Factor Analysis Report for Body Measurements Dataset

S/17/314

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# 1. Introduction

The Body Measurements Dataset is a comprehensive collection of anthropometric measurements captured from a diverse sample of individuals. Anthropometry refers to the measurement of human body dimensions and proportions, and it plays a crucial role in various fields such as health sciences, ergonomics, clothing design, and nutrition research.

Test the hypothesis that the selected factors are sufficient.

The objectives of factor analysis are to reduce data dimensionality, identify latent variables, summarize information, explore relationships among variables,

# Methodology

## variable Information

Gender (Male and Female (M=1 & F= 2) (391 Males & 324 Females) Age (1 year and above) HeadCircumference (in inches) ShoulderWidth (in inches) ChestWidth (in inches) Belly (in inches) Waist (in inches) Hips (in inches) ArmLength (in inches) ShoulderToWaist (in inches) WaistToKnee (in inches) LegLength (in inches) TotalHeight - from head to toe (in inches)

Factor analysis is a statistical approach used to identify the underlying factors or dimensions that explain the relationships between a group of observable data. It seeks to simplify the data by lowering its dimensionality and detecting common patterns among the variables.

library(tidyverse)

## ── Attaching core tidyverse packages ──────────────────────── tidyverse 2.0.0 ──  
## ✔ dplyr 1.1.2 ✔ readr 2.1.4  
## ✔ forcats 1.0.0 ✔ stringr 1.5.0  
## ✔ ggplot2 3.4.2 ✔ tibble 3.2.1  
## ✔ lubridate 1.9.2 ✔ tidyr 1.3.0  
## ✔ purrr 1.0.1   
## ── Conflicts ────────────────────────────────────────── tidyverse\_conflicts() ──  
## ✖ dplyr::filter() masks stats::filter()  
## ✖ dplyr::lag() masks stats::lag()  
## ℹ Use the conflicted package (<http://conflicted.r-lib.org/>) to force all conflicts to become errors

library(janitor)

##   
## Attaching package: 'janitor'  
##   
## The following objects are masked from 'package:stats':  
##   
## chisq.test, fisher.test

library(data.table)

##   
## Attaching package: 'data.table'  
##   
## The following objects are masked from 'package:lubridate':  
##   
## hour, isoweek, mday, minute, month, quarter, second, wday, week,  
## yday, year  
##   
## The following objects are masked from 'package:dplyr':  
##   
## between, first, last  
##   
## The following object is masked from 'package:purrr':  
##   
## transpose

library(factoextra)

## Welcome! Want to learn more? See two factoextra-related books at https://goo.gl/ve3WBa

library(psych)

##   
## Attaching package: 'psych'  
##   
## The following objects are masked from 'package:ggplot2':  
##   
## %+%, alpha

library(corrplot)

## corrplot 0.92 loaded

library(ggplot2)

Body\_measurement <- read\_csv(file="Data/Body\_measurement.csv")

## Rows: 716 Columns: 13  
## ── Column specification ────────────────────────────────────────────────────────  
## Delimiter: ","  
## dbl (13): Gender, Age, HeadCircumference, ShoulderWidth, ChestWidth, Belly, ...  
##   
## ℹ Use `spec()` to retrieve the full column specification for this data.  
## ℹ Specify the column types or set `show\_col\_types = FALSE` to quiet this message.

head(Body\_measurement)

## # A tibble: 6 × 13  
## Gender Age HeadCircumference ShoulderWidth ChestWidth Belly Waist Hips  
## <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>  
## 1 1 30 22 18 20 18 14 22  
## 2 1 28 19 22 17 18 21 25  
## 3 2 27 21 18 16 14 10 15  
## 4 1 29 20 20 18 11 19 14  
## 5 2 28 16 14 18 13 11 30  
## 6 2 22 17 19 18 14 16 18  
## # ℹ 5 more variables: ArmLength <dbl>, ShoulderToWaist <dbl>,  
## # WaistToKnee <dbl>, LegLength <dbl>, TotalHeight <dbl>

remove empty rows and columns

Body\_measurement <- Body\_measurement %>% remove\_empty(c("cols"))  
Body\_measurement <- Body\_measurement %>% drop\_na()

head(Body\_measurement)

