Reliability Analysis

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1. Overview

This document provides a full reproducible analysis of the inertial sensor reliability study as presented in the paper entitled: "Reliability of joint angular parameters measured with inertial sensors during gait".

The data from joint angular motion variables of 14 subjects (9 women and 5 men) were collected in two different days. The objective was to investigate the agreement statistics of each parameter (test-retest reliability).

Subjects performed 5 repetitions of a 10 meter walking test and a total of 30 gait cycles. A set of four inertial sensors was positioned on the participant's right leg (Technaid, S.L., Spain). The variables from each test were extracted by a trained researcher, averaged and stored in ".csv" tables. Each table contains data from different joints.

The variables on the datasets are presented in tidy format, where each column is a variable and each line represents one participant. Each parameter is identified by a capital letter representing the joint from where it was exctracted:
* H -> Hip joint
* K -> Knee joint
* A -> Ankle joint

Variables from the second day of testing are identified with an additional "_2" after the variable name.
* H1 -> represents the H1 variable from day 01
* H1_2 -> represent the H1 variable from day 02.

The definition of each discrete joint parameter was based on the previus work of Benedetti et al (1998).

1.1 Loading required packages

Initializing packages and loading libraries.

```
# Packages
require(ggplot2)
require(reshape2)
require(car)
require(psych)
```

2. Data Analysis

The statistical analyses of the angular parameters are presented for each joint separately in the following sections.

The analysis consists of the following steps:

1) Loading and transforming the data:
   The data is loaded from a github account (https://github.com/arlindoelias/Sensor_reliability_study) in ".csv" format. The variables are continuous numbers that represents joint angles. All three datasets are presented in tidy format. Some extra factor variables, such as 'Participants' and 'Test days' were added to the datasets to transform into 'long' format to run some specific statistics.

2) Descriptive statistics of each parameter:
   The central tendency parameters are provided, including, the mean, standard deviation, median and range. The data from this section were used to put up the descriptive statistics tables in the paper.

3) Comparison of the parameter's means between each day:
   This step provides analysis of normality with Shapiro-Wilk test and homoscedasticity check with Levene test to assess parametric properties of each parameter.
   We compared means across different test days with paired Student-T test.

4) Computation of the Intraclass correlation coefficients:
   We selected ICC(3,1) to provide agreement of the same variable across diferent test days. Additionally, we estimated Standard Error of Measurement (SEM) and Minimal Detectable Change (MDC) statistics that are relevant for clinical applications.

5) Graphics:
   The code presented in this section produce the graphics (boxplots) presented in the paper. Particularly, we were interested in explore and compare the distribution of each parameter (for each test day), inspect the differences in the median line and the presence of outliers.

2.1 Analysis of the Hip joint data.

```
# Loading hip dataset
con <- "https://raw.githubusercontent.com/arlindoelias/Sensor_reliability_study/master/hipData.csv"
hipdata <- read.csv(con, sep=";")
names(hipdata)[1] <- "H1"


# Descriptive statistics
# Summary Statistics of the hip joint variables
summary(hipdata)

##        H1              H2               H3                H4               H5              H6
##  Min.   :10.28   Min.   : 3.420   Min.   :-19.110   Min.   :-11.780   Min.   :15.55   Min.   :29.47
##  1st Qu.:15.79   1st Qu.: 9.973   1st Qu.:-12.848   1st Qu.: -5.155   1st Qu.:21.59   1st Qu.:33.09
##  Median :17.93   Median :12.710   Median :-12.440   Median : -4.920   Median :24.85   Median :36.84
##  Mean   :18.25   Mean   :13.128   Mean   :-11.852   Mean   : -4.466   Mean   :25.43   Mean   :37.02
##  3rd Qu.:22.42   3rd Qu.:15.717   3rd Qu.: -8.915   3rd Qu.: -2.498   3rd Qu.:29.06   3rd Qu.:38.60
##  Max.   :25.04   Max.   :20.520   Max.   : -7.130   Max.   :  1.900   Max.   :36.59   Max.   :51.26
##        H7              H8               H9              H10              H11             H12
```

```
##  Min.   :10.40   Min.   :-10.960   Min.   : 0.780   Min.   : 5.670   Min.   :-1.670   Min.   :-17.660
##  1st Qu.:14.04   1st Qu.: -9.980   1st Qu.: 6.378   1st Qu.: 8.425   1st Qu.: 1.565   1st Qu.: -8.275
##  Median :16.52   Median : -9.065   Median : 6.760   Median : 8.875   Median : 3.245   Median : -4.865
##  Mean   :16.12   Mean   : -9.038   Mean   : 7.264   Mean   :10.307   Mean   : 3.826   Mean   : -6.607
##  3rd Qu.:18.57   3rd Qu.: -8.335   3rd Qu.: 9.438   3rd Qu.: 9.793   3rd Qu.: 6.197   3rd Qu.: -3.868
##  Max.   :21.20   Max.   : -6.370   Max.   :11.120   Max.   :21.110   Max.   :10.850   Max.   : -1.270
##       H1_2            H2_2            H3_2              H4_2              H5_2            H6_2
##  Min.   :12.13   Min.   : 7.25   Min.   :-16.330   Min.   :-12.450   Min.   :19.52   Min.   :30.56
##  1st Qu.:17.05   1st Qu.:11.38   1st Qu.:-13.773   1st Qu.: -5.390   1st Qu.:23.73   1st Qu.:33.35
##  Median :18.98   Median :14.51   Median :-11.760   Median : -4.020   Median :25.39   Median :37.05
##  Mean   :19.44   Mean   :15.01   Mean   :-11.889   Mean   : -4.266   Mean   :26.94   Mean   :38.04
##  3rd Qu.:21.32   3rd Qu.:17.73   3rd Qu.: -9.262   3rd Qu.: -1.710   3rd Qu.:30.42   3rd Qu.:40.88
##  Max.   :27.19   Max.   :24.55   Max.   : -8.760   Max.   :  3.490   Max.   :36.23   Max.   :51.55
##       H7_2            H8_2              H9_2             H10_2            H11_2           H12_2
##  Min.   :14.06   Min.   :-11.650   Min.   : 3.730   Min.   : 5.48   Min.   :1.760   Min.   :-13.280
##  1st Qu.:15.72   1st Qu.:-10.682   1st Qu.: 7.032   1st Qu.: 8.97   1st Qu.:3.715   1st Qu.: -8.410
##  Median :16.99   Median : -9.515   Median : 7.990   Median :11.65   Median :4.415   Median : -5.100
##  Mean   :17.05   Mean   : -9.335   Mean   : 7.718   Mean   :11.28   Mean   :4.906   Mean   : -6.443
##  3rd Qu.:18.50   3rd Qu.: -7.975   3rd Qu.: 8.540   3rd Qu.:12.85   3rd Qu.:6.697   3rd Qu.: -4.192
##  Max.   :19.88   Max.   : -5.320   Max.   :10.690   Max.   :18.41   Max.   :8.290   Max.   : -1.840
```

```r
# describe(hipdata)
knitr::kable(describe(hipdata), caption = "Descriptive Statistics of the hip joint variables" )
```

