HASIL PRAKTIKUM STATISTIKA

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D4 SDT B

POLITEKNIK ELEKTRONIKA NEGERI SURABAYA

Percobaan 1

1. Hitung PCA & Standarisasi dataset

Coding dan Output

```
> #Hitung PCA
> library(DT) #Menampilkan tabel agar mudah dilihat di browser
> library(factoextra) #Visualisasi
> PCAdf <- read.csv("C:/Users/fawza/Documents/Kuliah PENS/Semester 2/Permodelan Statistika Terapa
n/Dataset/data_pca.csv")
> PCAdf
  X1 X2 X3
1  2  4  1
2  3  3  3
3  5  2  4
4  6  1  7
5  8  0 10
> #Standarisasi dataset
> sdf<- scale(x = PCAdf)
> sdf
             X1         X2         X3
[1,] -1.17279094  1.2649111 -1.1313708
[2,] -0.75393703  0.6324555 -0.5656854
[3,]  0.08377078  0.0000000 -0.2828427
[4,]  0.50262469 -0.6324555  0.5656854
[5,]  1.34033251 -1.2649111  1.4142136
attr(,"scaled:center")
 X1  X2  X3
4.8 2.0 5.0
attr(,"scaled:scale")
      X1       X2       X3
2.387467 1.581139 3.535534
```

Hasil Analisis Singkat

Kode diatas menampilkan dataset PCAdf lalu menerapkan Standarisasi pada setiap variabel sdf.
Standardisasi dataset PCAdf mengubah setiap variabel sehingga memiliki rata-rata nol dan variansi satu. Hal ini membantu dalam membandingkan data dari kolom yang berbeda.

2. Hitung Kovarians

Coding dan Output

```
> #Hitung matriks kovarians (ragam-peragam)
> kov <- cov(sdf)
> kov
           X1         X2         X3
X1  1.0000000 -0.9933993  0.9773756
X2 -0.9933993  1.0000000 -0.9838699
X3  0.9773756 -0.9838699  1.0000000
```

Hasil Analisis Singkat

Kode diatas menampilkan hasil dari hitung kovarian antar variable pada dataset.
Hasil matriks kovarians menunjukkan terdapat hubungan yang kuat antara variabel-variabel dalam dataset sdf
- X1 dan X2 memiliki hubungan negatif yang kuat (kovarians -0.9933993).
- X1 dan X3 memiliki hubungan positif yang kuat (kovarians 0.9773756).
- X2 dan X3 memiliki hubungan negatif yang kuat (kovarians -0.9838699).

3. Hitung Eigen

Coding dan Output

```
> #Hitung vektor eigen dan nilai eigen
> vn_eigen <- eigen(kov)
> vn_eigen
eigen() decomposition
$values
[1] 2.969777889 0.024415078 0.005807033

$vectors
           [,1]       [,2]      [,3]
[1,]  0.5775521 -0.5442442 0.6084668
[2,] -0.5788138  0.2526048 0.7753486
[3,]  0.5756806  0.7999932 0.1691236
```

Hasil Analisis Singkat

Nilai eigen matriks kovariansi mengukur pentingnya setiap komponen utama. Dari kode tersebut didapat nilai eigen dan vektor dari kovarian yang telah dihitung sebelumnya. Ini berguna untuk mengevaluasi berapa banyak variasi dalam data yang dapat dijelaskan.

4. PCA Fungsi prcomp

Coding dan Output

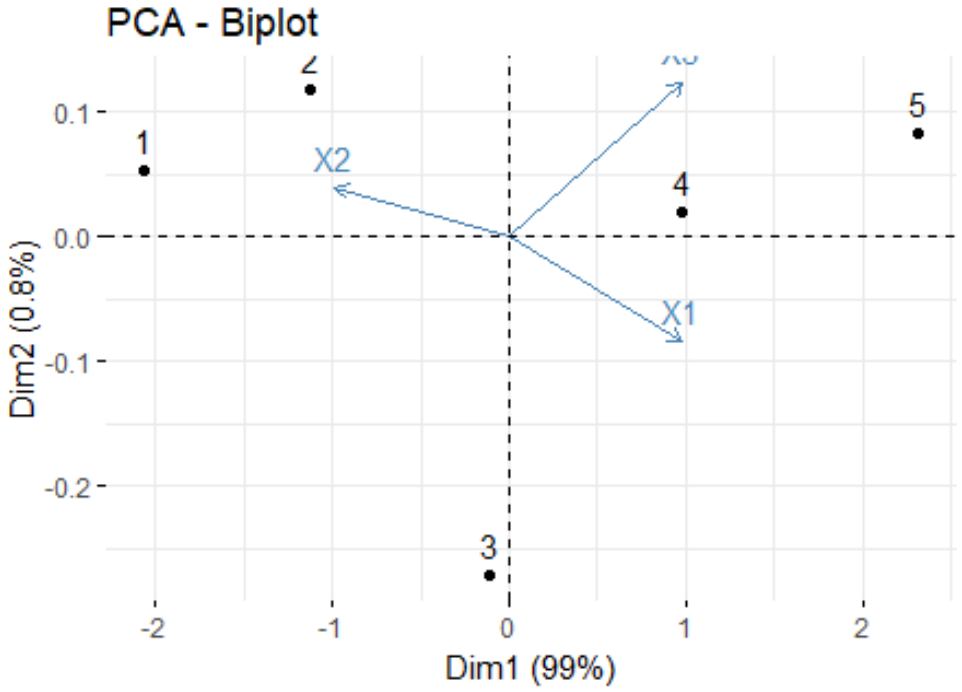
```
> #PCA dengan fungsi prcomp
> pca <- prcomp(x = PCAdf, scale. = TRUE, center = TRUE)
> names(pca)
[1] "sdev"     "rotation" "center"   "scale"    "x"
> #nilai standar deviasi dari komponen utama
> pca$sdev
[1] 1.72330435 0.15625325 0.07620389
> #nilai data setelah dimasukkan ke dalam persamaan komponen utama (hasil transformasi)
> pca$x
            PC1         PC2          PC3
[1,] -2.0608041  0.05271830  0.075801120
[2,] -1.1271660  0.11754267 -0.064042914
[3,] -0.1144451 -0.27186400  0.003136354
[4,]  0.9820201  0.01923261 -0.088872297
[5,]  2.3203951  0.08237041  0.073977737
> #nilai loadings
> pca$rotation
          PC1        PC2       PC3
X1  0.5775521 -0.5442442 0.6084668
X2 -0.5788138  0.2526048 0.7753486
X3  0.5756806  0.7999932 0.1691236
> #menentukan jumlah komponen utama
> summary(pca)
Importance of components:
                          PC1     PC2     PC3
Standard deviation     1.7233 0.15625 0.07620
Proportion of Variance 0.9899 0.00814 0.00194
Cumulative Proportion  0.9899 0.99806 1.00000
> #persamaan komponen utama
> pca$rotation
          PC1        PC2       PC3
X1  0.5775521 -0.5442442 0.6084668
X2 -0.5788138  0.2526048 0.7753486
X3  0.5756806  0.7999932 0.1691236
> #rekontruksi data
> head(pca$x[,1:2])
            PC1         PC2
[1,] -2.0608041  0.05271830
[2,] -1.1271660  0.11754267
[3,] -0.1144451 -0.27186400
[4,]  0.9820201  0.01923261
[5,]  2.3203951  0.08237041
```

