A Study of Human Proportions, Climbing Advantage, and Limb Dominance
Insights from the FALL 2020 STAT 419 Measure Dataset

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This study uses a student-collected dataset containing quantitative biometric variables inspired by the Leonardo Da Vinci's Vitruvian Man to investigate how these measurements are correlated with height, how relative arm span to height size compares to that of famous rock climbers, and how limb dominance may relate to size assymetries. A combination of correlation analysis, summary statistics, and kmeans were used to evaluate these questions. Height was found to be the best predictor for hand-elbow length, foot length, floor to hip height, and floor to armpit height, and not a good predictor for hand length. The average ape-index for the climbers (2.3 inches) was greater than that of the class dataset (0 inches), but the standard deviation was much lower. More members of the class dataset had dominant limbs that were smaller than their nondominant limbs.

Keywords: vitruvian man; biometric; ape-index; correlation; WSU STATS 419

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1 Introduction

The Fall 2020 STAT 419 measure dataset presents an interesting opportunity to investigate which biometrics are best associated with height. According to Leonardo Da Vinci's Vitruvian Man, the perfectly-proportioned man is a paragon of mathematics: his body is eight times his head, four times his shoulder width, knee height, and thigh length, and two times his groin height. And yet, a modern study of 65 thousand Air Force recruits found that these idealized proportions were not represented true to Vitruvian standards (Thomas et al. 2020). If all persons in the dataset assessed herein were "ideal" by Vitruvian standards, all correlations between height and other biometrics would be 1, therefore it is far more interesting to understand the relationship of these variables as they exist in true populations. I can best illustrate this bias with a personal example: I am as tall as my mother, but my feet are 2 shoe sizes smaller, possibly because I danced pointe as a child before my bones fully developed. Given the variability that may be introduced by gender, ethnicity, age, and lifestyle factors, are there biometrics that are well-correlated with height? This evaluation will use correlation to evaluate where these stronger relationships lie.

A secondary question of interest related to this dataset was inspired by my experience in the world of sport climbing, where it is fashionable to conflate climbing ability to ape index. The ape-index, which may be calculated either as the wingspan minus height, or the wingspan divided by height, enumerates an individual's reach relative to their height. In a sport where the difference between victory and a critical fall may be a game of a few centimeters, it is easy to understand why sponsors proudly display photos of their athletes immediately aside this "all-important" metric. For the record, Da Vinci's man, with an arm span 4/5 the length of total body height, would have made an exceptionally poor climber by this standard (Thomas et al. 2020). As an ammature rock climber, I have an anecdotal understanding that the most elite athletes in my community tend to have a positive ape index. Researchers have evaluated this phenomenon in assorted climbing groups. Watts (2003) found that a set of competitive child climbers (average age of 13) had a significantly greater (p = 0,02) ape index (cm/cm) of 1.01, relative to non-climbers of similar age. Within groups of climbers, however, Ape Index was not significantly different between advanced and elite athletes (Ozimek et al. 2017). Given this, I wanted to understand how Ape Index data for famous climbers (for more information on data collection see section 3.0.1) compared with our Fall 2020 STAT 419 measure dataset.

The STAT 419 measure dataset also contains qualitative variables. I was interested in understanding how two variables that would pertain to almost everyone in the dataset - writing hand and swinging arm dominance - related to the measures of size in both the hand length and arm length, respectively. In a study of 196 participants, Maleki-Ghahfarokhi et al. (2019) found that hand dominance was associated with 5.3% to 7.5% greater strength relative to the non-dominant hand. Furthermore, longer hand and forearm length were positively correlated with greater pinch strength (Maleki-Ghahfarokhi et al. 2019). Based on this, my hypothesis is that the dominant hand will be larger than the non-dominant hand in the dataset, and that this pattern will also be observed in the relationship between dominant swinging arm and larger arm.

Figure 1: The New Ideal?

