vertical_jump.R

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```r
# Install and load packages
packages <- c("dplyr", "tidyr", "lme4", "lmerTest", "emmeans", "ggplot2",
              "ggpubr", "pwr", "performance", "patchwork", "effects")

install_if_missing <- function(pkg) {
  if (!require(pkg, character.only = TRUE)) {
    install.packages(pkg, dependencies = TRUE)
    library(pkg, character.only = TRUE)
  }
}

lapply(packages, install_if_missing)
```

```
## Loading required package: dplyr
```

```
##
## Attaching package: 'dplyr'
```

```
## The following objects are masked from 'package:stats':
##
##     filter, lag
```

```
## The following objects are masked from 'package:base':
##
##     intersect, setdiff, setequal, union
```

```
## Loading required package: tidyr
```

```
## Loading required package: lme4
```

```
## Loading required package: Matrix
```

```
##
## Attaching package: 'Matrix'
```

```
## The following objects are masked from 'package:tidyr':
##
##     expand, pack, unpack
```

```
## Loading required package: lmerTest
```

```
##
## Attaching package: 'lmerTest'
```

```
## The following object is masked from 'package:lme4':
##
##     lmer
```

```
## The following object is masked from 'package:stats':
##
##     step

## Loading required package: emmeans

## Welcome to emmeans.
## Caution: You lose important information if you filter this package's results.
## See '? untidy'

## Loading required package: ggplot2

## Loading required package: ggpubr

## Loading required package: pwr

## Loading required package: performance

## Loading required package: patchwork

## Loading required package: effects

## Loading required package: carData

## lattice theme set by effectsTheme()
## See ?effectsTheme for details.

## [[1]]
## NULL
##
## [[2]]
## NULL
##
## [[3]]
## NULL
##
## [[4]]
## NULL
##
## [[5]]
## NULL
##
## [[6]]
## NULL
##
## [[7]]
## NULL
##
## [[8]]
## NULL
##
## [[9]]
## NULL
##
## [[10]]
## NULL
##
## [[11]]
## NULL
```

```r
# Load data
data_wide <- read.csv("vertical_jump_data_wide.csv")

# View data
head(data_wide)
```

```
##   sub_id age sex group dynamic_pre dynamic_post static_pre static_post
## 1      1  29   f     a          22           23         24          24
## 2      2  37   m     b          38           42         36          37
## 3      3  55   f     c          20           20         19          20
## 4      4  32   f     a          38           38         35          39
## 5      5  43   m     b          38           40         37          40
## 6      6  42   m     c          39           41         34          36
##   control_pre control_post
## 1          21           22
## 2          39           40
## 3          21           21
## 4          34           35
## 5          36           38
## 6          34           35
```

```r
str(data_wide)
```

```
## 'data.frame':    11 obs. of  10 variables:
##  $ sub_id      : int  1 2 3 4 5 6 7 8 9 10 ...
##  $ age         : int  29 37 55 32 43 42 28 30 28 21 ...
##  $ sex         : chr  "f" "m" "f" "f" ...
##  $ group       : chr  "a" "b" "c" "a" ...
##  $ dynamic_pre : int  22 38 20 38 38 39 36 48 26 31 ...
##  $ dynamic_post: int  23 42 20 38 40 41 42 54 34 36 ...
##  $ static_pre  : int  24 36 19 35 37 34 32 50 24 23 ...
##  $ static_post : int  24 37 20 39 40 36 39 53 32 28 ...
##  $ control_pre : int  21 39 21 34 36 34 34 53 23 30 ...
##  $ control_post: int  22 40 21 35 38 35 37 55 25 33 ...
```

```r
summary(data_wide)
```

```
##      sub_id          age           sex               group
##  Min.   : 1.0   Min.   :21.0   Length:11          Length:11
##  1st Qu.: 3.5   1st Qu.:28.5   Class :character   Class :character
##  Median : 6.0   Median :30.0   Mode  :character   Mode  :character
##  Mean   : 6.0   Mean   :34.0
##  3rd Qu.: 8.5   3rd Qu.:39.5
##  Max.   :11.0   Max.   :55.0
##   dynamic_pre     dynamic_post     static_pre     static_post
##  Min.   :20.00   Min.   :20.00   Min.   :19.00   Min.   :20.00
##  1st Qu.:28.50   1st Qu.:35.00   1st Qu.:24.00   1st Qu.:30.00
##  Median :38.00   Median :40.00   Median :34.00   Median :37.00
##  Mean   :34.45   Mean   :38.45   Mean   :32.73   Mean   :36.18
##  3rd Qu.:38.50   3rd Qu.:42.00   3rd Qu.:36.50   3rd Qu.:39.50
##  Max.   :48.00   Max.   :54.00   Max.   :50.00   Max.   :53.00
##   control_pre     control_post
##  Min.   :21.00   Min.   :21.00
##  1st Qu.:26.50   1st Qu.:29.00
##  Median :34.00   Median :35.00
```