Hasil Analisis Singkat

Kode diatas menampilkan hasil PCA dengan fungsi prcomp (principal component). Dengan menerapkan beberapa parameter seperti dilakukan standarisasi sehingga memiliki varians satu dan rata-rata nol sebelum PCA dilakukan. Lalu dilakukan rotasi untuk hasil transformasi dari x1 x3 ke pc1 pc3. Lalu untuk jumlah komponen

5. Visualisasi PCA

Coding dan Output



Hasil Analisis Singkat

Kode diatas menampilkan biplot dari hasil hitung PCA yang telah dilakukan. Dalam biplot diatas Dim 1 didominasi oleh X1 dan X3 dan Dim 2 didominasi oleh X2.
Ini adalah gambaran menggunakan vektor. Jadi ini semacam vektor dari x1, x2, dan x3 yang dilihat dari 2D pakai biplot.

Percobaan 2

1. Komputasi PCA dan scree plot

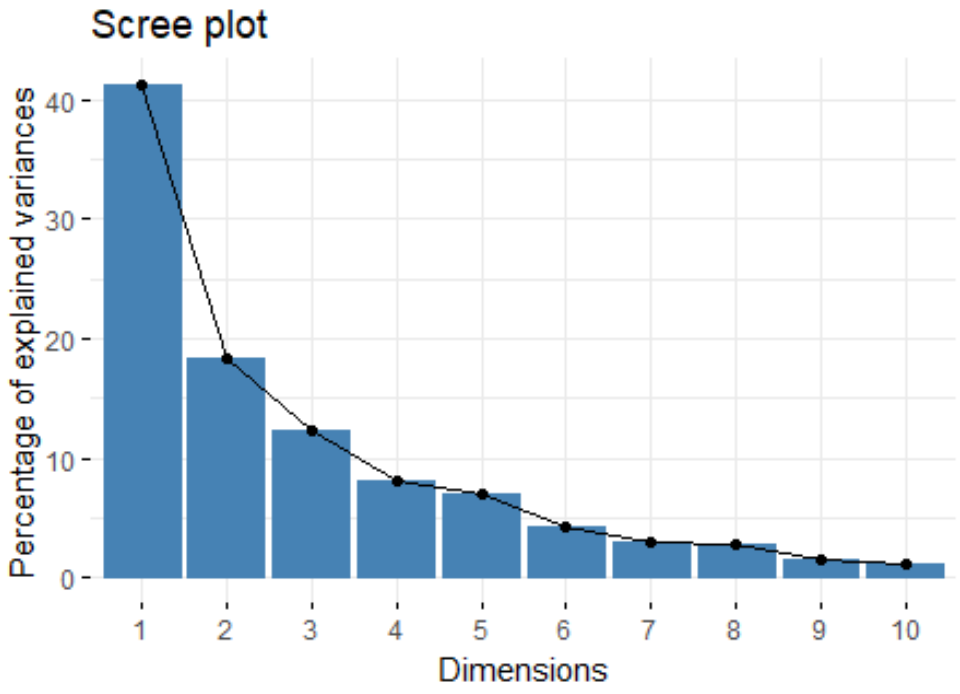
Coding dan Output

```r
# 3.2 Percobaan ke-2: Studi Kasus 1
library(factoextra)
data(decathlon2)
decathlon2.active <- decathlon2[1:23, 1:10]
head(decathlon2.active[, 1:6])
```

```
> # Komputasi PCA
> res.pca <- prcomp(decathlon2.active, scale = TRUE)
> summary(res.pca)
Importance of components:
                          PC1    PC2    PC3     PC4     PC5     PC6     PC7     PC8     PC9
Standard deviation     2.0308 1.3559 1.1132 0.90523 0.83759 0.65029 0.55007 0.52390 0.39398
Proportion of Variance 0.4124 0.1839 0.1239 0.08194 0.07016 0.04229 0.03026 0.02745 0.01552
Cumulative Proportion  0.4124 0.5963 0.7202 0.80213 0.87229 0.91458 0.94483 0.97228 0.98780
                          PC10
Standard deviation     0.3492
Proportion of Variance 0.0122
Cumulative Proportion  1.0000
> res.pca
Standard deviations (1, .., p=10):
 [1] 2.0308159 1.3559244 1.1131668 0.9052294 0.8375875 0.6502944 0.5500742 0.5238988
 [9] 0.3939758 0.3492435

Rotation (n x k) = (10 x 10):
                     PC1         PC2         PC3         PC4         PC5         PC6
X100m        -0.418859080 -0.13230683 -0.27089959  0.03708806 -0.2321476 -0.054398099
Long.jump     0.391064807  0.20713320  0.17117519 -0.12746997  0.2783669  0.051865558
Shot.put      0.361388111  0.06298590 -0.46497777  0.14191803 -0.2970589  0.368739186
High.jump     0.300413236 -0.34309742 -0.29652805  0.15968342  0.4807859  0.437716883
X400m        -0.345478567  0.21400770 -0.25470839  0.47592968  0.1240569  0.075796432
X110m.hurdle -0.376265119 -0.01824645 -0.40325254 -0.01866477  0.2676975 -0.004048005
Discus        0.365965721  0.03662510 -0.15857927  0.43636361 -0.4873988 -0.305315353
Pole.vault   -0.106985591  0.59549862 -0.08449563 -0.37447391 -0.2646712  0.503563524
Javeline      0.210864329  0.28475723 -0.54270782 -0.36646463  0.2361698 -0.556821016
X1500m        0.002106782  0.57855748  0.19715884  0.49491281  0.3142987 -0.064663250
                    PC7         PC8         PC9        PC10
X100m        -0.16604375 -0.19988005 -0.76924639  0.12718339
Long.jump    -0.28056361 -0.75850657 -0.13094589  0.08509665
Shot.put     -0.01797323  0.04649571  0.12129309  0.62263702
High.jump     0.05118848  0.16111045 -0.28463225 -0.38244596
X400m         0.52012255 -0.44579641  0.20854176 -0.09784197
X110m.hurdle -0.67276768 -0.01592804  0.41058421 -0.04475363
Discus       -0.25946615 -0.07550934  0.03391600 -0.49418361
Pole.vault   -0.01889413  0.06282691 -0.06540692 -0.39288155
Javeline      0.24281145  0.10086127 -0.10268134 -0.01103627
X1500m       -0.20245828  0.37119711 -0.25950868  0.17991689
```

```r
> #Visualize eigenvalues (scree plot). Show the percentage of variances explained by each princip
al component.
> fviz_eig(res.pca)
```