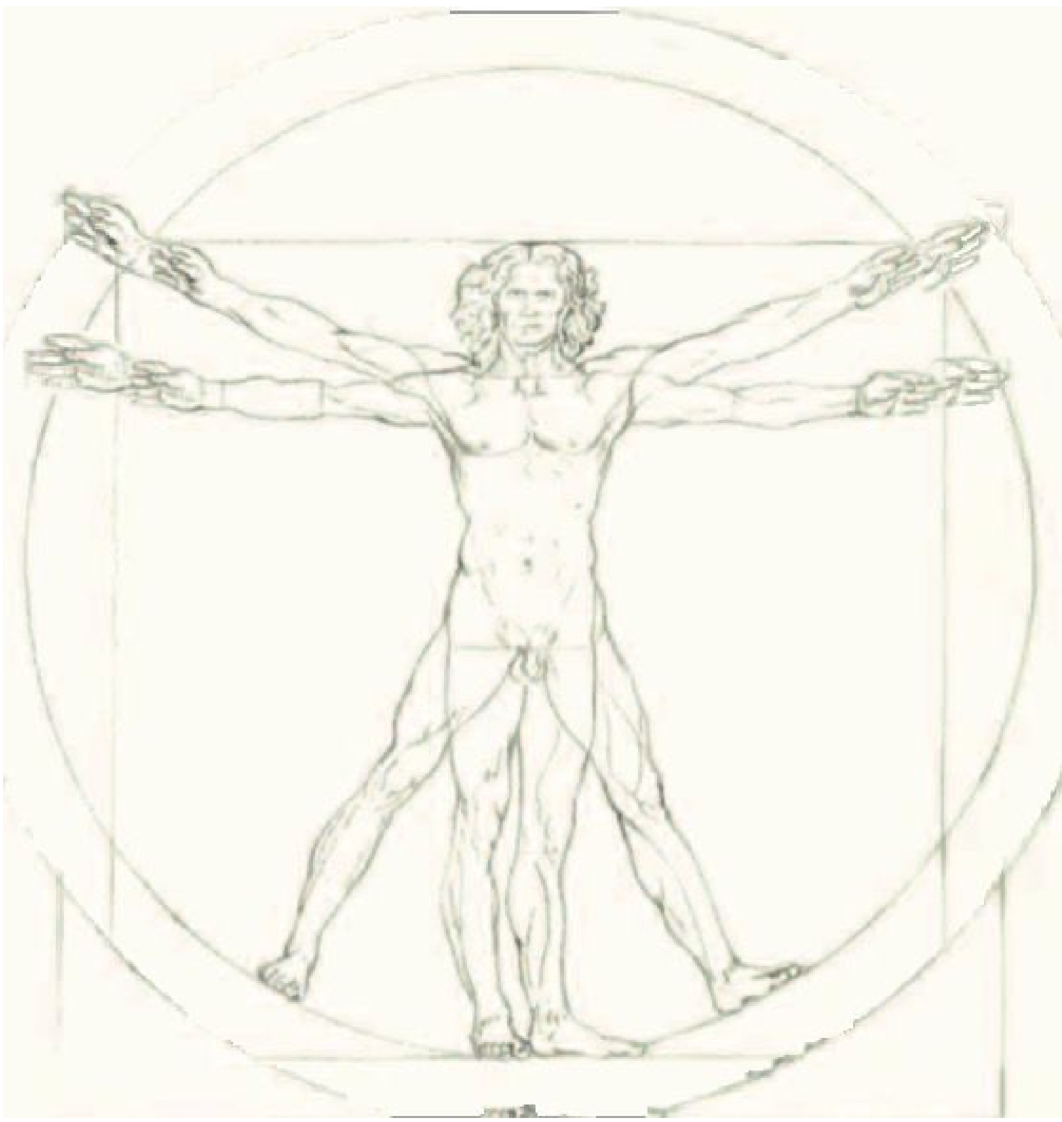


Image modified from Thomas et al. (2020). Da Vinci's Vitruvian Man reflected concepts of ideal symmetry and proportion, yet the meaning of ideal is fluid depending on an individual's lifestyle. This study investigates the Vitruvian proportions as they pertain to the STAT 419 student measure dataset, how one's status as a professional sport climber makes them more or less likely to exceed average wingspan proportions, and how dominance is associated with relative side size.

2 Research Question: Which biometrics are best correlated with height?

This question will be investigated using correlations of select biometrics scaled relative to the height. Then the means will be used to determine the STAT 419 student measure dataset values for the proportions listed by Thomas et al. (2020).

2.1 How do famous climbers compare to the FALL 2020 STAT 419 Measure dataset for ape index?

A supplementary dataset containing the Ape-Index of 29 professional climbers will be collected for comparison to the STAT 419 measure dataset described in section. The average ape-index will be calculated for each dataset. Then Kmeans clustering will be applied on the combined datasets to determine how the climbers group among the class data.

2.2 Are dominant limbs of consistent greater or lesser relative size?

Count information will be collected for each observance of dominant side being greater than or lesser than the non-dominant side. Ambidextrous individuals and persons missing data on either side will not be counted.

3 Data Description

The Fall 2020 Stat 419 measure dataset was collected by the enrolled students in August and September of 2020. The data contains 23 quantitative biometric variables and 9 supplementary variables for each student, and approximately 9 members of their family and friends. The final dataset compiled 428 observations that may have been collected by the students themselves, or by participants due to COVID-19 social-distancing guidelines in place at the time of data collection. For this reason, data collection practices were not uniform; some observations are missing, duplicated, and in some cases both left and right side information is provided.

3.0.1 Climbers Measure Data

The climbers measure dataset is comprised of name, height, wingspan, ape-index, gender, and source data for 29 professional rock climbers (Beale n.d.; Ondra 2019; Sportiva n.d.; gymclimber.com 2019), Ape index was calculated as in the STAT 419 measure dataset by subtracting the height from wingspan.

3.1 Summary Statistics of Data

Summary statistics and correlation tables of the STAT 419 measure data can be found in Section 6.2.1.

4 Key Findings

4.0.1 Findings: Which biometrics are best correlated with height?

All biometric measurements had significant correlations relative to total height. Hand-elbow length and foot-length were as strongly correlated with height (0.95), as floor to hip and floor to armpit. This conflicts somewhat with my hypothesis that lifestyle factors may contribute to relative foot size, and suggests that overall, height is a good predictor for footlength. Hand-length was the least correlated with height (0.38), which was unexpected given that the hand-to-elbow measurement also includes the length of the hand.