Descriptive Statistics of the hip joint variables

	vars	n	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
H1	1	14	18.247857	4.765873	17.930	18.345833	5.952639	10.28	25.04	14.76	-0.2386772	-1.3701098	1.2737330
H2	2	14	13.127857	4.904101	12.710	13.320833	4.692429	3.42	20.52	17.10	-0.0491372	-0.9047502	1.3106760
H3	3	14	-11.852143	3.390891	-12.440	-11.640833	1.134189	-19.11	-7.13	11.98	-0.3624465	-0.5490235	0.9062537
H4	4	14	-4.465714	3.896444	-4.920	-4.386667	2.268378	-11.78	1.90	13.68	-0.1756899	-0.6508279	1.0413683
H5	5	14	25.432857	6.088729	24.850	25.326667	6.019356	15.55	36.59	21.04	0.2951611	-1.0245781	1.6272813
H6	6	14	37.022857	6.056795	36.840	36.465833	3.928890	29.47	51.26	21.79	0.9544864	0.0767575	1.6187464
H7	7	14	16.118571	3.187637	16.520	16.171667	3.239481	10.40	21.20	10.80	-0.1258618	-1.2596008	0.8519318
H8	8	14	-9.037857	1.296327	-9.065	-9.100000	1.378818	-10.96	-6.37	4.59	0.3716641	-0.8868973	0.3464580
H9	9	14	7.263571	2.793032	6.760	7.482500	2.068227	0.78	11.12	10.34	-0.4700569	-0.2141711	0.7464691
H10	10	14	10.307143	4.318054	8.875	9.793333	1.141602	5.67	21.11	15.44	1.3501481	0.6309054	1.1540485
H11	11	14	3.825714	3.428661	3.245	3.698333	3.521175	-1.67	10.85	12.52	0.3452818	-0.8907639	0.9163483
H12	12	14	-6.607143	4.562104	-4.865	-6.130833	4.099389	-17.66	-1.27	16.39	-0.9556786	0.0345230	1.2192735
H1_2	13	14	19.438571	4.224884	18.980	19.401667	3.246894	12.13	27.19	15.06	0.1668122	-0.7153803	1.1291477
H2_2	14	14	15.010000	5.250369	14.505	14.861667	5.292882	7.25	24.55	17.30	0.3509750	-1.1097933	1.4032200
H3_2	15	14	-11.889286	2.563848	-11.760	-11.780000	3.602718	-16.33	-8.76	7.57	-0.2053755	-1.5112744	0.6852171
H4_2	16	14	-4.265714	4.054738	-4.020	-4.230000	3.232068	-12.45	3.49	15.94	-0.3449538	-0.2651305	1.0836744
H5_2	17	14	26.937143	5.379549	25.395	26.780833	5.522685	19.52	36.23	16.71	0.4393515	-1.1542285	1.4377449
H6_2	18	14	38.039286	6.065283	37.055	37.536667	6.241746	30.56	51.55	20.99	0.6737899	-0.5989769	1.6210150
H7_2	19	14	17.050714	1.735035	16.990	17.064167	2.023749	14.06	19.88	5.82	0.0358676	-1.3319168	0.4637075
H8_2	20	14	-9.335000	1.840321	-9.515	-9.476667	1.845837	-11.65	-5.32	6.33	0.5837034	-0.7251581	0.4918464
H9_2	21	14	7.717857	1.867105	7.990	7.802500	1.297275	3.73	10.69	6.96	-0.5999678	-0.3592814	0.4990047
H10_2	22	14	11.278571	3.580896	11.655	11.167500	3.217242	5.48	18.41	12.93	0.0482206	-0.7434455	0.9570346
H11_2	23	14	4.906429	2.217554	4.415	4.886667	3.246894	1.76	8.29	6.53	-0.0408135	-1.4855236	0.5926664
H12_2	24	14	-6.442857	3.413420	-5.100	-6.256667	3.610131	-13.28	-1.84	11.44	-0.4888812	-1.0379214	0.9122749

```r
# Normality assessment (Shapiro-Wilk test)
test.norm.vector <- NULL
for(i in 1:24){
  test.norm <- shapiro.test(hipdata[,i])
  test.norm.vector[i] <- round(test.norm$p.value,2)
}
names(test.norm.vector) <- names(hipdata)
# test.norm.vector
knitr::kable(test.norm.vector, caption = "Significance of the Shapiro-Wilk Test for each hip joint parameter"
)
```

Significance of the Shapiro-Wilk Test for each hip joint parameter

	x
H1	0.44
H2	0.64
H3	0.10
H4	0.33
H5	0.88
H6	0.08
H7	0.89
H8	0.92
H9	0.28
H10	0.00
H11	0.95
H12	0.11
H1_2	0.83
H2_2	0.54
H3_2	0.18
H4_2	0.50
H5_2	0.34
H6_2	0.35
H7_2	0.84
H8_2	0.35
H9_2	0.46
H10_2	0.89
H11_2	0.29
H12_2	0.46

```
# Homogeneity of variance (Levene test)
# Reorganizing the Hip dataset
hipdata2 <- hipdata[c("H1", "H1_2", "H2", "H2_2", "H3", "H3_2", "H4", "H4_2", "H5", "H5_2", "H6", "H6_2", "H7
", "H7_2", "H8", "H8_2", "H9", "H9_2", "H10", "H10_2", "H11", "H11_2", "H12", "H12_2")]
hipdata2$Participants <- c(1:14)

hipdata.m <- melt(hipdata2, id.var = "Participants") # Changing dataset into "long" format
hipdata.m$days <- c(rep(c(rep("Day 01", 14), rep("Day 02", 14)), 12)) # Add test days as a factor variable

leveneTest(hipdata.m$value, hipdata.m$days, center = mean)

## Levene's Test for Homogeneity of Variance (center = mean)
##        Df F value Pr(>F)
## group   1  0.1804 0.6713
##       334

# Analysing parameter means between days
hip01 <- hipdata[1:12]  # Dataframe with hip paramenters from day 1
hip02 <- hipdata[13:24]  # Dataframe with hip paramenters from day 2

hip.statistics <- data.frame(t_statistic = rep(NA, 12), df = rep(NA, 12), p.value = rep(NA, 12), conf.int.low
er = rep(NA, 12), conf.int.upper = rep(NA, 12)) # Definition of a dataframe to store t.test parameters
for(i in 1:12){
  test <- t.test(hip01[,i], hip02[,i], paired = T)
  hip.statistics$t_statistic[i] <- round(test$statistic[[1]], 2)
  hip.statistics$df[i] <- round(test$parameter[[1]], 2)
  hip.statistics$p.value[i] <- round(test$p.value, 2)
  hip.statistics$conf.int.lower[i] <- round(test$conf.int[1], 2)
  hip.statistics$conf.int.upper[i] <- round(test$conf.int[2], 2)
}

knitr::kable(hip.statistics, caption = "Mean differences of the hip joint variables across different test day
s " )
```

Mean differences of the hip joint variables across different test days

t_statistic	df	p.value	conf.int.lower	conf.int.upper
-1.64	13	0.13	-2.76	0.38
-2.16	13	0.05	-3.77	0.00
0.08	13	0.93	-0.93	1.00
-0.33	13	0.75	-1.52	1.12
-1.31	13	0.21	-3.98	0.97
-1.22	13	0.24	-2.82	0.78
-1.54	13	0.15	-2.24	0.37
0.59	13	0.56	-0.78	1.38
-0.74	13	0.47	-1.77	0.87
-0.93	13	0.37	-3.23	1.28
-1.87	13	0.08	-2.33	0.17
-0.17	13	0.87	-2.22	1.89

```
# ICC hip parameters
hip.icc <- data.frame(type = rep(NA, 12), icc = rep(NA, 12), f = rep(NA, 12), df1 = rep(NA, 12), df2 = rep(NA
, 12), lower.bound = rep(NA, 12), upper.bound = rep(NA, 12))
for(i in 1:12){
  data <- matrix(c(hip01[,i], hip02[,i]), ncol= 2, byrow = FALSE)
  test <- ICC(data)
  hip.icc[i,] <- test$results[3,]
}
hip.icc$parameter <- names(hip01)
hip.icc <- hip.icc[, c(8, 1:7)]
knitr::kable(hip.icc, caption = "Agreement statistics (ICC 3,1) of the hip joint variables" )
```