Hasil Analisis Singkat

Kode di atas menggunakan dataset decathlon2 dari beberapa atletik dengan mengambil 23 (individu) baris pertama dan 10 (atribut) kolom pertama. Datasetnya kemudian diterapkan PCA parameter standarisasi aktif agar memiliki varians unit sebelum analisis. Kemudian dengan fungsi summary() untuk menampilkan ringkasan statistik dari data tersebut.

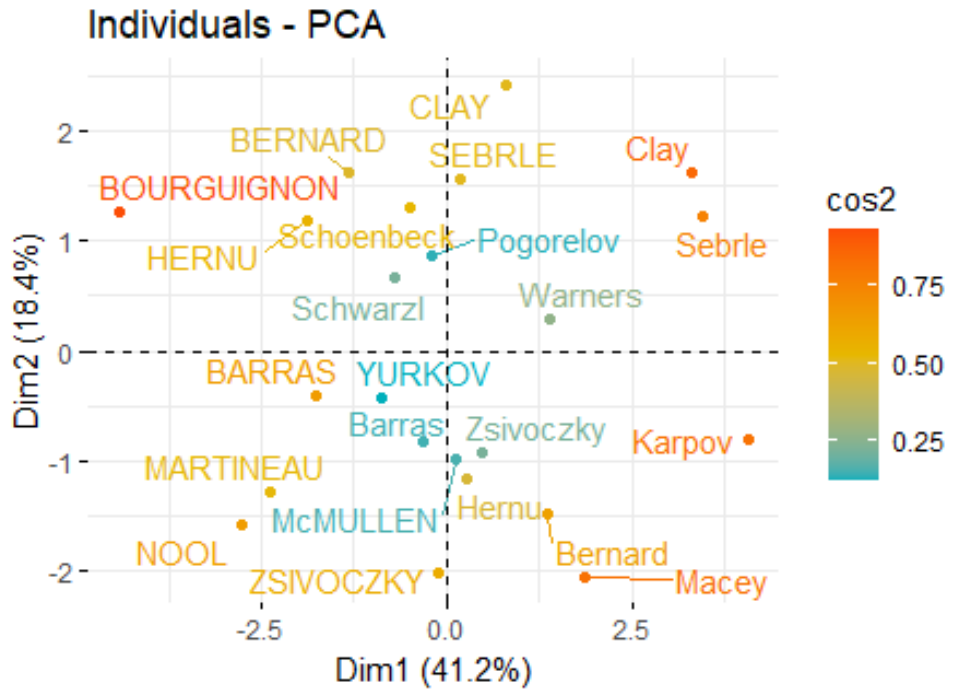
Dalam analisis subjektif. Idealnya mengambil komponen utama yang kumulatifnya mendekati 100. Kemudian menampilkan hasil rotasi/hasil transformasi ke PCA.

Disini untuk menentukan jumlah komponen yang akan kita pakai, menggunakan Scree Plot (Visualisasi agent value, merupakan visualisasi dari agent tertinggi ke terendah.). Pada analisis komponen utama (PCA), untuk mengetahui komponen yang mampu menunjukkan perubahan nilai eigen yang besar yaitu dengan melihat scree plot yang dapat menggantikan variabel-variabel yang berpengaruh terhadap dataset decathlon2. Dilihat dari grafik bahwa semakin banyak jumlah komponen yang akan kita pakai, semakin kecil persentase dari total varians dalam data yang dijelaskan oleh setiap komponen utama.