Another observation of interest was that foot-length was very highly correlated with hand-to-elbow (0.97), The play-ground myth that one's foot is exactly the size of their forearm may have some merit given this finding.

The averages collected as a part of this first research question were used to calculate the proportions of interest that were also calculated in the paper by Thomas et al. (2020).

Proportions to body length: Head Height: 0.13 Arm span: 1.00 Groin height: 0.57 Knee height: 0.27 Thigh length: 0.30

Head height and knee height proportions were very close to the Vitruvian man proportions of 0.125 and 0.25, respectively. The arm span proportion was the most different; much greater at 1, compared with

0.8. Groin height was also larger - 0.57 compared to 0.5 - but I used the floor to hip measurement, which likely leads to an over-approximation of this measurement. This over-approximation may also be responsible for the fact that the thigh length proportion was greater - 0.3 compared with 0.25 - as thigh length was calculated by subtracting the knee height from the hip-height value.

4.0.2 Findings: How do famous climbers compare to the FALL 2020 STAT 419 Measure dataset for ape index?

The average wingspan of the climbers dataset is 2.2 inches with a standard deviation of 1.76 inches. This is much greater than the average of the student measure dataset, 0.0 inches; the standard deviation of the student measure dataset is 7.95 inches, which suggests that while the subset of climbers averaged greater, more extremes are present in the student dataset.

4.0.3 Findings: Are dominant limbs of consistent greater or lesser relative size?

Dominance appears to be associated with the smaller limb of the two sides. In 51% of the observations of the sample subset, the dominant swinging arm was smaller than the non-dominant arm. In 52% of the observations of the sample subset, the dominant writing hand was smaller than the non-dominant hand.

5 Conclusion

The FALL 2020 STAT 419 Student measure dataset was collected at the beginning of the Fall 2020 semester by student participants and compiled for this analysis. Upon appropriate cleaning of the data, three questions were formulated, informed by the study written by Thomas et al. (2020) examining the proportions behind Da Vinci's Vitruvian Man with a modern dataset.

The class data was comparable to the Vitruvian man for the proportions of head height and knee height, but were greater for the proportions of armspan, thigh length, and groin height. Height was found to be the best predictor for hand-elbow length, foot length, floor to hip height, and floor to armpit height, and not a good predictor for hand length.

A dataset of height, wingspan, and ape-index measurements was collected for 29 professional climbers. The average of this dataset was greater than that of the class dataset, as was somewhat expected based on work conducted by Ozimek et al. (2017), although it is not clear how conclusive this comparison is, given the high standard deviation for ape-index that was observed in the class dataset. Kmeans clustering of the results did not suggest any particular trends for the climbers among the class data. This is likely a product of the fact that some of the data collectors in the STAT 419 may have misunderstood armspan measurement. At least one data collector regularly produced ape-index values of above 15, which if biologically possible, is expected to be extremely unlikely. Further analysis of this data should involve removal of such outliers, although data removal is a process that can easily contribute to skewed results. This criteria should not be taken lightly, and was considered to be beyond the scope of this work at this time.

A preliminary look into the assocations between dominance and size was completed based on count data. These data show that more persons in the STAT 419 dataset had dominant limbs that were smaller than their nondominant limbs. However, statistics were not applied to this assessment and to conclude based on count data is to accept a high Type II error risk. However, this finding was interesting in that it conflicted with a study that was found assessing the relationship between dominance, size, and grip strength, which lead to the hypothesis that the dominant limb would more often be of greater size (Maleki-Ghahfarokhi et al. 2019). However, the scope of the size difference was not evaluated as it was in this study, it is possible that these differences are rather nominal and do not have a large impact.

In conclusion, these data were sufficient for a preliminary view of the research questions, but the overall reliability of these observations is limited by suspected occurrences of poor data provenance among some of the data collectors. On the whole, it is interesting that the final proportions were so close to those of the "ideal" man given the non-ideal circumstances of data collection.