## # A tibble: 6 × 13  
## Gender Age HeadCircumference ShoulderWidth ChestWidth Belly Waist Hips  
## <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>  
## 1 1 30 22 18 20 18 14 22  
## 2 1 28 19 22 17 18 21 25  
## 3 2 27 21 18 16 14 10 15  
## 4 1 29 20 20 18 11 19 14  
## 5 2 28 16 14 18 13 11 30  
## 6 2 22 17 19 18 14 16 18  
## # ℹ 5 more variables: ArmLength <dbl>, ShoulderToWaist <dbl>,  
## # WaistToKnee <dbl>, LegLength <dbl>, TotalHeight <dbl>

describe(Body\_measurement)

## vars n mean sd median trimmed mad min max range skew  
## Gender 1 715 1.45 0.50 1 1.44 0.00 1 2 1 0.19  
## Age 2 715 15.35 11.84 11 13.61 8.90 1 68 67 1.51  
## HeadCircumference 3 715 20.57 3.75 20 20.55 1.48 5 80 75 5.31  
## ShoulderWidth 4 715 14.32 4.77 14 14.20 4.45 4 87 83 4.98  
## ChestWidth 5 715 14.57 5.32 13 13.81 4.45 6 38 32 1.42  
## Belly 6 715 20.20 10.14 20 19.50 4.45 5 213 208 9.87  
## Waist 7 715 19.26 8.78 20 18.22 8.90 2 91 89 1.74  
## Hips 8 715 19.39 8.75 18 18.33 8.90 7 63 56 1.49  
## ArmLength 9 715 18.81 5.38 19 18.75 4.45 6 66 60 1.89  
## ShoulderToWaist 10 715 17.91 5.38 18 17.66 5.93 1 39 38 0.38  
## WaistToKnee 11 715 16.56 5.21 16 16.32 4.45 4 45 41 0.55  
## LegLength 12 715 26.84 7.93 26 26.48 7.41 9 50 41 0.43  
## TotalHeight 13 715 48.12 12.16 48 47.92 10.38 19 89 70 0.27  
## kurtosis se  
## Gender -1.97 0.02  
## Age 2.53 0.44  
## HeadCircumference 88.02 0.14  
## ShoulderWidth 73.88 0.18  
## ChestWidth 2.16 0.20  
## Belly 180.99 0.38  
## Waist 7.35 0.33  
## Hips 3.58 0.33  
## ArmLength 16.00 0.20  
## ShoulderToWaist -0.27 0.20  
## WaistToKnee 0.85 0.19  
## LegLength -0.47 0.30  
## TotalHeight 0.68 0.45

mean of each variable

apply(Body\_measurement, 2, mean)

## Gender Age HeadCircumference ShoulderWidth   
## 1.453147 15.349650 20.574825 14.318881   
## ChestWidth Belly Waist Hips   
## 14.574825 20.198601 19.258741 19.390210   
## ArmLength ShoulderToWaist WaistToKnee LegLength   
## 18.812587 17.906294 16.562238 26.836364   
## TotalHeight   
## 48.124476

variance of each variable

apply(Body\_measurement, 2, var)

## Gender Age HeadCircumference ShoulderWidth   
## 0.2481518 140.1240720 14.0318583 22.7076962   
## ChestWidth Belly Waist Hips   
## 28.2671525 102.8204462 77.0015866 76.4875791   
## ArmLength ShoulderToWaist WaistToKnee LegLength   
## 28.9340150 28.9561928 27.1204208 62.9045582   
## TotalHeight   
## 147.9690780

Correlation Matrix for the data

cor(Body\_measurement, method = "spearman")

