The Modern Vitruvian Man
Body Proportions

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In this article we compare the *empirical characteristic function* (Tukey 1977; Becker et al. 1988) to a *moment-generating-functional form* to compute the proportion of hypotheses m that are rejected under the null hypothesis.

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Generally, we write this abstract last. Often it is called the executive summary. It should succinctly summarize the entire document. You can include references such as this one to the Appendices section 6 if necessary.

Keywords: multiple comparisons to control; multivariate chi-square distribution; nonlinear growth curves; Richard's curve; simulated critical points

November 08, 2020

1 Introduction

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2 Research Question: Are the Vitruvian Man proportions realistic? How likely are men to be close to these proportions?

The Vitruvian Man was designed with certain proportions in mind. Vitruvius was a Roman architect and in his writings he describes the human body as a set of proportions of one's height.

> "the open hand from the wrist to the tip of the middle finger is [a tenth part of the whole height]; the head from the chin to the crown is an eighth, ... The length of the foot is one sixth of the height of the body... and the breadth of the breast is also one fourth... outstretched arms... will be found to be the same as the height"

(Vitruvius 2006)

Body length	Vitruvian Man proportions
Head height	0.125
Arm span	1.000
Hand length	0.100
Foot length	0.167
Knee height	0.250
Shoulder width	0.250

2.1 *Does height affect the body proportions for men and women?*

2.2 *What body proportions for men and women are realistic today?*

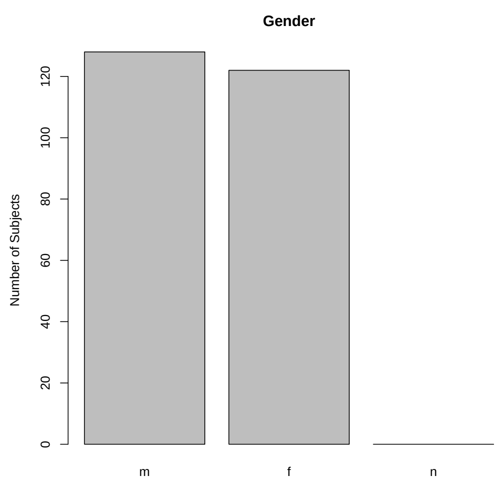
3 Data Description

The data was collected by approximately 30 students who are enrolled in STAT 419 at WSU. Students were supposed to gather measurements from at least ten people. The measurements gathered were: height, head height, head circumference, arm span, floor to navel, hand length, hand width, hand to elbow, elbow to armpit, arm reach, foot length, floor to knee-pit, floor to hip, and floor to armpit. The measurements were collected by having either the student or another measure the subject with a measuring tape such as the ones used by tailors. Students were also asked to record which side of the body the measurements came from. Some students chose to gather measurements from both sides for the sake of completeness.

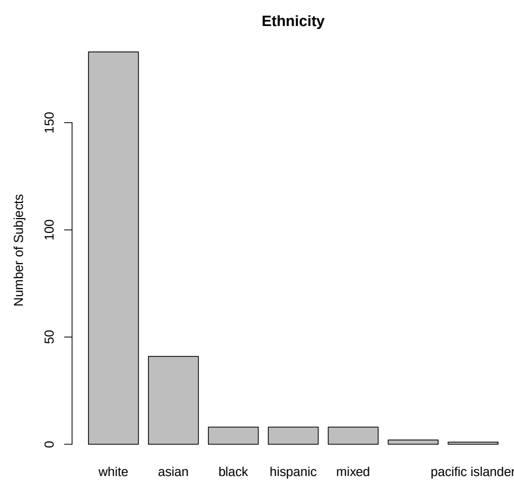
The data from all students was then compiled into one dataset. The total dataset contains 263 rows of measurements. Covariates for each row were also collected. Each subject was instructed to identify their writing hand, swinging hand, dominant eye, eye color, age, gender, and ethnicity. The data collector then assigned a value (1-10) assessing the quality of the measurements taken, and recorded the amount of minutes that it took to complete the measurements.

3.1 *Summary of Sample*

The sample contained about equal parts male and female subjects. Subjects identifying as white made up about 70% of the dataset, the next largest ethnicity was Asian, which contained about 15% of subjects. The majority of those sampled were in their 20s. There were not many under 10 or over 70 sampled. Subjects who preferred their right-side made up about 80% of the sample. Most subjects had brown or blue eyes –46 and 31 percent respectively– with a a lesser number of hazel or green eyed persons. The quality of the data collected ranged mostly between 8-10 on a 10-point scale. Most data collectors took between 10-20 minutes to gather all measurements required.