2. Individuals – PCA

Coding dan Output

```
> #Graph of individuals. Individuals with a similar profile are grouped together.
> fviz_pca_ind(res.pca,
+              col.ind = "cos2", # Color by the quality of representation
+              gradient.cols = c("#00AFBB", "#E7B800", "#FC4E07"),
+              repel = TRUE # Avoid text overlapping
+ )
```



Hasil Analisis Singkat

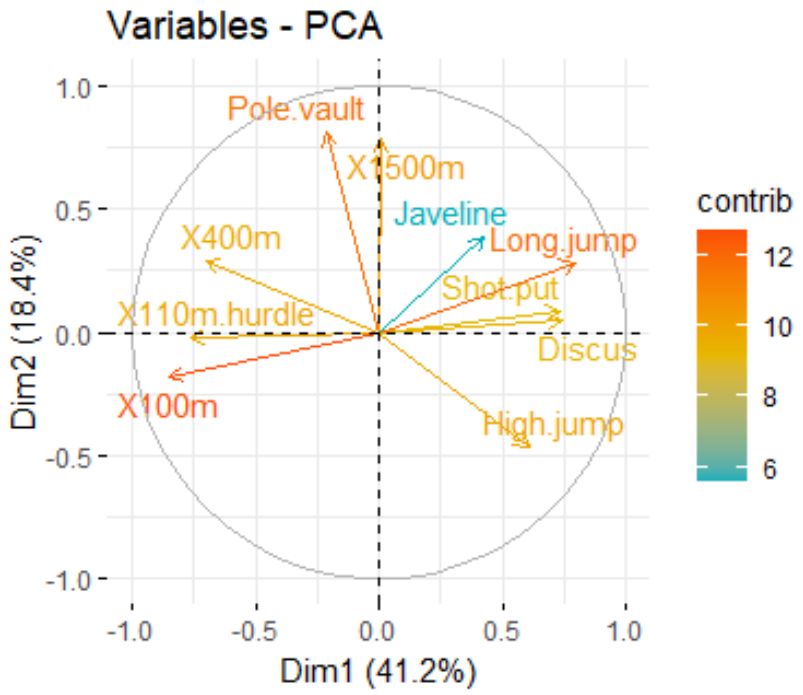
Kode diatas akan menampilkan biplot dengan dataset decathlon2 yaitu data performa dari 10 atlet. cos2 merupakan kuadrat kosinus

- Dimensi 1 (Dim1) pada sumbu X, yang menjelaskan 41.2% variabilitas data.
- Dimensi 2 (Dim2) pada sumbu Y, yang menjelaskan 18.4% variabilitas data.

3. Variables – BCA

Coding dan Output

```
> #Visualize eigenvalues (scree plot). Show the percentage of variances
> #explained by each principal component.
> fviz_eig(res.pca)
```



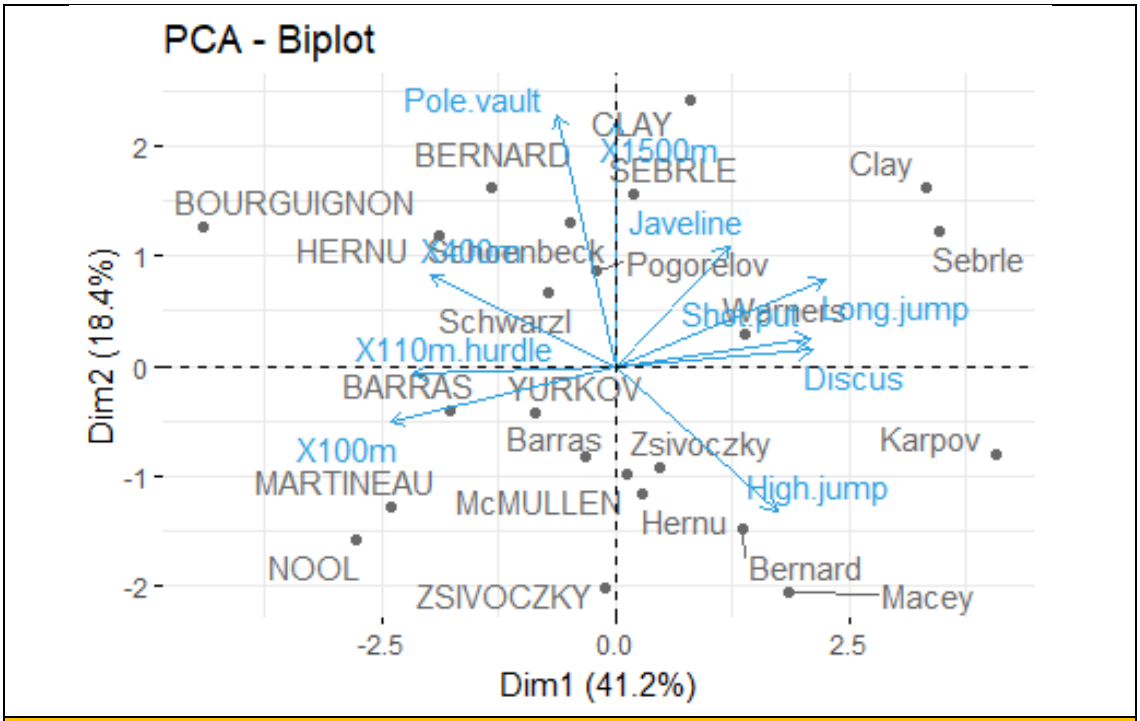
Hasil Analisis Singkat

Kode diatas akan menampilkan biplot dari 10 atribut data pada dataset decathlon2 dan arah panah menunjukan korelasi dari setiap variable. Di tampilan 2D, arah vektornya memperngaruhi korelasi sehingga semakin panjang vektornya maka dia mempunyai pengaruh yang besar, dan mendominasi tiap jenis olahraga