## Gender Age HeadCircumference ShoulderWidth  
## Gender 1.00000000 -0.14940640 0.02869548 -0.13144471  
## Age -0.14940640 1.00000000 0.28589327 0.73509925  
## HeadCircumference 0.02869548 0.28589327 1.00000000 0.29953893  
## ShoulderWidth -0.13144471 0.73509925 0.29953893 1.00000000  
## ChestWidth -0.05147592 0.44797116 0.25183739 0.48335280  
## Belly 0.12136013 0.03509798 0.36680796 0.02128412  
## Waist 0.03355142 0.27797896 0.31208540 0.31847260  
## Hips 0.04672076 0.35863506 0.35133933 0.37217713  
## ArmLength -0.09959764 0.61050966 0.41889152 0.50794563  
## ShoulderToWaist -0.16500562 0.67706010 0.35472608 0.67802258  
## WaistToKnee -0.16041264 0.70179735 0.38753249 0.65431923  
## LegLength -0.07867575 0.45651840 0.48011417 0.42757507  
## TotalHeight -0.06429561 0.66281879 0.46537594 0.59537502  
## ChestWidth Belly Waist Hips ArmLength  
## Gender -0.05147592 0.12136013 0.03355142 0.04672076 -0.09959764  
## Age 0.44797116 0.03509798 0.27797896 0.35863506 0.61050966  
## HeadCircumference 0.25183739 0.36680796 0.31208540 0.35133933 0.41889152  
## ShoulderWidth 0.48335280 0.02128412 0.31847260 0.37217713 0.50794563  
## ChestWidth 1.00000000 0.19003778 0.27579629 0.44913190 0.38420495  
## Belly 0.19003778 1.00000000 0.46877507 0.42659171 0.19640743  
## Waist 0.27579629 0.46877507 1.00000000 0.68007970 0.27740223  
## Hips 0.44913190 0.42659171 0.68007970 1.00000000 0.37057951  
## ArmLength 0.38420495 0.19640743 0.27740223 0.37057951 1.00000000  
## ShoulderToWaist 0.45031151 0.01478123 0.38662671 0.43365794 0.56852356  
## WaistToKnee 0.44223705 0.13352818 0.40320759 0.45043011 0.57200580  
## LegLength 0.26088280 0.34385458 0.30230118 0.30428371 0.53343294  
## TotalHeight 0.41472257 0.35659955 0.39407948 0.41216337 0.57723853  
## ShoulderToWaist WaistToKnee LegLength TotalHeight  
## Gender -0.16500562 -0.1604126 -0.07867575 -0.06429561  
## Age 0.67706010 0.7017973 0.45651840 0.66281879  
## HeadCircumference 0.35472608 0.3875325 0.48011417 0.46537594  
## ShoulderWidth 0.67802258 0.6543192 0.42757507 0.59537502  
## ChestWidth 0.45031151 0.4422370 0.26088280 0.41472257  
## Belly 0.01478123 0.1335282 0.34385458 0.35659955  
## Waist 0.38662671 0.4032076 0.30230118 0.39407948  
## Hips 0.43365794 0.4504301 0.30428371 0.41216337  
## ArmLength 0.56852356 0.5720058 0.53343294 0.57723853  
## ShoulderToWaist 1.00000000 0.6878258 0.49471111 0.57509064  
## WaistToKnee 0.68782581 1.0000000 0.51902699 0.64375375  
## LegLength 0.49471111 0.5190270 1.00000000 0.63461782  
## TotalHeight 0.57509064 0.6437537 0.63461782 1.00000000

scaled\_df <- apply(Body\_measurement, 2, scale)  
head(scaled\_df)

## Gender Age HeadCircumference ShoulderWidth ChestWidth Belly  
## [1,] -0.9096623 1.2376322 0.3804614 0.77249078 1.0204053 -0.2168237  
## [2,] -0.9096623 1.0686762 -0.4204117 1.61189946 0.4561441 -0.2168237  
## [3,] 1.0977715 0.9841982 0.1135037 0.77249078 0.2680570 -0.6112994  
## [4,] -0.9096623 1.1531542 -0.1534540 1.19219512 0.6442311 -0.9071562  
## [5,] 1.0977715 1.0686762 -1.2212847 -0.06691789 0.6442311 -0.7099183  
## [6,] 1.0977715 0.5618082 -0.9543270 0.98234295 0.6442311 -0.6112994  
## Waist Hips ArmLength ShoulderToWaist WaistToKnee LegLength  
## [1,] -0.5992830 0.2984078 0.5925622 1.31826425 1.6202390 -0.6097866  
## [2,] 0.1984328 0.6414328 1.7080039 0.94659274 1.6202390 -0.8619540  
## [3,] -1.0551206 -0.5019839 0.4066552 0.01741398 -0.4920069 -1.1141214  
## [4,] -0.0294860 -0.6163256 0.9643761 0.57492124 0.6601272 -0.7358703  
## [5,] -0.9411612 1.2131412 1.1502831 0.76075699 2.9643954 -1.7445399  
## [6,] -0.3713642 -0.1589589 0.2207483 1.13242849 0.8521495 -0.9880377  
## TotalHeight  
## [1,] 0.31859943  
## [2,] 0.64743176  
## [3,] 0.40080752  
## [4,] -0.25685714  
## [5,] -0.09244098  
## [6,] 0.97626409