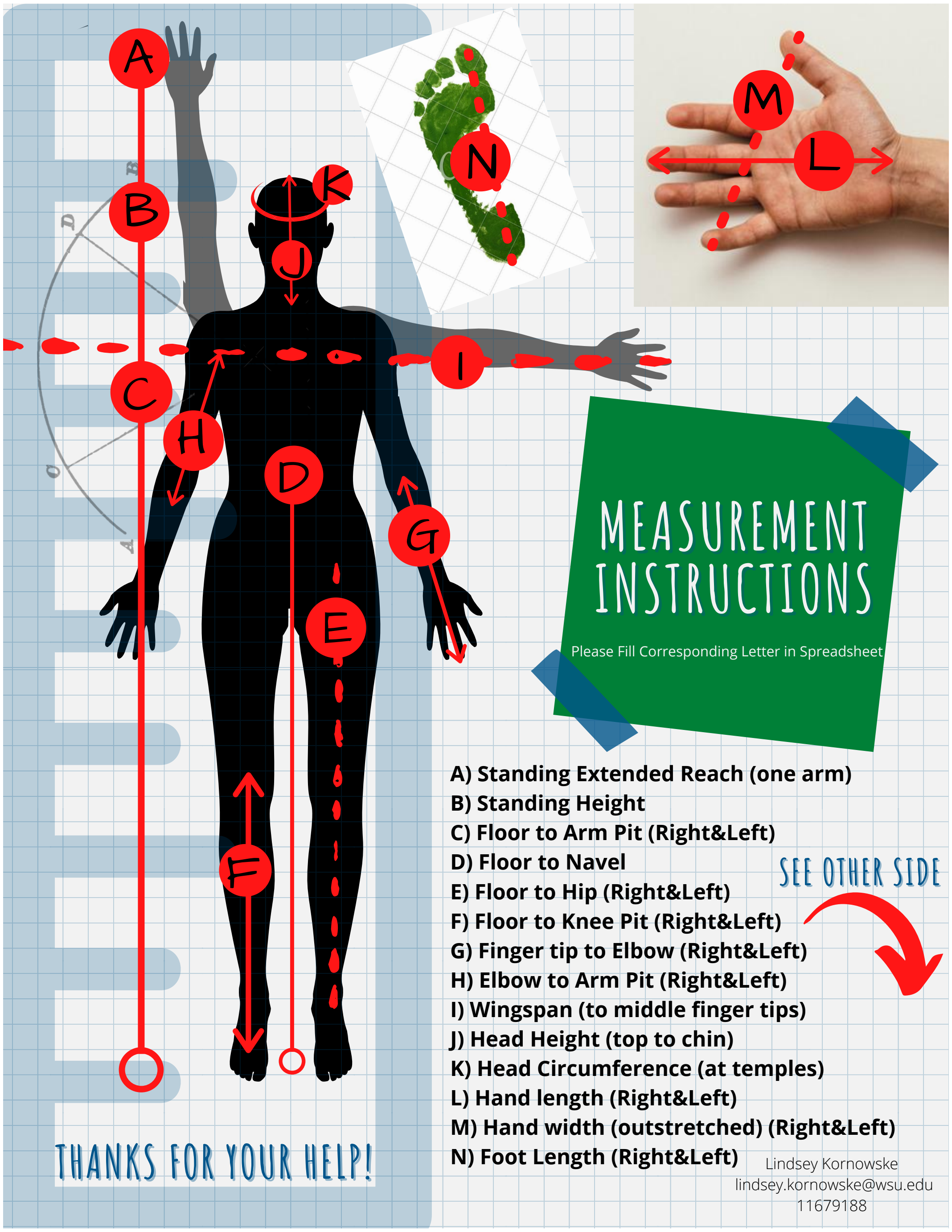
6 APPENDICES

6.1 Data Provenance

For my contribution to the dataset, measurements were collected as indicated on the handout. My participants were responsible for collecting and reporting their own data. A spreadsheet with the mandatory measurements as well as the handout were supplied by email to the participants. The compiled class dataset was cleaned with the function cleanMeasureData. This function corrects for data entry mistakes that inappropriately affected the number of levels viewed for each variable: quotations, variations on NA, capitalizations, mispellings, or abbreviations. In some cases, a quantitative variable and qualitative variable were switched, or incorrect units were assigned, these mistakes had to be adjusted on a row-by-row basis. All units were converted to inches, expressed as "in." Variables for which sidedness was a factor were averaged, but the individual sides were retained in order to investigate the third research question on limb dominance. A variable for ape-index was created by subtracting the height by the armspan for each respective column. All individuals that were missing data for height for armspan information were removed. All duplicate rows were removed to ensure that only unique observations informed the data analysis.

6.1.1 Data Collection Handout

Figure 2: Handout Page 1



Handout was assembled with the tools provided by Canva.com

Figure 3: Handout Page 2

DATA COLLECTOR: LINDSEY MK
YOUR NAME (WILL NOT BE SHARED):

Please Circle One:
What Units of Measure did you use: in cm other- please specify:
Dominant Writing Hand: right. left. both
Dominant Arm (golf or baseball): right left both
Dominant Eye: right left both
Eye Color: brown green blue hazel gray other-please specify:
Gender: Female Male Bigender Gender Fluid Gender Questioning
other- please specify:

Please specify:
Age:
Ethnicity:

NOTES:
(TO BE COMPLETED LATER BY DATA COLLECTOR)

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6.2 Data, Data Cleaning, and Analysis

Below is the necessary functions and libraries required to run the code referenced in this document.

```
library(devtools);       # required for source_url
library(tidyverse);
library(Hmisc);
library(kableExtra);

path.humanVerseWSU = "https://raw.githubusercontent.com/MonteShaffer/humanVerseWSU/"
source_url( paste0(path.humanVerseWSU,"master/misc/functions-project-measure.R") );
```