4. PCA – Biplot

Coding dan Output

```
> #Biplot of individuals and variables
> fviz_pca_biplot(res.pca, repel = TRUE,
+                 col.var = "#2E9FDF", # Variables color
+                 col.ind = "#696969" # Individuals color
+
+ )
>
```



Hasil Analisis Singkat

Menggabungkan 2 gambar sebelumnya, Artinya semacam visual lanjutan supaya dapat menapatkan insight dari data tersebut. Yang hitam merupakan individunya, dan warna biru untuk jenis olahraganya. Perform yang bagus itu ketika koordinat jauh dari (0,0)

5. Eigenvalues

Coding dan Output

```
> library(factoextra)
> # Eigenvalues
> eig.val <- get_eigenvalue(res.pca)
> eig.val
       eigenvalue variance.percent cumulative.variance.percent
Dim.1   4.1242133        41.242133                    41.24213
Dim.2   1.8385309        18.385309                    59.62744
Dim.3   1.2391403        12.391403                    72.01885
Dim.4   0.8194402         8.194402                    80.21325
Dim.5   0.7015528         7.015528                    87.22878
Dim.6   0.4228828         4.228828                    91.45760
Dim.7   0.3025817         3.025817                    94.48342
Dim.8   0.2744700         2.744700                    97.22812
Dim.9   0.1552169         1.552169                    98.78029
Dim.10  0.1219710         1.219710                   100.00000
> # Results for Variables
> res.var <- get_pca_var(res.pca)
> res.var$coord # Coordinates
                   Dim.1       Dim.2       Dim.3       Dim.4       Dim.5       Dim.6
X100m         -0.850625692 -0.17939806 -0.30155643  0.03357320 -0.1944440 -0.035374780
Long.jump      0.794180641  0.28085695  0.19054653 -0.11538956  0.2331567  0.033727883
Shot.put       0.733912733  0.08540412 -0.51759781  0.12846837 -0.2488129  0.239789034
High.jump      0.610083985 -0.46521415 -0.33008517  0.14455012  0.4027002  0.284644846
X400m         -0.701603377  0.29017826 -0.28353292  0.43082552  0.1039085  0.049289996
X110m.hurdle -0.764125197 -0.02474081 -0.44888733 -0.01689589  0.2242200 -0.002632395
Discus         0.743209016  0.04966086 -0.17652518  0.39500915 -0.4082391 -0.198544870
Pole.vault    -0.217268042  0.80745110 -0.09405773 -0.33898477 -0.2216853  0.327464549
Javeline       0.428226639  0.38610928 -0.60412432 -0.33173454  0.1978128 -0.362097598
X1500m         0.004278487  0.78448019  0.21947068  0.44800961  0.2632527 -0.042050151
```

```
                    Dim.7        Dim.8       Dim.9       Dim.10
X100m        -0.091336386 -0.104716925 -0.30306448  0.044417974
Long.jump    -0.154330810 -0.397380703 -0.05158951  0.029719453
Shot.put     -0.009886612  0.024359049  0.04778655  0.217451948
High.jump     0.028157465  0.084405578 -0.11213822 -0.133566774
X400m         0.286106008 -0.233552216  0.08216041 -0.034170673
X110m.hurdle -0.370072158 -0.008344682  0.16176025 -0.015629914
Discus       -0.142725641 -0.039559255  0.01336209 -0.172590426
Pole.vault   -0.010393176  0.032914942 -0.02576874 -0.137211339
Javeline      0.133564318  0.052841099 -0.04045397 -0.003854347
X1500m       -0.111367083  0.194469730 -0.10224014  0.062834809
> res.var$contrib # Contributions to the PCs
                    Dim.1       Dim.2       Dim.3       Dim.4     Dim.5        Dim.6
X100m        1.754429e+01  1.7505098   7.3386590  0.13755240  5.389252  0.295915322
Long.jump    1.529317e+01  4.2904162   2.9300944  1.62485936  7.748815  0.269003613
Shot.put     1.306014e+01  0.3967224  21.6204325  2.01407269  8.824401 13.596858744
High.jump    9.024811e+00 11.7715838   8.7928883  2.54987951 23.115504 19.159607001
X400m        1.193554e+01  4.5799296   6.4876363 22.65090599  1.539012  0.574509906
X110m.hurdle 1.415754e+01  0.0332933  16.2612611  0.03483735  7.166193  0.001638634
Discus       1.339309e+01  0.1341398   2.5147385 19.04132022 23.755756  9.321746508
Pole.vault   1.144592e+00 35.4618611   0.7139512 14.02307063  7.005084 25.357622290
Javeline     4.446377e+00  8.1086683  29.4531777 13.42963254  5.577615 31.004964393
X1500m       4.438531e-04 33.4728757   3.8871610 24.49386930  9.878367  0.418133591
                    Dim.7       Dim.8       Dim.9      Dim.10
X100m         2.75705260  3.99520353  59.1740009  1.61756139
Long.jump     7.87159392 57.53322220   1.7146826  0.72414393
Shot.put      0.03230371  0.21618512   1.4712015 38.76768578
High.jump     0.26202607  2.59565787   8.1015517 14.62649091
X400m        27.05274658 19.87344405   4.3489667  0.95730504
X110m.hurdle 45.26163460  0.02537025  16.8579392  0.20028870
