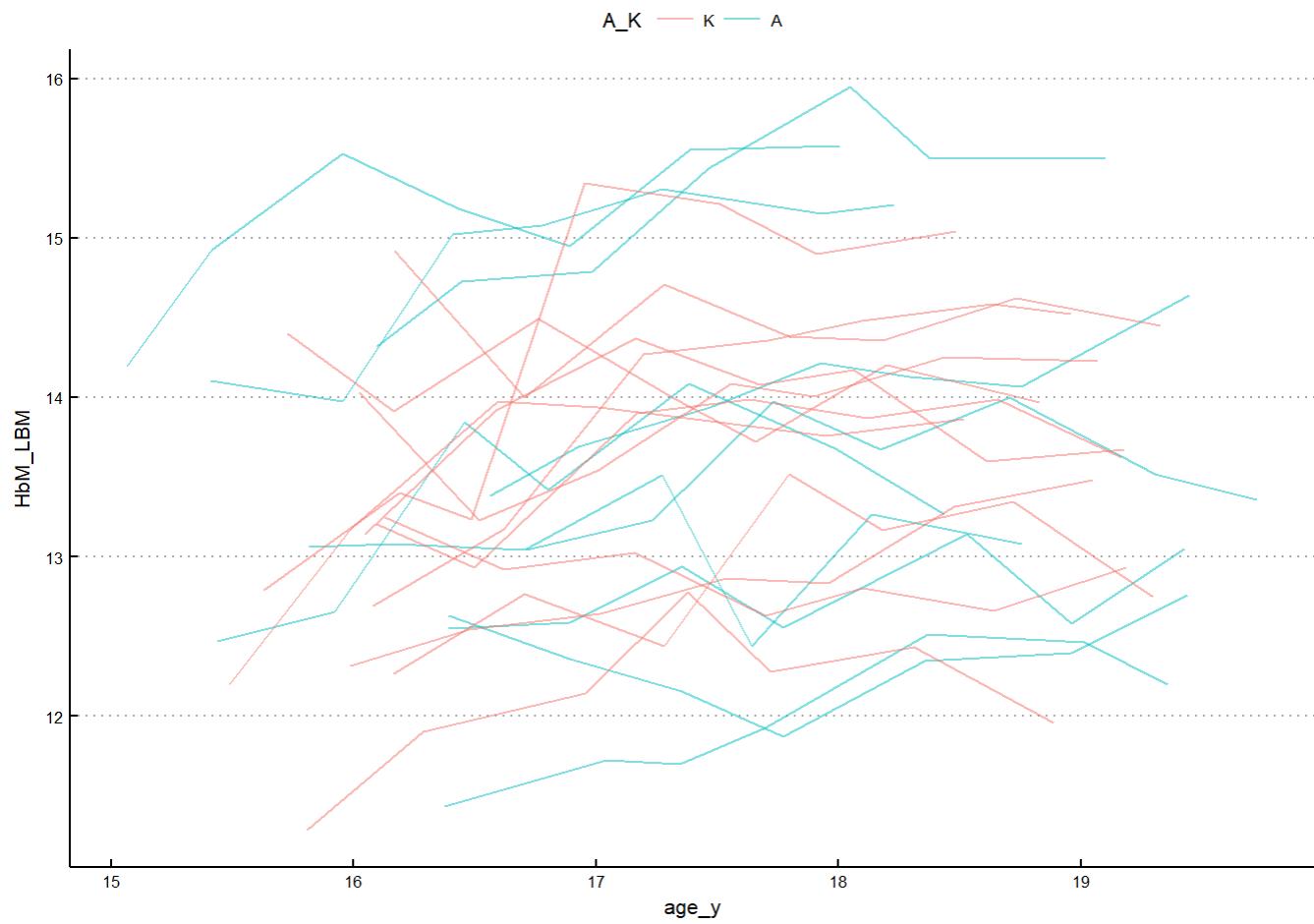
Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
##  
## Correlation of Fixed Effects:  
##          (Intr)  
## age_16  0.028
```



```
## [1] "-----"  
## [1] "HbM_LBM"  
## [1] "-----"
```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence



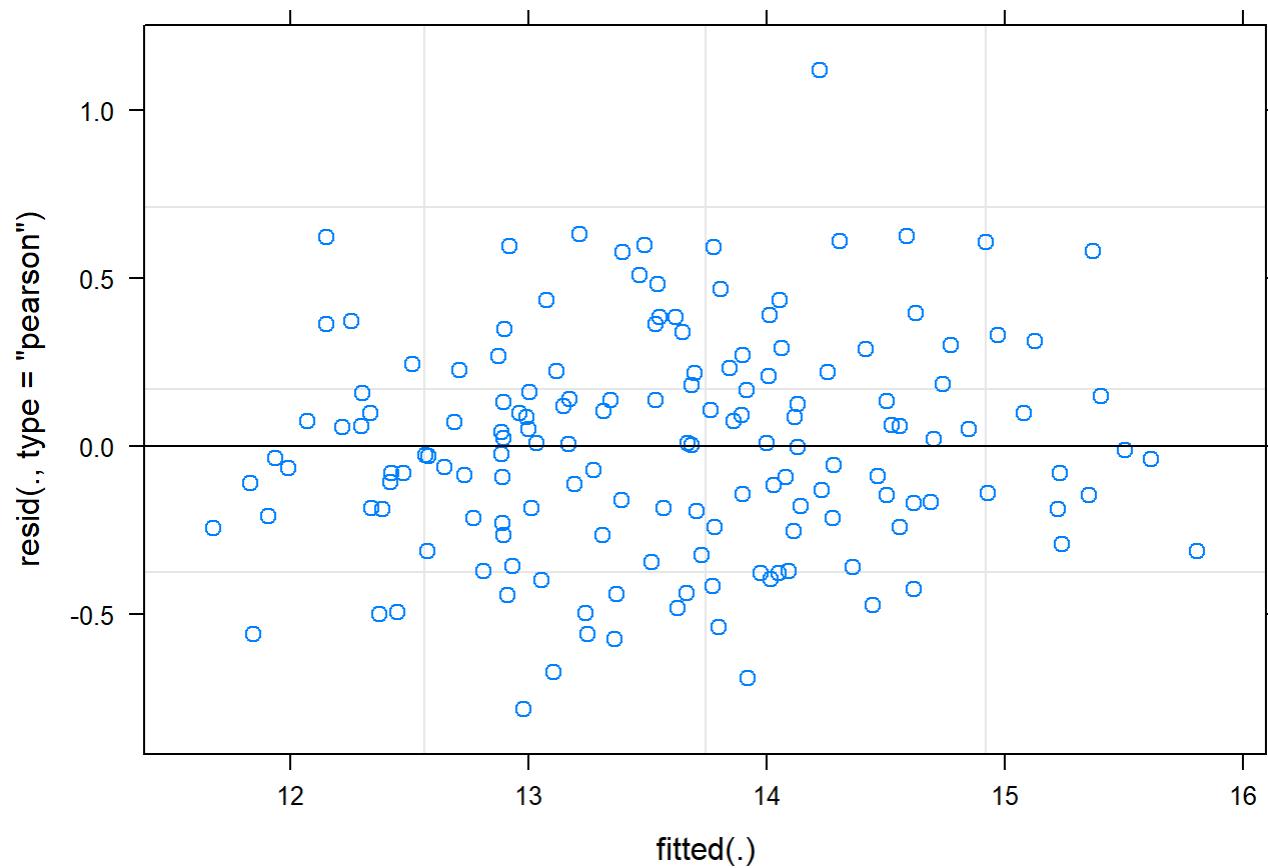
```

## [1] "baseline to lmem_age: 4.40893341816593e-05"
## [1] "baseline to lmem_tr: 0.796690717779169"
## [1] "baseline to lmem_age_tr_i: 0.000792829111660354"
## [1] "lmem_age to lmem_age_tr: 0.803351532693272"
## [1] "lmem_age to lmem_age_tr_i: 0.965361650660138"
## Linear mixed model fit by REML ['lmerMod']
## Formula: HbM_LBM ~ age_16 + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: 241
##
## Scaled residuals:
##      Min       1Q     Median       3Q      Max
## -2.11311 -0.57254  0.00248  0.54531  3.02417
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 0.78795  0.8877
##          age_16       0.03756  0.1938   0.11
##   Residual            0.13712  0.3703
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 13.24398    0.19672 67.324
## age_16       0.24820    0.05097  4.869

```

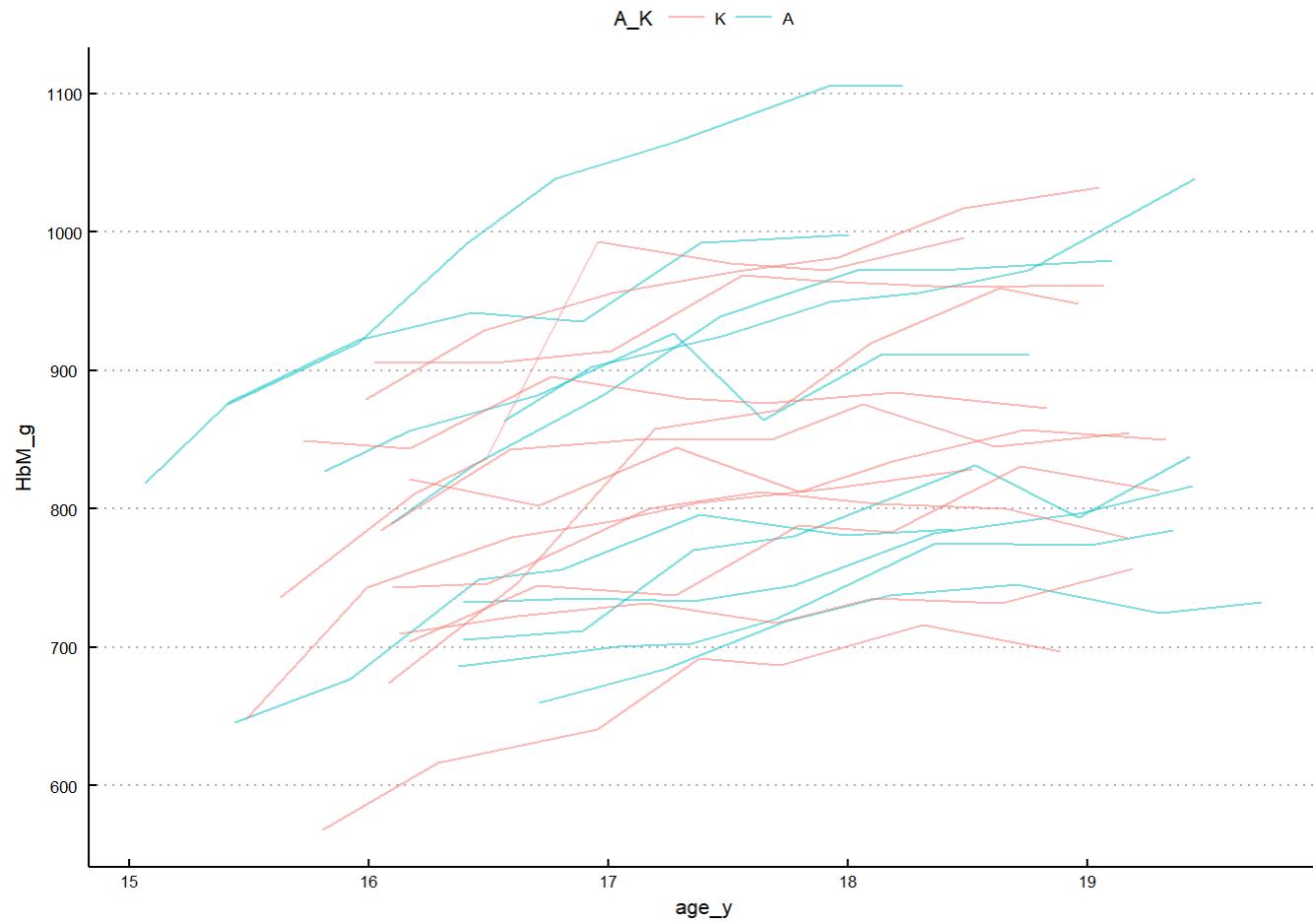
Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
##  
## Correlation of Fixed Effects:  
##          (Intr)  
## age_16 -0.041
```



```
## [1] "--"  
## [1] "HbM_g"  
## [1] "--"
```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence



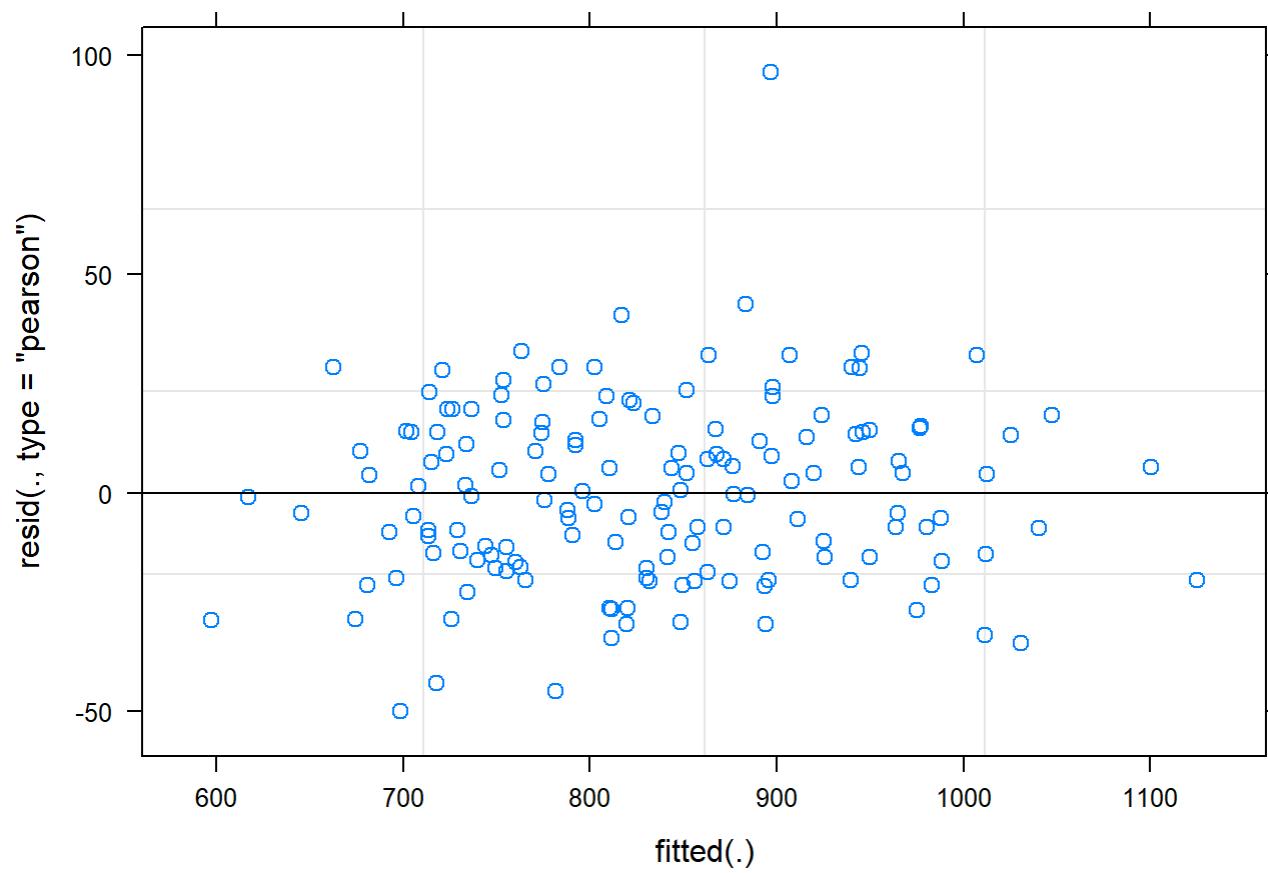
```

## [1] "baseline to lmem_age: 6.50293558122721e-08"
## [1] "baseline to lmem_tr: 0.958155735043722"
## [1] "baseline to lmem_age_tr_i: 1.55150475223909e-06"
## [1] "lmem_age to lmem_age_tr: 0.967104144547207"
## [1] "lmem_age to lmem_age_tr_i: 0.759279628379613"
## Linear mixed model fit by REML ['lmerMod']
## Formula: HbM_g ~ age_16 + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: 1548
##
## Scaled residuals:
##      Min     1Q Median     3Q    Max
## -2.1029 -0.6230 -0.0170  0.5861  4.0476
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 8738.3   93.48
##          age_16       587.7   24.24    0.14
##   Residual            565.9   23.79
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 775.396    20.230  38.328
## age_16      42.041     5.514   7.624

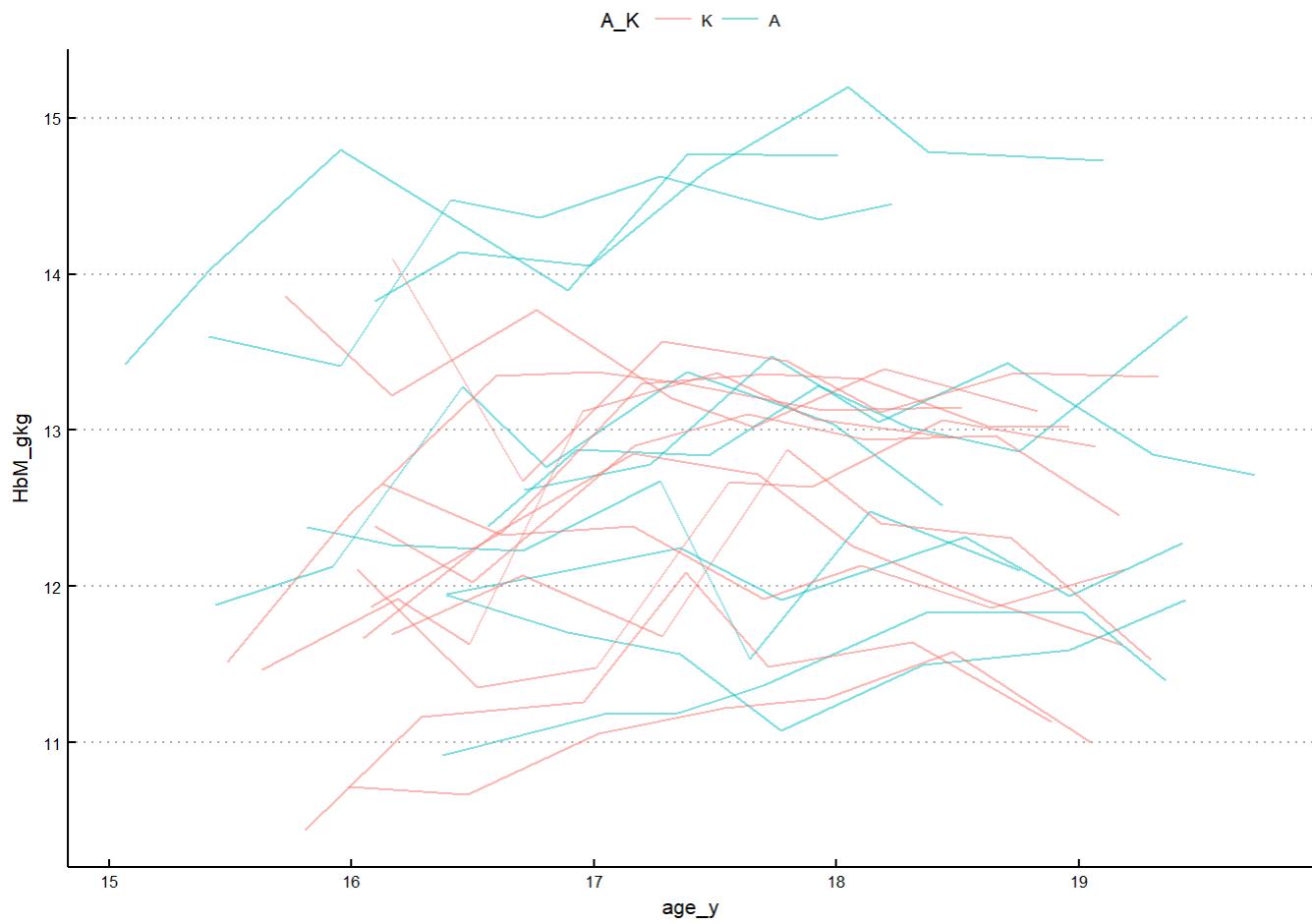
```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
##  
## Correlation of Fixed Effects:  
##          (Intr)  
## age_16  0.083
```