The test measures sampling adequacy for each variable in the model

KMO(scaled\_df)

## Kaiser-Meyer-Olkin factor adequacy  
## Call: KMO(r = scaled\_df)  
## Overall MSA = 0.9  
## MSA for each item =   
## Gender Age HeadCircumference ShoulderWidth   
## 0.75 0.90 0.92 0.93   
## ChestWidth Belly Waist Hips   
## 0.91 0.80 0.83 0.82   
## ArmLength ShoulderToWaist WaistToKnee LegLength   
## 0.94 0.92 0.93 0.91   
## TotalHeight   
## 0.91

Dimention of the dataset

dim(scaled\_df)

## [1] 715 13

Get the covariance matrix of standardized data

df\_cov <-cov(scaled\_df)  
df\_cov

## Gender Age HeadCircumference ShoulderWidth  
## Gender 1.000000000 -0.1755899 0.01407799 -0.08868823  
## Age -0.175589911 1.0000000 0.16861270 0.49385535  
## HeadCircumference 0.014077987 0.1686127 1.00000000 0.18524333  
## ShoulderWidth -0.088688230 0.4938554 0.18524333 1.00000000  
## ChestWidth -0.057240478 0.2901962 0.30490678 0.36855368  
## Belly 0.086412149 0.1202104 0.17947305 0.07132430  
## Waist 0.009986189 0.4142915 0.19236194 0.25900838  
## Hips 0.049048134 0.4169683 0.27000076 0.29140070  
## ArmLength -0.089001646 0.4357789 0.34580817 0.32973781  
## ShoulderToWaist -0.155511451 0.5991891 0.32118232 0.50530121  
## WaistToKnee -0.132358962 0.5484113 0.35358610 0.47174954  
## LegLength -0.103149666 0.3843852 0.36535840 0.33048877  
## TotalHeight -0.070340008 0.5069285 0.39450198 0.43628091  
## ChestWidth Belly Waist Hips ArmLength  
## Gender -0.05724048 0.08641215 0.009986189 0.04904813 -0.08900165  
## Age 0.29019622 0.12021038 0.414291526 0.41696825 0.43577886  
## HeadCircumference 0.30490678 0.17947305 0.192361940 0.27000076 0.34580817  
## ShoulderWidth 0.36855368 0.07132430 0.259008380 0.29140070 0.32973781  
## ChestWidth 1.00000000 0.16378082 0.303762256 0.39357607 0.28830515  
## Belly 0.16378082 1.00000000 0.383374116 0.44257855 0.13343754  
## Waist 0.30376226 0.38337412 1.000000000 0.69779331 0.25436876  
## Hips 0.39357607 0.44257855 0.697793311 1.00000000 0.29960005  
## ArmLength 0.28830515 0.13343754 0.254368760 0.29960005 1.00000000  
## ShoulderToWaist 0.47194369 0.07560000 0.385925168 0.41798606 0.49564722  
## WaistToKnee 0.51311933 0.16319701 0.377461731 0.40763837 0.51449238  
## LegLength 0.34732607 0.24797488 0.298260947 0.33500784 0.47595583  
## TotalHeight 0.46449292 0.30017715 0.409374392 0.43038057 0.52518226  
## ShoulderToWaist WaistToKnee LegLength TotalHeight  
## Gender -0.1555115 -0.1323590 -0.1031497 -0.07034001  
## Age 0.5991891 0.5484113 0.3843852 0.50692847  
## HeadCircumference 0.3211823 0.3535861 0.3653584 0.39450198  
## ShoulderWidth 0.5053012 0.4717495 0.3304888 0.43628091  
## ChestWidth 0.4719437 0.5131193 0.3473261 0.46449292  
## Belly 0.0756000 0.1631970 0.2479749 0.30017715  
## Waist 0.3859252 0.3774617 0.2982609 0.40937439  
## Hips 0.4179861 0.4076384 0.3350078 0.43038057  
## ArmLength 0.4956472 0.5144924 0.4759558 0.52518226  
## ShoulderToWaist 1.0000000 0.6686453 0.5208620 0.58777297  
## WaistToKnee 0.6686453 1.0000000 0.5530453 0.65606008  
## LegLength 0.5208620 0.5530453 1.0000000 0.66215510  
## TotalHeight 0.5877730 0.6560601 0.6621551 1.00000000