```
##  Mean   :33.55   Mean   :35.45
##  3rd Qu.:37.50   3rd Qu.:39.00
##  Max.   :53.00   Max.   :55.00
```

```
n <- nrow(data_wide)
n
```

```
## [1] 11
```

```
sex_count <- data_wide %>%
  count(sex)
print(sex_count)
```

```
##   sex n
## 1   f 5
## 2   m 6
```

```
mean(data_wide$age)
```

```
## [1] 34
```

```
sd(data_wide$age)
```

```
## [1] 9.518403
```

```
data <- data_wide %>%
  pivot_longer(
    cols = c(dynamic_pre, dynamic_post, static_pre, static_post,
             control_pre, control_post),
    names_to = c("condition", ".value"),
    names_pattern = "(.*)_(.*)"
  ) %>%
  rename(pre_stretch = pre,
         post_stretch = post)

data$condition <- as.factor(data$condition)
data$condition <- factor(data$condition,
                         levels = c("static", "dynamic", "control"))

data <- data %>%
  mutate(jump_diff = post_stretch - pre_stretch)

# View data
head(data)
```

```
## # A tibble: 6 x 8
##   sub_id   age sex   group condition pre_stretch post_stretch jump_diff
##    <int> <int> <chr> <chr> <fct>           <int>        <int>     <int>
## 1      1    29 f     a     dynamic            22           23         1
## 2      1    29 f     a     static             24           24         0
## 3      1    29 f     a     control            21           22         1
## 4      2    37 m     b     dynamic            38           42         4
## 5      2    37 m     b     static             36           37         1
## 6      2    37 m     b     control            39           40         1
```

```
str(data)
```

```
## tibble [33 x 8] (S3: tbl_df/tbl/data.frame)
##  $ sub_id      : int [1:33] 1 1 1 2 2 2 3 3 3 4 ...
```

```
##  $ age         : int [1:33] 29 29 29 37 37 37 55 55 55 32 ...
##  $ sex         : chr [1:33] "f" "f" "f" "m" ...
##  $ group       : chr [1:33] "a" "a" "a" "b" ...
##  $ condition   : Factor w/ 3 levels "static","dynamic",..: 2 1 3 2 1 3 2 1 3 2 ...
##  $ pre_stretch : int [1:33] 22 24 21 38 36 39 20 19 21 38 ...
##  $ post_stretch: int [1:33] 23 24 22 42 37 40 20 20 21 38 ...
##  $ jump_diff   : int [1:33] 1 0 1 4 1 1 0 1 0 0 ...
```

```
summary(data)
```

```
##      sub_id        age         sex               group             condition
##  Min.   : 1   Min.   :21   Length:33          Length:33          static :11
##  1st Qu.: 3   1st Qu.:28   Class :character   Class :character   dynamic:11
##  Median : 6   Median :30   Mode  :character   Mode  :character   control:11
##  Mean   : 6   Mean   :34
##  3rd Qu.: 9   3rd Qu.:42
##  Max.   :11   Max.   :55
##   pre_stretch     post_stretch    jump_diff
##  Min.   :19.00   Min.   :20.0   Min.   : 0.000
##  1st Qu.:24.00   1st Qu.:32.0   1st Qu.: 1.000
##  Median :34.00   Median :37.0   Median : 2.000
##  Mean   :33.58   Mean   :36.7   Mean   : 3.121
##  3rd Qu.:38.00   3rd Qu.:41.0   3rd Qu.: 5.000
##  Max.   :53.00   Max.   :55.0   Max.   :10.000
```

```
# Linear mixed-effects model
lmer_model <- lmer(jump_diff ~ condition + (1|sub_id), data = data)
summary(lmer_model)
```

```
## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula: jump_diff ~ condition + (1 | sub_id)
##    Data: data
##
## REML criterion at convergence: 139
##
## Scaled residuals:
##      Min       1Q   Median       3Q      Max
## -1.69936 -0.52954  0.07747  0.42722  2.06133
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  sub_id   (Intercept) 3.582    1.893
##  Residual             2.806    1.675
## Number of obs: 33, groups:  sub_id, 11
##
## Fixed effects:
##                  Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)        3.4545     0.7620 18.4183   4.533 0.000244 ***
## conditiondynamic   0.5455     0.7143 20.0000   0.764 0.453994
## conditioncontrol  -1.5455     0.7143 20.0000  -2.164 0.042772 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Correlation of Fixed Effects:
```