```
## [1] "-----"  
## [1] "HbM_gkg"  
## [1] "-----"
```



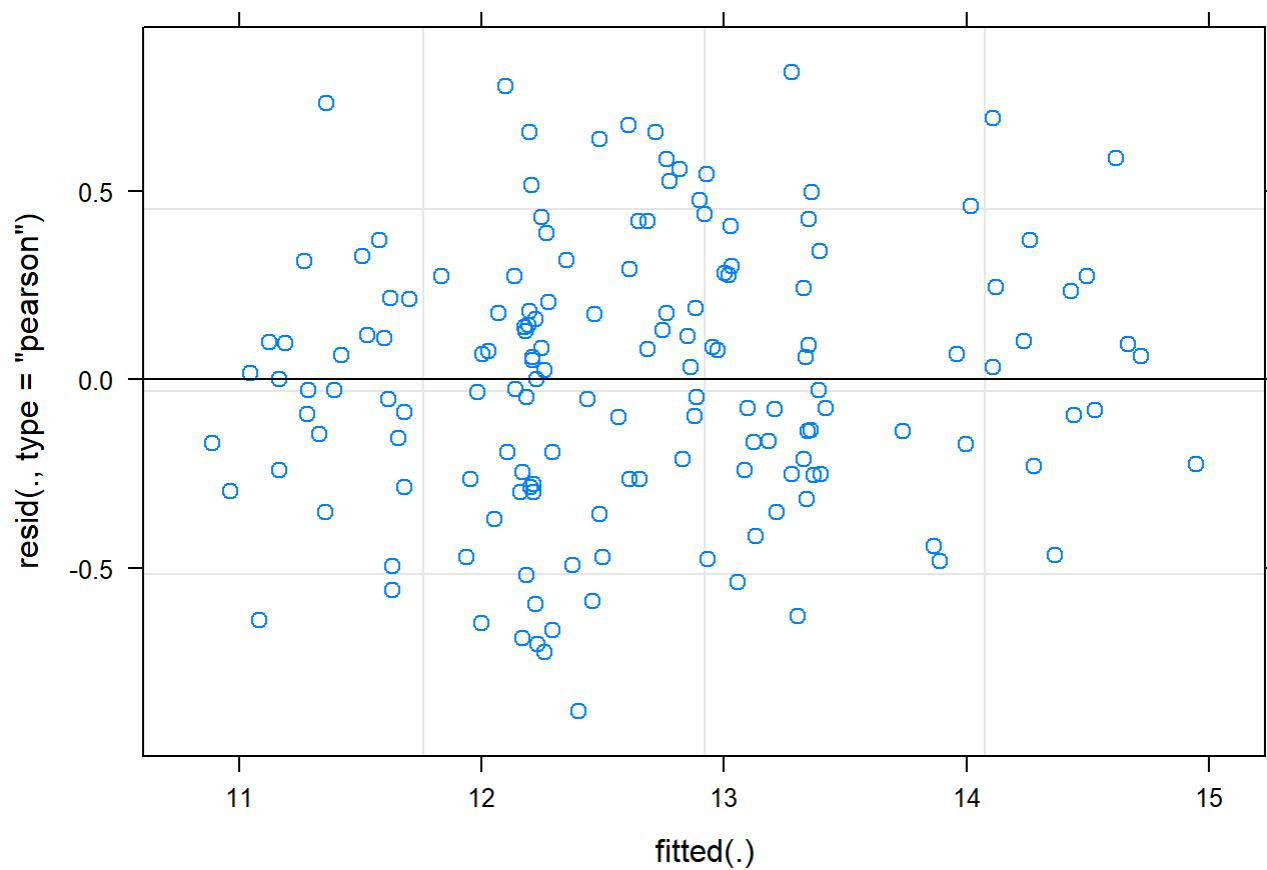
```

## [1] "baseline to lmem_age: 0.00146278409049112"
## [1] "baseline to lmem_tr: 0.205418296998794"
## [1] "baseline to lmem_age_tr_i: 0.0084677643210548"
## [1] "lmem_age to lmem_age_tr: 0.210228376837079"
## [1] "lmem_age to lmem_age_tr_i: 0.453976685115016"
## Linear mixed model fit by REML ['lmerMod']
## Formula: HbM_gkg ~ age_16 + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: 258.3
##
## Scaled residuals:
##      Min       1Q     Median       3Q      Max
## -2.18833 -0.61944  0.02217  0.59601  2.02979
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 0.85014  0.9220
##   age_16    0.02941  0.1715   0.01
##   Residual   0.16117  0.4015
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 12.40620   0.20499 60.521
## age_16      0.17014   0.04882  3.485

```

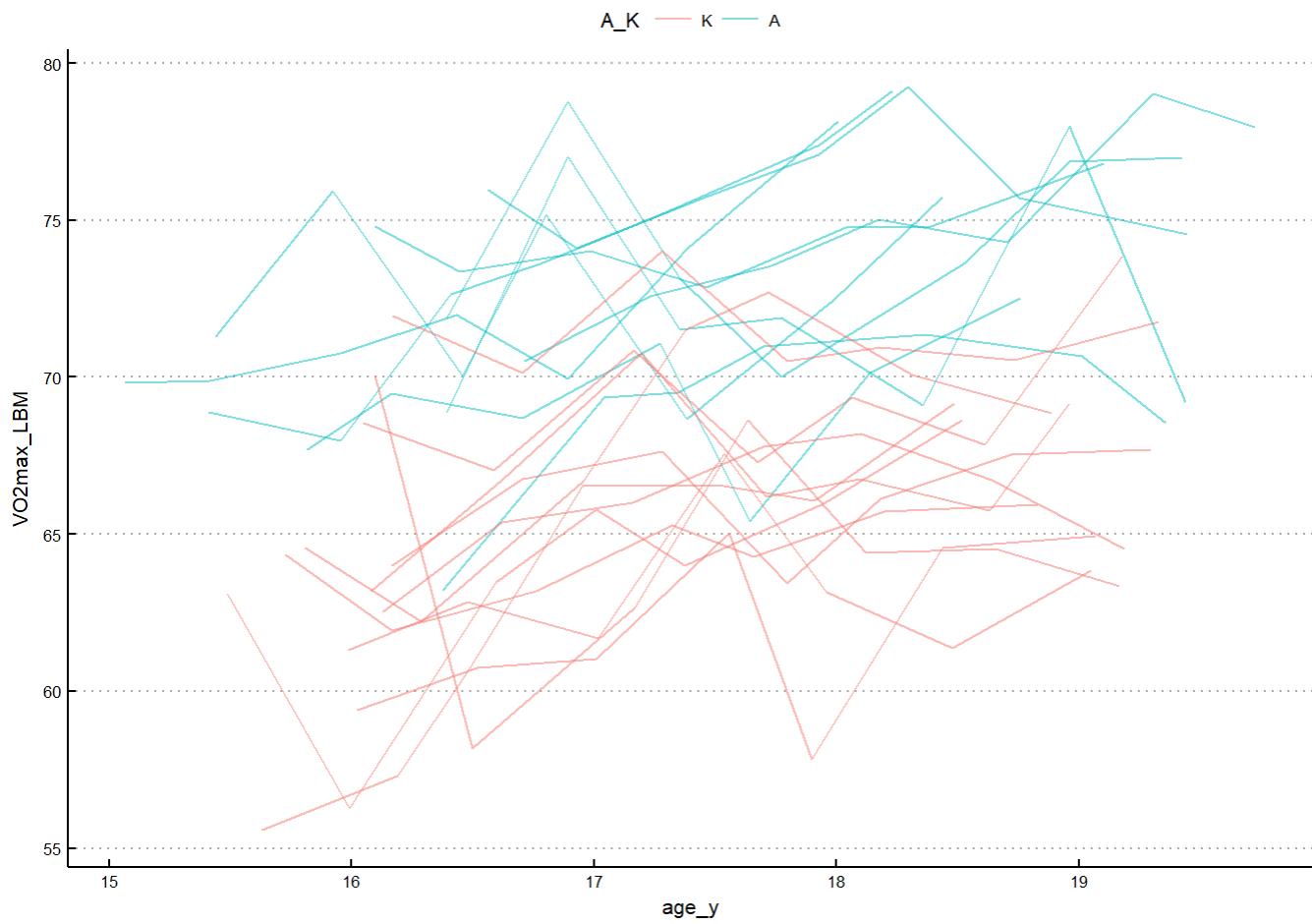
Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
##  
## Correlation of Fixed Effects:  
##          (Intr)  
## age_16 -0.143
```



```
## [1] "-----"  
## [1] "VO2max_LBM"  
## [1] "-----"
```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence



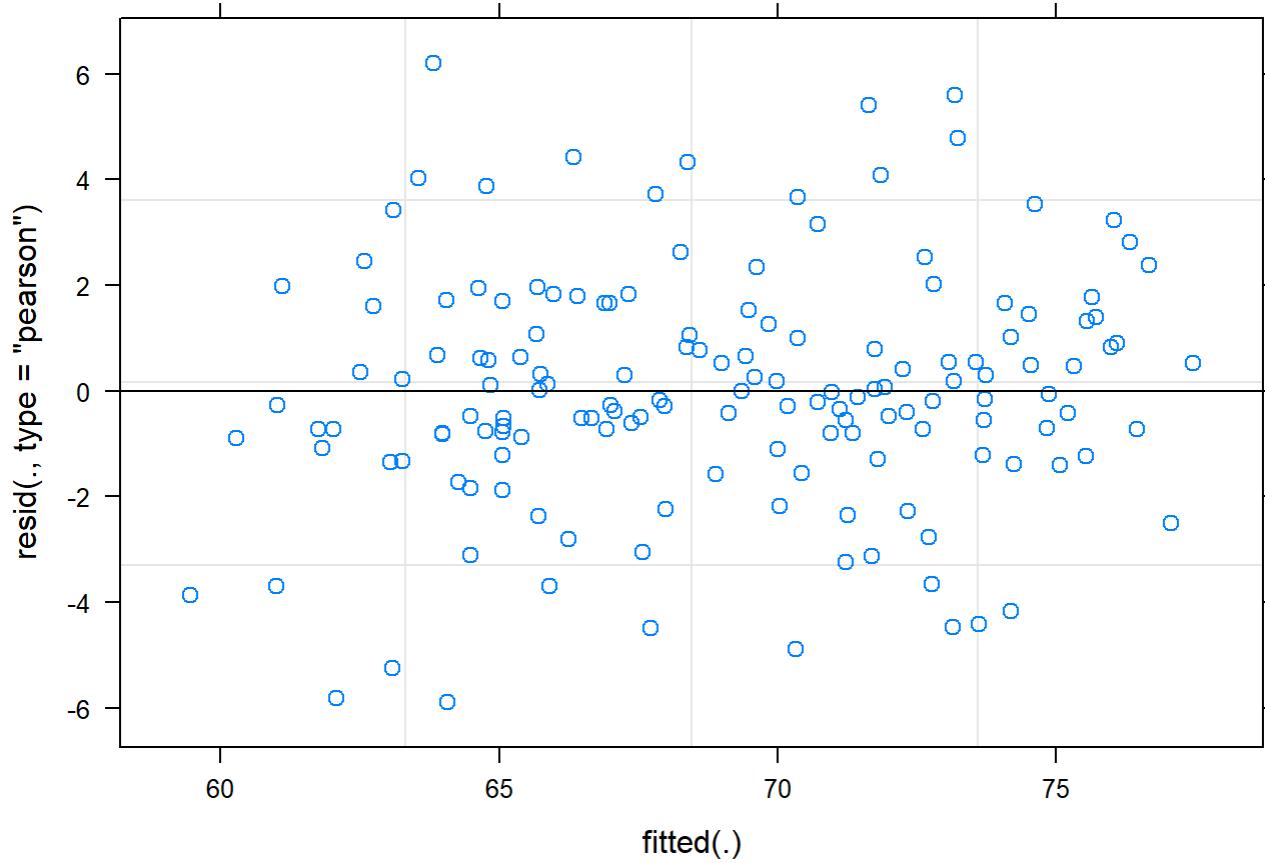
```

## [1] "baseline to lmem_age: 3.95690095457991e-05"
## [1] "baseline to lmem_tr: 5.90362390665445e-07"
## [1] "baseline to lmem_age_tr_i: 3.13790752784746e-09"
## [1] "lmem_age to lmem_age_tr: 4.18237467831802e-07"
## [1] "lmem_age_tr to lmem_age_tr_i: 0.958873195029178"
## Linear mixed model fit by REML ['lmerMod']
## Formula: VO2max_LBM ~ age_16 + A_K + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: 767.6
##
## Scaled residuals:
##      Min       1Q     Median       3Q      Max
## -2.37877 -0.42027 -0.03865  0.52653  2.50250
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 7.2417   2.6910
##          age_16       0.6519   0.8074  -0.51
##   Residual            6.1507   2.4801
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 63.9088    0.8310 76.908
## age_16      1.3250    0.2622  5.053

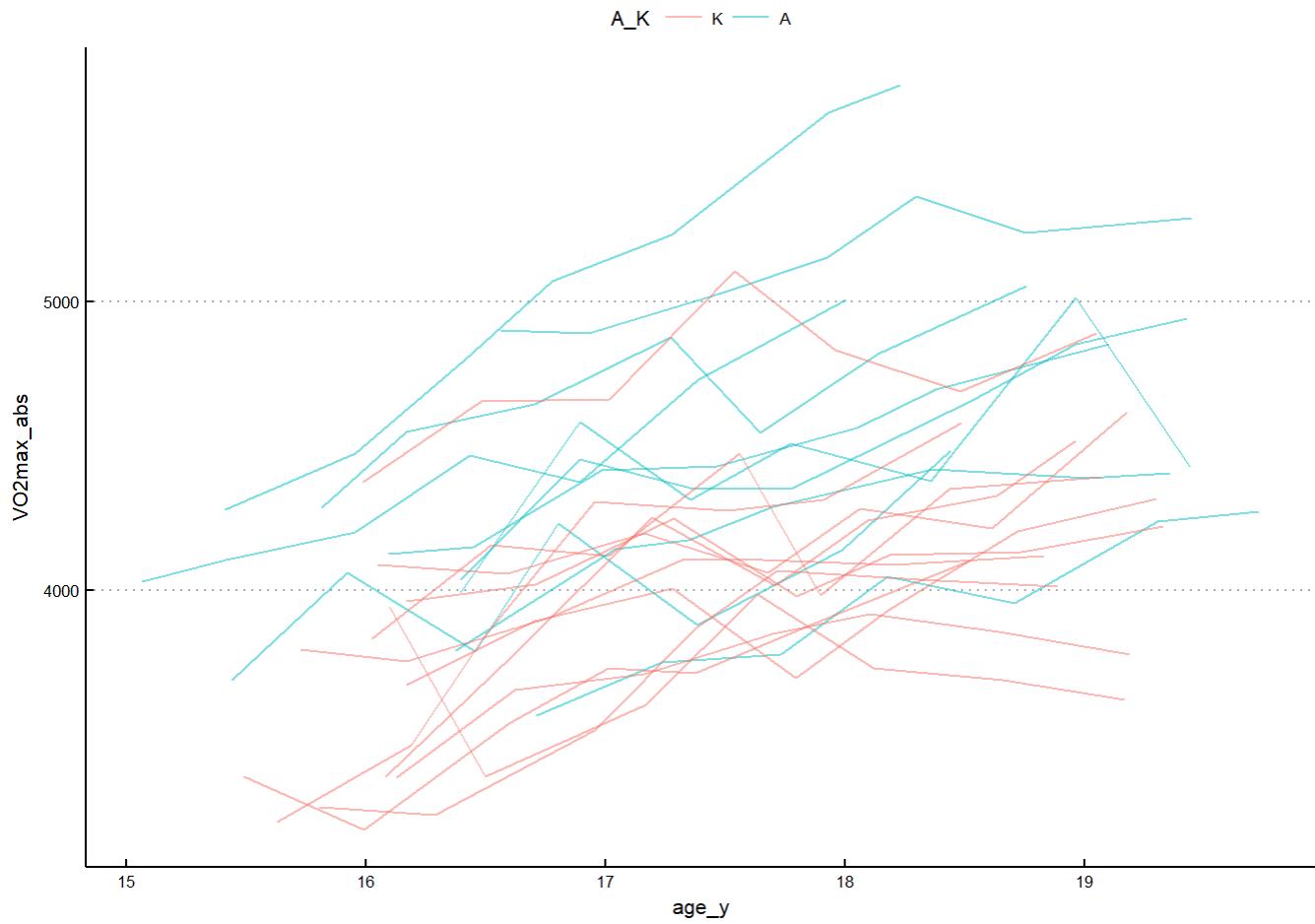
```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
## A_KA           7.0930    1.0747    6.600
##
## Correlation of Fixed Effects:
##          (Intr) age_16
## age_16   -0.495
## A_KA     -0.582 -0.003
```