6.2.1 Analysis: Which biometrics are best correlated with height?

Below is the code to load the data and prepare it for analysis.

```
path.project = "/Users/lindseykornowske/.git/STAT419/project-measure/";
path.to.secret = "/Users/lindseykornowske/Documents/FS Classes HW & Resources/STAT 419 Multivariate/_SE
measure = utils::read.csv( paste0(path.to.secret, "measure-students.txt"), header=TRUE, sep="|");
source(file = "https://raw.githubusercontent.com/lindseymaek/STAT419/master/functions/functions-project-
measure.df = prepareMeasureData(measure);

sum.list = list(summary(measure.df[,c(3:9)]),
summary(measure.df[,c(11:16)]),
summary(measure.df[,c(17:21)]),
summary(measure.df[,c(22:27)]),
summary(measure.df[,c(28:33)]),
summary(measure.df[,c(34:39)]),
summary(measure.df[,c(40:45)]),
summary(measure.df[,c(46:47)]));

kable(sum.list, caption = "Summary Statistics", format = "simple") %>% kable_styling(latex_options = "s
```

side	writing	eye	eye_color	swinging	gender	ethnicity
left : 51	both : 3	both : 24	brown :113	both : 3	female :122	caucasian :182
NA : 1	left : 32	brown: 0	blue : 78	left : 49	male :126	asian : 29
right:161	right:214	left : 71	hazel : 31	right:197	non-binary: 1	african american: 7
NA's : 36	NA	right:150	green : 16	NA	NA	hispanic : 6
NA	NA	NA's : 4	blue/green: 4	NA	NA	korean : 5
NA	NA	NA	black : 3	NA	NA	caucasian/asian : 4
NA	NA	NA	(Other) : 4	NA	NA	(Other) : 16

age	quality	minutes	units	height.NA	head.height.NA
Min. : 1.00	Min. : 5.000	Min. :-2.209e+09	in:249	Min. :10.75	Min. : 2.559
1st Qu.:22.00	1st Qu.: 8.000	1st Qu.: 1.000e+01	NA	1st Qu.:62.99	1st Qu.: 8.071
Median :27.00	Median : 9.000	Median : 1.500e+01	NA	Median :66.26	Median : 8.661
Mean :34.55	Mean : 8.582	Mean :-9.128e+07	NA	Mean :65.30	Mean : 8.699
3rd Qu.:51.00	3rd Qu.:10.000	3rd Qu.: 2.000e+01	NA	3rd Qu.:70.00	3rd Qu.: 9.250
Max. :94.00	Max. :10.000	Max. : 4.500e+01	NA	Max. :75.24	Max. :15.000
NA	NA	NA's :7	NA	NA	NA's :9

head.circumference.NA	hand.length.left	hand.length.right	hand.width.left	hand.width.right
Min. : 7.874	Min. : 1.968	Min. : 1.968	Min. : 2.165	Min. : 2.165
1st Qu.:21.654	1st Qu.: 6.693	1st Qu.: 6.693	1st Qu.: 7.250	1st Qu.: 7.395
Median :22.250	Median : 7.125	Median : 7.087	Median : 7.874	Median : 7.874
Mean :22.000	Mean : 7.705	Mean : 7.681	Mean : 7.702	Mean : 7.720
3rd Qu.:23.000	3rd Qu.: 7.677	3rd Qu.: 7.677	3rd Qu.: 8.465	3rd Qu.: 8.473
Max. :25.236	Max. :87.875	Max. :87.875	Max. :10.433	Max. :10.433
NA's :16	NA's :6	NA's :2	NA's :16	NA's :13

hand.elbow.left	hand.elbow.right	elbow.armpit.left	elbow.armpit.right	arm.reach.left	arm.reach.right
Min. : 4.429	Min. : 4.429	Min. : 2.362	Min. : 2.362	Min. :14.96	Min. :20.47
1st Qu.:15.750	1st Qu.:15.750	1st Qu.: 9.004	1st Qu.: 9.000	1st Qu.:74.33	1st Qu.:74.05
Median :16.929	Median :16.929	Median :10.118	Median :10.039	Median :81.10	Median :81.10
Mean :16.664	Mean :16.650	Mean :10.452	Mean :10.481	Mean :74.61	Mean :74.93
3rd Qu.:17.913	3rd Qu.:17.913	3rd Qu.:11.500	3rd Qu.:11.811	3rd Qu.:87.22	3rd Qu.:87.62
Max. :20.472	Max. :20.669	Max. :27.953	Max. :27.953	Max. :96.46	Max. :96.06
NA's :16	NA's :13	NA's :15	NA's :12	NA's :17	NA's :14

arm.span.NA	foot.length.left	foot.length.right	floor.kneepit.left	floor.kneepit.right	floor.hip.left
Min. : 3.50	Min. : 2.756	Min. : 2.756	Min. : 5.118	Min. : 5.118	Min. : 9.646
1st Qu.:62.25	1st Qu.: 9.055	1st Qu.: 9.055	1st Qu.:16.535	1st Qu.:16.500	1st Qu.:35.710
Median :66.14	Median : 9.750	Median : 9.750	Median :17.750	Median :17.795	Median :37.795
Mean :65.28	Mean : 9.703	Mean : 9.735	Mean :17.733	Mean :17.781	Mean :37.266
3rd Qu.:70.47	3rd Qu.:10.287	3rd Qu.:10.433	3rd Qu.:19.000	3rd Qu.:19.000	3rd Qu.:39.764
Max. :88.19	Max. :15.000	Max. :18.504	Max. :28.425	Max. :39.764	Max. :44.488
NA	NA's :15	NA's :12	NA's :15	NA's :12	NA's :25