```
##             (Intr) cndtnd
## condtndynmc -0.469
## condtncntrl -0.469  0.500
```

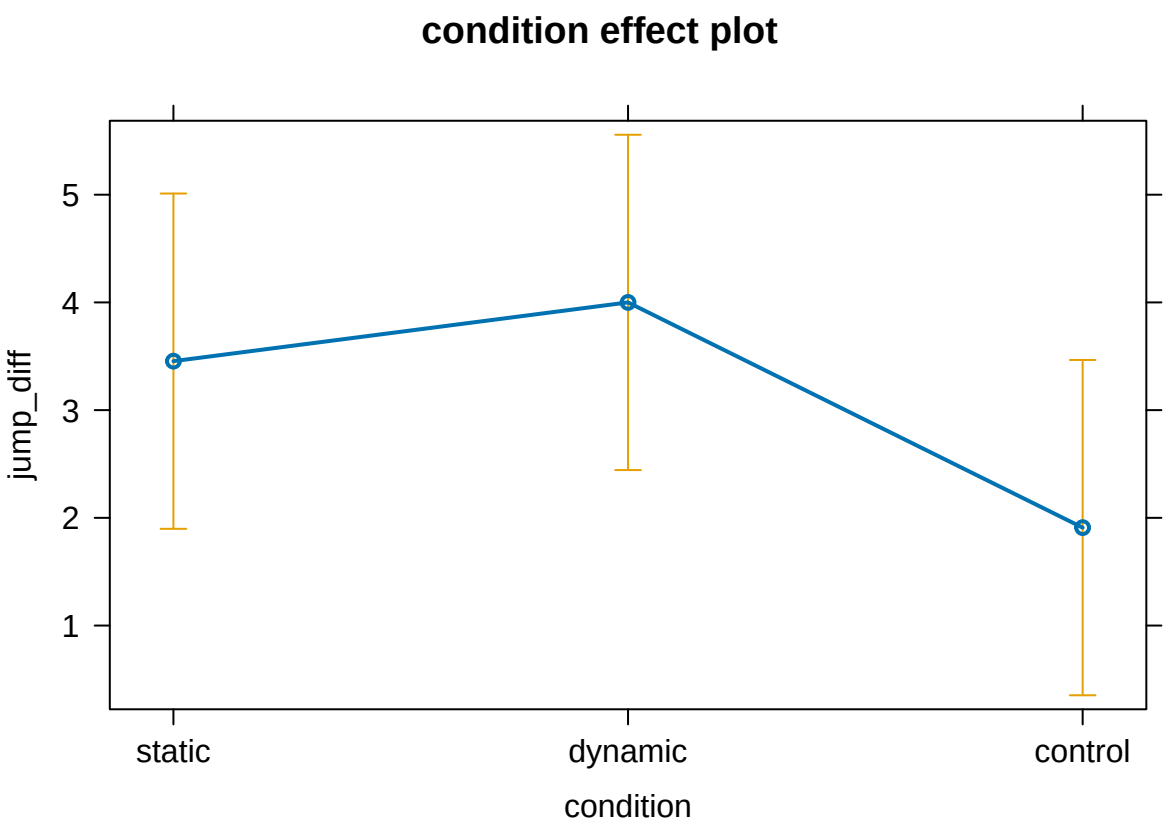
```
lmer_model
```

```
## Linear mixed model fit by REML ['lmerModLmerTest']
## Formula: jump_diff ~ condition + (1 | sub_id)
##    Data: data
## REML criterion at convergence: 139.0306
## Random effects:
##  Groups   Name        Std.Dev.
##  sub_id   (Intercept) 1.893
##  Residual             1.675
## Number of obs: 33, groups:  sub_id, 11
## Fixed Effects:
##      (Intercept)  conditiondynamic  conditioncontrol
##           3.4545            0.5455           -1.5455
```

```
effects_model <- allEffects(lmer_model)
print(effects_model)
```

```
##  model: jump_diff ~ condition
##
##  condition effect
## condition
##   static  dynamic  control
## 3.454545 4.000000 1.909091
```

```
plot(effects_model)
```



```
effects_model
```

```
##  model: jump_diff ~ condition
##
##  condition effect
## condition
##   static  dynamic  control
## 3.454545 4.000000 1.909091
```

```
lmer_null <- lmer(jump_diff ~ (1|sub_id), data = data)
summary(lmer_null)
```

```
## Linear mixed model fit by REML. t-tests use Satterthwaite's method [
## lmerModLmerTest]
## Formula: jump_diff ~ (1 | sub_id)
##    Data: data
##
## REML criterion at convergence: 149.3
##
## Scaled residuals:
##     Min      1Q  Median      3Q     Max
## -1.6618 -0.5698 -0.2330  0.5180  2.3568
##
## Random effects:
##  Groups   Name        Variance Std.Dev.
##  sub_id   (Intercept) 3.275    1.810
##  Residual             3.727    1.931
## Number of obs: 33, groups:  sub_id, 11
##
## Fixed effects:
##             Estimate Std. Error      df t value Pr(>|t|)
## (Intercept)   3.1212     0.6408 10.0000   4.871 0.000651 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
lmer_null
```