Agreement statistics (ICC 3,1) of the hip joint variables

parameter	type	icc	f	df1	df2	lower.bound	upper.bound
H1	ICC3	0.8170602	9.932556	13	13	0.0001002	0.5225118
H2	ICC3	0.7933928	8.680204	13	13	0.0002078	0.4718148
H3	ICC3	0.8459931	11.986428	13	13	0.0000352	0.5874525
H4	ICC3	0.8351667	11.133467	13	13	0.0000533	0.5627561
H5	ICC3	0.7223307	6.202814	13	13	0.0011772	0.3313831
H6	ICC3	0.8677640	14.124469	13	13	0.0000138	0.6386166
H7	ICC3	0.6118141	4.152171	13	13	0.0076780	0.1427145
H8	ICC3	0.3076061	1.888529	13	13	0.1323577	-0.2451265
H9	ICC3	0.5366234	3.316144	13	13	0.0195846	0.0312708
H10	ICC3	0.5147382	3.121487	13	13	0.0248019	0.0010344
H11	ICC3	0.7188586	6.113858	13	13	0.0012645	0.3249384
H12	ICC3	0.6089079	4.113885	13	13	0.0079939	0.1381741

2.2 Analysis of the knee joint data

```
# Loading hip dataset
con <- "https://raw.githubusercontent.com/arlindoelias/Sensor_reliability_study/master/kneeData.csv"
kneedata <- read.csv(con, sep=";")
names(kneedata)[1] <- "K1"


# Descriptive statistics
# Summary Statistics of the hip joint variables
summary(kneedata)
```

```
##        K1               K2               K3                K4               K5               K6       
##  Min.   :-1.800   Min.   : 2.00   Min.   :-3.700   Min.   :30.74   Min.   :55.55   Min.   :57.64  
##  1st Qu.: 5.188   1st Qu.:12.11   1st Qu.:-1.655   1st Qu.:38.86   1st Qu.:61.09   1st Qu.:67.29  
##  Median : 7.635   Median :16.27   Median : 1.225   Median :42.92   Median :65.95   Median :68.94  
##  Mean   : 8.413   Mean   :14.75   Mean   : 1.694   Mean   :42.16   Mean   :65.49   Mean   :68.97  
##  3rd Qu.:13.140   3rd Qu.:17.07   3rd Qu.: 4.952   3rd Qu.:46.41   3rd Qu.:69.21   3rd Qu.:72.23  
##  Max.   :15.800   Max.   :22.14   Max.   : 7.670   Max.   :49.77   Max.   :73.20   Max.   :79.87  
##        K7               K8                K9                K10              K11               K12         
##  Min.   : 9.79   Min.   :-0.780   Min.   :-15.330   Min.   :10.20   Min.   :11.97   Min.   :-13.830  
##  1st Qu.:10.94   1st Qu.: 2.598   1st Qu.:-11.102   1st Qu.:12.47   1st Qu.:17.37   1st Qu.:-11.092  
##  Median :12.60   Median : 5.755   Median : -5.865   Median :15.23   Median :24.10   Median : -6.600  
##  Mean   :13.32   Mean   : 6.001   Mean   : -7.321   Mean   :16.95   Mean   :24.38   Mean   : -5.828  
##  3rd Qu.:14.40   3rd Qu.: 8.315   3rd Qu.: -4.225   3rd Qu.:20.41   3rd Qu.:29.61   3rd Qu.: -1.698  
##  Max.   :20.54   Max.   :13.150   Max.   :  0.320   Max.   :31.12   Max.   :42.53   Max.   : 10.070  
##       K1_2             K2_2             K3_2              K4_2             K5_2             K6_2      
##  Min.   :-2.320   Min.   : 1.09   Min.   :-4.3400   Min.   :31.58   Min.   :57.25   Min.   :58.11  
##  1st Qu.: 5.143   1st Qu.:11.68   1st Qu.:-0.6625   1st Qu.:39.52   1st Qu.:60.98   1st Qu.:63.72  
##  Median : 7.470   Median :15.30   Median : 1.3150   Median :44.04   Median :65.80   Median :69.74  
##  Mean   : 8.199   Mean   :14.52   Mean   : 1.8886   Mean   :42.75   Mean   :65.65   Mean   :68.64  
##  3rd Qu.:12.428   3rd Qu.:16.55   3rd Qu.: 4.7800   3rd Qu.:45.82   3rd Qu.:69.01   3rd Qu.:73.78  
##  Max.   :15.100   Max.   :27.23   Max.   : 7.0600   Max.   :50.20   Max.   :75.19   Max.   :81.08  
##       K7_2             K8_2              K9_2              K10_2            K11_2            K12_2        
##  Min.   : 9.32   Min.   :-1.210   Min.   :-20.510   Min.   :12.08   Min.   :14.95   Min.   :-19.300  
##  1st Qu.:10.91   1st Qu.: 1.630   1st Qu.: -9.150   1st Qu.:13.40   1st Qu.:16.03   1st Qu.: -9.505  
##  Median :13.36   Median : 3.625   Median : -7.935   Median :16.02   Median :21.40   Median : -4.630  
##  Mean   :14.91   Mean   : 5.659   Mean   : -8.979   Mean   :17.18   Mean   :23.08   Mean   : -5.958  
##  3rd Qu.:18.09   3rd Qu.: 7.268   3rd Qu.: -5.295   3rd Qu.:19.12   3rd Qu.:29.61   3rd Qu.: -2.197  
##  Max.   :25.25   Max.   :20.370   Max.   : -2.190   Max.   :29.21   Max.   :38.51   Max.   :  3.770  
```

```r
# describe(hipdata)
knitr::kable(describe(kneedata), caption = "Descriptive Statistics of the knee joint variables" )
```

Descriptive Statistics of the knee joint variables

	vars	n	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
K1	1	14	8.412857	5.182793	7.635	8.648333	5.670945	-1.80	15.80	17.60	-0.2024821	-1.1855035	1.3851597
K2	2	14	14.751429	5.139221	16.270	15.198333	3.602718	2.00	22.14	20.14	-0.8720131	0.3085784	1.3735147
K3	3	14	1.694286	3.982198	1.225	1.645833	5.063079	-3.70	7.67	11.37	0.1298479	-1.6162405	1.0642873
K4	4	14	42.162857	5.277704	42.925	42.480833	5.908161	30.74	49.77	19.03	-0.5329362	-0.6976566	1.4105257
K5	5	14	65.494286	5.365255	65.950	65.680833	6.182442	55.55	73.20	17.65	-0.2995143	-1.1732481	1.4339248
K6	6	14	68.965714	5.810719	68.945	69.000833	4.647951	57.64	79.87	22.23	-0.1786230	-0.5803489	1.5529800
K7	7	14	13.322857	3.042983	12.600	13.015833	2.928135	9.79	20.54	10.75	0.8436604	-0.1696390	0.8132714
K8	8	14	6.001429	4.486816	5.755	5.970833	4.692429	-0.78	13.15	13.93	0.1092046	-1.3067303	1.1991521
K9	9	14	-7.321429	4.659504	-5.865	-7.290833	5.507859	-15.33	0.32	15.65	-0.1385164	-1.3465410	1.2453050
K10	10	14	16.952857	6.068331	15.230	16.335000	5.945226	10.20	31.12	20.92	0.8812133	-0.2859977	1.6218296
K11	11	14	24.382143	8.826909	24.100	23.904167	9.851877	11.97	42.53	30.56	0.3469131	-0.9385011	2.3590907
K12	12	14	-5.827857	6.591560	-6.600	-6.485833	7.679868	-13.83	10.07	23.90	0.8094699	-0.0792708	1.7616685
K1_2	13	14	8.199286	5.006698	7.470	8.500833	4.462626	-2.32	15.10	17.42	-0.2105432	-0.8273696	1.3380963
K2_2	14	14	14.515000	5.835149	15.305	14.574167	3.847347	1.09	27.23	26.14	-0.1541601	0.7180929	1.5595092
K3_2	15	14	1.888571	3.483464	1.315	1.976667	3.491523	-4.34	7.06	11.40	-0.0404385	-1.3157243	0.9309949
K4_2	16	14	42.751429	5.099384	44.040	43.061667	4.736907	31.58	50.20	18.62	-0.6528668	-0.5774348	1.3628678
K5_2	17	14	65.650000	5.614417	65.800	65.555000	6.152790	57.25	75.19	17.94	0.1351440	-1.2220978	1.5005160
K6_2	18	14	68.636429	6.763459	69.740	68.476667	8.028279	58.11	81.08	22.97	0.0296340	-1.2096005	1.8076105
K7_2	19	14	14.907857	5.409765	13.360	14.511667	4.588647	9.32	25.25	15.93	0.6900469	-1.0912352	1.4458205
K8_2	20	14	5.658571	6.388158	3.625	5.005000	4.573821	-1.21	20.37	21.58	1.0036437	-0.1971539	1.7073071
K9_2	21	14	-8.979286	5.457281	-7.935	-8.584167	3.276546	-20.51	-2.19	18.32	-0.9073656	-0.3364671	1.4585197
K10_2	22	14	17.176429	4.732621	16.020	16.598333	4.329192	12.08	29.21	17.13	1.0909359	0.4010741	1.2648462
K11_2	23	14	23.081429	7.630458	21.400	22.473333	9.036447	14.95	38.51	23.56	0.5442982	-1.1055911	2.0393257
K12_2	24	14	-5.957857	5.999019	-4.630	-5.656667	5.989704	-19.30	3.77	23.07	-0.4656021	-0.4540395	1.6033054

```r
# Normality assessment (Shapiro-Wilk test)
test.norm.vector <- NULL
for(i in 1:24){
  test.norm <- shapiro.test(hipdata[,i])
  test.norm.vector[i] <- round(test.norm$p.value,2)
}
names(test.norm.vector) <- names(kneedata)
```

```r
# test.norm.vector
knitr::kable(test.norm.vector, caption = "Significance of the Shapiro-Wilk Test for each knee joint parameter
" )
```