Find the eigen value and eigen vectors of covariance matrix

df\_eigen <- eigen(df\_cov)  
df\_eigen

## eigen() decomposition  
## $values  
## [1] 5.3487192 1.4824935 1.0638068 0.8886332 0.7694302 0.6630440 0.5935894  
## [8] 0.5134637 0.4310680 0.3462939 0.3389440 0.2900234 0.2704906  
##   
## $vectors  
## [,1] [,2] [,3] [,4] [,5] [,6]  
## [1,] 0.0554769 -0.405395873 -0.35919795 0.766667057 -0.29001457 0.05292329  
## [2,] -0.3038769 0.147175662 0.36294990 0.087257553 -0.28738623 -0.14710620  
## [3,] -0.2120071 -0.045112092 -0.58763370 -0.117168683 0.25989658 -0.52818272  
## [4,] -0.2634713 0.204315455 0.21532602 0.374547871 0.03411121 0.25664410  
## [5,] -0.2684410 0.007372549 -0.07393813 0.197059485 0.72073058 0.23225525  
## [6,] -0.1527996 -0.559534857 -0.04542201 -0.360124094 -0.08068522 0.44966638  
## [7,] -0.2641817 -0.412793300 0.34595172 -0.029121348 0.00809255 -0.30582353  
## [8,] -0.2859843 -0.432138087 0.23648872 0.008810006 0.09800289 -0.24476828  
## [9,] -0.2834527 0.161384667 -0.21795944 -0.080563774 -0.40747152 -0.22220266  
## [10,] -0.3440899 0.207822909 0.08320077 0.129806961 0.01242609 -0.10107467  
## [11,] -0.3520696 0.156866687 -0.04007640 0.058535678 0.04428472 0.07837602  
## [12,] -0.3073830 0.073124267 -0.28077036 -0.222757564 -0.21631871 0.30888663  
## [13,] -0.3550340 0.027361836 -0.17192801 -0.068977793 -0.11838831 0.24492846  
## [,7] [,8] [,9] [,10] [,11] [,12]  
## [1,] -0.10795830 0.04282976 0.10110334 -0.01907533 -0.02969712 0.003524233  
## [2,] 0.12281588 0.04655542 0.54628337 -0.53649329 -0.01978615 -0.112408510  
## [3,] 0.44239785 0.17556242 0.11603811 -0.05198263 0.02856853 0.005018129  
## [4,] 0.68107984 -0.01313810 -0.40182102 0.08141490 0.03700759 -0.033601052  
## [5,] -0.26280244 -0.31421457 0.03211167 -0.32576147 -0.06011834 0.051004990  
## [6,] 0.32413802 -0.24468225 0.30962458 0.15024760 -0.13757795 0.093706454  
## [7,] -0.15140215 0.16077820 -0.29218836 0.08196467 0.30372961 0.330101036  
## [8,] -0.06848364 -0.01249793 -0.18501848 -0.04543631 -0.23648519 -0.457117623  
## [9,] -0.10511505 -0.73612764 -0.25836277 -0.01517394 -0.01945465 0.025865228  
## [10,] -0.12992700 0.12581696 0.19668955 0.42252595 -0.57744976 0.455068724  
## [11,] -0.17967705 0.02128117 0.28963230 0.55641674 0.40911841 -0.480212725  
## [12,] -0.20449441 0.44023464 -0.33255447 -0.19701601 -0.31213409 -0.251105061  
## [13,] -0.09950105 0.16859469 0.00239872 -0.19449841 0.47664428 0.394306358  
## [,13]  
## [1,] -0.06241918  
## [2,] -0.16090898  
## [3,] -0.06250112  
## [4,] -0.02296553  
## [5,] -0.17037428  
## [6,] -0.10966026  
## [7,] -0.45122357  
## [8,] 0.54765387  
## [9,] -0.05695198  
## [10,] 0.11750483  
## [11,] -0.11873526  
## [12,] -0.28982259  
## [13,] 0.55321966