```
## Linear mixed model fit by REML ['lmerModLmerTest']
## Formula: jump_diff ~ (1 | sub_id)
##    Data: data
## REML criterion at convergence: 149.3184
## Random effects:
##  Groups   Name        Std.Dev.
##  sub_id   (Intercept) 1.810
##  Residual             1.931
## Number of obs: 33, groups:  sub_id, 11
## Fixed Effects:
## (Intercept)
##       3.121
```

```
# ANOVA of model and null
anova(lmer_model, lmer_null)
```

```
## refitting model(s) with ML (instead of REML)
```

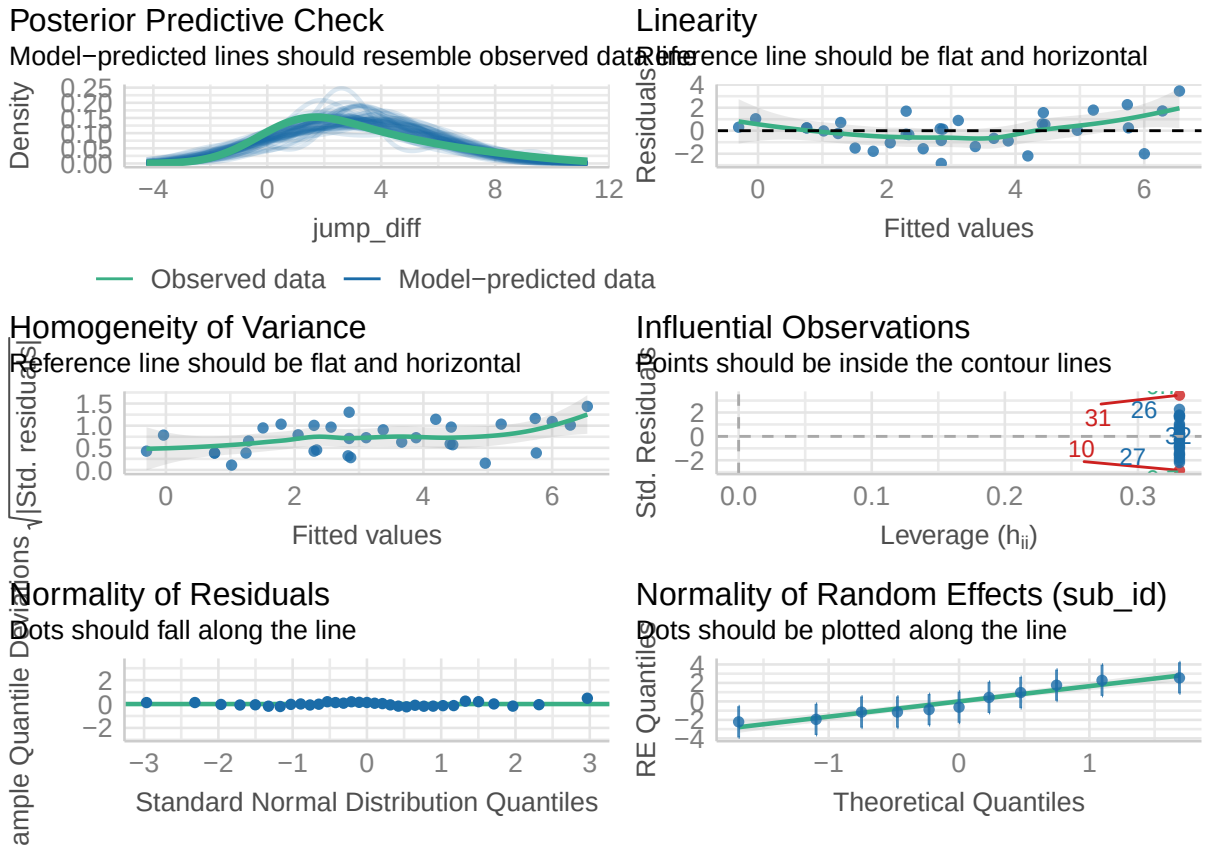
```
## Data: data
## Models:
```

```
## lmer_null: jump_diff ~ (1 | sub_id)
## lmer_model: jump_diff ~ condition + (1 | sub_id)
##            npar    AIC    BIC  logLik deviance  Chisq Df Pr(>Chisq)
## lmer_null     3 156.22 160.71 -75.109   150.22
## lmer_model    5 151.88 159.36 -70.938   141.88 8.3425  2    0.01543 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