Significance of the Shapiro-Wilk Test for each knee joint parameter

	x
K1	0.44
K2	0.64
K3	0.10
K4	0.33
K5	0.88
K6	0.08
K7	0.89
K8	0.92
K9	0.28
K10	0.00
K11	0.95
K12	0.11
K1_2	0.83
K2_2	0.54
K3_2	0.18
K4_2	0.50
K5_2	0.34
K6_2	0.35
K7_2	0.84
K8_2	0.35
K9_2	0.46
K10_2	0.89
K11_2	0.29
K12_2	0.46

```r
# Homogeneity of variance (Levene test)
# Reorganizing the Hip dataset
kneedata2 <- kneedata[c("K1", "K1_2", "K2", "K2_2", "K3", "K3_2", "K4", "K4_2", "K5", "K5_2", "K6", "K6_2", "
K7", "K7_2", "K8", "K8_2", "K9", "K9_2", "K10", "K10_2", "K11", "K11_2", "K12", "K12_2")]
kneedata2$Participants <- c(1:14)

kneedata.m <- melt(kneedata2, id.var = "Participants") # Changing dataset into "long" format
kneedata.m$days <- c(rep(c(rep("Day 01", 14), rep("Day 02", 14)), 12))

leveneTest(kneedata.m$value, kneedata.m$days)

## Levene's Test for Homogeneity of Variance (center = median)
##        Df F value Pr(>F)
## group   1   0.019 0.8904
##       334

# Analysing parameter means between days
knee01 <- kneedata[1:12]  # Dataframe with knee paramenters from day 1
knee02 <- kneedata[13:24]  # Dataframe with knee paramenters from day 2
knee.statistics <- data.frame(statistic = rep(NA, 12), df = rep(NA, 12), p.value = rep(NA, 12), conf.int.lowe
r = rep(NA, 12), conf.int.upper = rep(NA, 12)) # Definition of a dataframe to store t.test parameters

for(i in 1:12){
  test <- t.test(knee01[,i], knee02[,i], paired = T)
  knee.statistics$statistic[i] <- round(test$statistic[[1]], 2)
  knee.statistics$df[i] <- round(test$parameter[[1]], 2)
  knee.statistics$p.value[i] <- round(test$p.value, 2)
  knee.statistics$conf.int.lower[i] <- round(test$conf.int[1], 2)
  knee.statistics$conf.int.upper[i] <- round(test$conf.int[2], 2)
}
```

```
knitr::kable(knee.statistics, caption = "Mean differences of the knee joint variables across different test d
ays " )
```

Mean differences of the knee joint variables across different test days

statistic	df	p.value	conf.int.lower	conf.int.upper
0.80	13	0.44	-0.36	0.79
0.41	13	0.69	-1.01	1.48
-0.22	13	0.83	-2.09	1.70
-0.84	13	0.42	-2.11	0.93
-0.23	13	0.83	-1.65	1.34
0.31	13	0.76	-1.94	2.60
-1.14	13	0.27	-4.58	1.41
0.20	13	0.85	-3.40	4.08
1.54	13	0.15	-0.67	3.99
-0.14	13	0.89	-3.68	3.23
0.53	13	0.61	-4.04	6.64
0.05	13	0.96	-5.08	5.34

```
# ICC hip parameters
knee.icc <- data.frame(type = rep(NA, 12), icc = rep(NA, 12), f = rep(NA, 12), df1 = rep(NA, 12), df2 = rep(N
A, 12), lower.bound = rep(NA, 12), upper.bound = rep(NA, 12))
for(i in 1:12){
  data <- matrix(c(knee01[,i], knee02[,i]), ncol= 2, byrow = FALSE)
  test <- ICC(data)
  knee.icc[i,] <- test$results[3,]
}
knee.icc$parameter <- names(knee01)
knee.icc <- knee.icc[, c(8, 1:7)]
knitr::kable(knee.icc, caption = "Agreement statistics (ICC 3,1) of the knee joint variables" )
```

Agreement statistics (ICC 3,1) of the knee joint variables

parameter	type	icc	f	df1	df2	lower.bound	upper.bound
K1	ICC3	0.9809081	103.7566640	13	13	0.0000000	0.9417051
K2	ICC3	0.9226645	24.8613449	13	13	0.0000005	0.7773096
K3	ICC3	0.6145541	4.1887958	13	13	0.0073890	0.1470133
K4	ICC3	0.8708973	14.4915430	13	13	0.0000119	0.6461509
K5	ICC3	0.8893732	17.0788010	13	13	0.0000046	0.6914865
K6	ICC3	0.8054083	9.2779297	13	13	0.0001452	0.4972897
K7	ICC3	0.3017597	1.8643433	13	13	0.1371850	-0.2511744
K8	ICC3	0.3109759	1.9026560	13	13	0.1296226	-0.2416210
K9	ICC3	0.6842100	5.3333231	13	13	0.0024513	0.2625702
K10	ICC3	0.3950634	2.3061313	13	13	0.0725022	-0.1492122
K11	ICC3	0.3725735	2.1876241	13	13	0.0857128	-0.1748955
K12	ICC3	-0.0257214	0.9498473	13	13	0.5362498	-0.5326570