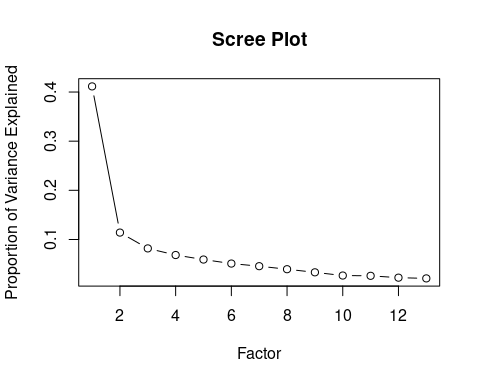
proportion of variance

PVE <- df\_eigen$values / sum(df\_eigen$values)  
PVE

## [1] 0.41143994 0.11403796 0.08183129 0.06835640 0.05918694 0.05100339  
## [7] 0.04566072 0.03949721 0.03315907 0.02663799 0.02607262 0.02230949  
## [13] 0.02080697

Scree Plot

# Create scree plot  
plot(PVE, type = "b", xlab = "Factor", ylab = "Proportion of Variance Explained", main = "Scree Plot")



`

Factor Analysis from Principal component Method

df\_st\_fa\_pc <- fa(df\_cov ,nfactors = 3,rotate = "none",n.obs = 252 ,covar = TRUE,fm = "pa")  
df\_st\_fa\_pc

## Factor Analysis using method = pa  
## Call: fa(r = df\_cov, nfactors = 3, n.obs = 252, rotate = "none", covar = TRUE,   
## fm = "pa")  
## Standardized loadings (pattern matrix) based upon correlation matrix  
## PA1 PA2 PA3 h2 u2 com  
## Gender -0.11 0.22 0.13 0.078 0.92 2.2  
## Age 0.68 -0.12 -0.34 0.592 0.41 1.6  
## HeadCircumference 0.44 -0.01 0.29 0.282 0.72 1.7  
## ShoulderWidth 0.56 -0.17 -0.19 0.384 0.62 1.4  
## ChestWidth 0.57 -0.02 0.04 0.321 0.68 1.0  
## Belly 0.33 0.45 0.21 0.356 0.64 2.3  
## Waist 0.60 0.50 -0.18 0.634 0.37 2.1  
## Hips 0.66 0.57 -0.12 0.773 0.23 2.0  
## ArmLength 0.61 -0.17 0.11 0.411 0.59 1.2  
## ShoulderToWaist 0.78 -0.24 -0.16 0.694 0.31 1.3  
## WaistToKnee 0.80 -0.20 0.01 0.673 0.33 1.1  
## LegLength 0.68 -0.12 0.29 0.560 0.44 1.4  
## TotalHeight 0.81 -0.08 0.23 0.716 0.28 1.2  
##   
## PA1 PA2 PA3  
## SS loadings 4.93 1.01 0.53  
## Proportion Var 0.38 0.08 0.04  
## Cumulative Var 0.38 0.46 0.50  
## Proportion Explained 0.76 0.16 0.08  
## Cumulative Proportion 0.76 0.92 1.00  
##   
## Mean item complexity = 1.6  
## Test of the hypothesis that 3 factors are sufficient.  
##   
## df null model = 78 with the objective function = 5.38 with Chi Square = 1321.6  
## df of the model are 42 and the objective function was 0.18   
##   
## The root mean square of the residuals (RMSR) is 0.02   
## The df corrected root mean square of the residuals is 0.03   
##   
## The harmonic n.obs is 252 with the empirical chi square 24.1 with prob < 0.99   
## The total n.obs was 252 with Likelihood Chi Square = 44.16 with prob < 0.38   
##   
## Tucker Lewis Index of factoring reliability = 0.997  
## RMSEA index = 0.014 and the 90 % confidence intervals are 0 0.046  
## BIC = -188.08  
## Fit based upon off diagonal values = 1  
## Measures of factor score adequacy   
## PA1 PA2 PA3  
## Correlation of (regression) scores with factors 0.96 0.86 0.73  
## Multiple R square of scores with factors 0.93 0.74 0.54  
## Minimum correlation of possible factor scores 0.86 0.49 0.08