```
## [1] "-----"
## [1] "VO2max_abs"
## [1] "-----"
```



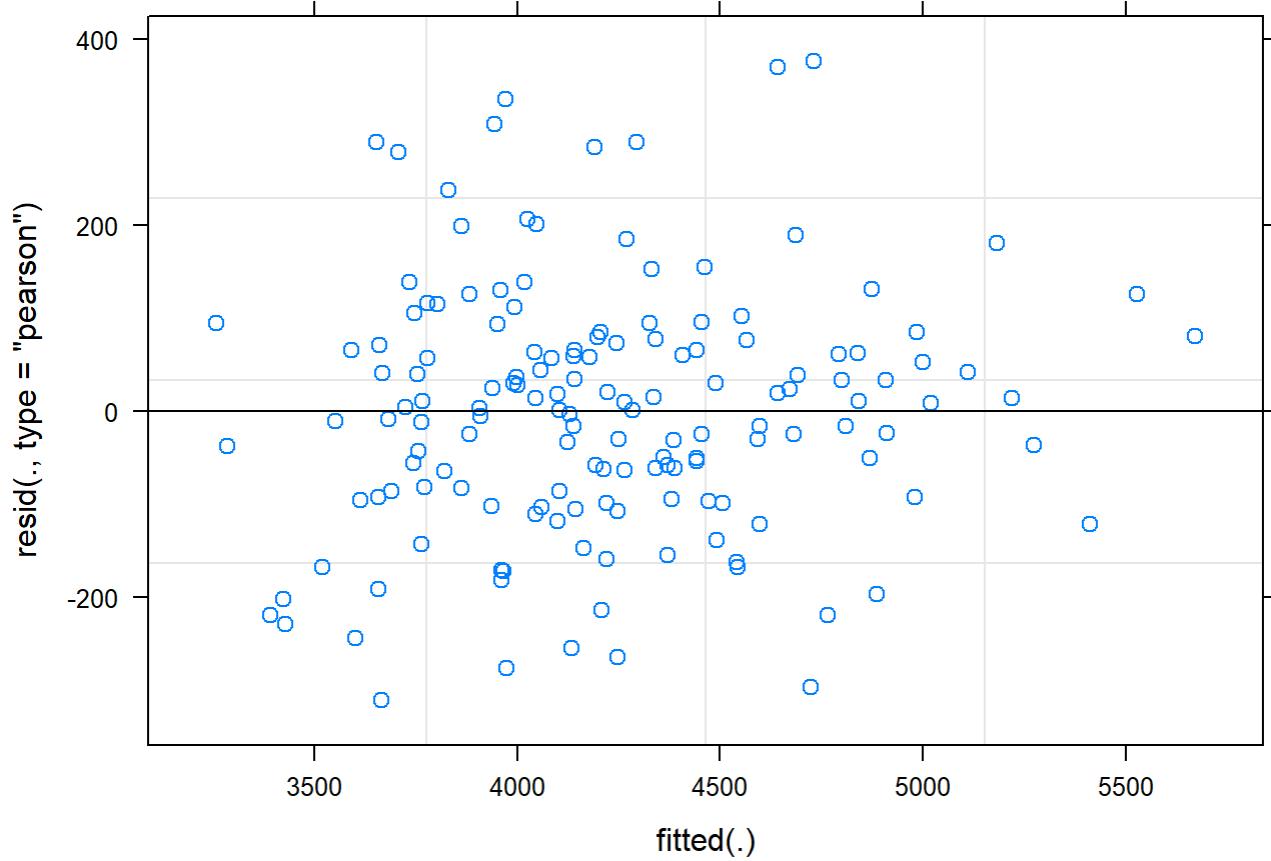
```

## [1] "baseline to lmem_age: 1.82067644253205e-08"
## [1] "baseline to lmem_tr: 0.00659471027681868"
## [1] "baseline to lmem_age_tr_i: 9.39548202782665e-09"
## [1] "lmem_age to lmem_age_tr: 0.00651551672281263"
## [1] "lmem_age_tr to lmem_age_tr_i: 0.277586775151503"
## Linear mixed model fit by REML ['lmerMod']
## Formula: VO2max_abs ~ age_16 + A_K + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: 2068
##
## Scaled residuals:
##      Min       1Q     Median      3Q      Max
## -2.01996 -0.58979  0.02481  0.46945  2.44125
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 121603    348.7
##          age_16       11915    109.2    -0.10
##   Residual            23796    154.3
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 3724.62     104.13  35.767
## age_16       216.88      26.39   8.220

```

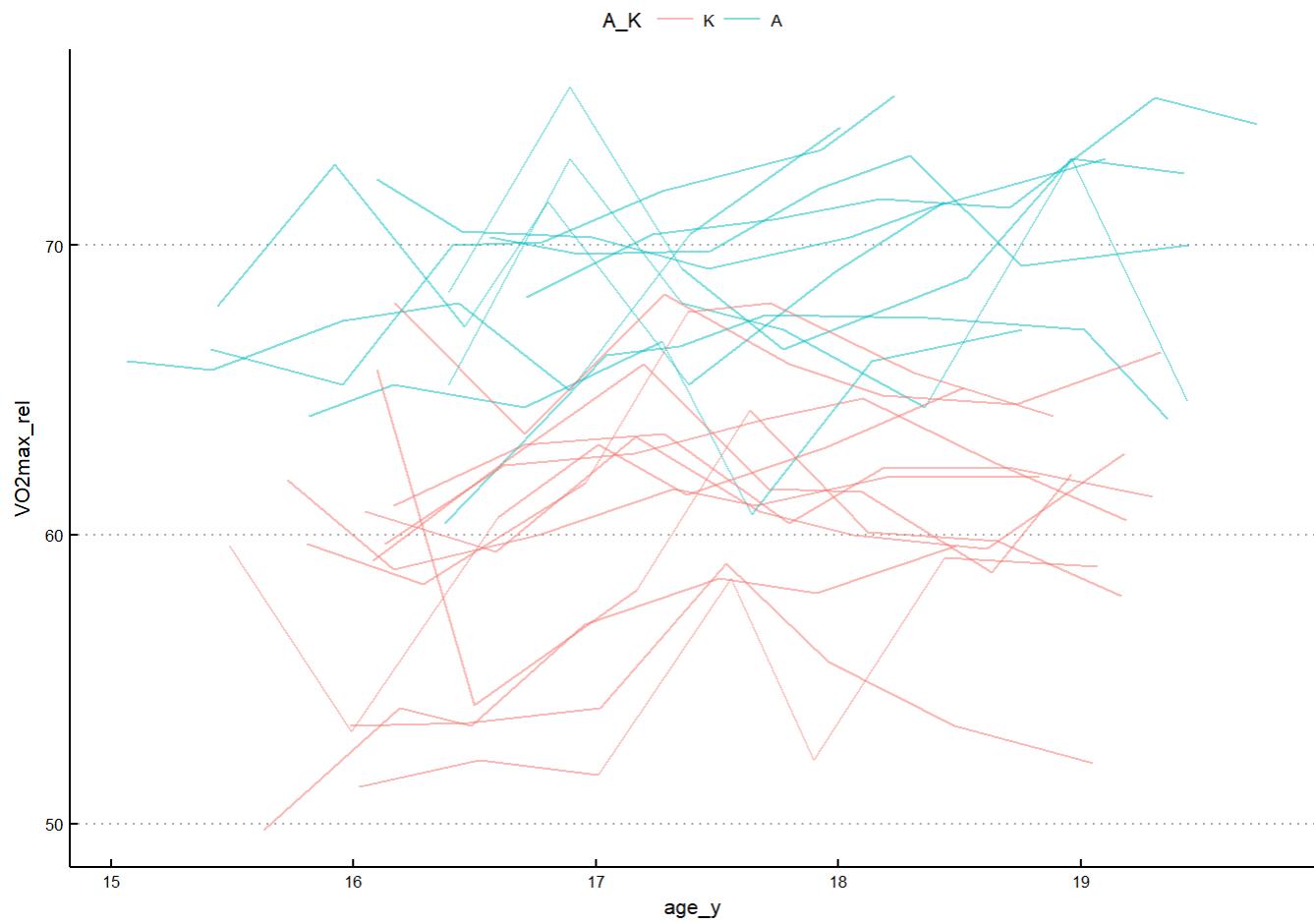
Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
## A_KA          445.14      153.12     2.907  
##  
## Correlation of Fixed Effects:  
##           (Intr) age_16  
## age_16 -0.142  
## A_KA   -0.666 -0.001
```



```
## [1] "-----"  
## [1] "VO2max_rel"  
## [1] "-----"
```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence



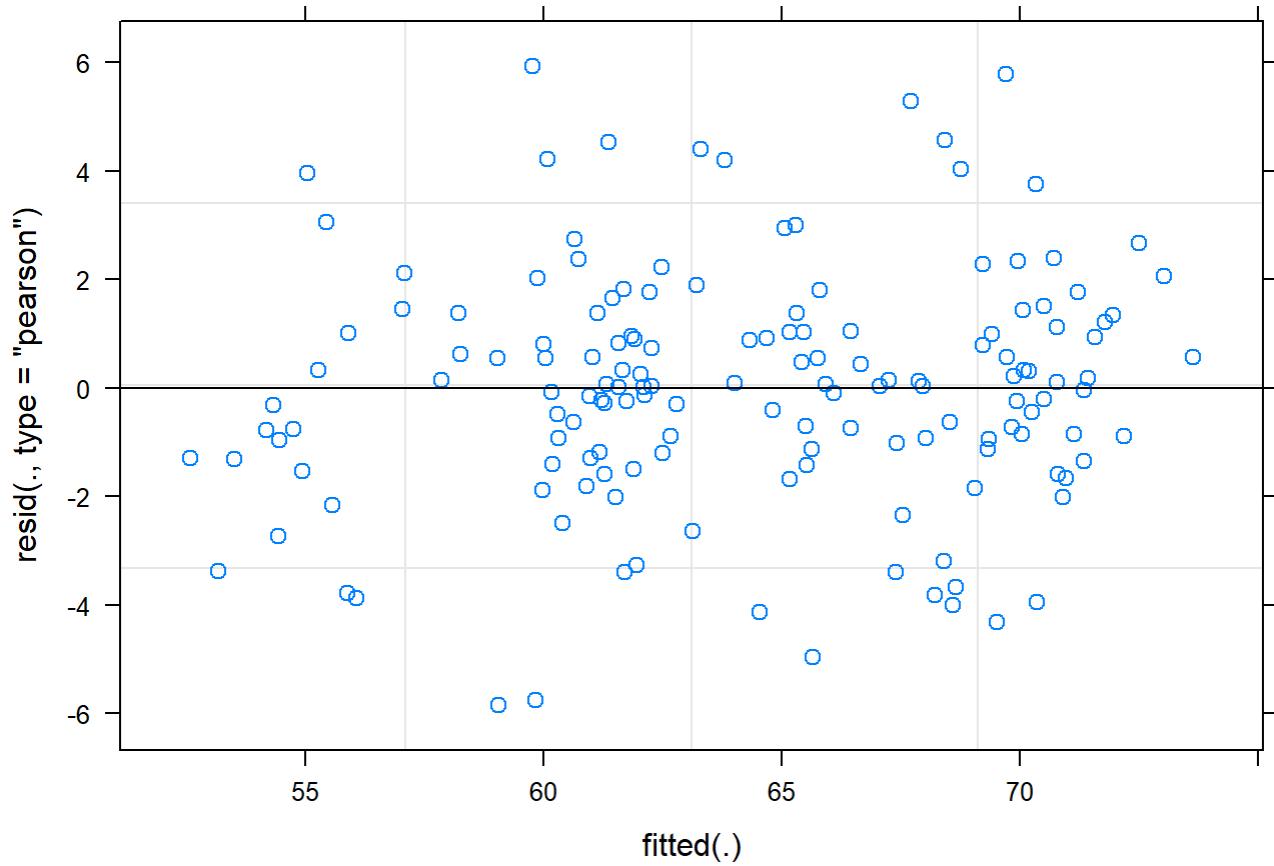
```

## [1] "baseline to lmem_age: 0.00190749371299934"
## [1] "baseline to lmem_tr: 3.28242766635589e-07"
## [1] "baseline to lmem_age_tr_i: 7.57121461487558e-08"
## [1] "lmem_age to lmem_age_tr: 2.89758843980826e-07"
## [1] "lmem_age_tr to lmem_age_tr_i: 0.876574181383188"
## Linear mixed model fit by REML ['lmerMod']
## Formula: VO2max_rel ~ age_16 + A_K + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: 771.7
##
## Scaled residuals:
##      Min       1Q     Median       3Q      Max
## -2.39881 -0.49169  0.01296  0.45157  2.43083
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 10.8752  3.2977
##          age_16       0.7189  0.8479  -0.52
##   Residual           5.9590  2.4411
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 59.0571    0.9772 60.438
## age_16      0.9137    0.2662  3.432