(a) Gender Distribution



(b) Ethnicity Distribution

Figure 1: Gender and Ethnicity Distributions

3.2 Summary Statistics of Data

By comparing tables below we can see that the average proportion for both male and female subjects are about the same. However, the standard deviations show that males vary more in arm span and shoulder width. To a lesser extent males vary more with hand length as well. Females have a more variable head.height proportion. Females also have a slightly more variable foot length and floor to knee-pit length.

Table 1: Descriptive Statistics and Correlation Analysis (FEMALE)

		M	SD	1	2	3	4	5
1	**head.height**	.13	.017	1				
2	**arm.span**	1.01	.050	-.04	1			
3	**hand.length**	.11	.007	.30**	.03	1		
4	**foot.length**	.15	.010	.22*	.18†	.48***	1	
5	**floor.kneepit**	.27	.019	.12	.06	.29**	.30**	1
6	**shoulder.width**	.19	.065	.01	.55***	-.06	-.04	-.10

Notes: Pearson pairwise correlations are reported;
a two-side test was performed to report correlation significance.

† $p < .10$ * $p < .05$ ** $p < .01$ *** $p < .001$

Table 2: Descriptive Statistics and Correlation Analysis (MALE)

		M	SD	1	2	3	4	5
1	**head.height**	.13	.013	1				
2	**arm.span**	1.01	.062	-.28**	1			
3	**hand.length**	.11	.008	.36***	-.09	1		
4	**foot.length**	.15	.009	.14	-.07	.52***	1	
5	**floor.kneepit**	.27	.018	.26**	-.20*	.05	.16†	1
6	**shoulder.width**	.20	.092	-.14	.55***	-.16	-.15	-.08

Notes: Pearson pairwise correlations are reported;
a two-side test was performed to report correlation significance.

† $p < .10$ * $p < .05$ ** $p < .01$ *** $p < .001$

Male and female subjects have the significant positive correlations for hand length and head height, shoulder width and arm span, and foot length and hand length. This means that for any person if they have wider shoulders, then they are likely to have a bigger arm span. If a person has longer hands they are more likely to have a taller head and longer feet. For male subjects there is also a negative correlation between arm span and head height, meaning that those with bigger arm spans are likely to have shorter heads. However, there is a positive correlation for males between the height of the knee and the height of the head, meaning that a male with a higher knee (or longer legs?) is more likely to have a longer head. For female subjects there are significant positive correlations between the height of the knee, and both hand length and foot length. This suggests that females with longer legs may have longer feet and hands.

4 Key Findings

5 Conclusion

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I was born on ______________________ in ______________________

$$Y_{jt} = \alpha + \boldsymbol{\beta} X_{jt} + \upsilon_j + \varepsilon_{jt}, \tag{1}$$

where α is the grand mean, υ_j is the fixed-time country mean, X_{jt} (country j at time t) is the matrix of country-level observations for the vector of aforementioned parameters $\boldsymbol{\beta}$, and ε_{jt} represents the residual idiosyncratic disturbance. Our panel data set consists of repeated observations of countries over time. Therefore, we employ cross-section time-series models. This approach redefines Equation~1 by subtracting time-demeaned values. This *within* transformation subtracts constant country effects for the dependent variable $\bar{Y}_j$, the predictor variables $\bar{X}_j$, and the intercept $\bar{\upsilon}_j$:

$$(Y_{jt} - \theta\bar{Y}_j) = (1-\theta)\alpha + \boldsymbol{\beta}(X_{jt} - \bar{X}_j) + (\upsilon_{jt} - \theta\bar{\upsilon}_j), \tag{2}$$

If $\theta = 0$, the model reduces to a basic pooled ordinary-least-squares (OLS) model; if $\theta = 1$, the model reduces to a fixed-effects model; otherwise the model represents a random-effects model. The pooled OLS estimation is biased if country effects exist (Hsiao 2003). The random-effects model may be susceptible to omitted-variable bias (Wooldridge 2006): bias because a predictor was excluded from the model specification. Conversely, the fixed-effects model is not susceptible to this bias as it captures unobserved intracountry variation around its average country-level “fixed effect." Panel-data analysis commonly has issues with heteroskedasticity, serial autocorrelation, and cross-sectional autocorrelation.