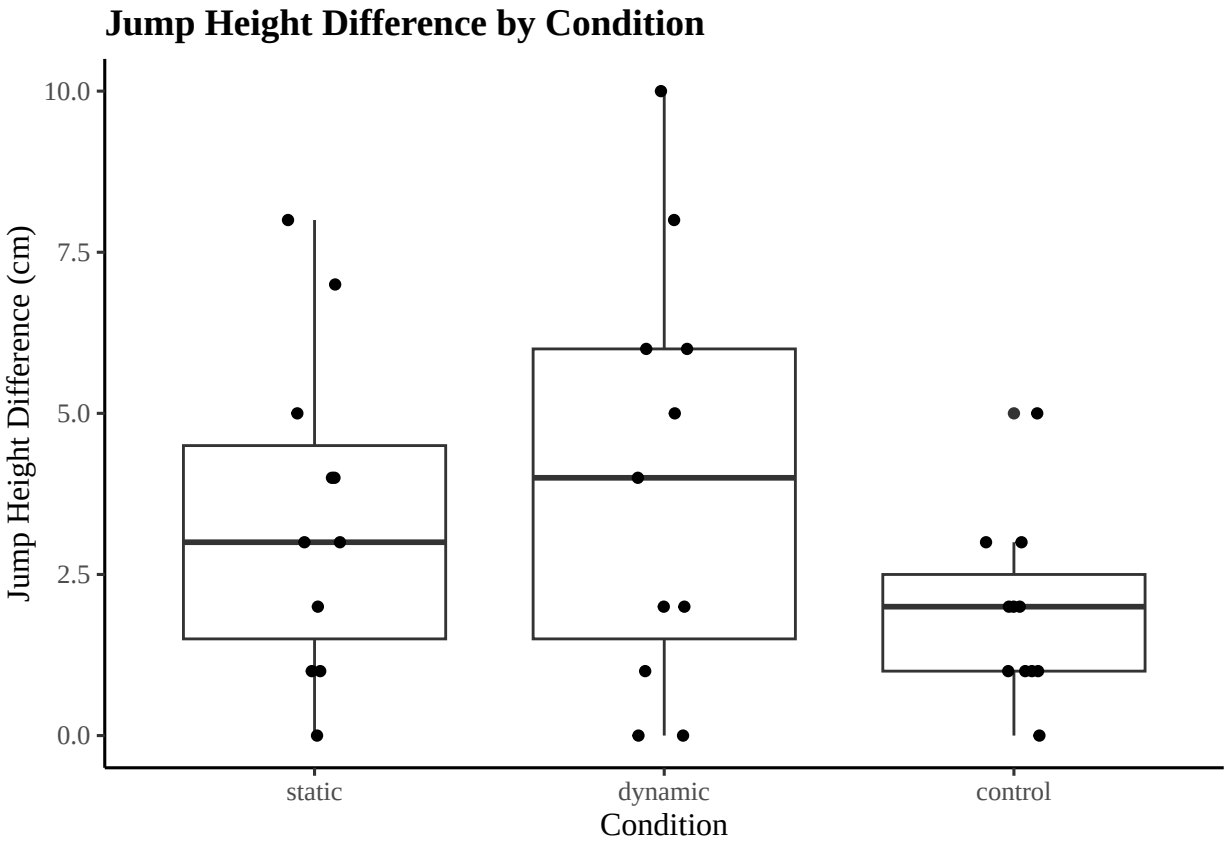
```
# post hoc Estimated marginal means
emmeans_results <- emmeans(lmer_model, pairwise ~ condition)
emmeans_results
```

```
## $emmeans
##  condition emmean    SE   df lower.CL upper.CL
##  static      3.45 0.762 18.4    1.856     5.05
##  dynamic     4.00 0.762 18.4    2.402     5.60
##  control     1.91 0.762 18.4    0.311     3.51
##
## Degrees-of-freedom method: kenward-roger
## Confidence level used: 0.95
##
## $contrasts
##  contrast          estimate    SE df t.ratio p.value
##  static - dynamic    -0.545 0.714 20  -0.764  0.7290
##  static - control     1.545 0.714 20   2.164  0.1024
##  dynamic - control    2.091 0.714 20   2.927  0.0217
##
## Degrees-of-freedom method: kenward-roger
## P value adjustment: tukey method for comparing a family of 3 estimates
```