Discus        6.73226823  0.57016606   0.1150295 24.42174410
Pole.vault    0.03569883  0.39472201   0.4278065 15.43559151
Javeline      5.89573984  1.01729950   1.0543458  0.01217993
X1500m        4.09893563 13.77872941   6.7344755  3.23700871
> res.var$cos2 # Quality of representation
                    Dim.1        Dim.2       Dim.3        Dim.4       Dim.5        Dim.6
X100m        7.235641e-01 0.0321836641 0.090936280 0.0011271597 0.03780845 1.251375e-03
Long.jump    6.307229e-01 0.0788806285 0.036307981 0.0133147506 0.05436203 1.137570e-03
Shot.put     5.386279e-01 0.0072938636 0.267907488 0.0165041211 0.06190783 5.749878e-02
High.jump    3.722025e-01 0.2164242070 0.108956221 0.0208947375 0.16216747 8.102269e-02
X400m        4.922473e-01 0.0842034209 0.080390914 0.1856106269 0.01079698 2.429504e-03
X110m.hurdle 5.838873e-01 0.0006121077 0.201499837 0.0002854712 0.05027463 6.929502e-06
Discus       5.523596e-01 0.0024662013 0.031161138 0.1560322304 0.16665918 3.942007e-02
Pole.vault   4.720540e-02 0.6519772763 0.008846856 0.1149106765 0.04914437 1.072330e-01
Javeline     1.833781e-01 0.1490803723 0.364966189 0.1100478063 0.03912992 1.311147e-01
X1500m       1.830545e-05 0.6154091638 0.048167378 0.2007126089 0.06930197 1.768215e-03
                    Dim.7        Dim.8        Dim.9       Dim.10
X100m        0.0083423353 1.096563e-02 0.0918480768 1.972956e-03
Long.jump    0.0238179990 1.579114e-01 0.0026614779 8.832459e-04
Shot.put     0.0000977451 5.933633e-04 0.0022835540 4.728535e-02
High.jump    0.0007928428 7.124302e-03 0.0125749811 1.784008e-02
X400m        0.0818566479 5.454664e-02 0.0067503333 1.167635e-03
X110m.hurdle 0.1369534023 6.963371e-05 0.0261663784 2.442942e-04
Discus       0.0203706085 1.564935e-03 0.0001785453 2.978746e-02
Pole.vault   0.0001080181 1.083393e-03 0.0006640282 1.882695e-02
Javeline     0.0178394271 2.792182e-03 0.0016365234 1.485599e-05
X1500m       0.0124026272 3.781848e-02 0.0104530472 3.948213e-03
> # Results for individuals
> res.ind <- get_pca_ind(res.pca)
> res.ind$coord # Coordinates
```

```
                  Dim.1      Dim.2      Dim.3      Dim.4       Dim.5       Dim.6
SEBRLE        0.1912074  1.5541282 -0.62836882 0.08205241  1.1426139415  0.46389755
CLAY          0.7901217  2.4204156  1.35688701 1.26984296 -0.8068483724 -1.30420016
BERNARD      -1.3292592  1.6118687 -0.19614996 -1.92092203  0.0823428202  0.40062867
YURKOV       -0.8694134 -0.4328779 -2.47398223 0.69723814  0.3988584116 -0.10286344
ZSIVOCZKY    -0.1057450 -2.0233632  1.30493117 -0.09929630 -0.1970241089 -0.89554111
McMULLEN      0.1185550 -0.9916237  0.84355824 1.31215266  1.5858708644 -0.18657283
MARTINEAU    -2.3923532 -1.2849234 -0.89816842 0.37309771 -2.2433515889  0.45666350
HERNU        -1.8910497  1.1784614 -0.15641037 0.89130068 -0.1267412520 -0.43623496
BARRAS       -1.7744575 -0.4125321  0.65817750 0.22872866 -0.2338366980 -0.09026010
NOOL         -2.7770058 -1.5726757  0.60724821 -1.55548081  1.4241839810 -0.49716399
BOURGUIGNON -4.4137335  1.2635770 -0.01003734 0.66675478  0.4191518468  0.08200220
Sebrle        3.4514485  1.2169193 -1.67816711 -0.80870696 -0.0250530746  0.08279306
Clay          3.3162243  1.6232908 -0.61840443 -0.31679906  0.5691645854 -0.77715960
Karpov        4.0703560 -0.7983510  1.01501662 0.31336354 -0.7974259553  0.32958134
Macey         1.8484623 -2.0638828 -0.97928455 0.58469073 -0.0002157834  0.19728082
Warners       1.3873514  0.2819083  1.99969621 -1.01959817 -0.0405401497  0.55673300
Zsivoczky     0.4715533 -0.9267436 -1.72815525 -0.18483138  0.4073029909  0.11383190
Hernu         0.2763118 -1.1657260  0.17056375 -0.84869401 -0.6894795441  0.33168404
Bernard       1.3672590 -1.4780354  0.83137913  0.74531557  0.8598016482  0.32806564
Schwarzl     -0.7102777  0.6584251  1.04075176 -0.92717510 -0.2887568007  0.68891640
Pogorelov    -0.2143524  0.8610557  0.29761010  1.35560294 -0.0150531057  1.59379599
Schoenbeck   -0.4953166  1.3000530  0.10300360 -0.24927712 -0.6452257128 -0.16172381
Barras       -0.3158867 -0.8193681 -0.86169481 -0.58935985 -0.7797389436 -1.17415412

                 Dim.7       Dim.8       Dim.9      Dim.10
SEBRLE      -0.20796012  0.043460568 -0.659344137  0.03273238
CLAY        -0.21291866  0.617240611 -0.060125359 -0.31716015
BERNARD     -0.40643754  0.703856040  0.170083313 -0.09908142
YURKOV      -0.32487448  0.114996135 -0.109524039 -0.11969720
ZSIVOCZKY    0.08825624 -0.202341299 -0.523103099 -0.34842265
McMULLEN     0.47828432  0.293089967 -0.105623196 -0.39317797