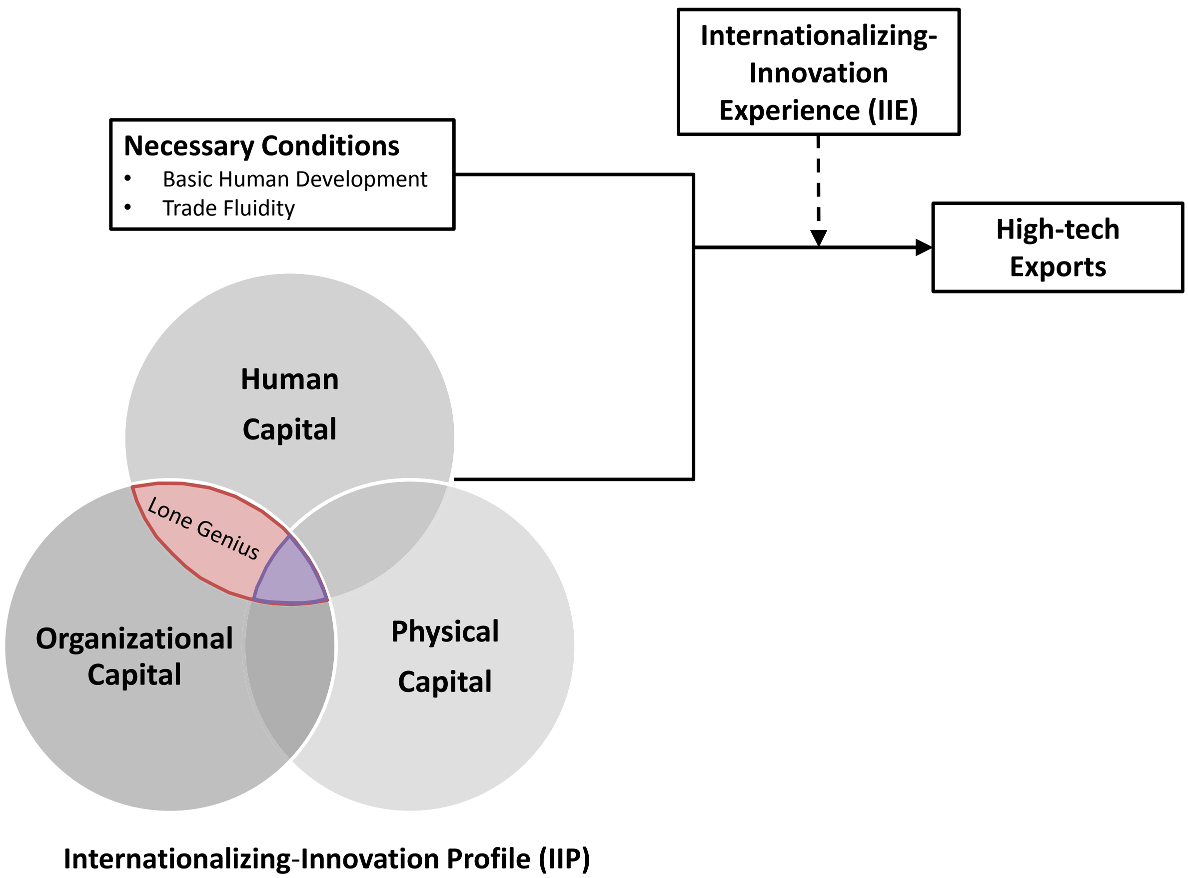
$i = 1$ and

$$i = 1$$

1	2	3	4	5
6	7	8	9	10

See Figure 2.

Figure 2: Conceptual Model



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Refer to the Appendices in section~6 where I am going to cite John (Tukey 1962, pp. 2-3).
Here is a quote by Tukey (1962, pp. 2-3):

> For a long time I have thought I was a statistician, interested in inferences from the particular to the general. But as I have watched mathematical statistics evolve, I have had to cause to wonder and to doubt. [...] All in all, I have come to feel that my central interest is in *data analysis*, which I take to include among other things: procedures for analyzing data, techniques for interpreting the results of such procedures, ways of planning the gathering of data to make its analysis easier, more precise or more accurate, and all the machinery and results of (mathematical) statistics which apply to analyzing the data.

Large parts of data analysis are inferential in the sample-to-population sense, but these are only parts, not the whole. Large parts of data analysis are incisive, laying bare indications which we could not perceive by simple and direct examination of the raw data, but these too are only parts, not the whole. Some parts of data analysis, as the term is her stretch beyond its philology, are allocation, in the sense that they guide us in the distribution of effort and other valuable considerations in observation, experimentation, or analysis. Data analysis is a larger and more varied field than inference, or incisive procedures, or allocation.

Statistics has contributed much to data analysis. In the future it can, and in my view should, contribute more. For such contributions to exist, and be valuable, it is not necessary that they be direct. They need not provide new techniques, or better tables for old techniques, in order to influence the practice of data analysis.