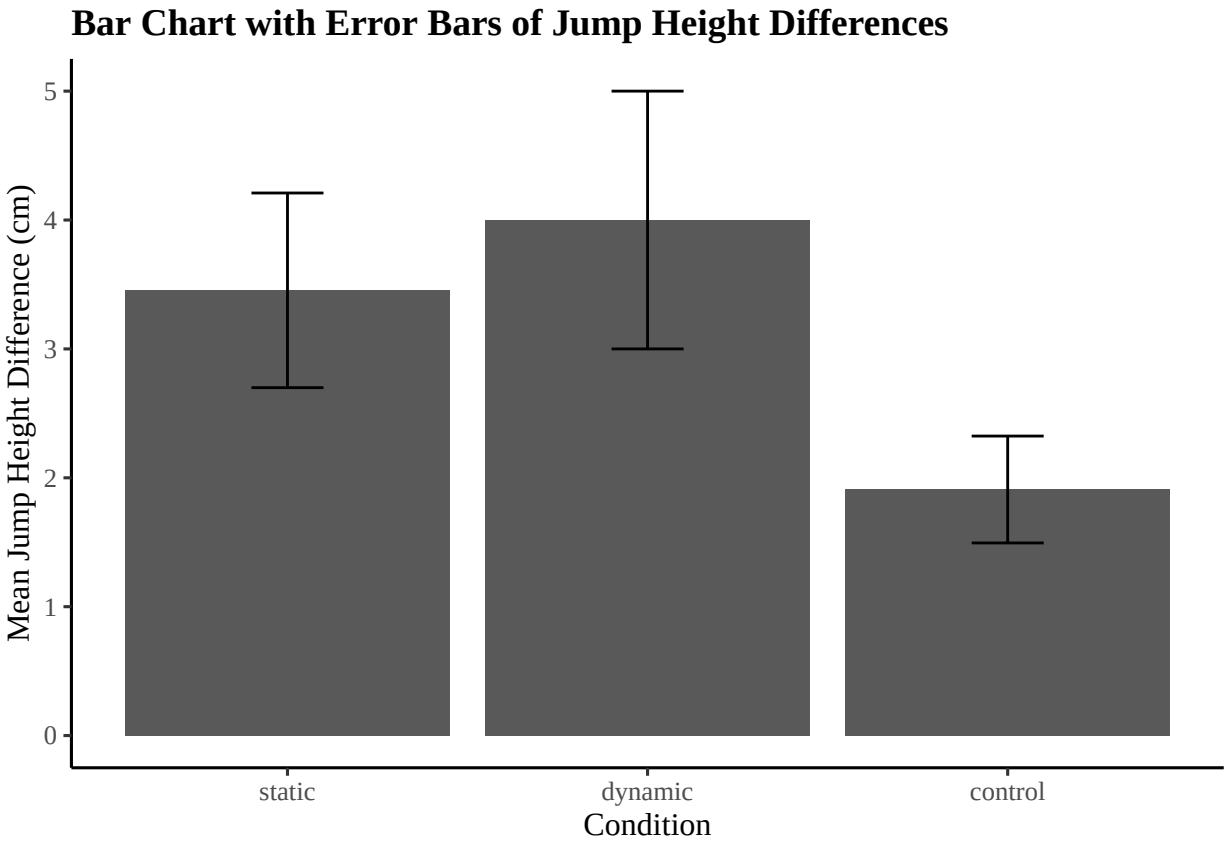
```
model_performance <- performance::check_model(lmer_model)
print(model_performance)
```




```
# emmeans_results <- emmeans(lmer_model, ~ condition)
# pairwise_comparisons <- pairs(emmeans_results)
# pairwise_comparisons

# Box plot
#stat_compare_means(jump_diff ~ condition, data = data, method = "t.test")

ggplot(data, aes(x = condition, y = jump_diff, fill = condition)) +
  geom_boxplot() +
  scale_fill_manual(values = c("white", "white", "white")) +
  geom_point(position = position_jitterdodge()) +
  labs(title = "Jump Height Difference by Condition",
       x = "Condition",
       y = "Jump Height Difference (cm)") +
  theme_bw(base_size = 12, base_family = "Times") +
  theme(plot.title = element_text(size = 14, face = "bold"),
        axis.title = element_text(size = 12),
        axis.text = element_text(size = 10),
        panel.border = element_blank(),
        panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        axis.line = element_line(color = "black")
        ) +
  guides(fill = "none")
```




```
ggsave("boxplot.pdf", width = 6, height = 4, units = "in", dpi = 300)

# Bar chart with error bars
summary_data <- data %>%
  group_by(condition) %>%
  summarise(mean_diff = mean(jump_diff),
            se_diff = sd(jump_diff) / sqrt(n()))

ggplot(summary_data, aes(x = condition, y = mean_diff)) +
  geom_bar(stat = "identity") +
  geom_errorbar(aes(
    ymin = mean_diff - se_diff,
    ymax = mean_diff + se_diff), width = 0.2) +
  labs(title = "Bar Chart with Error Bars of Jump Height Differences",
       x = "Condition",
       y = "Mean Jump Height Difference (cm)") +
  theme_bw(base_size = 12, base_family = "Times") +
  theme(plot.title = element_text(size = 14, face = "bold"),
        axis.title = element_text(size = 12),
        axis.text = element_text(size = 10),
        panel.border = element_blank(),
        panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        axis.line = element_line(color = "black")
  )
```




```
ggsave("barchart.pdf", width = 6, height = 4, units = "in", dpi = 300)

interaction_data <- data %>%
  gather(key = "time",
         value = "jump_height", pre_stretch, post_stretch)

interaction_data
```