2.3 Analysis of the ankle joint data

```
#Loading ankle joint dataset
con1 <- "https://raw.githubusercontent.com/arlindoelias/Sensor_reliability_study/master/ankleData.csv"
ankledata <- read.csv(con1, sep=";")
names(ankledata)[1] <- "A1"

# Summary statistics
summary(ankledata)
```

```
##        A1              A2               A3             A4              A5              A6       
##  Min.   :-4.050   Min.   :-9.4100   Min.   : 7.04   Min.   :-20.940   Min.   :-28.97   Min.   :19.99  
##  1st Qu.: 3.683   1st Qu.:-3.4850   1st Qu.:10.35   1st Qu.: -9.193   1st Qu.:-17.09   1st Qu.:23.91  
##  Median : 7.160   Median : 0.2200   Median :12.26   Median : -7.915   Median :-14.29   Median :25.50  
##  Mean   : 6.559   Mean   :-0.5086   Mean   :13.01   Mean   : -7.344   Mean   :-14.31   Mean   :27.33  
##  3rd Qu.:10.155   3rd Qu.: 2.2975   3rd Qu.:15.25   3rd Qu.: -3.567   3rd Qu.:-11.80   3rd Qu.:30.13  
##  Max.   :13.180   Max.   : 8.6200   Max.   :21.08   Max.   :  1.480   Max.   : -2.71   Max.   :38.99  
##        A7              A8              A9               A1_2            A2_2              A3_2      
##  Min.   :18.36   Min.   :-1.870   Min.   :-25.270   Min.   : 4.750   Min.   :-8.3700   Min.   :11.55  
##  1st Qu.:20.34   1st Qu.: 7.343   1st Qu.:-18.067   1st Qu.: 7.982   1st Qu.: 0.7675   1st Qu.:14.21  
##  Median :22.88   Median :11.000   Median :-12.020   Median : 9.570   Median : 1.9400   Median :15.86  
##  Mean   :23.45   Mean   :11.926   Mean   :-11.524   Mean   :10.296   Mean   : 1.9250   Mean   :16.73  
##  3rd Qu.:25.86   3rd Qu.:16.730   3rd Qu.: -5.525   3rd Qu.:12.383   3rd Qu.: 4.9600   3rd Qu.:20.29  
##  Max.   :32.38   Max.   :27.940   Max.   :  7.130   Max.   :16.310   Max.   :10.8900   Max.   :23.15  
##       A4_2              A5_2              A6_2            A7_2            A8_2              A9_2      
##  Min.   :-16.250   Min.   :-23.700   Min.   :21.68   Min.   :15.11   Min.   :-0.320   Min.   :-22.44  
##  1st Qu.: -9.665   1st Qu.:-16.830   1st Qu.:26.77   1st Qu.:20.59   1st Qu.: 8.685   1st Qu.:-18.70  
##  Median : -8.210   Median :-11.570   Median :29.37   Median :23.48   Median :11.370   Median :-11.78  
##  Mean   : -7.676   Mean   :-13.066   Mean   :29.79   Mean   :23.91   Mean   :11.593   Mean   :-12.32  
##  3rd Qu.: -6.213   3rd Qu.: -9.575   3rd Qu.:31.30   3rd Qu.:29.07   3rd Qu.:14.265   3rd Qu.: -5.39  
##  Max.   :  2.230   Max.   : -4.880   Max.   :38.81   Max.   :30.88   Max.   :20.630   Max.   : -2.91
```

```r
# Descriptive statistics
describe(ankledata)

knitr::kable(describe(ankledata), caption = "Descriptive Statistics of the ankle joint variables" )
```

Descriptive Statistics of the ankle joint variables

	vars	n	mean	sd	median	trimmed	mad	min	max	range	skew	kurtosis	se
A1	1	14	6.5592857	5.188131	7.160	6.891667	5.774727	-4.05	13.18	17.23	-0.5323068	-0.9114255	1.3865862
A2	2	14	-0.5085714	5.631511	0.220	-0.527500	4.751733	-9.41	8.62	18.03	-0.2091454	-1.1638480	1.5050847
A3	3	14	13.0142857	4.106786	12.255	12.840000	4.099389	7.04	21.08	14.04	0.4877430	-0.7732802	1.0975846
A4	4	14	-7.3442857	6.158421	-7.915	-6.946667	4.432974	-20.94	1.48	22.42	-0.5076201	-0.3403016	1.6459072
A5	5	14	-14.3121429	6.686927	-14.295	-14.057500	4.321779	-28.97	-2.71	26.26	-0.2445488	-0.1329357	1.7871563
A6	6	14	27.3264286	5.384278	25.505	26.965833	4.158693	19.99	38.99	19.00	0.6602209	-0.6791930	1.4390090
A7	7	14	23.4492857	4.008361	22.880	23.129167	4.240236	18.36	32.38	14.02	0.6899998	-0.6157681	1.0712796
A8	8	14	11.9264286	7.221300	11.000	11.741667	6.553092	-1.87	27.94	29.81	0.2771350	-0.1521190	1.9299737
A9	9	14	-11.5235714	8.974799	-12.020	-11.932500	10.185462	-25.27	7.13	32.40	0.2218184	-0.7849720	2.3986160
A1_2	10	14	10.2957143	3.697213	9.570	10.256667	3.254307	4.75	16.31	11.56	0.3430921	-1.2246348	0.9881216
A2_2	11	14	1.9250000	4.968536	1.940	2.035833	4.077150	-8.37	10.89	19.26	-0.3858399	-0.4029001	1.3278971
A3_2	12	14	16.7271429	3.814501	15.855	16.623333	5.604228	11.55	23.15	11.60	0.1331641	-1.5224165	1.0194684
A4_2	13	14	-7.6764286	5.360172	-8.210	-7.787500	2.727984	-16.25	2.23	18.48	0.3529039	-0.6443405	1.4325661
A5_2	14	14	-13.0657143	5.592649	-11.570	-12.861667	6.412245	-23.70	-4.88	18.82	-0.2381557	-1.1531859	1.4946982
A6_2	15	14	29.7928571	4.357371	29.370	29.717500	4.010433	21.68	38.81	17.13	0.1913555	-0.4700943	1.1645564
A7_2	16	14	23.9092857	5.413836	23.485	24.061667	7.264740	15.11	30.88	15.77	-0.1520033	-1.4286554	1.4469086
A8_2	17	14	11.5928571	5.396045	11.370	11.832500	5.003775	-0.32	20.63	20.95	-0.2578726	-0.3175662	1.4421536
A9_2	18	14	-12.3178571	7.108588	-11.775	-12.258333	10.052028	-22.44	-2.91	19.53	-0.0869385	-1.6647423	1.8998500

```r
# Normality assessment (Shapiro-Wilk test)
test.norm.vector <- NULL
for(i in 1:18){
  test.norm <- shapiro.test(ankledata[,i])
  test.norm.vector[i] <- round(test.norm$p.value,2)
}
names(test.norm.vector) <- names(ankledata)
# test.norm.vector
knitr::kable(test.norm.vector, caption = "Significance of the Shapiro-Wilk Test for each ankle joint paramete
r" )
```

Significance of the Shapiro-Wilk Test for each ankle joint parameter

	x
A1	0.37
A2	0.50
A3	0.53
A4	0.47
A5	0.65

A6	0.33
A7	0.32
A8	0.78
A9	0.86
A1_2	0.42
A2_2	0.78
A3_2	0.35
A4_2	0.36
A5_2	0.78
A6_2	0.89
A7_2	0.29
A8_2	0.70
A9_2	0.15

```
# Homogeneity of variance (leveneTest)
ankledata2 <- ankledata[c("A1", "A1_2", "A2", "A2_2", "A3", "A3_2", "A4", "A4_2", "A5", "A5_2", "A6", "A6_2",
"A7", "A7_2", "A8", "A8_2", "A9", "A9_2")]
ankledata2$Participants <- c(1:14)

ankledata.m <- melt(ankledata2, id.var = "Participants") # Changing dataset into "long" format
ankledata.m$days <- c(rep(c(rep("Day 01", 14), rep("Day 02", 14)), 9))

leveneTest(ankledata.m$value, ankledata.m$days)

## Levene's Test for Homogeneity of Variance (center = median)
##        Df F value Pr(>F)
## group   1  0.1102 0.7402
##       250

# Analysis of meand difference between days

ankle01 <- ankledata[1:9]  # Dataframe with ankle paramenters from day 1
ankle02 <- ankledata[10:18]  # Dataframe with ankle paramenters from day 2
ankle.statistics <- data.frame(statistic = rep(NA, 9), df = rep(NA, 9), p.value = rep(NA, 9), conf.int.lower
= rep(NA, 9), conf.int.upper = rep(NA, 9)) # Definition of a dataframe to store t.test parameters

for(i in 1:9){
  test <- t.test(ankle01[,i], ankle02[,i], paired = T)
  ankle.statistics$statistic[i] <- round(test$statistic[[1]], 2)
  ankle.statistics$df[i] <- round(test$parameter[[1]], 2)
  ankle.statistics$p.value[i] <- round(test$p.value, 2)
  ankle.statistics$conf.int.lower[i] <- round(test$conf.int[1], 2)
  ankle.statistics$conf.int.upper[i] <- round(test$conf.int[2], 2)
}

knitr::kable(ankle.statistics, caption = "Mean differences of the ankle joint variables across different test
days " )
```