MARTINEAU   -0.29975522 -0.291628488 -0.223417655 -0.61640509
HERNU       -0.56609980 -1.529404317  0.006184409  0.55368016
BARRAS       0.21594095  0.682583078 -0.669282042  0.53085420
NOOL        -0.53205687 -0.433385655 -0.115777808 -0.09622142
BOURGUIGNON -0.59833739  0.563619921  0.525814030  0.05855882
Sebrle       0.01016177 -0.030585843 -0.847210682  0.21970353
Clay         0.25750851 -0.580638301  0.409776590 -0.61601933
Karpov      -1.36365568  0.345306381  0.193055107  0.21721852
Macey       -0.26927772 -0.363219506  0.368260269  0.21249474
Warners     -0.26739400 -0.109470797  0.180283071  0.24208420
Zsivoczky    0.03991159  0.538039776  0.585966156 -0.14271715
Hernu        0.44308686  0.247293566  0.066908586 -0.20868256
Bernard      0.36357920  0.006165316  0.279488675  0.32067773
Schwarzl     0.56568604 -0.687053339 -0.008358849 -0.30211546
Pogorelov    0.78370119 -0.037623661 -0.130531397 -0.03697576
Schoenbeck   0.85752368 -0.255850722  0.564222295  0.29680481
Barras       0.94512710  0.365550568  0.102255763  0.61186706
> res.ind$contrib # Contributions to the PCs
```

```
                  Dim.1       Dim.2        Dim.3       Dim.4        Dim.5        Dim.6
SEBRLE       0.03854254   5.7118249 1.385418e+00  0.03572215 8.091161e+00   2.21256620
CLAY         0.65814114  13.8541889 6.460097e+00  8.55568792 4.034555e+00  17.48801877
BERNARD      1.86273218   6.1441319 1.349983e-01 19.57827284 4.202070e-02   1.65019840
YURKOV       0.79686310   0.4431309 2.147558e+01  2.57939100 9.859373e-01   0.10878629
ZSIVOCZKY    0.01178829   9.6816398 5.974848e+00  0.05231437 2.405750e-01   8.24561722
McMULLEN     0.01481737   2.3253860 2.496789e+00  9.13531719 1.558646e+01   0.35788945
MARTINEAU    6.03367104   3.9044125 2.830527e+00  0.73858431 3.118936e+01   2.14409841
HERNU        3.76996156   3.2842176 8.583863e-02  4.21505626 9.955149e-02   1.95655942
BARRAS       3.31942012   0.4024544 1.519980e+00  0.27758505 3.388731e-01   0.08376135
NOOL         8.12988880   5.8489726 1.293851e+00 12.83761115 1.257025e+01   2.54127369
BOURGUIGNON 20.53729577   3.7757623 3.534995e-04  2.35877858 1.088816e+00   0.06913582
Sebrle       12.55838616  3.5020697 9.881482e+00  3.47006223 3.889859e-03   0.07047579
Clay         11.59361384  6.2315181 1.341828e+00  0.53250375 2.007648e+00   6.20972751
Karpov       17.46609555  1.5072627 3.614914e+00  0.52101693 3.940874e+00   1.11680500
Macey        3.60207087  10.0732890 3.364879e+00  1.81387486 2.885677e-07   0.40014909
Warners      2.02910262   0.1879390 1.403071e+01  5.51585696 1.018550e-02   3.18673563
Zsivoczky    0.23441891   2.0310492 1.047894e+01  0.18126182 1.028128e+00   0.13322327
Hernu        0.08048777   3.2136178 1.020764e-01  3.82170515 2.946148e+00   1.13110069
Bernard      1.97075488   5.1661961 2.425213e+00  2.94737426 4.581507e+00   1.10655655
Schwarzl     0.53184785   1.0252129 3.800546e+00  4.56119277 5.167449e-01   4.87961053
Pogorelov    0.04843819   1.7533304 3.107757e-01  9.75034337 1.404313e-03  26.11665608
Schoenbeck   0.25864068   3.9969003 3.722687e-02  0.32970059 2.580092e+00   0.26890572
Barras       0.10519467   1.5876667 2.605305e+00  1.84296038 3.767994e+00  14.17432302
                  Dim.7        Dim.8        Dim.9      Dim.10
SEBRLE       0.621426384 2.992045e-02 12.177477305  0.03819185
CLAY         0.651413899 6.035125e+00  0.101262442  3.58568943
BERNARD      2.373652810 7.847747e+00  0.810319793  0.34994507
YURKOV       1.516564073 2.094806e-01  0.336009790  0.51072064
ZSIVOCZKY    0.111923276 6.485544e-01  7.664919832  4.32741147
McMULLEN     3.287016354 1.360753e+00  0.312501167  5.51053518
MARTINEAU    1.291109482 1.347216e+00  1.398195851 13.54402896
HERNU        4.604850849 3.705288e+01  0.001071345 10.92781554
NOOL         4.067669683 2.975270e+00  0.375477289  0.33003418
BOURGUIGNON  5.144247534 5.032108e+00  7.744571086  0.12223626
Sebrle       0.001483775 1.481898e-02 20.105546253  1.72063803
Clay         0.952824148 5.340583e+00  4.703566841 13.52708188
Karpov      26.720158115 1.888802e+00  1.043988269  1.68193477
Macey        1.041910483 2.089853e+00  3.798767930  1.60957713
Warners      1.027384225 1.898339e-01  0.910422384  2.08904756
Zsivoczky    0.022889042 4.585705e+00  9.617852173  0.72605208
Hernu        2.821027418 9.687304e-01  0.125399768  1.55234328
Bernard      1.899449022 6.021268e-04  2.188071254  3.66566729
Schwarzl     4.598122119 7.477531e+00  0.001957159  3.25357879
Pogorelov    8.825322559 2.242329e-02  0.477268755  0.04873597