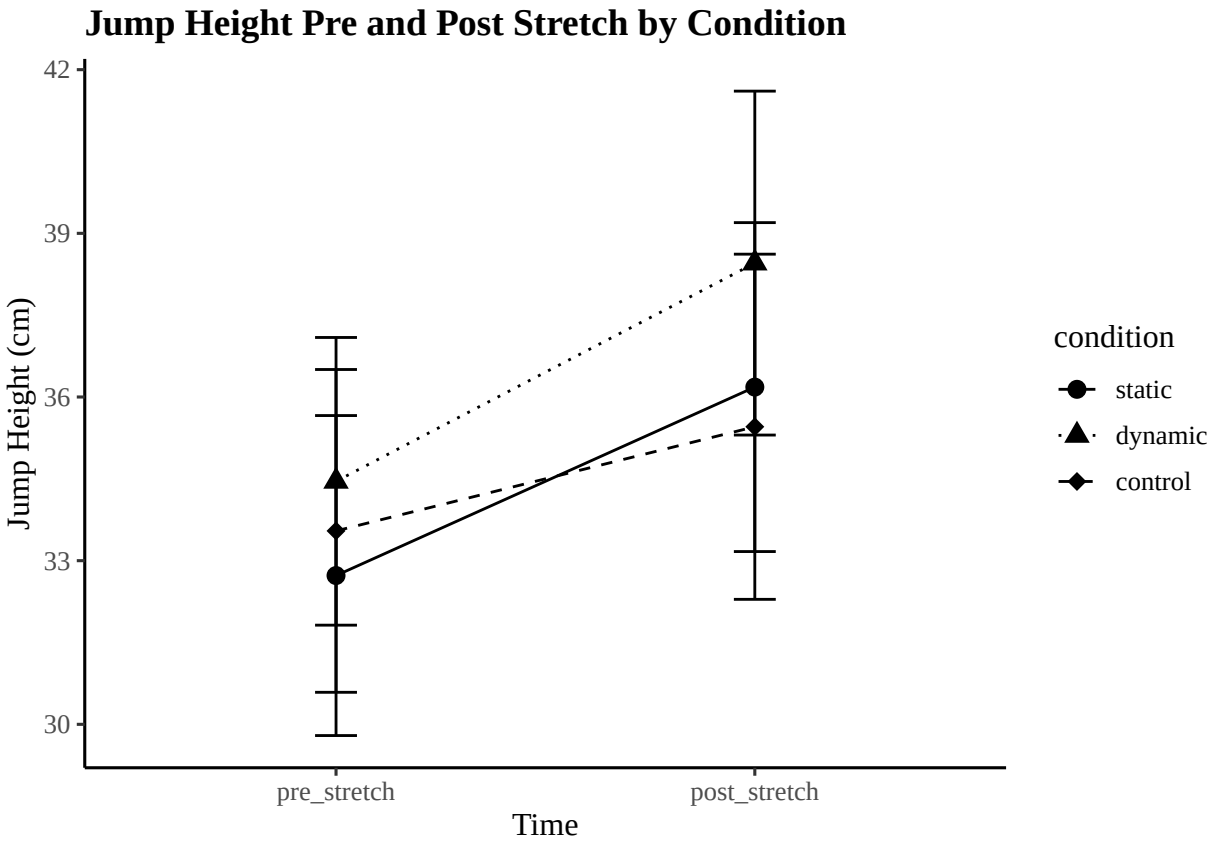
```
## # A tibble: 66 x 8
##    sub_id   age sex   group condition jump_diff time        jump_height
##     <int> <int> <chr> <chr> <fct>         <int> <chr>             <int>
##  1      1    29 f     a     dynamic           1 pre_stretch          22
##  2      1    29 f     a     static            0 pre_stretch          24
##  3      1    29 f     a     control           1 pre_stretch          21
##  4      2    37 m     b     dynamic           4 pre_stretch          38
##  5      2    37 m     b     static            1 pre_stretch          36
##  6      2    37 m     b     control           1 pre_stretch          39
##  7      3    55 f     c     dynamic           0 pre_stretch          20
##  8      3    55 f     c     static            1 pre_stretch          19
##  9      3    55 f     c     control           0 pre_stretch          21
## 10      4    32 f     a     dynamic           0 pre_stretch          38
## # i 56 more rows
```

```
summary(interaction_data)
```

```
##      sub_id        age         sex               group            condition
##  Min.   : 1   Min.   :21   Length:66          Length:66          static :22
##  1st Qu.: 3   1st Qu.:28   Class :character   Class :character   dynamic:22
```

```
##  Median : 6   Median :30   Mode  :character   Mode  :character   control:22
##  Mean   : 6   Mean   :34
##  3rd Qu.: 9   3rd Qu.:42
##  Max.   :11   Max.   :55
##    jump_diff          time            jump_height
##  Min.   : 0.000   Length:66          Min.   :19.00
##  1st Qu.: 1.000   Class :character   1st Qu.:26.50
##  Median : 2.000   Mode  :character   Median :36.00
##  Mean   : 3.121                      Mean   :35.14
##  3rd Qu.: 5.000                      3rd Qu.:40.00
##  Max.   :10.000                      Max.   :55.00
```

```r
# Interaction plot

interaction_data$time <- factor(interaction_data$time,
                                levels = c("pre_stretch", "post_stretch"))

ggplot(interaction_data, aes(
  x = time, y = jump_height, color = condition, group = condition)) +
  geom_line(aes(
    linetype = condition),
    stat = "summary", fun = mean, color = "black") +
  geom_point(aes(
    shape = condition),
    stat = "summary", fun = mean, size = 3, color = "black") +
  geom_errorbar(
    stat = "summary", fun.data = mean_se, width = 0.1, color = "black") +
  scale_linetype_manual(values = c("solid", "dotted", "dashed")) +
  scale_shape_manual(values = c(16, 17, 18)) +
  labs(title = "Jump Height Pre and Post Stretch by Condition",
       x = "Time",
       y = "Jump Height (cm)") +
  theme_bw(base_size = 12, base_family = "Times") +
  theme(plot.title = element_text(size = 14, face = "bold"),
        axis.title = element_text(size = 12),
        axis.text = element_text(size = 10),
        panel.border = element_blank(),
        panel.grid.major = element_blank(),
        panel.grid.minor = element_blank(),
        axis.line = element_line(color = "black")
        )
```




```
ggsave("interaction.pdf", width = 6, height = 4, units = "in", dpi = 300)

# Define the means and standard deviations for each condition
row_before_means <- rowMeans(data_wide[, c("dynamic_pre", "static_pre",
                                           "control_pre")])
mean_before <- mean(row_before_means)
mean_before
```

```