```

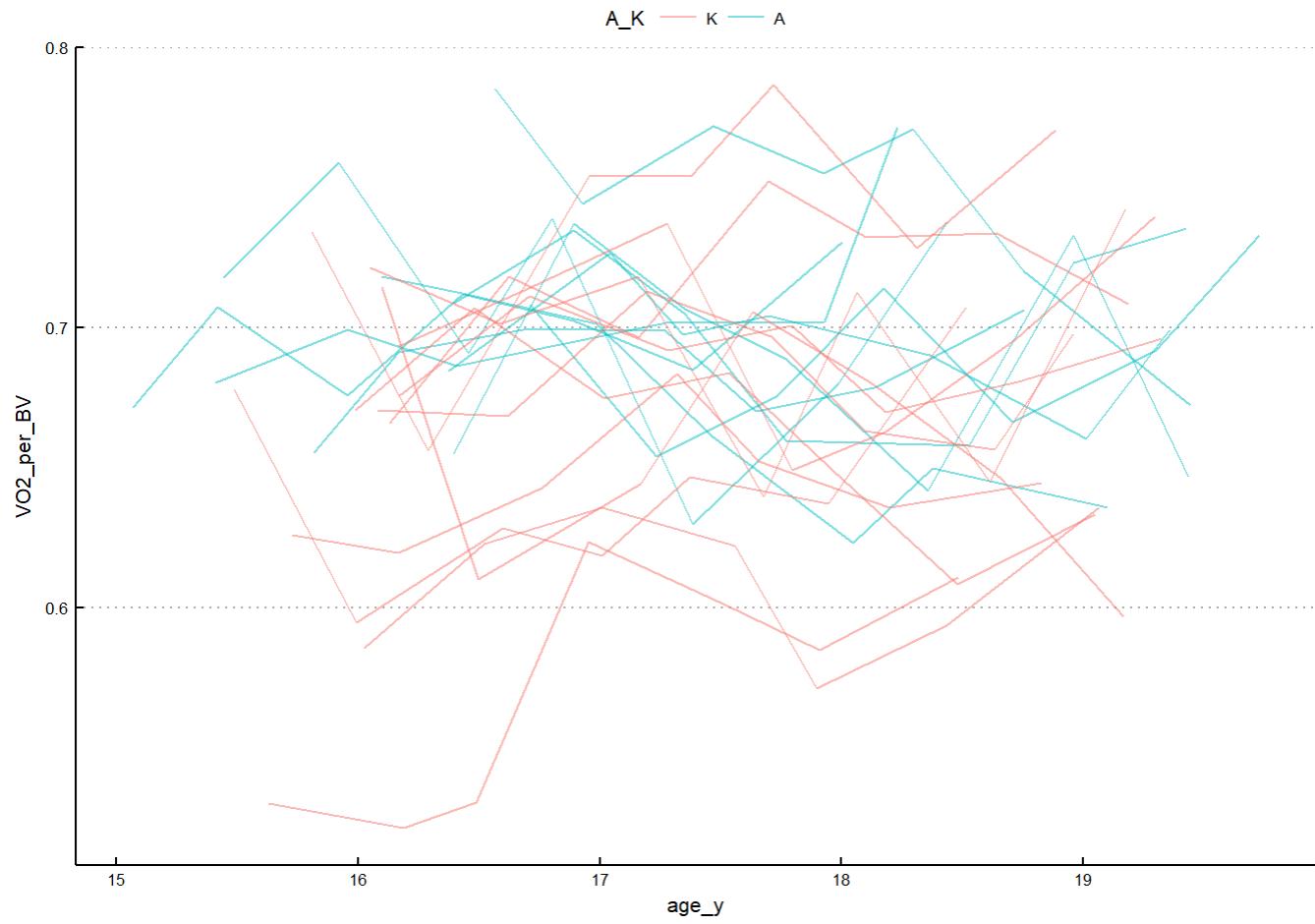
Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
## A_KA           8.6963    1.2845   6.770
##
## Correlation of Fixed Effects:
##          (Intr) age_16
## age_16 -0.468
## A_KA   -0.593 -0.002
```



```
## [1] "-----"
## [1] "VO2_per_BV"
## [1] "-----"
```

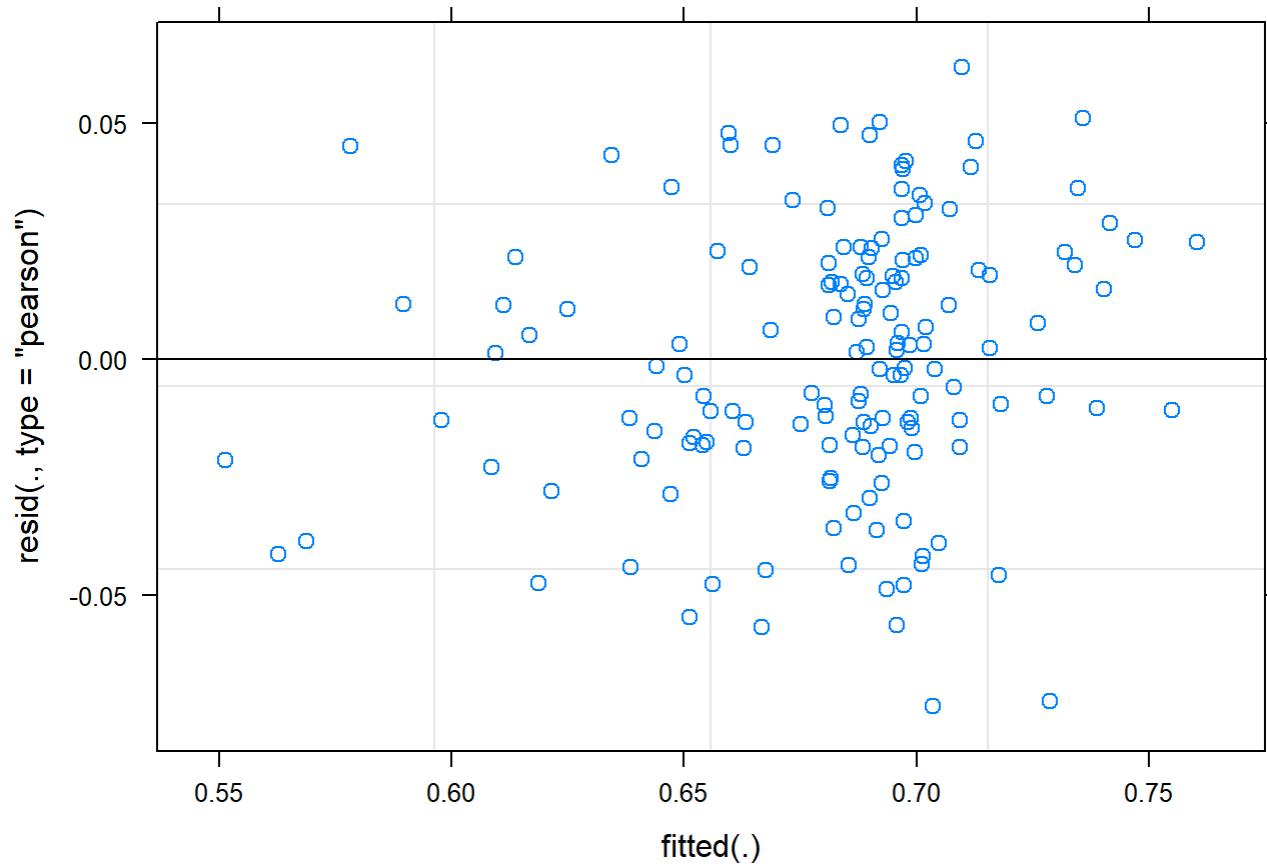
Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence



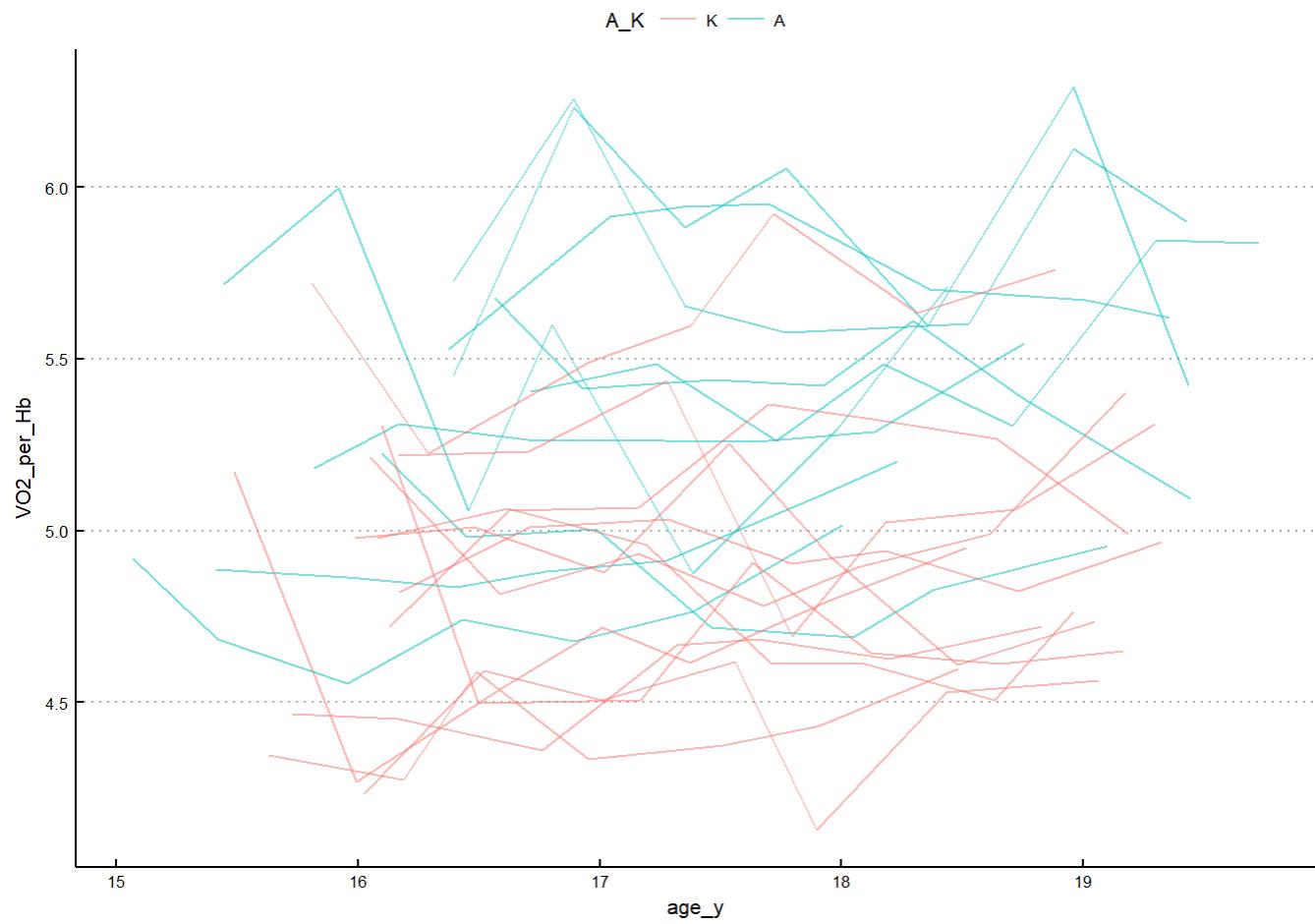
```

## [1] "baseline to lmem_age: 0.830525931271103"
## [1] "baseline to lmem_tr: 0.069144475761104"
## [1] "baseline to lmem_age_tr_i: 0.179430662559077"
## Linear mixed model fit by REML ['lmerMod']
## Formula: VO2_per_BV ~ 1 + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: -559.9
##
## Scaled residuals:
##      Min       1Q     Median       3Q      Max
## -2.35907 -0.57903  0.04661  0.66833  1.98519
##
## Random effects:
## Groups   Name        Variance Std.Dev. Corr
## ID       (Intercept) 0.0020410 0.04518
##         age_16       0.0001129 0.01063 -0.65
## Residual            0.0009720 0.03118
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 0.683370  0.008065 84.73

```



```
## [1] "--"
## [1] "VO2_per_Hb"
## [1] "--"
```



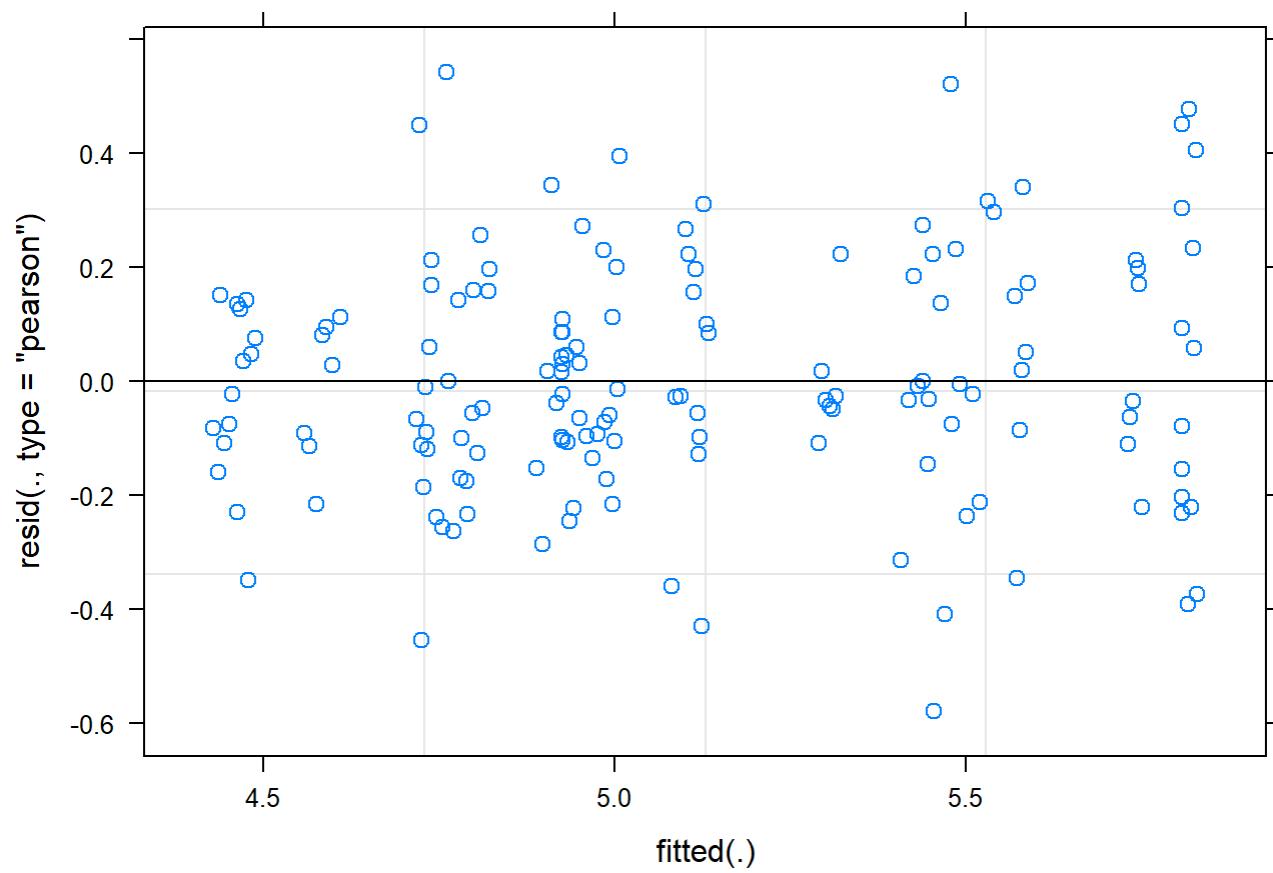
```

## [1] "baseline to lmem_age: 0.678122318821988"
## [1] "baseline to lmem_tr: 0.00183102418265141"
## [1] "baseline to lmem_age_tr_i: 0.0188635860043452"
## [1] "lmem_tr to lmem_age_tr: 0.614793764811338"
## [1] "lmem_tr to lmem_age_tr_i: 0.880901625284346"
## Linear mixed model fit by REML ['lmerMod']
## Formula: VO2_per_Hb ~ A_K + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: 45.1
##
## Scaled residuals:
##      Min       1Q   Median      3Q     Max
## -2.6010 -0.5138 -0.1029  0.6358  2.4302
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 0.127367  0.35689
##          age_16       0.001084  0.03292 -0.23
##   Residual            0.049797  0.22315
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 4.8697    0.1036 47.002
## A_K         0.5131    0.1537  3.337

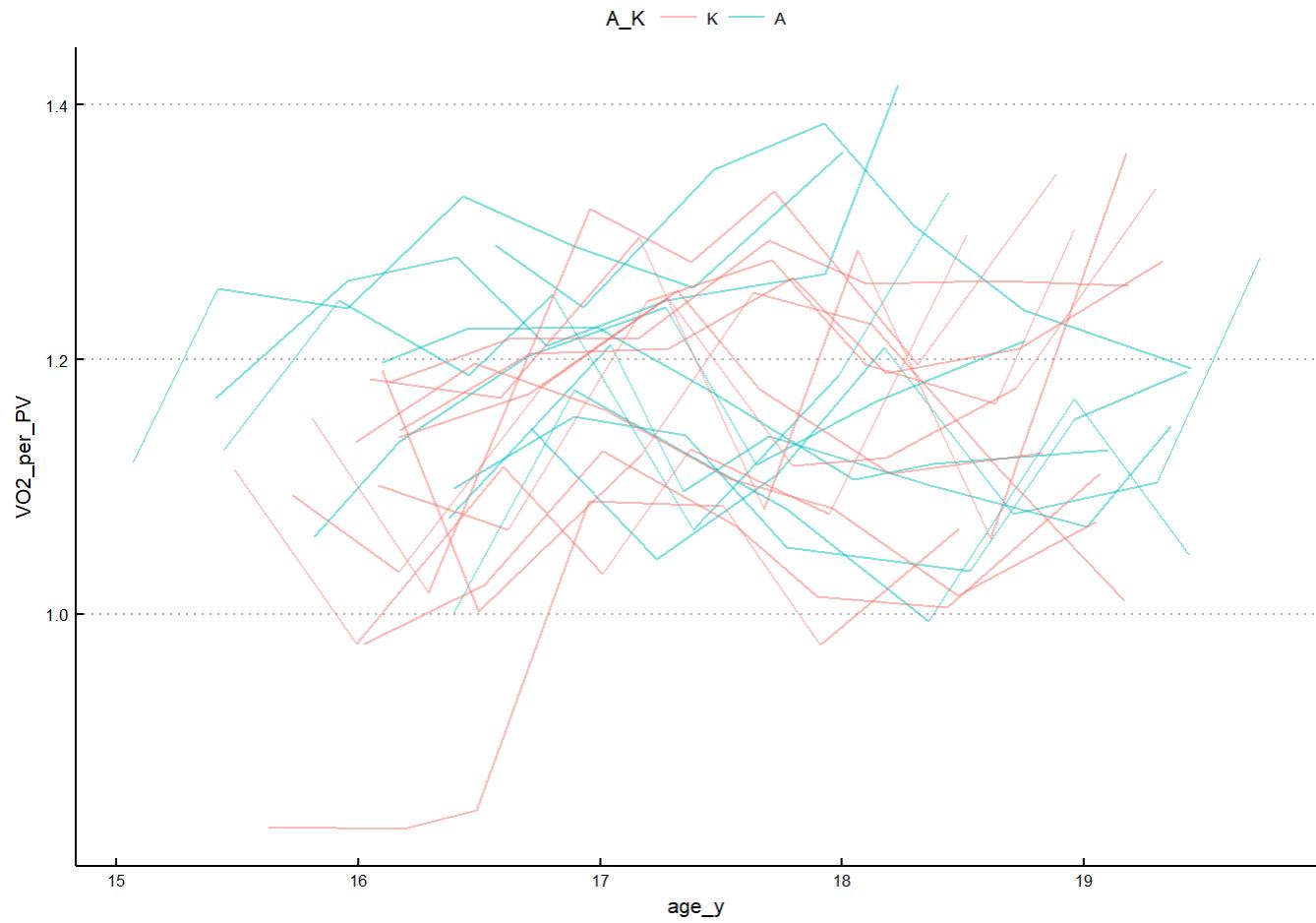
```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
##  
## Correlation of Fixed Effects:  
##      (Intr)  
## A_KA -0.674
```



```
## [1] "-----"  
## [1] "VO2_per_PV"  
## [1] "-----"
```