6 APPENDICES

6.1 Data Provenance

As was listed in 3 the data collection was assigned to the STAT 419 class at WSU, which is around 30 people. This can lead to some discrepancies in the way that the data was collected. The data may not always have been measured by students, but by the people which their handouts were sent to. For the 10 people that I gathered measurements for I measured seven people personally, and then had three others send me their results by email. The number of data collectors involved can also lead to different interpretations of what each measurement means.

The data collector was given the option to pick which units they wished to measure in, and the subject was also asked to identify their preferred hand in writing and swinging, what eye is dominant, what their eye color is, how old they are, what gender they are, and what ethnicity they identify as. These covariates give us a better picture of our sample. For example, since we have about equal amounts of male and female measurements (1a) we can make some generalizations. But on the other hand, we do not have much diversity of ethnicity in subjects (1b) so we can not generalize our results as easily.

Some of the measurements seemed like they had more outliers than others. This is likely because they were either entered incorrectly or they were measured differently. The measurements with significant outliers are: hand length, arm reach, floor to knee-pit, and head height. Hand length was supposed to be measured from the tip of the middle finger to the wrist. Arm reach is supposed to be the measurement from the floor to the tip of the middle finger when the arms are pointed upwards above the head. The floor to knee-pit measurement is from the heel to the back of knee. Lastly the head height measurement is from the chin to the top of the head.

6.1.1 Data Collection Handout

Figure 3: Handout Page 1

Measurement Project Handout

Name (first name + last initial):
Covariates:

Units	**Writing**	**Eye**	**Eye Color**	**Swinging**	**Age**	**Gender**	**Ethnicity**

Measurements:

	Info	Measurement	Side (L/R)
Height	No shoes		N/A
Head Height	Top of head to chin		N/A
Head Circumference	Right above ears/eyes		N/A
Hand Length	Middle finger to wrist		
Hand Length			
Hand Width	Thumb to pinky outstretched		
Hand Width			
Hand to Elbow	Middle finger to elbow		
Hand to Elbow			
Elbow to Armpit			
Elbow to Armpit			
Arm Reach	Floor to arm streched above head		
Arm Reach			
Arm Span	Arm to arm extended		N/A
Foot Length	From big toe to heel		
Foot Length			
Floor to Kneepit			
Floor to Kneepit			
Floor to Hip			
Floor to Hip			
Floor to Navel			N/A
Floor to Armpit			
Floor to Armpit			

Notes for Data Collector:

Quality	**Minutes**	**Notes**

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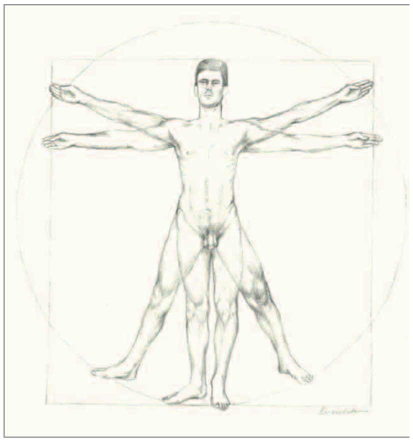
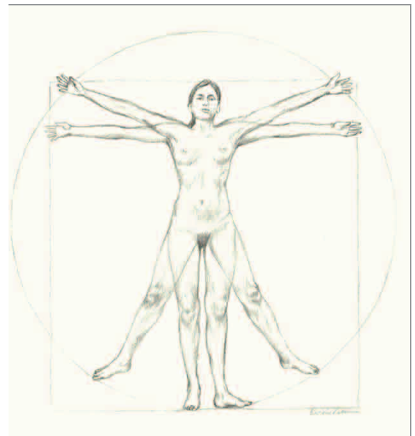


(a) Thomas et al. (2020) discuss this.



(b) Schnitt realer Sensor (Thomas et al. 2020)

Figure 4: Der Sensor in Theorie und Verwirklichung... caption at bottom instead? I can write a really long caption if I want.
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6.2 Preparing the Report Workspace as a subsection

6.2.1 Preparing the Report Workspace as a subsubsection

Preparing the Report Workspace as a paragraph

Preparing the Report Workspace as a subparagrah Below is the necessary functions and libraries required to run the code referenced in this document.

```
library(devtools);        # required for source_url

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

```
## Warning: package 'Hmisc' was built under R version 4.0.3
```

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