floor.hip.right	floor.navel.NA	floor.armpit.left	floor.armpit.right	hand.length	hand.width
Min. : 9.646	Min. :10.63	Min. :13.98	Min. :13.78	Min. : 1.968	Min. : 2.165
1st Qu.:35.467	1st Qu.:37.40	1st Qu.:49.00	1st Qu.:48.43	1st Qu.: 6.732	1st Qu.: 7.336
Median :37.795	Median :39.76	Median :51.70	Median :51.50	Median : 7.165	Median : 7.874
Mean :37.228	Mean :39.87	Mean :51.46	Mean :50.76	Mean : 7.712	Mean : 7.725
3rd Qu.:39.764	3rd Qu.:42.13	3rd Qu.:54.93	3rd Qu.:54.72	3rd Qu.: 7.675	3rd Qu.: 8.465
Max. :44.488	Max. :67.00	Max. :61.71	Max. :62.00	Max. :87.875	Max. :10.433
NA's :22	NA's :40	NA's :15	NA's :14	NA's :8	NA's :19

floor.armpit	hand.elbow	elbow.armpit	floor.kneepit	floor.hip	arm.reach
Min. :13.88	Min. : 4.429	Min. : 2.362	Min. : 5.118	Min. : 9.646	Min. :20.67
1st Qu.:48.62	1st Qu.:15.901	1st Qu.: 9.000	1st Qu.:16.535	1st Qu.:35.500	1st Qu.:75.12
Median :51.50	Median :16.929	Median :10.150	Median :17.815	Median :37.795	Median :81.40
Mean :51.14	Mean :16.686	Mean :10.478	Mean :17.806	Mean :37.273	Mean :74.89
3rd Qu.:54.72	3rd Qu.:17.928	3rd Qu.:11.620	3rd Qu.:19.094	3rd Qu.:39.764	3rd Qu.:87.40
Max. :61.61	Max. :20.571	Max. :27.953	Max. :29.134	Max. :44.488	Max. :96.26
NA's :20	NA's :19	NA's :18	NA's :18	NA's :28	NA's :20

foot.length	ape.index
Min. : 2.756	Min. :-59.00000
1st Qu.: 9.090	1st Qu.: -1.18110
Median : 9.803	Median : 0.30000
Mean : 9.732	Mean : -0.01708
3rd Qu.:10.375	3rd Qu.: 1.75000
Max. :15.256	Max. : 61.95000
NA's :18	NA

Below is the code to generate the summary statistics and save them as a table.

```
measure.collapsed = measure.df[,c(15:17,28,35, 38:46)]
names = colnames(measure.collapsed);
summary = summarizeMeanSD(measure.collapsed);

mean = t(summary[1,]);
sd = t(summary[2,]);
measure.scale = measure.collapsed/measure.collapsed[,1];

my.corr = rcorr( as.matrix(measure.scale), type="pearson");

#str(my.corr);

my.corr.r = my.corr$r;
my.corr.pval = my.corr$P;

my.corr.r.2 = round(my.corr.r,2);
my.corr.p.3 = as.numeric( round(my.corr.pval,3) ); # flatten

cuts = c(0.10, 0.05, 0.01, 0.001);
symb = c("+", "*", "**", "***");

my.corr.p.3.symb = "";
my.corr.p.3.symb[is.na(my.corr.p.3)] = "";
my.corr.p.3.symb[my.corr.p.3 <= 0.10] = "+";
my.corr.p.3.symb[my.corr.p.3 <= 0.05] = "*";
my.corr.p.3.symb[my.corr.p.3 <= 0.01] = "**";
my.corr.p.3.symb[my.corr.p.3 <= 0.001] = "***";

include.diag = FALSE;  # the 1's on the diagonal are not included
# this is a lower triangular form ...

char.matrix = as.character(my.corr.r.2);


my.matrix = matrix(
                paste0(char.matrix, my.corr.p.3.symb),
                nrow=ncol(measure.collapsed));
my.matrix = as.data.frame(my.matrix);
colnames(my.matrix) = names;
rownames(my.matrix) = names;
my.matrix$mean = mean;
my.matrix$sd = sd[1,];
```

```
my.matrix = my.matrix[,c(15,16,1:14)];

my.matrix.1=my.matrix[,c(1:4)];
my.matrix.2=my.matrix[,c(6:8)];
my.matrix.3=my.matrix[,c(9:12)];
my.matrix.4=my.matrix[,c(13:16)];

kable(my.matrix.1,
      format = "latex", booktabs = TRUE) %>% kable_styling(latex_options = "scale_down", font_size = 7 
```

	mean	sd	height.NA	head.height.NA
height.NA	65.3	8.02	1	NaN
head.height.NA	8.7	8.02	NaN	1
head.circumference.NA	22.0	8.02	NaN	0.93***
arm.span.NA	65.3	8.02	NaN	0.86***
floor.navel.NA	39.9	8.02	NaN	0.9***
hand.length	7.7	8.02	NaN	0.33***
hand.width	7.7	8.02	NaN	0.89***
floor.armpit	51.1	8.02	NaN	0.91***
hand.elbow	16.7	8.02	NaN	0.91***
elbow.armpit	10.5	8.02	NaN	0.78***
floor.kneepit	17.8	8.02	NaN	0.9***
floor.hip	37.3	8.02	NaN	0.91***
arm.reach	74.9	8.02	NaN	0.8***
foot.length	9.7	8.02	NaN	0.91***

```
kable(my.matrix.2,
      format = "latex", booktabs = TRUE) %>% kable_styling(latex_options = "scale_down", font_size = 7 
```