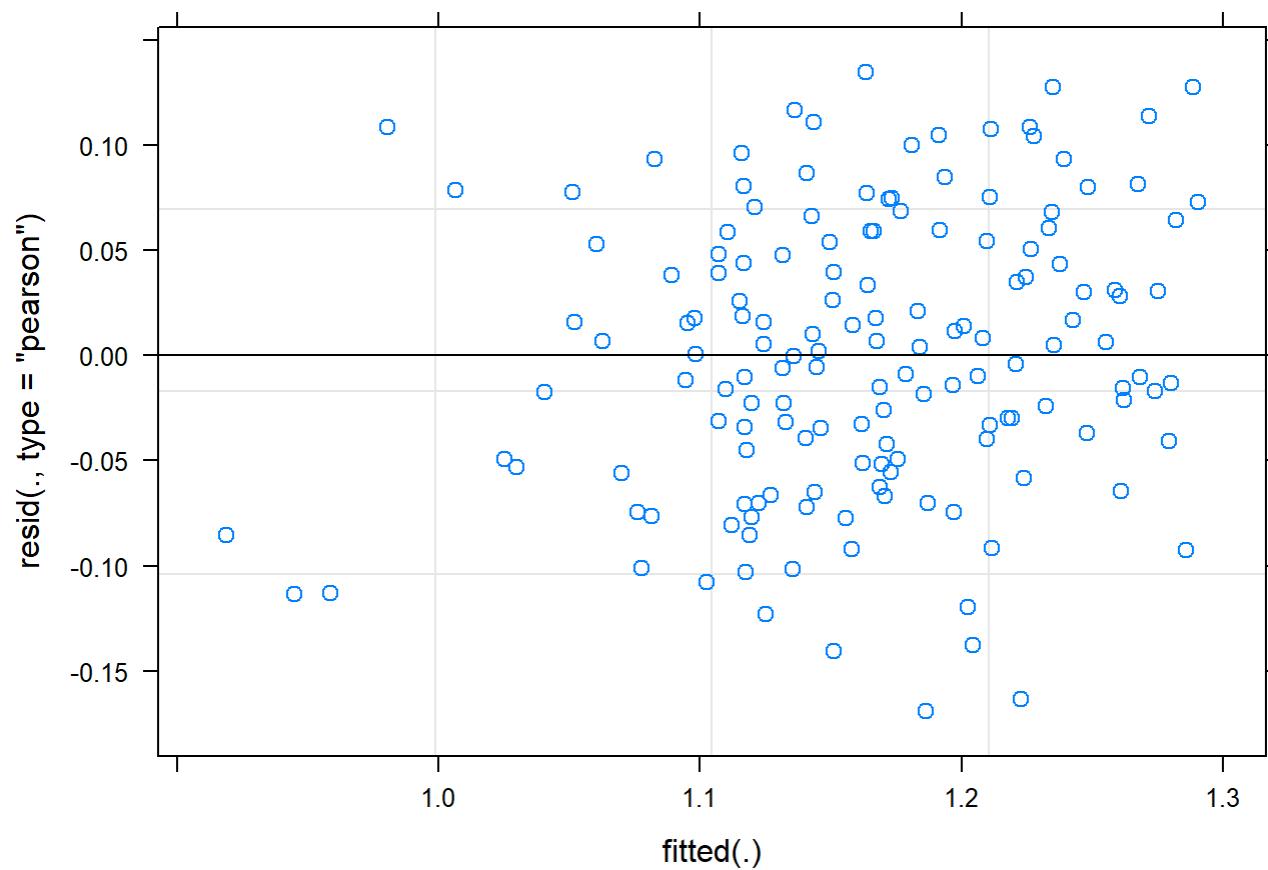
```

## [1] "baseline to lmem_age: 0.00468287008461115"
## [1] "baseline to lmem_tr: 0.273903455047344"
## [1] "baseline to lmem_age_tr_i: 0.00975486650505664"
## [1] "lmem_age to lmem_age_tr: 0.271441897599715"
## [1] "lmem_age to lmem_age_tr_i: 0.182633767496736"
## Linear mixed model fit by REML ['lmerMod']
## Formula: VO2_per_PV ~ age_16 + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: -299.6
##
## Scaled residuals:
##      Min       1Q     Median      3Q      Max
## -2.29782 -0.67068  0.01658  0.72803  1.83007
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 0.0063081 0.07942
##          age_16       0.0003672 0.01916 -0.37
##   Residual            0.0054236 0.07364
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 1.13255   0.01996 56.739
## age_16      0.02180   0.00716  3.045

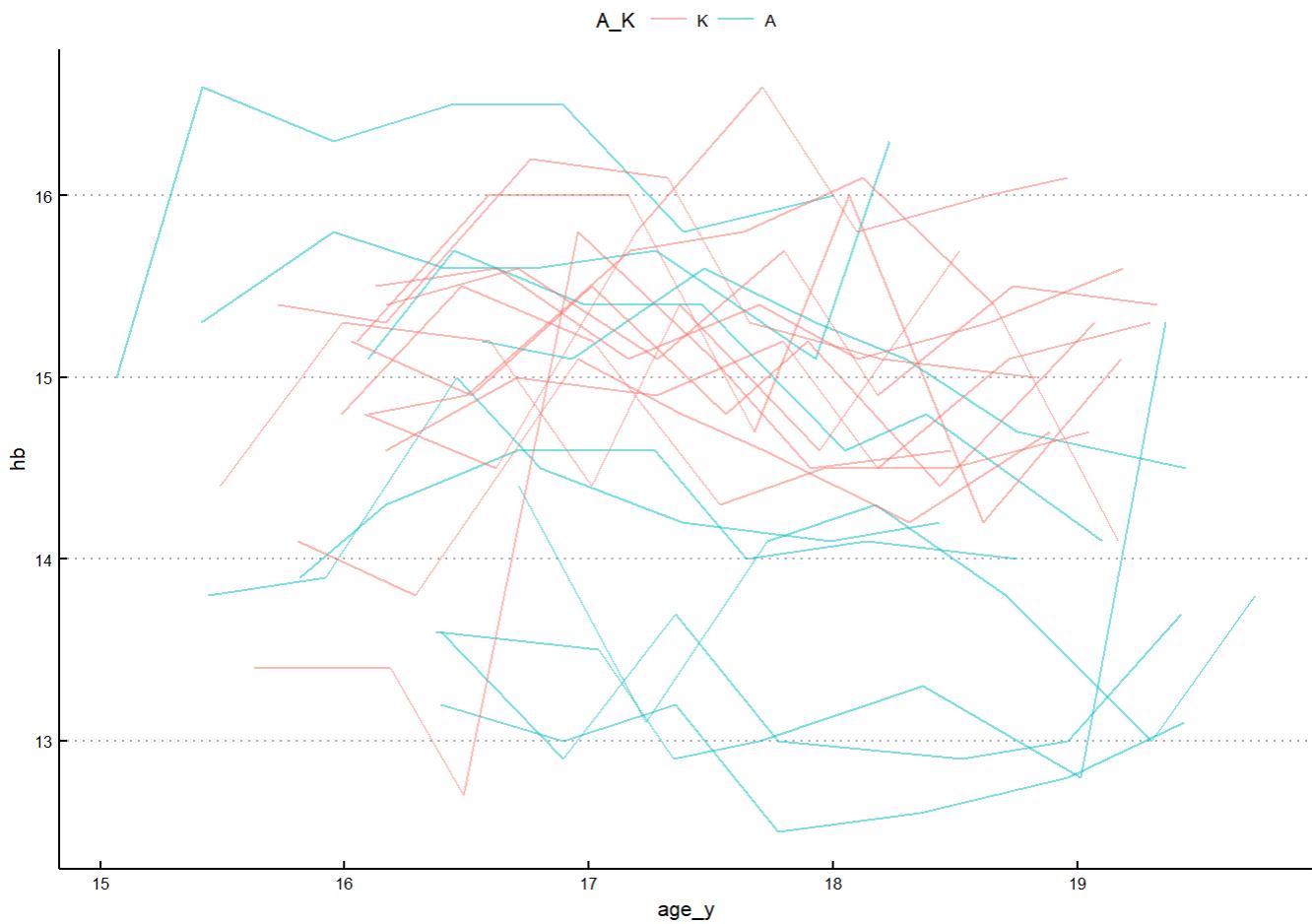
```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
##  
## Correlation of Fixed Effects:  
##          (Intr)  
## age_16 -0.536
```



```
## [1] "--"  
## [1] "hb"  
## [1] "--"
```



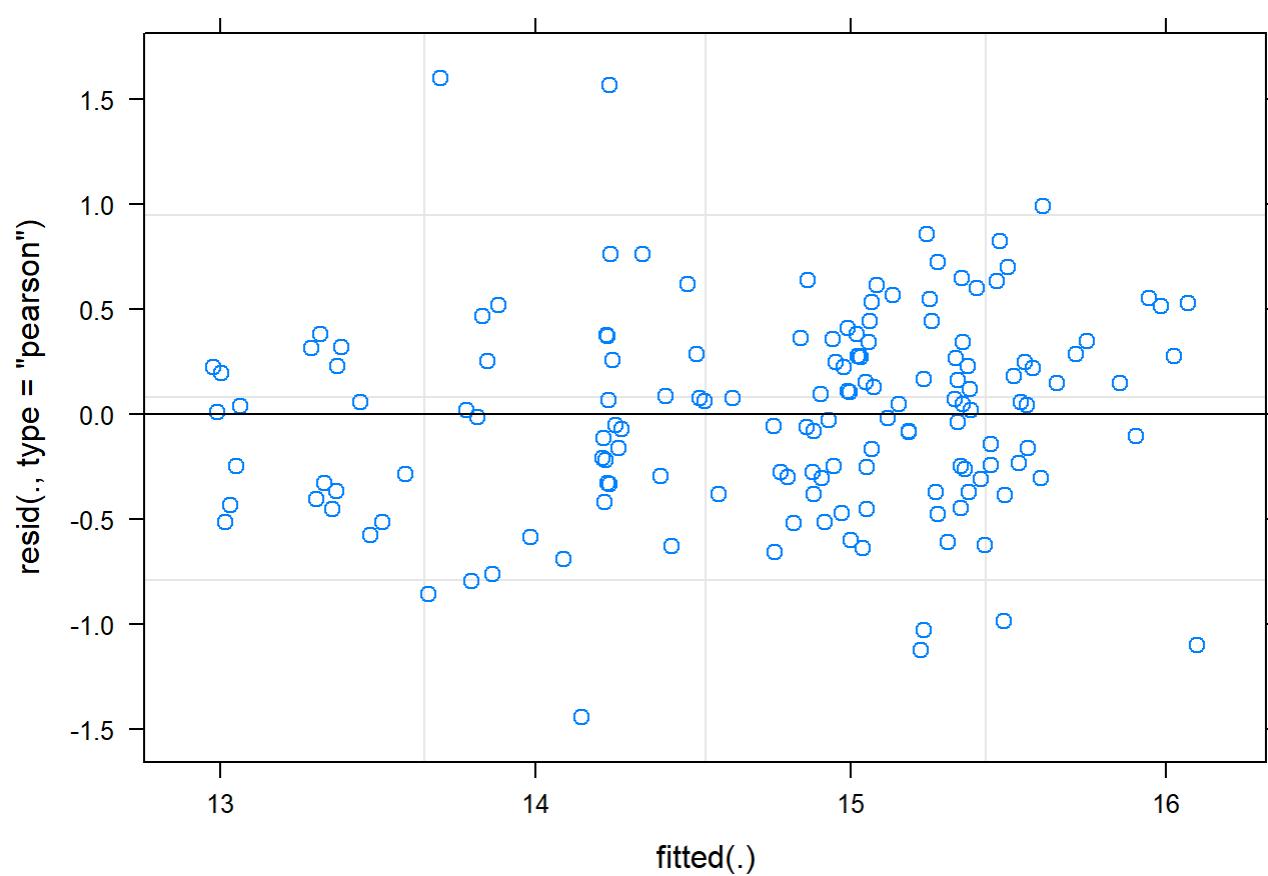
```

## [1] "baseline to lmem_age: 0.927399218206841"
## [1] "baseline to lmem_tr: 0.0204580244537933"
## [1] "baseline to lmem_age_tr_i: 0.0568271784500187"
## [1] "lmem_tr to lmem_age_tr: 0.997133211908229"
## [1] "lmem_tr to lmem_age_tr_i: 0.340231875805212"
## Linear mixed model fit by REML ['lmerMod']
## Formula: hb ~ A_K + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: 303.9
##
## Scaled residuals:
##      Min       1Q     Median       3Q      Max
## -2.76366 -0.59333  0.07593  0.54393  3.06648
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 0.68308  0.8265
##          age_16       0.01604  0.1267  -0.56
##   Residual            0.27357  0.5230
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 15.1266    0.2164 69.887
## A_K         -0.8140    0.3213 -2.534

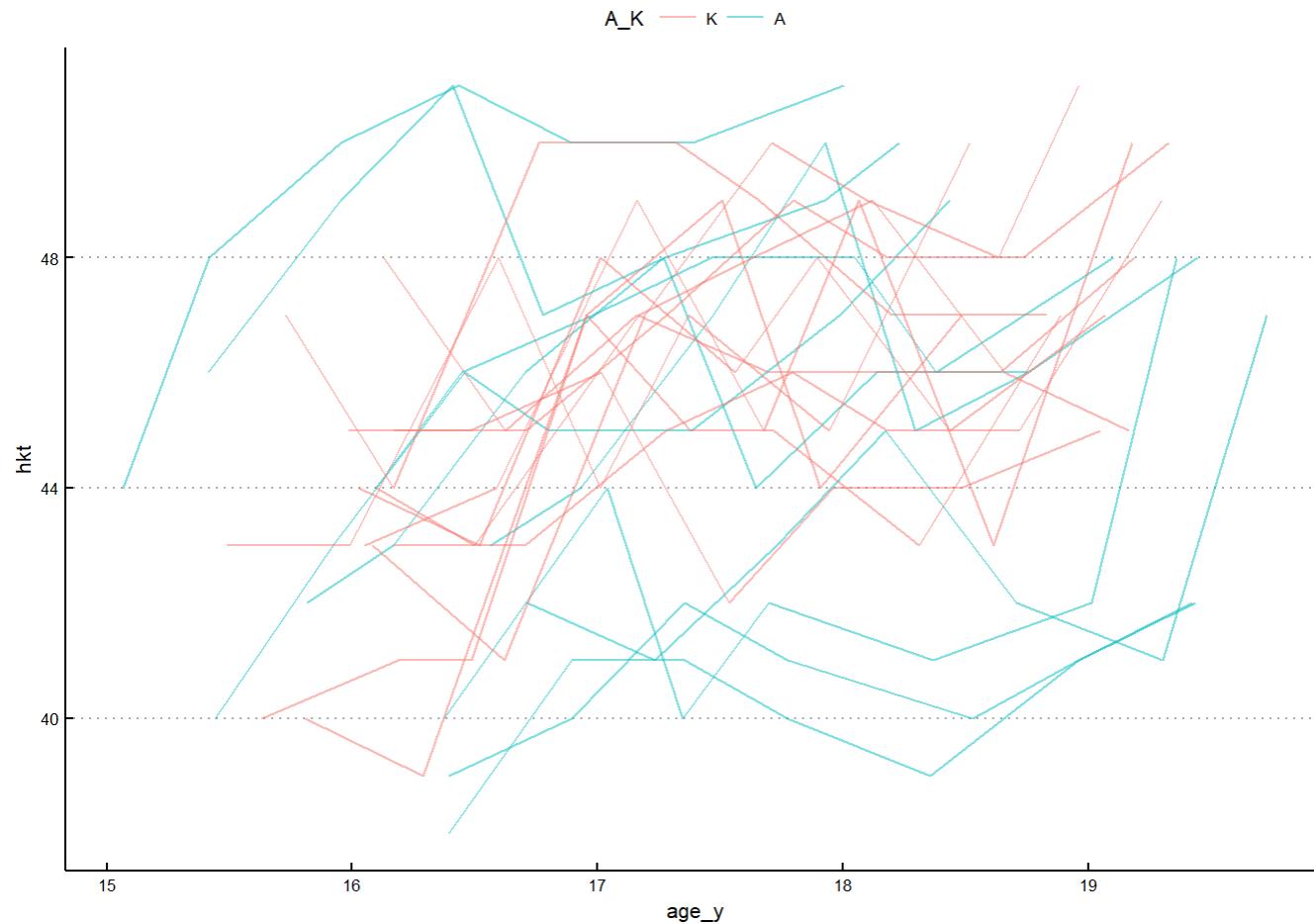
```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
##  
## Correlation of Fixed Effects:  
##      (Intr)  
## A_KA -0.674
```



```
## [1] "--"  
## [1] "hkt"  
## [1] "--"
```