Mean differences of the ankle joint variables across different test days

statistic	df	p.value	conf.int.lower	conf.int.upper
-2.77	13	0.02	-6.65	-0.82
-1.31	13	0.21	-6.45	1.58
-2.79	13	0.02	-6.59	-0.84
0.18	13	0.86	-3.60	4.26
-0.65	13	0.52	-5.37	2.87
-1.80	13	0.09	-5.42	0.49
-0.23	13	0.82	-4.81	3.89
0.16	13	0.87	-4.06	4.73
0.35	13	0.73	-4.12	5.71

```
# ICC hip parameters
ankle.icc <- data.frame(type = rep(NA, 9), icc = rep(NA, 9), f = rep(NA, 9), df1 = rep(NA, 9), df2 = rep(NA,
9), lower.bound = rep(NA, 9), upper.bound = rep(NA, 9))
```

```r
for(i in 1:9){
  data <- matrix(c(ankle01[,i], ankle02[,i]), ncol= 2, byrow = FALSE)
  test <- ICC(data)
  ankle.icc[i,] <- test$results[3,]
}
ankle.icc$parameter <- names(ankle01)
ankle.icc <- ankle.icc[, c(8, 1:7)]
knitr::kable(ankle.icc, caption = "Agreement statistics (ICC 3,1) of the ankle joint variables" )
```

Agreement statistics (ICC 3,1) of the ankle joint variables

parameter	type	icc	f	df1	df2	lower.bound	upper.bound
A1	ICC3	0.3731630	2.1906222	13	13	0.0853476	-0.1742316
A2	ICC3	0.1433624	1.3347095	13	13	0.3051249	-0.4000962
A3	ICC3	0.2105778	1.5334984	13	13	0.2256290	-0.3402228
A4	ICC3	0.3047111	1.8765023	13	13	0.1347350	-0.2481266
A5	ICC3	0.3303609	1.9866835	13	13	0.1145627	-0.2211710
A6	ICC3	0.4546234	2.6671907	13	13	0.0443261	-0.0774520
A7	ICC3	-0.2490299	0.6012427	13	13	0.8146156	-0.6764275
A8	ICC3	0.2871152	1.8055024	13	13	0.1497336	-0.2661362
A9	ICC3	0.4465065	2.6134120	13	13	0.0476142	-0.0875671

3. Computation of the Standard Error of Measurement and Minimal Detectable Change (MDC)

The parameters SEM and MDC were derived from the previously estimated ICCs, by using the formulas below:

Formula: SEM = SD * (sqrt(1-ICC))

Formula: 1.96 * SEM * sqrt(2)

```
# HIP DATA
hip01 <- hipdata[1:12]  # Dataframe with hip paramenters from day 1
hip02 <- hipdata[13:24]  # Dataframe with hip paramenters from day 2
ICCvec <-c(0.82, 0.79, 0.85, 0.84, 0.72, 0.87, 0.61, 0.31, 0.54, 0.51, 0.72, 0.61)  # A vector to store ICC3 
values
SEMvec <- NULL  # A vector to store SEM values
MDCvec <- NULL  # A vector to store MDC values

for(i in 1:12){
  SEM <- mean(sd(hip01[,i]) + sd(hip02[,i])) * (sqrt(1-ICCvec[i]))
  SEMvec[i] <- SEM
  MDC <- 1.96 * SEM * sqrt(2)
  MDCvec[i] <- MDC
}

#round(SEMvec, 2)
# round(MDCvec, 2)
hip.table <- data.frame(Parameter = names(hip01), ICC = ICCvec, SEM = round(SEMvec, 2), MDC = round(MDCvec, 2
))
knitr::kable(hip.table, caption = "Agreement statistics of the hip joint variables" )
```

Agreement statistics of the hip joint variables

Parameter	ICC	SEM	MDC
H1	0.82	3.81	10.57
H2	0.79	4.65	12.90
H3	0.85	2.31	6.39
H4	0.84	3.18	8.82
H5	0.72	6.07	16.82
H6	0.87	4.37	12.11
H7	0.61	3.07	8.52
H8	0.31	2.61	7.22
H9	0.54	3.16	8.76
H10	0.51	5.53	15.33
H11	0.72	2.99	8.28
H12	0.61	4.98	13.81

```
# KNEE DATA
knee01 <- kneedata[1:12]  # Dataframe with knee paramenters from day 1
knee02 <- kneedata[13:24]  # Dataframe with knee paramenters from day 2
ICCknee <-c(0.98, 0.93, 0.61, 0.86, 0.89, 0.81, 0.31, 0.30, 0.68, 0.40, 0.37, 0.02)  # A vector to store ICC3 
values
SEMknee <- NULL  # A vector to store SEM values
MDCknee <- NULL  # A vector to store MDC values

for(i in 1:12){
  SEM <- mean(sd(knee01[,i]) + sd(knee02[,i])) * (sqrt(1-ICCknee[i]))
  SEMknee[i] <- SEM
  MDC <- 1.96 * SEM * sqrt(2)
  MDCknee[i] <- MDC
}

#round(SEMknee, 2)
#round(MDCknee, 2)
```

```r
knee.table <- data.frame(Parameter = names(knee01), ICC = ICCknee, SEM = round(SEMknee, 2), MDC = round(MDCkn
ee, 2))
knitr::kable(knee.table, caption = "Agreement statistics of the knee joint variables" )
```

Agreement statistics of the knee joint variables

Parameter	ICC	SEM	MDC
K1	0.98	1.44	3.99
K2	0.93	2.90	8.05
K3	0.61	4.66	12.92
K4	0.86	3.88	10.76
K5	0.89	3.64	10.09
K6	0.81	5.48	15.19
K7	0.31	7.02	19.46
K8	0.30	9.10	25.22
K9	0.68	5.72	15.86
K10	0.40	8.37	23.19
K11	0.37	13.06	36.21
K12	0.02	12.46	34.55

```r
# ANKLE DATA
ankle01 <- ankledata[1:9]  # Dataframe with ankle paramenters from day 1
ankle02 <- ankledata[10:18]  # Dataframe with ankle paramenters from day 2
ICCankle <-c(0.37, 0.14, 0.21, 0.30, 0.33, 0.45, 0.25, 0.29, 0.45)  # A vector to store ICC3 values
SEMankle <- NULL  # A vector to store SEM values
MDCankle <- NULL  # A vector to store MDC values

for(i in 1:9){
  SEM <- mean(sd(ankle01[,i]) + sd(ankle02[,i])) * (sqrt(1-ICCankle[i]))
  SEMankle[i] <- SEM
  MDC <- 1.96 * SEM * sqrt(2)
  MDCankle[i] <- MDC
}

#round(SEMankle, 2)
#round(MDCankle, 2)
ankle.table <- data.frame(Parameter = names(ankle01), ICC = ICCankle, SEM = round(SEMankle, 2), MDC = round(M
DCankle, 2))
knitr::kable(ankle.table, caption = "Agreement statistics of the ankle joint variables" )
```

Agreement statistics of the ankle joint variables

Parameter	ICC	SEM	MDC
A1	0.37	7.05	19.55
A2	0.14	9.83	27.25
A3	0.21	7.04	19.52
A4	0.30	9.64	26.71
A5	0.33	10.05	27.86
A6	0.45	7.22	20.03
A7	0.25	8.16	22.62
A8	0.29	10.63	29.47
A9	0.45	11.93	33.06

4. GRAPHICS

The code in this section produce boxplots that shows the distribution of each parameter.