	arm.span.NA	floor.navel.NA	hand.length
height.NA	NaN	NaN	NaN
head.height.NA	0.86***	0.9***	0.33***
head.circumference.NA	0.89***	0.92***	0.36***
arm.span.NA	1	0.93***	0.38***
floor.navel.NA	0.93***	1	0.38***
hand.length	0.38***	0.38***	1
hand.width	0.93***	0.94***	0.36***
floor.armpit	0.95***	0.96***	0.39***
hand.elbow	0.95***	0.96***	0.38***
elbow.armpit	0.83***	0.85***	0.34***
floor.kneepit	0.92***	0.95***	0.38***
floor.hip	0.95***	0.98***	0.39***
arm.reach	0.85***	0.81***	0.36***
foot.length	0.95***	0.96***	0.38***

```
kable(my.matrix.3,
      format = "latex", booktabs = TRUE) %>% kable_styling(latex_options = "scale_down", font_size = 7 )
```

	hand.width	floor.armpit	hand.elbow	elbow.armpit
height.NA	NaN	NaN	NaN	NaN
head.height.NA	0.89***	0.91***	0.91***	0.78***
head.circumference.NA	0.91***	0.94***	0.93***	0.78***
arm.span.NA	0.93***	0.95***	0.95***	0.83***
floor.navel.NA	0.94***	0.96***	0.96***	0.85***
hand.length	0.36***	0.39***	0.38***	0.34***
hand.width	1	0.94***	0.94***	0.8***
floor.armpit	0.94***	1	0.97***	0.86***
hand.elbow	0.94***	0.97***	1	0.87***
elbow.armpit	0.8***	0.86***	0.87***	1
floor.kneepit	0.9***	0.96***	0.95***	0.85***
floor.hip	0.94***	0.98***	0.96***	0.85***
arm.reach	0.88***	0.88***	0.83***	0.7***
foot.length	0.94***	0.97***	0.97***	0.85***

```
kable(my.matrix.4,
      format = "latex", booktabs = TRUE) %>% kable_styling(latex_options = "scale_down", font_size = 7 )
```

	floor.kneepit	floor.hip	arm.reach	foot.length
height.NA	NaN	NaN	NaN	NaN
head.height.NA	0.9***	0.91***	0.8***	0.91***
head.circumference.NA	0.93***	0.94***	0.83***	0.94***
arm.span.NA	0.92***	0.95***	0.85***	0.95***
floor.navel.NA	0.95***	0.98***	0.81***	0.96***
hand.length	0.38***	0.39***	0.36***	0.38***
hand.width	0.9***	0.94***	0.88***	0.94***
floor.armpit	0.96***	0.98***	0.88***	0.97***
hand.elbow	0.95***	0.96***	0.83***	0.97***
elbow.armpit	0.85***	0.85***	0.7***	0.85***
floor.kneepit	1	0.95***	0.83***	0.96***
floor.hip	0.95***	1	0.88***	0.97***
arm.reach	0.83***	0.88***	1	0.86***
foot.length	0.96***	0.97***	0.86***	1

6.2.2 Analysis: How do famous climbers compare to the FALL 2020 STAT 419 Measure dataset for ape index?

```
#read in climber data
measure.climbers = utils::read.csv( paste0(path.to.secret, "measure_climbers.csv"), header=TRUE, quote=
climbers = measure.climbers$Climber;
rownames(measure.climbers) = climbers;
measure.climbers = measure.climbers[,c(2:4)];
colnames(measure.climbers) = c("height.NA", "arm.span.NA", "ape.index");

summarizeMeanSD(measure.climbers);
```

	height.NA	arm.span.NA	ape.index
mean	67.50	69.80	2.30
standard deviation	4.36	5.31	1.75

```
measure.rq2 = as.data.frame(cbind(measure.df$height.NA, measure.df$arm.span.NA, measure.df$ape.index));
rownames(measure.rq2) = rownames(measure.df);
colnames(measure.rq2) = c("height.NA", "arm.span.NA", "ape.index");

measure.rq2 = as.data.frame(rbind(measure.climbers,measure.rq2));
measure.rq2 = na.omit(measure.rq2);

m.kmeans = kmeans(measure.rq2, 5);

m.kmeans$centers;
```

```
##   height.NA arm.span.NA   ape.index
## 1  67.89193    67.38850  -0.5036246
## 2  71.15596    73.18522   2.0289076
## 3  46.04543    31.70260 -14.3428225
## 4  63.37854    82.38575  19.0072047
## 5  61.88488    61.48858  -0.3963022
```

```
membership = as.data.frame( matrix( m.kmeans$cluster, ncol=1)) ;

rownames(membership) = rownames(measure.rq2);


#print( table(membership) ) ;
```