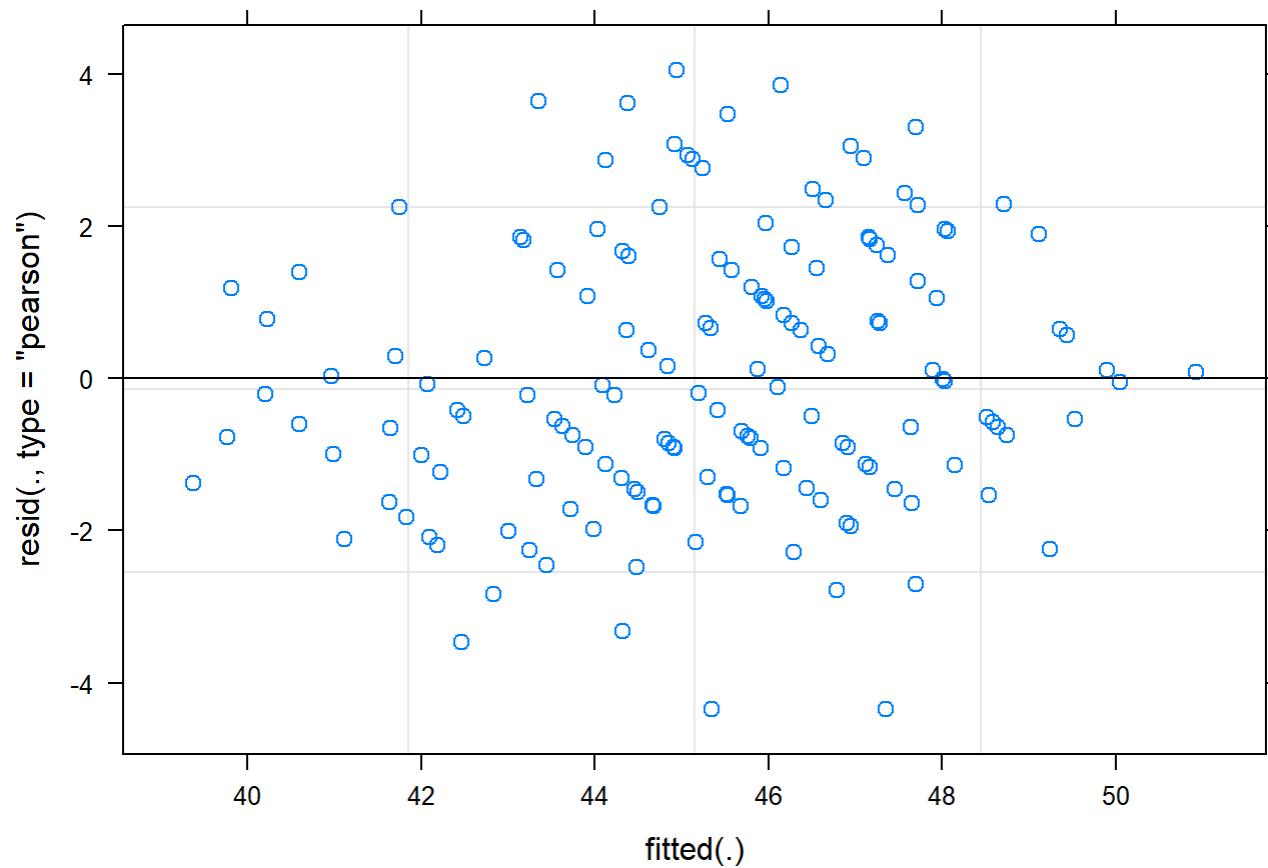
```

## [1] "baseline to lmem_age: 3.20532403570735e-07"
## [1] "baseline to lmem_tr: 0.331476259693046"
## [1] "baseline to lmem_age_tr_i: 4.78738440486987e-06"
## [1] "lmem_age to lmem_age_tr: 0.345779491666498"
## [1] "lmem_age to lmem_age_tr_i: 0.520360557012096"
## Linear mixed model fit by REML ['lmerMod']
## Formula: hkt ~ age_16 + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: 696.1
##
## Scaled residuals:
##      Min       1Q   Median      3Q     Max 
## -2.2819 -0.6716 -0.1114  0.7167  2.1271 
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 5.6252   2.3718  
##          age_16       0.1457   0.3817   0.07 
##   Residual            3.6359   1.9068  
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 43.5830    0.5745 75.859
## age_16       1.2049    0.1732  6.958

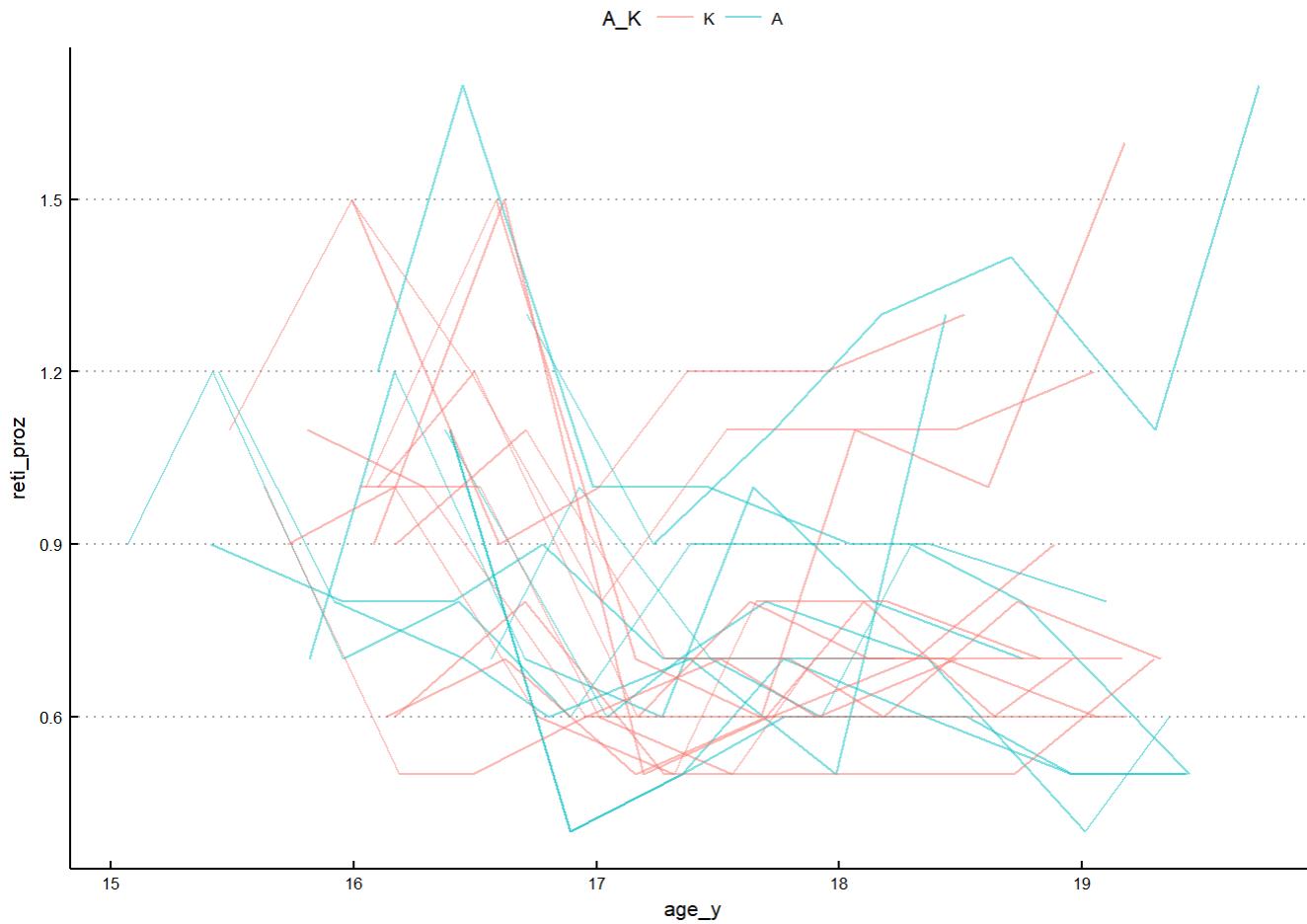
```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
##  
## Correlation of Fixed Effects:  
##          (Intr)  
## age_16 -0.313
```



```
## [1] "-----"  
## [1] "reti_proz"  
## [1] "-----"
```



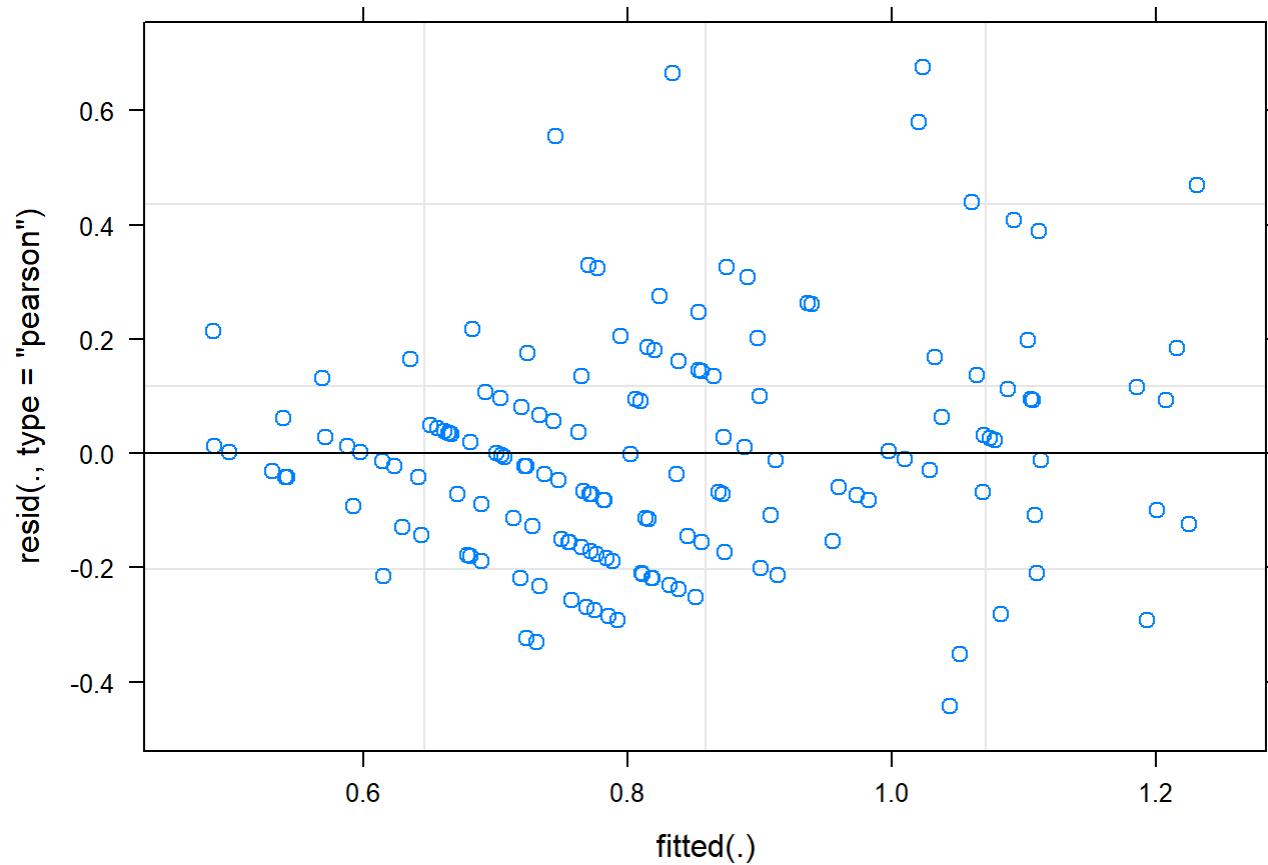
```

## [1] "baseline to lmem_age: 0.00161412234817861"
## [1] "baseline to lmem_tr: 0.953891304115965"
## [1] "baseline to lmem_age_tr_i: 0.0188104315879513"
## [1] "lmem_age to lmem_age_tr: 0.975605908506663"
## [1] "lmem_age to lmem_age_tr_i: 0.98615915445703"
## Linear mixed model fit by REML ['lmerMod']
## Formula: reti_proz ~ age_16 + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: 6.2
##
## Scaled residuals:
##      Min       1Q   Median      3Q     Max 
## -2.0953 -0.6857 -0.0596  0.4550  3.1965 
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 0.014292 0.1195    
##          age_16       0.001246 0.0353    1.00  
##   Residual            0.044794 0.2116    
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)  0.91505   0.03906  23.429
## age_16      -0.06126   0.01839  -3.332

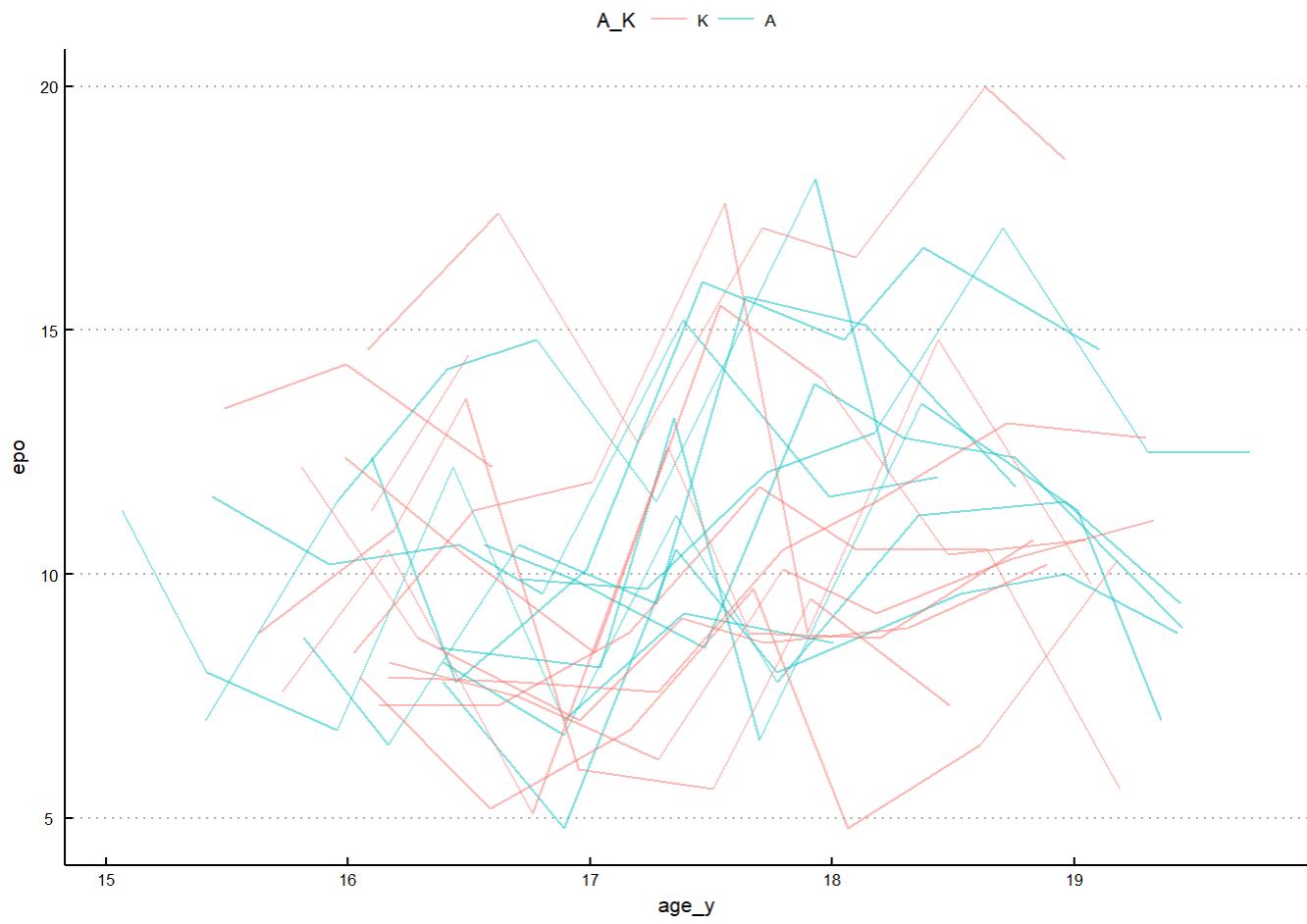
```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
##  
## Correlation of Fixed Effects:  
##          (Intr)  
## age_16 -0.297
```



```
## [1] "--"  
## [1] "epo"  
## [1] "--"
```