```
path.to.secret = "C:/Users/Nathan/Dropbox/__student_access__/_SECRET_/";

measure = utils::read.csv( paste0(path.to.secret, "measure-students.txt"), header=TRUE, quote="", sep="
#path.my.github = "https://raw.githubusercontent.com/nshine787/WSU_STATS419_FALL2020/";
# source_url(paste0(path.my.github, 'master/functions/functions-project-measure.R'))

path.project = "C:/Users/Nathan/Documents/GitHub/WSU_STATS419_FALL2020/"
source(paste0(path.project, 'functions/functions-project-measure.R'))

# this is your function
# put in the same "units"
# merge left/right
# build proportion data
# and so on ...
# relevantColumns = c('height', )
relevantColumns = c('height', 'head.height','arm.span','hand.length','foot.length','floor.kneepit','shou
measure.df = prepareMeasureData(measure);
```

```
## Warning: package 'measurements' was built under R version 4.0.3

## Warning in `[<-.factor`(`*tmp*`, iseq, value = "nb"): invalid factor level, NA
## generated
```

```
measure.males.df = grabGenderRows(measure.df,'m')[,relevantColumns]
measure.females.df = grabGenderRows(measure.df,'f')[,relevantColumns]

proportions.male = measure.males.df/measure.males.df$height
proportions.female = measure.females.df/measure.females.df$height
```

Below is the code to generate the summary statistics and save them as a table that you see in Section 3.2.

```
summary(measure.males.df)
```

```
##      height       head.height       arm.span      hand.length
##  Min.   :137.0   Min.   :17.78   Min.   :139.0   Min.   :15.00
##  1st Qu.:172.0   1st Qu.:21.59   1st Qu.:169.5   1st Qu.:18.30
```

```
##  Median :177.8   Median :23.00   Median :177.8   Median :19.05
##  Mean   :176.4   Mean   :22.98   Mean   :178.3   Mean   :19.15
##  3rd Qu.:182.7   3rd Qu.:24.00   3rd Qu.:185.2   3rd Qu.:20.00
##  Max.   :191.1   Max.   :29.50   Max.   :224.0   Max.   :24.00
##  NA's   :8       NA's   :7       NA's   :8       NA's   :4
##   foot.length    floor.kneepit   shoulder.width
##  Min.   :20.00   Min.   :38.00   Min.   : 1.50
##  1st Qu.:25.09   1st Qu.:44.77   1st Qu.:23.81
##  Median :26.02   Median :47.00   Median :36.00
##  Mean   :26.15   Mean   :47.23   Mean   :35.80
##  3rd Qu.:27.59   3rd Qu.:50.00   3rd Qu.:44.00
##  Max.   :30.50   Max.   :58.00   Max.   :92.00
##  NA's   :9       NA's   :10      NA's   :18
```

```
summary(measure.females.df)
```

```
##      height       head.height       arm.span      hand.length
##  Min.   :140.0   Min.   :17.50   Min.   :141.7   Min.   :13.97
##  1st Qu.:158.0   1st Qu.:20.31   1st Qu.:157.2   1st Qu.:16.80
##  Median :162.6   Median :21.50   Median :163.0   Median :17.35
##  Mean   :162.5   Mean   :21.75   Mean   :164.1   Mean   :17.57
##  3rd Qu.:167.7   3rd Qu.:22.86   3rd Qu.:171.4   3rd Qu.:18.38
##  Max.   :181.0   Max.   :33.02   Max.   :198.5   Max.   :21.20
##  NA's   :8       NA's   :7       NA's   :9       NA's   :3
##   foot.length    floor.kneepit   shoulder.width
##  Min.   :13.50   Min.   :34.92   Min.   : 1.70
##  1st Qu.:22.54   1st Qu.:41.00   1st Qu.:22.00
##  Median :23.50   Median :43.00   Median :31.11
##  Mean   :23.62   Mean   :43.49   Mean   :30.28
##  3rd Qu.:24.40   3rd Qu.:45.72   3rd Qu.:36.83
##  Max.   :27.50   Max.   :52.38   Max.   :61.50
##  NA's   :13      NA's   :13      NA's   :13
```

ENDNOTES

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In this section, we review the regression results to summarize our findings. First, we examine each model for significance, and conclude the hypothesized models fit well with the data. Second, we conclude that the fixed country effects represent consistent and unbiased parameter estimates. Third, with the use of the Driscoll and Kraay (1998) robust standard errors, we adjust any variance bias to ascertain the significance of these consistent estimates. Therefore, we are able to make inferences about the hypotheses using our model estimates. For ease of interpretation across these 12 models, we introduce ${}^{\text{M1}}_{\text{Total}}\hat{\beta}_1$ as notation to refer to parameter estimate $\hat{\beta}_1$ (HDI) for the Total Sample and (M1) Model 1: Main Effects. We proceed by reporting findings for the total sample.

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