## [1] 33.57576
```

```
mean_after_static <- mean(data_wide$static_post)
mean_after_static
```

```
## [1] 36.18182
```

```
mean_after_dynamic <- mean(data_wide$dynamic_post)
mean_after_dynamic
```

```
## [1] 38.45455
```

```
mean_after_rest <- mean(data_wide$control_post)
mean_after_rest
```

```
## [1] 35.45455
```

```
combined_scores <- c(data_wide$static_post,
                     data_wide$dynamic_post, data_wide$control_post)

mean_before_static <- mean(data_wide$static_pre)
mean_before_static
```

```
## [1] 32.72727
```

```
mean_before_dynamic <- mean(data_wide$dynamic_pre)
mean_before_dynamic
```

```
## [1] 34.45455
```

```
mean_before_rest <- mean(data_wide$control_pre)
mean_before_rest
```

```
## [1] 33.54545
```

```
sd_before <- sd(combined_scores)
sd_before
```

```
## [1] 10.07312
```

```
sd_after_static <- sd(data_wide$control_post)
sd_after_static
```

```
## [1] 10.49156
```

```
sd_after_dynamic <- sd(data_wide$dynamic_post)
sd_after_dynamic
```

```
## [1] 10.45336
```

```
sd_after_rest <- sd(data_wide$control_post)
sd_after_rest
```

```
## [1] 10.49156
```

```
sd_before_static <- sd(data_wide$control_pre)
sd_before_static
```

```
## [1] 9.811867
```

```
sd_before_dynamic <- sd(data_wide$dynamic_pre)
sd_before_dynamic
```

```
## [1] 8.744869
```

```
sd_before_rest <- sd(data_wide$control_pre)
sd_before_rest
```

```
## [1] 9.811867
```

```
# Calculate the effect sizes
effect_size_static <- (mean_before - mean_after_static) / sd_before
effect_size_dynamic <- (mean_before - mean_after_dynamic) / sd_before
effect_size_rest <- (mean_before - mean_after_rest) / sd_before

# Calculate the power for each condition
power_static <- pwr.t.test(d = effect_size_static,
                           n = n, type = "paired",
                           alternative = "two.sided")$power
power_dynamic <- pwr.t.test(d = effect_size_dynamic,
                            n = n, type = "paired",
                            alternative = "two.sided")$power
power_rest <- pwr.t.test(d = effect_size_rest,
                         n = n, type = "paired",
```

```
                          alternative = "two.sided")$power

# Print the results
cat("Power for static stretching:", power_static, "\n")
```

```
## Power for static stretching: 0.121735
```

```
cat("Power for dynamic stretching:", power_dynamic, "\n")
```

```
## Power for dynamic stretching: 0.3066805
```

```
cat("Power for rest:", power_rest, "\n")
```

```
## Power for rest: 0.08680512
```

```
# Define the effect size
row_after_means <- rowMeans(data_wide[, c("dynamic_post",
                                          "static_post", "control_post")])
mean_after <- mean(row_after_means)

# Calculate the effect size (Cohen's d)
effect_size <- (mean_before - mean_after) / sd_before
effect_size
```

```
## [1] -0.3098555
```

```
# Calculate the required sample size for a power of 0.8
required_sample_size <- pwr.t.test(d = effect_size,
                                   power = 0.8, type = "paired",
                                   alternative = "two.sided")$n

# Print the result
cat("Minimum number of participants needed:",
    ceiling(required_sample_size), "\n")
```

```
## Minimum number of participants needed: 84
```

```
write.csv(data_wide, "data_wide_output.csv")
write.csv(data, "data_output.csv")
```