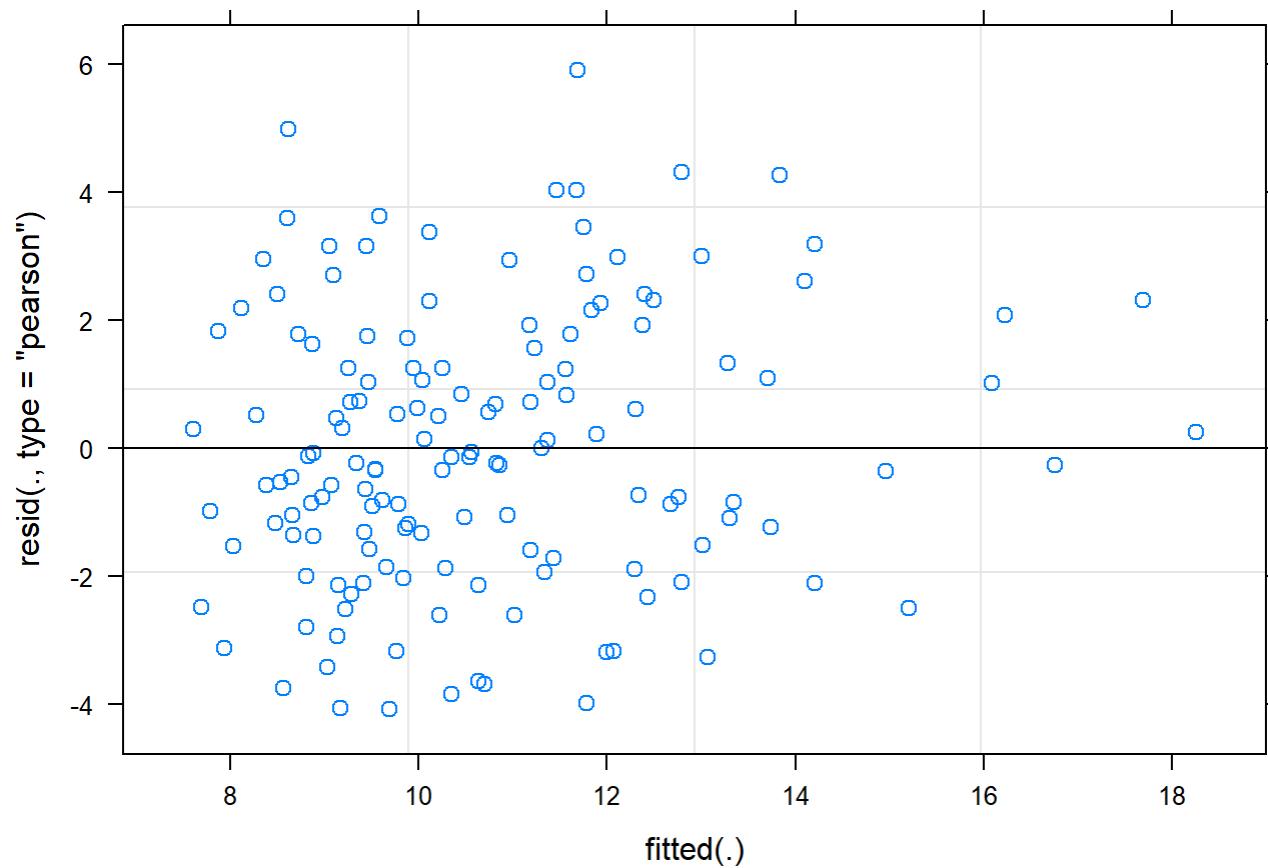
```

## [1] "baseline to lmem_age: 0.000703111177174793"
## [1] "baseline to lmem_tr: 0.587766639093916"
## [1] "baseline to lmem_age_tr_i: 0.00630581478778203"
## [1] "lmem_age to lmem_age_tr: 0.705516579066661"
## [1] "lmem_age to lmem_age_tr_i: 0.650954579900834"
## Linear mixed model fit by REML ['lmerMod']
## Formula: epo ~ age_16 + (age_16 | ID)
## Data: data
##
## REML criterion at convergence: 700.2
##
## Scaled residuals:
##      Min       1Q     Median       3Q      Max
## -1.77286 -0.66087 -0.08092  0.69931  2.56440
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 2.4515   1.5657
##          age_16       0.1955   0.4422   1.00
##   Residual            5.3154   2.3055
## Number of obs: 146, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 9.7665     0.4664 20.942
## age_16      0.7769     0.2121  3.664

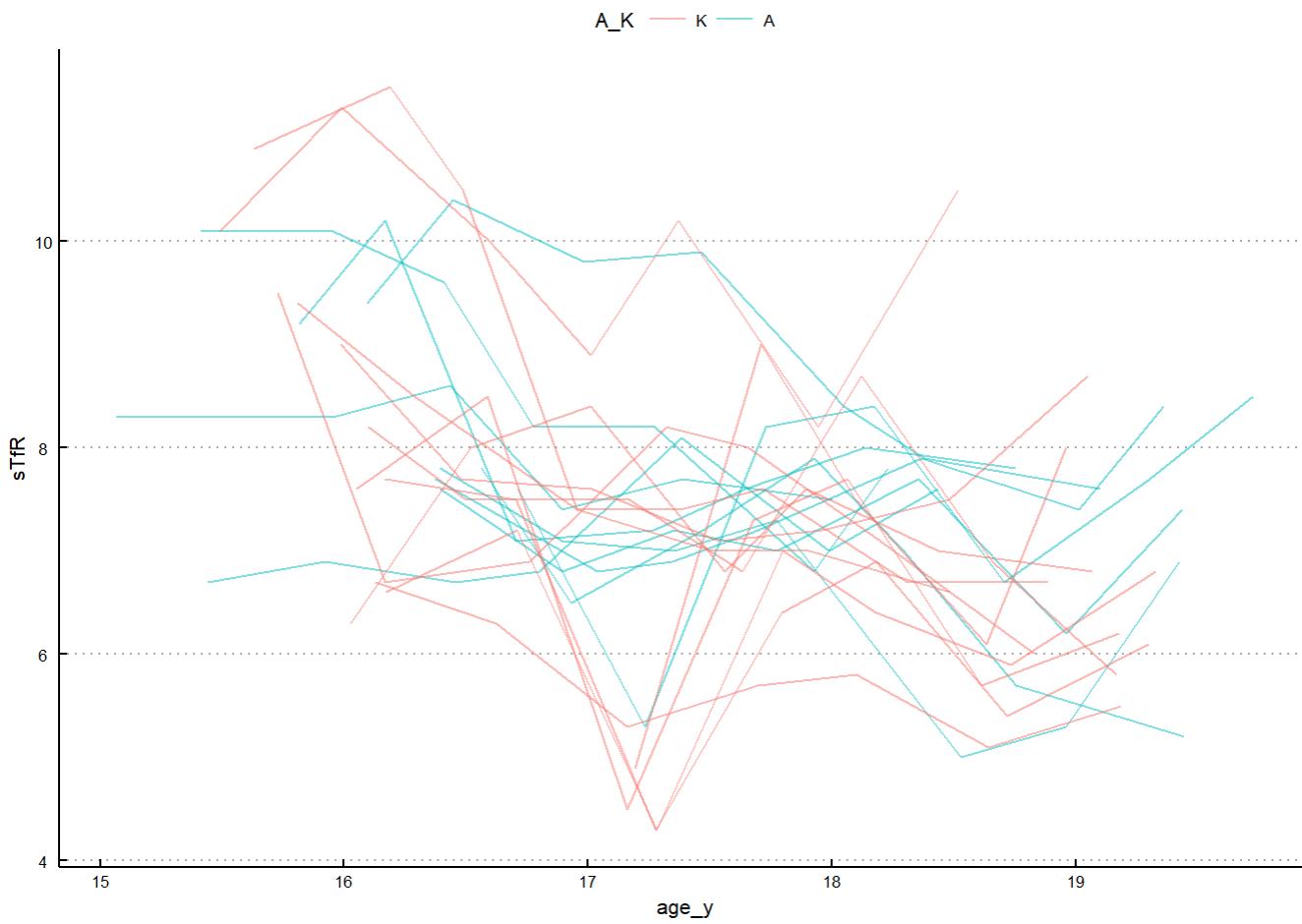
```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
##  
## Correlation of Fixed Effects:  
##          (Intr)  
## age_16 -0.175
```



```
## [1] "-----"  
## [1] "sTfR"  
## [1] "-----"
```



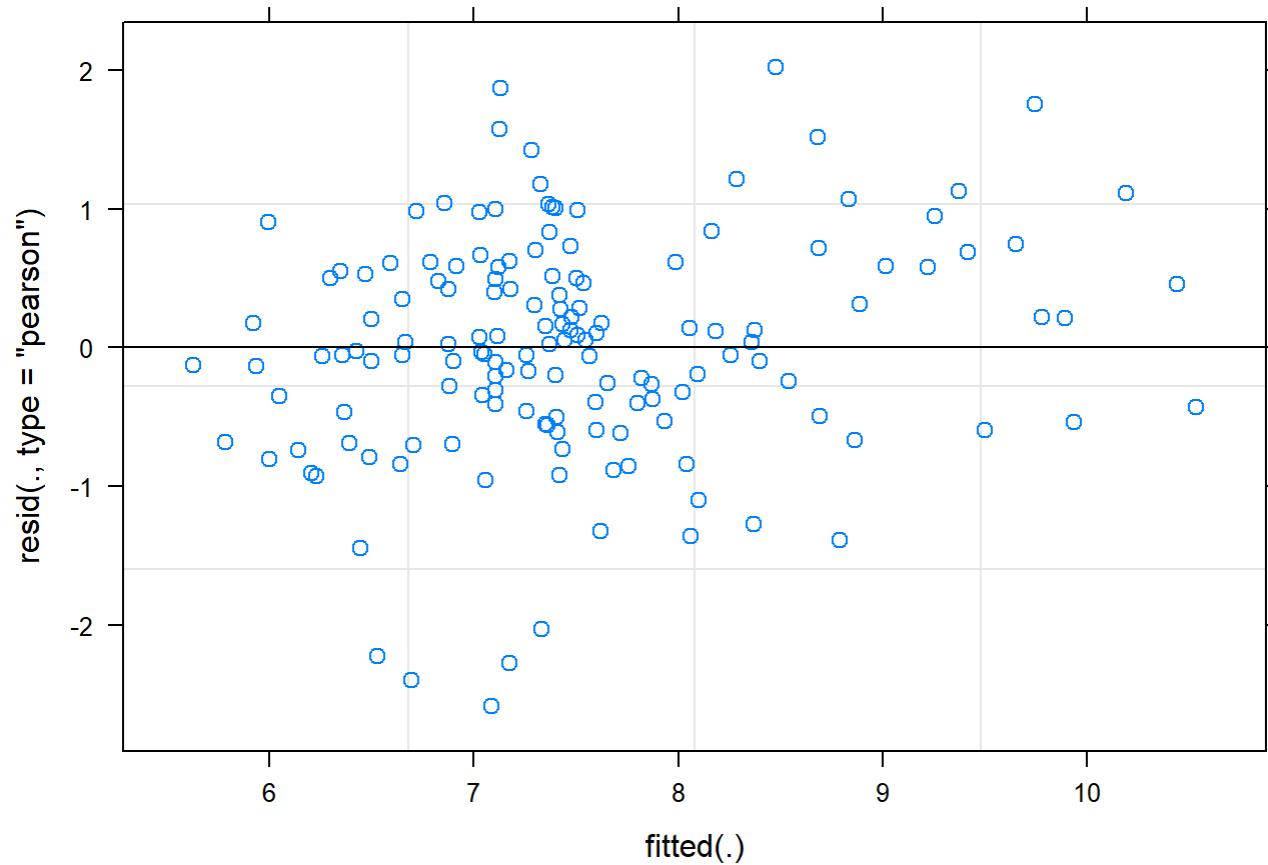
```

## [1] "baseline to lmem_age: 0.00100403314739059"
## [1] "baseline to lmem_tr: 0.272303144006043"
## [1] "baseline to lmem_age_tr_i: 0.00580841414528383"
## [1] "lmem_age to lmem_age_tr: 0.268406458384257"
## [1] "lmem_age to lmem_age_tr_i: 0.42822823182741"
## Linear mixed model fit by REML ['lmerMod']
## Formula: sTfR ~ age_16 + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: 458.1
##
## Scaled residuals:
##      Min       1Q     Median      3Q      Max
## -2.87754 -0.52489  0.02802  0.59450  2.24882
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 1.3818   1.1755
##          age_16       0.1652   0.4064  -0.81
##   Residual            0.8092   0.8995
## Number of obs: 152, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept)  8.0609    0.2850 28.281
## age_16      -0.4212    0.1135 -3.709

```

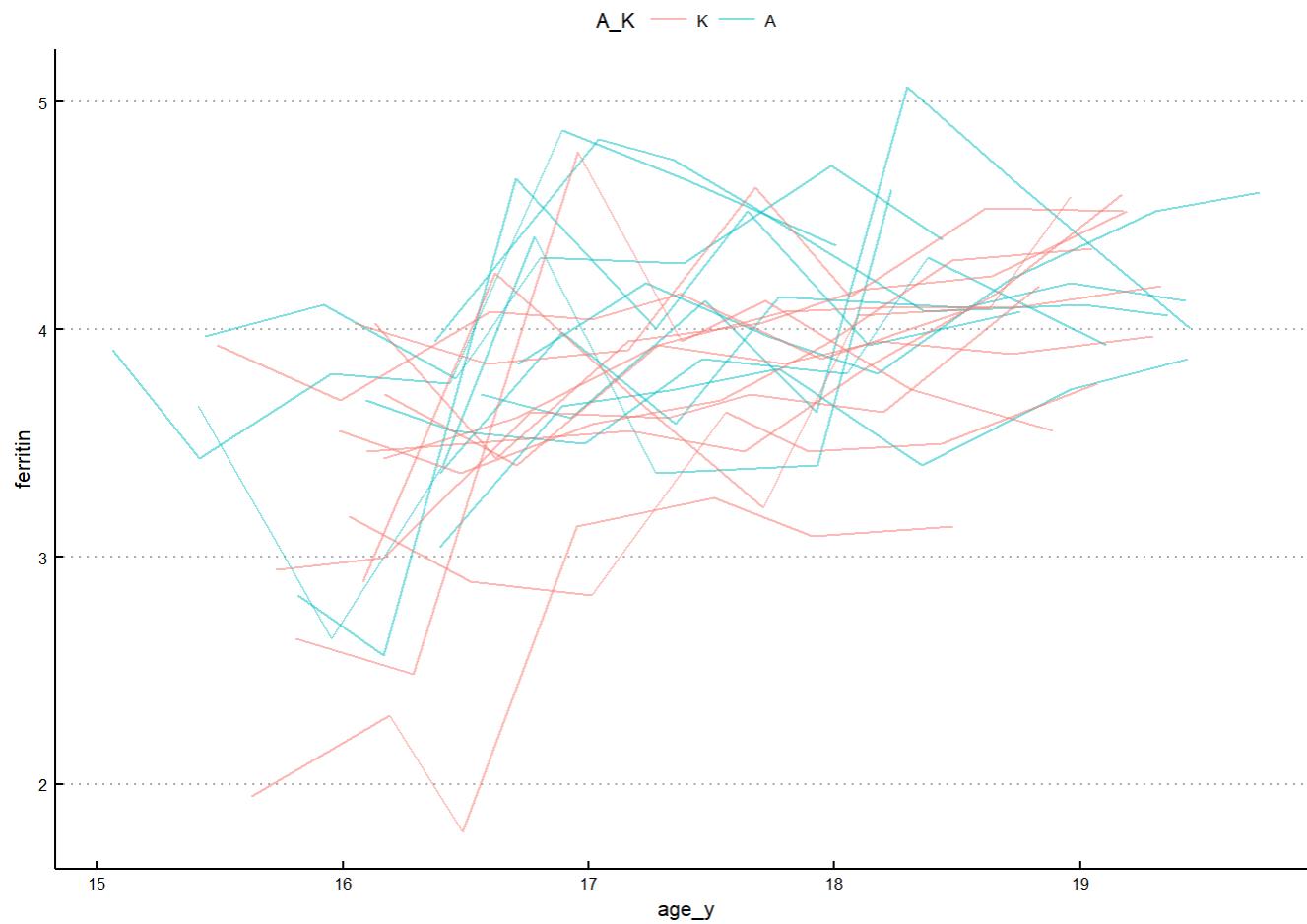
Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
##  
## Correlation of Fixed Effects:  
##          (Intr)  
## age_16 -0.798
```



```
## [1] "-----"  
## [1] "ferritin"  
## [1] "-----"
```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