Get unrotated loadings from PC method

df\_st\_fa\_pc$loadings

##   
## Loadings:  
## PA1 PA2 PA3   
## Gender -0.111 0.221 0.131  
## Age 0.677 -0.120 -0.344  
## HeadCircumference 0.441 0.295  
## ShoulderWidth 0.562 -0.173 -0.195  
## ChestWidth 0.565   
## Belly 0.325 0.454 0.209  
## Waist 0.596 0.496 -0.181  
## Hips 0.661 0.566 -0.121  
## ArmLength 0.607 -0.173 0.109  
## ShoulderToWaist 0.781 -0.236 -0.164  
## WaistToKnee 0.796 -0.199   
## LegLength 0.679 -0.124 0.288  
## TotalHeight 0.809 0.232  
##   
## PA1 PA2 PA3  
## SS loadings 4.928 1.014 0.529  
## Proportion Var 0.379 0.078 0.041  
## Cumulative Var 0.379 0.457 0.498

Get unrotated PC loadings as dataframe

unrotated\_pc\_loadings <- as.data.frame(unclass(df\_st\_fa\_pc$loadings))  
unrotated\_pc\_loadings

## PA1 PA2 PA3  
## Gender -0.1105716 0.22050221 0.130847611  
## Age 0.6773864 -0.12046288 -0.343755842  
## HeadCircumference 0.4413128 -0.01210356 0.294918810  
## ShoulderWidth 0.5617129 -0.17331425 -0.194989289  
## ChestWidth 0.5650118 -0.01763383 0.035887137  
## Belly 0.3251140 0.45444622 0.209223391  
## Waist 0.5959879 0.49620797 -0.181369239  
## Hips 0.6614982 0.56593406 -0.121262640  
## ArmLength 0.6074239 -0.17267712 0.109474272  
## ShoulderToWaist 0.7814148 -0.23634731 -0.164463090  
## WaistToKnee 0.7958160 -0.19908740 0.006636323  
## LegLength 0.6791580 -0.12440055 0.287911146  
## TotalHeight 0.8092583 -0.08243135 0.232199117

Get unrotated PC method communalities as dataframe

unrotated\_pc\_com <- as.data.frame(unclass(df\_st\_fa\_pc$communality))  
unrotated\_pc\_com

## unclass(df\_st\_fa\_pc$communality)  
## Gender 0.07796841  
## Age 0.59153174  
## HeadCircumference 0.28188060  
## ShoulderWidth 0.38358003  
## ChestWidth 0.32083718  
## Belly 0.35599492  
## Waist 0.63431876  
## Hips 0.77256581  
## ArmLength 0.41076576  
## ShoulderToWaist 0.69351723  
## WaistToKnee 0.67300298  
## LegLength 0.55962385  
## TotalHeight 0.71561037

Rotate the PC method factor loadings using ‘Varimax’ method

library(GPArotation)

##   
## Attaching package: 'GPArotation'

## The following objects are masked from 'package:psych':  
##   
## equamax, varimin

df\_st\_fa\_pc\_rotate <- fa(df\_cov ,nfactors = 3,rotate = "varimax",n.obs = 252 ,covar = TRUE,fm = 'pa')  
df\_st\_fa\_pc\_rotate