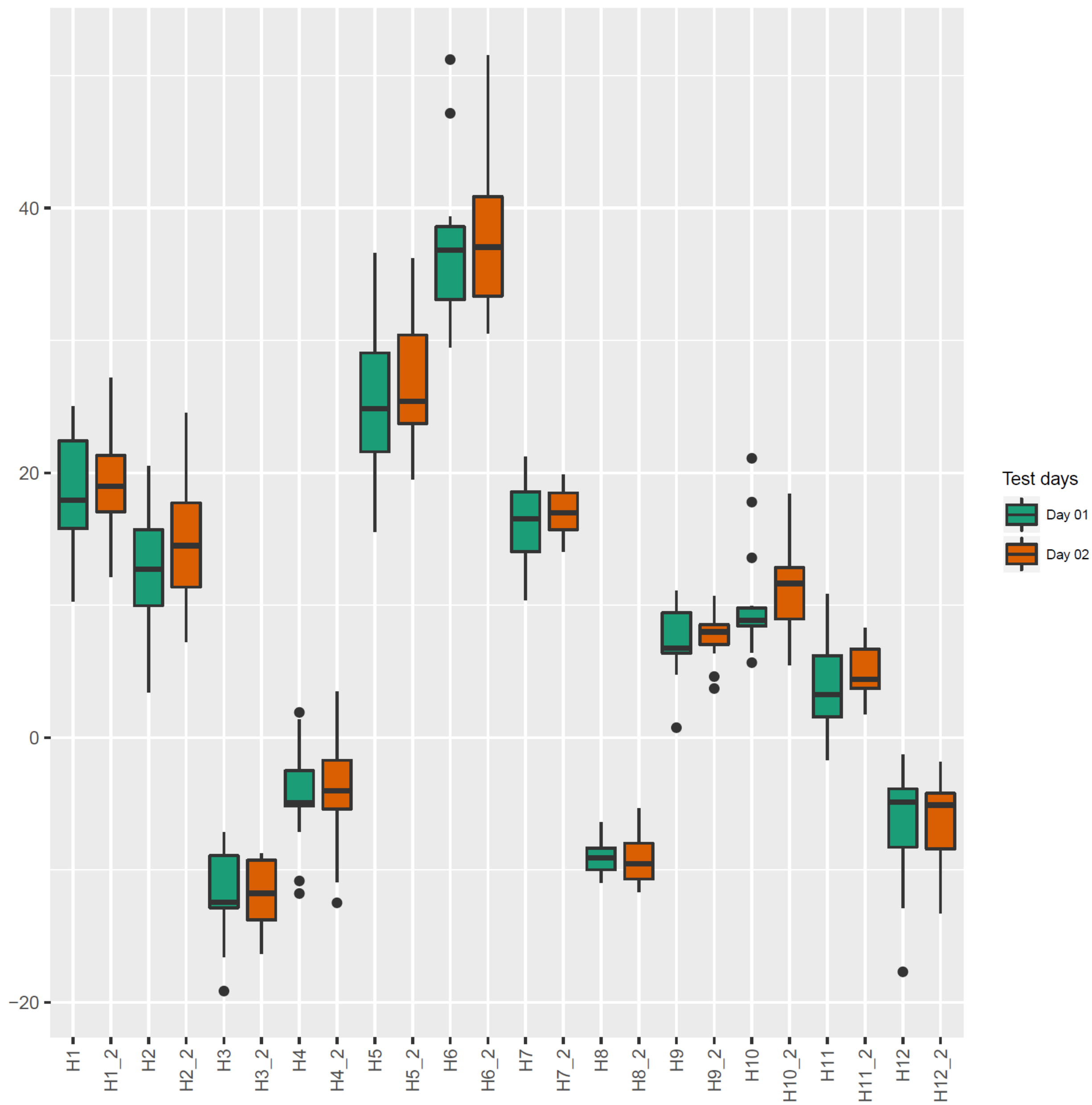
```
## GRAPHICS

# Reorganizing the Hip dataset
hipdata2 <- hipdata[c("H1", "H1_2", "H2", "H2_2", "H3", "H3_2", "H4", "H4_2", "H5", "H5_2", "H6", "H6_2", "H7
", "H7_2", "H8", "H8_2", "H9", "H9_2", "H10", "H10_2", "H11", "H11_2", "H12", "H12_2")]
hipdata2$Participants <- c(1:14)

hipdata.m <- melt(hipdata2, id.var = "Participants") # Changing dataset into "long" format
hipdata.m$days <- c(rep(c(rep("Day 01", 14), rep("Day 02", 14)), 12))

# Boxplot of the hip parameters
hip.graph <- ggplot(data = hipdata.m, aes(x=variable, y=value, fill = days)) + geom_boxplot() + ylab("") + xl
ab("")

hip.graph + scale_fill_brewer(palette = "Dark2") + guides(fill=guide_legend(title= "Test days")) + theme(axis
.text.x = element_text(size = 6))
```