6.2.3 Analysis:Are dominant limbs of consistent greater or lesser relative size?

Below is the code used to assess the number of occurances for which dominant hand was the larger or smaller of the hand sizes.

```
measure.rl = measure.df[,c(4,7,18:21,22:25)]; #separate variables of interest

#calculate arm length
measure.rl$left.arm = measure.rl$hand.elbow.left+measure.rl$elbow.armpit.left;
measure.rl$right.arm = measure.rl$hand.elbow.right + measure.rl$elbow.armpit.right;

measure.rl = measure.rl[,c(1:6,11,12)];

measure.rl$RminusL.arm.diff = round((measure.rl$right.arm - measure.rl$left.arm), 2); #positive value i
measure.rl$RminusL.hand.diff = round((measure.rl$hand.length.right - measure.rl$hand.length.left),2);

measure.rl.diff = measure.rl[,c(1,2,9,10)];
measure.rl.diff = na.omit(measure.rl.diff);

  same = 0;
  different = 0;
ndiffs = length(measure.rl.diff$writing);
for (i in 1:ndiffs) {
  names = c("Same", "Different")
  count.table.hand = matrix(ncol =2);
  if(measure.rl.diff$writing[i] == "right"){
    if(measure.rl.diff$RminusL.hand.diff[i] > 0){
      same = same +1;
    } else if(measure.rl.diff$RminusL.hand.diff[i] < 0){
      different = different +1;
    }
  } else if(measure.rl.diff$writing[i] == "left"){
    if(measure.rl.diff$RminusL.hand.diff[i] < 0){
      same = same +1;
    } else if(measure.rl.diff$RminusL.hand.diff[i] > 0){
      different = different +1;
    }
  }
  count.table.hand[1,1] = same;
  count.table.hand[1,2] = different;
}

colnames(count.table.hand) = c("Dominant Hand Larger", "Dominant Hand Smaller");
rownames(count.table.hand) = c("Count");
count.table.hand;
```

```
##       Dominant Hand Larger Dominant Hand Smaller
## Count                   48                    52
```

```
  same = 0;
  different = 0;
ndiffs = length(measure.rl.diff$swinging);
for (i in 1:ndiffs) {
  names = c("Same", "Different")
```

```r
  count.table.arm = matrix(ncol =2);
  if(measure.rl.diff$swinging[i] == "right"){
    if(measure.rl.diff$RminusL.arm.diff[i] > 0){
      same = same +1;
    } else if(measure.rl.diff$RminusL.arm.diff[i] < 0){
      different = different +1;
    }
  } else if(measure.rl.diff$swinging[i] == "left"){
    if(measure.rl.diff$RminusL.arm.diff[i] < 0){
      same = same +1;
    } else if(measure.rl.diff$RminusL.arm.diff[i] > 0){
      different = different +1;
    }
  }
  count.table.arm[1,1] = same;
  count.table.arm[1,2] = different;
}

colnames(count.table.arm) = c("Dominant Arm Larger", "Dominant Arm Smaller");
rownames(count.table.arm) = c("Count");
count.table.arm;
```

```
##       Dominant Arm Larger Dominant Arm Smaller
## Count                  74                   78
```

```r
## A different approach I thought about for this is below,
##ultimately I was not certain that it was appropriate to calculate correlations this way

#ndiffs = nrow(measure.rl.diff);
#  for (i in 1:ndiffs) {
 #   if (measure.rl.diff$writing[i] == "right"){
  #    measure.rl.diff$writingNum[i] = 1;
   # } else if (measure.rl.diff$writing[i] == "left") {
    #  measure.rl.diff$writingNum[i] = c(-1);
 #   }
  #  measure.rl.diff;
  #}

#    for (i in 1:ndiffs) {
#    if (measure.rl.diff$swinging[i] == "right"){
#      measure.rl.diff$swingingNum[i] = 1;
#    } else if (measure.rl.diff$swinging[i] == "left") {
#      measure.rl.diff$swingingNum[i] = c(-1);
#    }
#    measure.rl.diff;
#  }

#  measure.rl.diff = measure.rl.diff[,-c(1,2)];

#  my.corr = rcorr( as.matrix(measure.rl.diff), type="pearson");

#my.corr.r = my.corr$r;
#my.corr.pval = my.corr$P;
```

```
#my.corr.r;
#  my.corr.r.2 = round(my.corr.r,2);
#my.corr.p.3 = as.numeric( round(my.corr.pval,3) ); # flatten
#cuts = c(0.10, 0.05, 0.01, 0.001);
#symb = c("+", "*", "**", "***");
#my.corr.p.3.symb = "";
#my.corr.p.3.symb[is.na(my.corr.p.3)] = "";
#my.corr.p.3.symb[my.corr.p.3 <= 0.10] = "+";
#my.corr.p.3.symb[my.corr.p.3 <= 0.05] = "*";
#my.corr.p.3.symb[my.corr.p.3 <= 0.01] = "**";
#my.corr.p.3.symb[my.corr.p.3 <= 0.001] = "***";
#include.diag = FALSE;  # the 1's on the diagonal are not included
# this is a lower triangular form ...

#char.matrix = as.character(my.corr.r.2);

#names = as.list(row.names(my.corr.r));
#my.matrix = matrix(
#                 paste0(char.matrix, my.corr.p.3.symb),
#                 nrow=ncol(measure.rl.diff),ncol = 4,);
#as.table(my.matrix);
```

NOTES

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