## Factor Analysis using method = pa  
## Call: fa(r = df\_cov, nfactors = 3, n.obs = 252, rotate = "varimax",   
## covar = TRUE, fm = "pa")  
## Standardized loadings (pattern matrix) based upon correlation matrix  
## PA1 PA3 PA2 h2 u2 com  
## Gender -0.03 -0.25 0.11 0.078 0.92 1.4  
## Age 0.24 0.67 0.29 0.592 0.41 1.6  
## HeadCircumference 0.51 0.05 0.15 0.282 0.72 1.2  
## ShoulderWidth 0.28 0.53 0.16 0.384 0.62 1.7  
## ChestWidth 0.41 0.30 0.25 0.321 0.68 2.5  
## Belly 0.27 -0.17 0.51 0.356 0.64 1.8  
## Waist 0.16 0.23 0.75 0.634 0.37 1.3  
## Hips 0.23 0.19 0.83 0.773 0.23 1.3  
## ArmLength 0.53 0.35 0.12 0.411 0.59 1.9  
## ShoulderToWaist 0.46 0.66 0.20 0.694 0.31 2.0  
## WaistToKnee 0.59 0.53 0.21 0.673 0.33 2.2  
## LegLength 0.69 0.24 0.16 0.560 0.44 1.4  
## TotalHeight 0.73 0.33 0.27 0.716 0.28 1.7  
##   
## PA1 PA3 PA2  
## SS loadings 2.56 2.02 1.90  
## Proportion Var 0.20 0.16 0.15  
## Cumulative Var 0.20 0.35 0.50  
## Proportion Explained 0.39 0.31 0.29  
## Cumulative Proportion 0.39 0.71 1.00  
##   
## Mean item complexity = 1.7  
## Test of the hypothesis that 3 factors are sufficient.  
##   
## df null model = 78 with the objective function = 5.38 with Chi Square = 1321.6  
## df of the model are 42 and the objective function was 0.18   
##   
## The root mean square of the residuals (RMSR) is 0.02   
## The df corrected root mean square of the residuals is 0.03   
##   
## The harmonic n.obs is 252 with the empirical chi square 24.1 with prob < 0.99   
## The total n.obs was 252 with Likelihood Chi Square = 44.16 with prob < 0.38   
##   
## Tucker Lewis Index of factoring reliability = 0.997  
## RMSEA index = 0.014 and the 90 % confidence intervals are 0 0.046  
## BIC = -188.08  
## Fit based upon off diagonal values = 1  
## Measures of factor score adequacy   
## PA1 PA3 PA2  
## Correlation of (regression) scores with factors 0.85 0.83 0.89  
## Multiple R square of scores with factors 0.73 0.69 0.80  
## Minimum correlation of possible factor scores 0.45 0.38 0.60

df\_st\_fa\_pc\_rotate$loadings

##   
## Loadings:  
## PA1 PA3 PA2   
## Gender -0.254 0.111  
## Age 0.242 0.672 0.286  
## HeadCircumference 0.508 0.146  
## ShoulderWidth 0.280 0.529 0.157  
## ChestWidth 0.410 0.301 0.249  
## Belly 0.265 -0.172 0.506  
## Waist 0.164 0.228 0.745  
## Hips 0.235 0.192 0.825  
## ArmLength 0.525 0.346 0.123  
## ShoulderToWaist 0.464 0.661 0.203  
## WaistToKnee 0.586 0.534 0.210  
## LegLength 0.689 0.242 0.165  
## TotalHeight 0.728 0.333 0.274  
##   
## PA1 PA3 PA2  
## SS loadings 2.555 2.019 1.897  
## Proportion Var 0.197 0.155 0.146  
## Cumulative Var 0.197 0.352 0.498

Roatate factor loadings as a dataframe from PC method

rotated\_pc\_loadings <- as.data.frame(unclass(df\_st\_fa\_pc\_rotate$loadings))  
rotated\_pc\_loadings

## PA1 PA3 PA2  
## Gender -0.03170199 -0.25407997 0.1113856  
## Age 0.24198619 0.67162343 0.2861755  
## HeadCircumference 0.50794947 0.05119991 0.1457618  
## ShoulderWidth 0.28041076 0.52930544 0.1574344  
## ChestWidth 0.41037206 0.30068127 0.2490436  
## Belly 0.26521227 -0.17188513 0.5060760  
## Waist 0.16380918 0.22838413 0.7452020  
## Hips 0.23474986 0.19159214 0.8250762  
## ArmLength 0.52534029 0.34603794 0.1226421  
## ShoulderToWaist 0.46417003 0.66094818 0.2030047  
## WaistToKnee 0.58596888 0.53449149 0.2096719  
## LegLength 0.68852515 0.24161429 0.1648621  
## TotalHeight 0.72773734 0.33331776 0.2736933

Get rotated communalities in PC method

rotated\_pc\_com <- as.data.frame(unclass(df\_st\_fa\_pc\_rotate$communality))  
rotated\_pc\_com

## unclass(df\_st\_fa\_pc\_rotate$communality)  
## Gender 0.07796841  
## Age 0.59153174  
## HeadCircumference 0.28188060  
## ShoulderWidth 0.38358003  
## ChestWidth 0.32083718  
## Belly 0.35599492  
## Waist 0.63431876  
## Hips 0.77256581  
## ArmLength 0.41076576  
## ShoulderToWaist 0.69351723  
## WaistToKnee 0.67300298  
## LegLength 0.55962385  
## TotalHeight 0.71561037