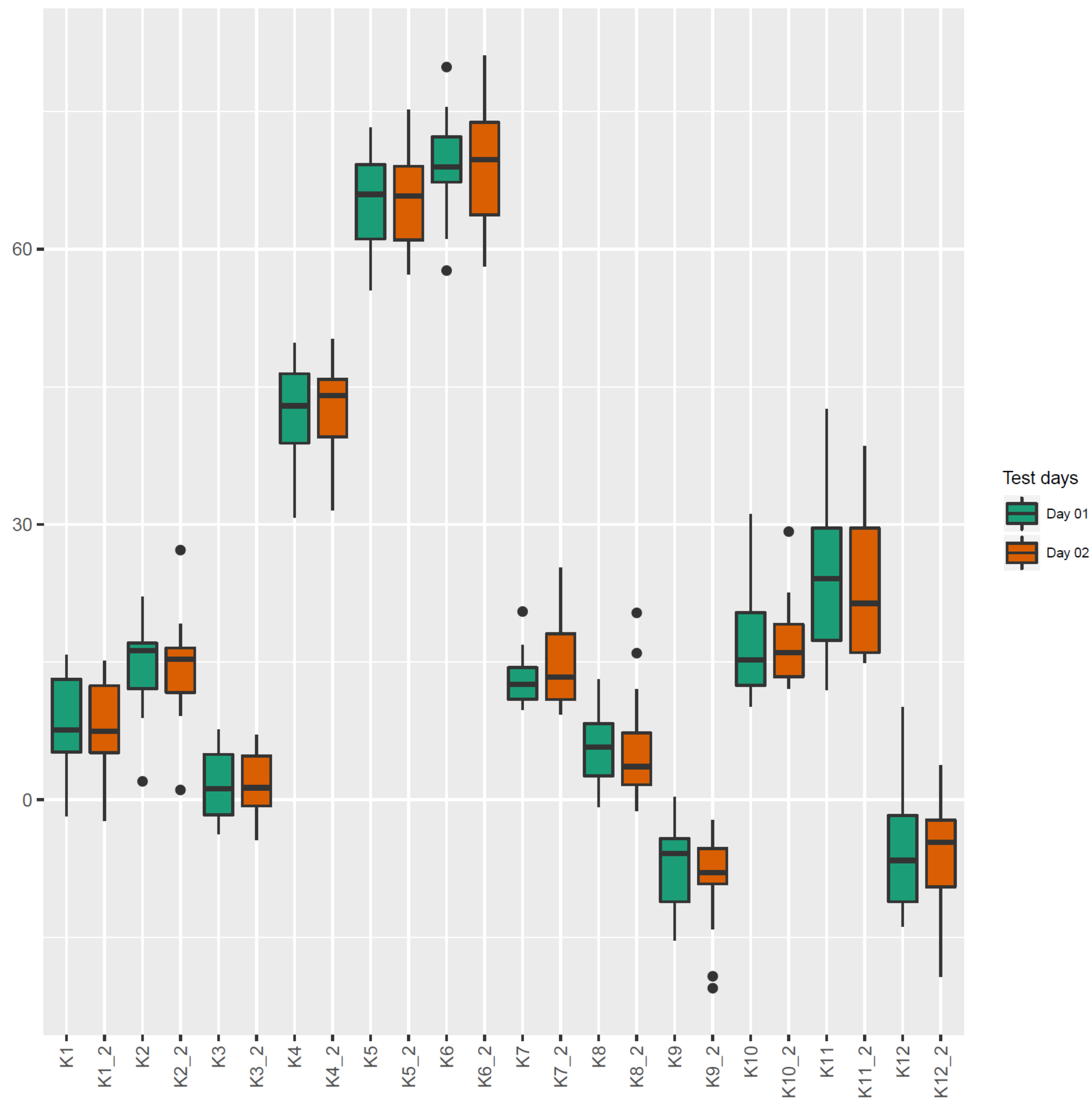
```
# KNEE
# Reorganizing the Knee dataset
kneedata2 <- kneedata[c("K1", "K1_2", "K2", "K2_2", "K3", "K3_2", "K4", "K4_2", "K5", "K5_2", "K6", "K6_2", "
K7", "K7_2", "K8", "K8_2", "K9", "K9_2", "K10", "K10_2", "K11", "K11_2", "K12", "K12_2")]
kneedata2$Participants <- c(1:14)

kneedata.m <- melt(kneedata2, id.var = "Participants") # Changing dataset into "long" format
kneedata.m$days <- c(rep(c(rep("Day 01", 14), rep("Day 02", 14)), 12))



# Boxplot of the knee parameters
knee.graph <- ggplot(data = kneedata.m, aes(x=variable, y=value, fill = days)) + geom_boxplot() + ylab("") +
xlab("")

knee.graph + scale_fill_brewer(palette = "Dark2") + guides(fill=guide_legend(title= "Test days")) + theme(axi
s.text.x = element_text(size = 6), axis.text.y = element_text (size = 5), legend.text = element_text (size =
6), legend.text = element_text (size = 8))
```




```
# ANKLE
# Reorganizing the ankle dataset
```

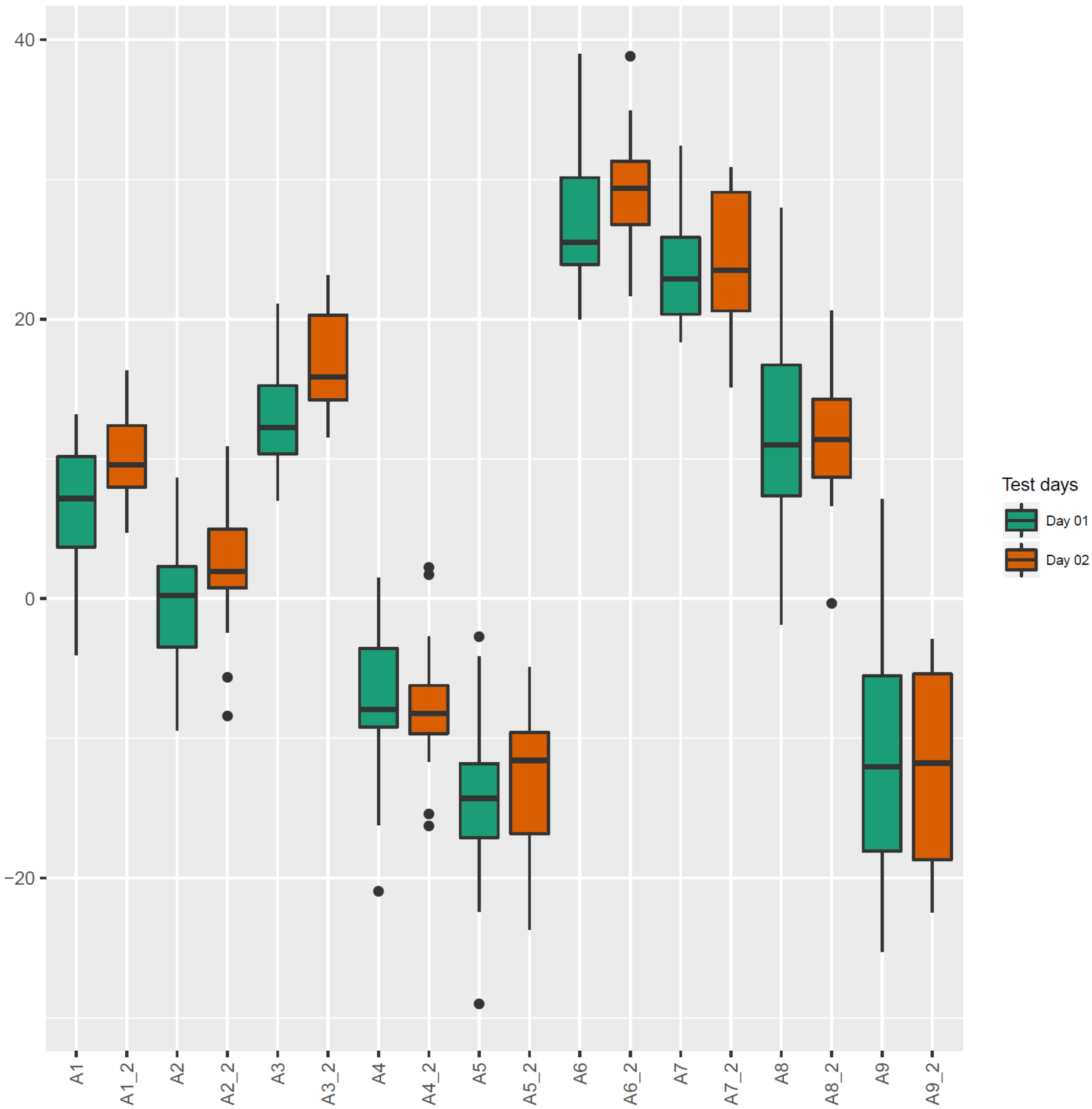
```
ankledata2 <- ankledata[c("A1", "A1_2", "A2", "A2_2", "A3", "A3_2", "A4", "A4_2", "A5", "A5_2", "A6", "A6_2",
"A7", "A7_2", "A8", "A8_2", "A9", "A9_2")]
ankledata2$Participants <- c(1:14)

ankledata.m <- melt(ankledata2, id.var = "Participants") # Changing dataset into "long" format
ankledata.m$days <- c(rep(c(rep("Day 01", 14), rep("Day 02", 14)), 9))



# Boxplot of the hip parameters
ankle.graph <- ggplot(data = ankledata.m, aes(x=variable, y=value, fill = days)) + geom_boxplot() + ylab("")
+ xlab("")

ankle.graph + scale_fill_brewer(palette = "Dark2") + guides(fill=guide_legend(title= "Test days")) + theme(ax
is.text.x = element_text(size = 6))
```




```
# SAVING FIGURES IN .pdf FORMAT

# Figures were saved in .pdf format by using the command pdf("figure_name.pdf) in the source code, without an
y additional parameters
```