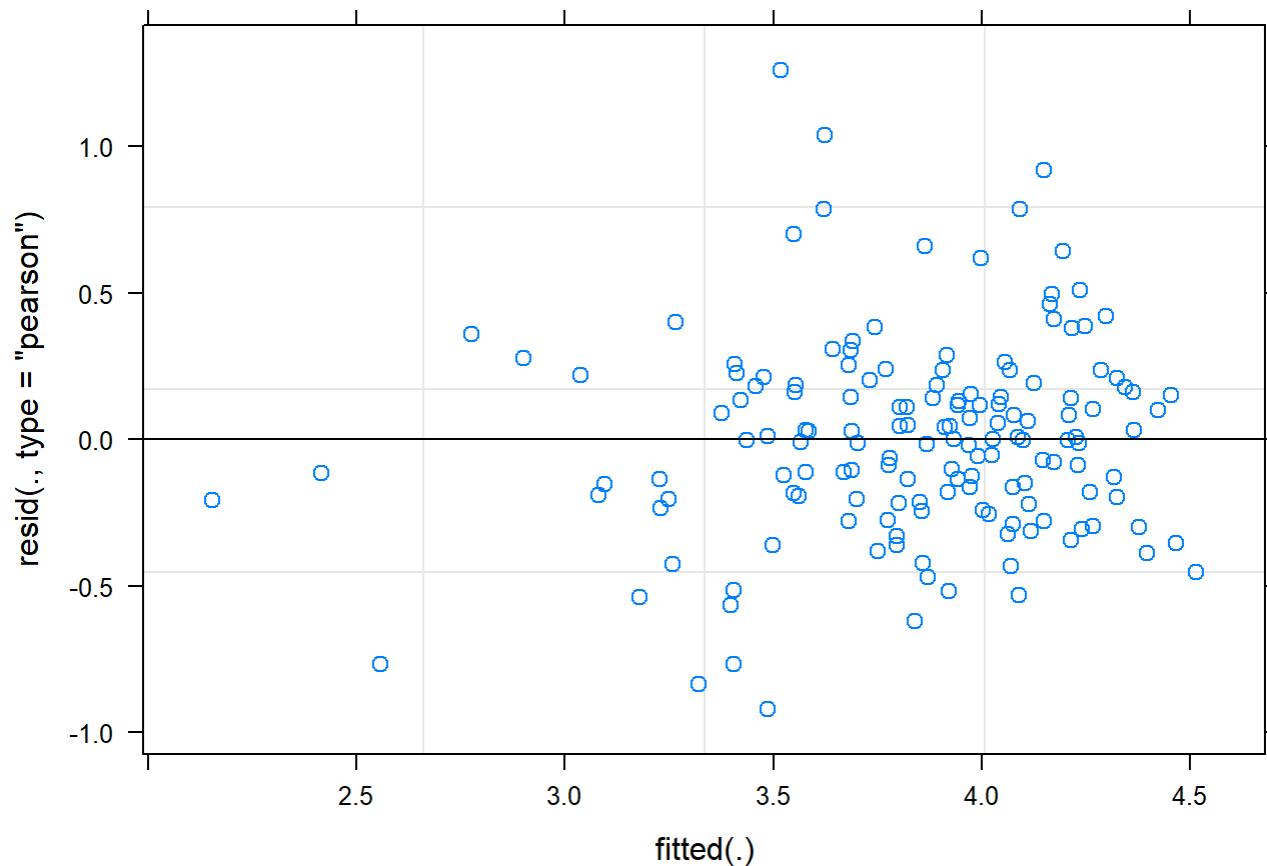


```

## [1] "baseline to lmem_age: 4.78822316526038e-08"
## [1] "baseline to lmem_tr: 0.248620775037785"
## [1] "baseline to lmem_age_tr_i: 2.76496573271033e-07"
## [1] "lmem_age to lmem_age_tr: 0.17313936013315"
## [1] "lmem_age to lmem_age_tr_i: 0.17261492638739"
## Linear mixed model fit by REML ['lmerMod']
## Formula: ferritin ~ age_16 + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: 174.8
##
## Scaled residuals:
##      Min       1Q   Median      3Q     Max
## -2.5116 -0.5632 -0.0024  0.5015  3.4369
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 0.180082  0.42436
##          age_16       0.006716  0.08195 -1.00
##   Residual            0.134725  0.36705
## Number of obs: 154, groups: ID, 22
##
## Fixed effects:
##             Estimate Std. Error t value
## (Intercept) 3.46445   0.10477 33.068
## age_16      0.25124   0.03389  7.413

```

```
## 
## Correlation of Fixed Effects:
##           (Intr)
## age_16 -0.802
```



```
data$A_K <- data$A_K %>% fct_relevel("A", "K")
```

Table with fitted values at age 16

We can use the mixed models to predict individual values at age 16.

```
data_at16 <- data %>%
  select(ID, A_K, testnumber) %>%
  filter(testnumber == 1) %>%
  mutate(age_16 = 0)

# define function that fits model, predicts values at 16 and returns mean ± sd
return_meansd_16_df <- function(variable){

  model <- get_lmer(variable)

  data_at16 %>%
    add_predictions(model) %>%
    group_by(A_K) %>%
    summarise(mean = mean(pred) %>% round(4),
```

```

sd = sd(pred) %>% round(4)) %>%
  unite(mean, sd, col = "mean_sd", sep= " ± ") %>%
  spread(A_K, mean_sd) %>%
  mutate(model = variable)
}

# apply function to all variables
meansd_16 <- map_df(important_vars, return_meanstd_16_df)

meansd_16 %>% print(n = 100)

```

```

## # A tibble: 25 x 3
##   A           K      model
##   <chr>     <chr>    <chr>
## 1 58.5017 ± 5.064 58.5264 ± 5.9682 LBM_kg
## 2 1.033 ± 0.3078 1.49 ± 0.5304 fat_kg
## 3 1.524 ± 0.2291 1.95 ± 0.4198 fat_perc
## 4 61.4123 ± 5.8373 63.6221 ± 8.7475 weight_kg
## 5 176.7958 ± 4.997 176.5996 ± 8.0726 height_cm
## 6 16.3482 ± 0.3654 16.3591 ± 0.4171 biolage_y
## 7 15.5944 ± 0.4066 12.9844 ± 0.7264 vmax_kmh
## 8 61.8791 ± 3.0698 57.6724 ± 2.7445 PV_LBM
## 9 101.2739 ± 2.6105 96.4262 ± 4.4031 BV_LBM
## 10 39.6297 ± 3.2449 38.6947 ± 2.1647 EV_LBM
## 11 13.2905 ± 1.0737 13.2052 ± 0.6865 HbM_LBM
## 12 778.33 ± 102.7272 772.9518 ± 87.0965 HbM_g
## 13 12.6569 ± 1.0438 12.1973 ± 0.7294 HbM_gkg
## 14 71.011 ± 2.0188 63.9011 ± 2.6306 VO2max_LBM
## 15 4162.4943 ± 364.1558 3730.6793 ± 310.3456 VO2max_abs
## 16 67.7116 ± 2.0273 59.092 ± 3.6617 VO2max_rel
## 17 0.7023 ± 0.025 0.6659 ± 0.0471 VO2_per_BV
## 18 5.3798 ± 0.3738 4.8666 ± 0.3177 VO2_per_Hb
## 19 1.1541 ± 0.0672 1.1146 ± 0.072 VO2_per_PV
## 20 14.3931 ± 1.0579 15.0567 ± 0.4556 hb
## 21 43.1064 ± 3.1034 43.9801 ± 1.0948 hkt
## 22 0.9139 ± 0.1111 0.916 ± 0.1113 reti_proz
## 23 9.789 ± 1.0978 9.7477 ± 1.7238 epo
## 24 8.1341 ± 0.9639 7.9998 ± 1.1483 sTfR
## 25 3.6211 ± 0.3014 3.3339 ± 0.4139 ferritin

```

Mixed model for training time

For this variable, we exclude the first values, because they were reported from memory before training was actually tracked in a training log.

```

data <- data %>% filter(testnumber != 1)

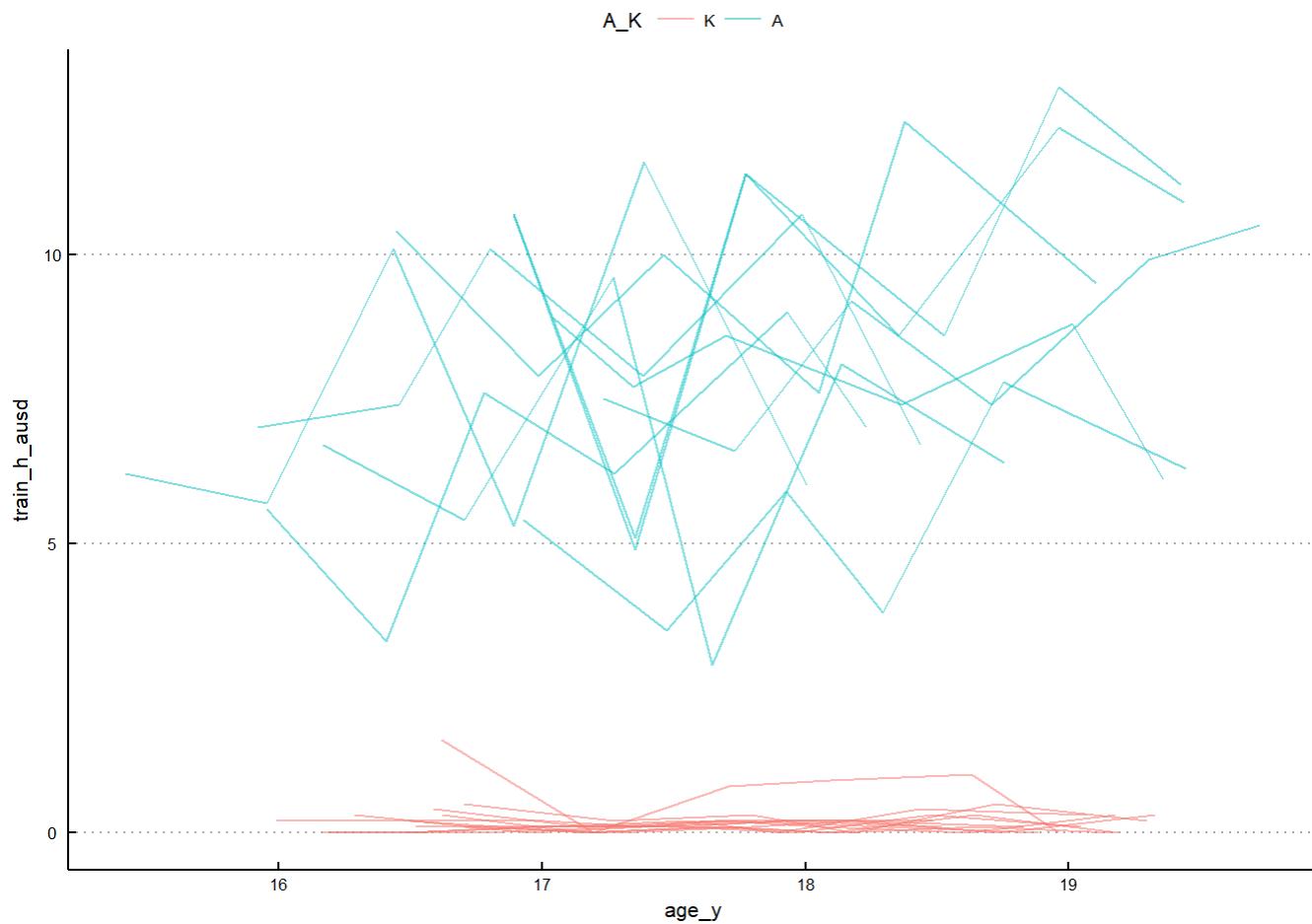
data$A_K <- data$A_K %>% fct_relevel("K", "A")
print_lmer("train_h_ausd")

## [1] "-----"

```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
## [1] "train_h_ausd"
## [1] "-----"
```

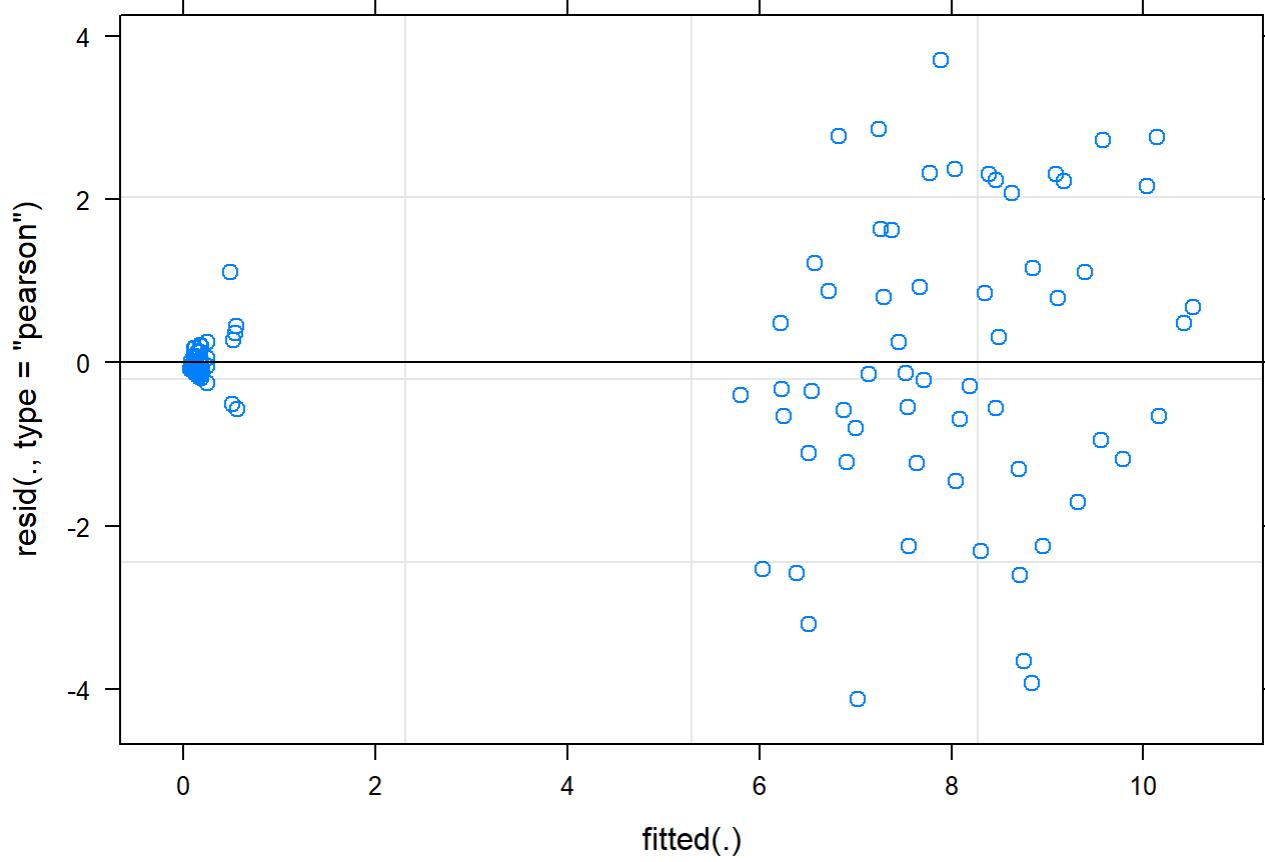


```
## [1] "baseline to lmem_age: 0.0705273294570296"
## [1] "baseline to lmem_tr: 6.55713431212708e-14"
## [1] "baseline to lmem_age_tr_i: 1.52537911633164e-14"
## [1] "lmem_tr to lmem_age_tr: 0.0247951906081345"
## [1] "lmem_age_tr to lmem_age_tr_i: 0.0129100498801037"
## Linear mixed model fit by REML ['lmerMod']
## Formula: train_h_ausd ~ age_16 * A_K + (age_16 | ID)
##   Data: data
##
## REML criterion at convergence: 480.7
##
## Scaled residuals:
##       Min      1Q  Median      3Q     Max
## -3.04263 -0.14470 -0.02919  0.18315  2.73260
##
## Random effects:
##   Groups   Name        Variance Std.Dev. Corr
##   ID       (Intercept) 0.39583  0.6291
##          age_16       0.01066  0.1032  1.00
##   Residual            1.84261  1.3574
## Number of obs: 132, groups: ID, 22
##
## Fixed effects:
```

```

##             Estimate Std. Error t value
## (Intercept) 0.202901  0.398212  0.510
## age_16      -0.009516  0.187173 -0.051
## A_KA         6.651585  0.576570 11.536
## age_16:A_KA  0.674714  0.268996  2.508
##
## Correlation of Fixed Effects:
##          (Intr) age_16 A_KA
## age_16    -0.711
## A_KA     -0.691  0.491
## age_16:A_KA 0.495 -0.696 -0.695

```



This is obviously a bad model fit, but the differences are clear.

```
return_meanstd_16_df("train_h_ausd")
```

```

## [1] "baseline to lmem_age: 0.0705273294570296"
## [1] "baseline to lmem_tr: 6.55713431212708e-14"
## [1] "baseline to lmem_age_tr_i: 1.52537911633164e-14"
## [1] "lmem_tr to lmem_age_tr: 0.0247951906081345"
## [1] "lmem_age_tr to lmem_age_tr_i: 0.0129100498801037"

```

```

## # A tibble: 1 x 3
##   A                 K           model
##   <chr>            <chr>        <chr>

```

Effect of Endurance Training and Growth on Hbmass and VO2max in Adolescence

```
## 1 6.8545 ± 0.7647 0.2029 ± 0.0888 train_h_ausd
```