Schoenbeck  10.566272800 1.036933e+00  8.917302863  3.14020004
Barras      12.835417603 2.116763e+00  0.292892746 13.34533825
> res.ind$cos2 # Quality of representation
                  Dim.1       Dim.2        Dim.3       Dim.4        Dim.5        Dim.6
SEBRLE       0.007530179 0.49747323 8.132523e-02 0.001386688 2.689027e-01 0.0443241299
CLAY         0.048701249 0.45701660 1.436281e-01 0.125791741 5.078506e-02 0.1326907339
BERNARD      0.197199804 0.28996555 4.294015e-03 0.411819183 7.567259e-04 0.0179131165
YURKOV       0.096109800 0.02382571 7.782303e-01 0.061812637 2.022798e-02 0.0013453555
ZSIVOCZKY    0.001574385 0.57641944 2.397542e-01 0.001388216 5.465497e-03 0.1129176906
McMULLEN     0.002175437 0.15219499 1.101379e-01 0.266486530 3.892621e-01 0.0053876990
MARTINEAU    0.404013915 0.11654676 5.694575e-02 0.009826320 3.552552e-01 0.0147210347
HERNU        0.399282749 0.15506199 2.731529e-03 0.088699901 1.793538e-03 0.0212478795
BARRAS       0.616241975 0.03330700 8.478249e-02 0.010239088 1.070152e-02 0.0015944528
NOOL         0.489872515 0.15711146 2.342405e-02 0.153694675 1.288433e-01 0.0157010551
BOURGUIGNON  0.859698130 0.07045912 4.446015e-06 0.019618511 7.753120e-03 0.0002967459
Sebrle       0.675380606 0.08395940 1.596674e-01 0.037079012 3.558507e-05 0.0003886276
Clay         0.687592867 0.16475409 2.391051e-02 0.006274965 2.025440e-02 0.0377627839
Karpov       0.783666922 0.03014772 4.873187e-02 0.004644764 3.007790e-02 0.0051379747
Macey        0.363436037 0.45308203 1.020057e-01 0.036362957 4.952707e-09 0.0041397727
Warners      0.255651956 0.01055582 5.311341e-01 0.138081100 2.182965e-04 0.0411689767
Zsivoczky    0.045053176 0.17401353 6.051030e-01 0.006921739 3.361236e-02 0.0026253777
```

```
Hernu        0.024824321 0.44184663 9.459148e-03 0.234196727 1.545686e-01 0.0357707217
Bernard      0.289347476 0.33813318 1.069834e-01 0.085980212 1.144234e-01 0.0166586433
Schwarzl     0.116721435 0.10030142 2.506043e-01 0.198892209 1.929118e-02 0.1098063093
Pogorelov    0.007803472 0.12591966 1.504272e-02 0.312101619 3.848427e-05 0.4314162233
Schoenbeck   0.067070098 0.46204603 2.900467e-03 0.016987442 1.138116e-01 0.0071500829
Barras       0.018972684 0.12765099 1.411800e-01 0.066043061 1.156018e-01 0.2621297474
                    Dim.7        Dim.8        Dim.9       Dim.10
SEBRLE       8.907507e-03 3.890334e-04 8.954067e-02 0.0002206741
CLAY         3.536548e-03 2.972084e-02 2.820119e-04 0.0078471026
BERNARD      1.843634e-02 5.529104e-02 3.228572e-03 0.0010956493
YURKOV       1.341980e-02 1.681440e-03 1.525225e-03 0.0018217256
ZSIVOCZKY    1.096685e-03 5.764478e-03 3.852703e-02 0.0170924251
McMULLEN     3.540616e-02 1.329562e-02 1.726733e-03 0.0239268142
MARTINEAU    6.342774e-03 6.003515e-03 3.523552e-03 0.0268211980
HERNU        3.578167e-02 2.611676e-01 4.270425e-06 0.0342288717
BARRAS       9.126203e-03 9.118662e-02 8.766746e-02 0.0551531863
NOOL         1.798232e-02 1.193105e-02 8.514912e-04 0.0005881295
BOURGUIGNON  1.579887e-02 1.401866e-02 1.220108e-02 0.0001513277
Sebrle       5.854423e-06 5.303795e-05 4.069384e-02 0.0027366539
Clay         4.145976e-03 2.107924e-02 1.049876e-02 0.0237264222
Karpov       8.795817e-02 5.639959e-03 1.762907e-03 0.0022318265
Macey        7.712721e-03 1.403282e-02 1.442502e-02 0.0048028954
Warners      9.496848e-03 1.591742e-03 4.317040e-03 0.0077841113
Zsivoczky    3.227467e-04 5.865332e-02 6.956790e-02 0.0041268259
Hernu        6.383462e-02 1.988402e-02 1.455601e-03 0.0141595965
Bernard      2.046050e-02 5.883405e-06 1.209056e-02 0.0159167991
Schwarzl     7.403638e-02 1.092132e-01 1.616543e-05 0.0211173850
Pogorelov    1.043115e-01 2.404103e-04 2.893750e-03 0.0002322016
Schoenbeck   2.010275e-01 1.789520e-02 8.702893e-02 0.0240826922
Barras       1.698426e-01 2.540745e-02 1.988116e-03 0.0711836486
> res.var$contrib # Contributions to the PCs
                  Dim.1      Dim.2      Dim.3       Dim.4     Dim.5        Dim.6
X100m        1.754429e+01  1.7505098  7.3386590  0.13755240  5.389252  0.295915322
Long.jump    1.529317e+01  4.2904162  2.9300944  1.62485936  7.748815  0.269003613
Shot.put     1.306014e+01  0.3967224 21.6204325  2.01407269  8.824401 13.596858744
High.jump    9.024811e+00 11.7715838  8.7928883  2.54987951 23.115504 19.159607001
X400m        1.193554e+01  4.5799296  6.4876363 22.65090599  1.539012  0.574509906
X110m.hurdle 1.415754e+01  0.0332933 16.2612611  0.03483735  7.166193  0.001638634
Discus       1.339309e+01  0.1341398  2.5147385 19.04132022 23.755756  9.321746508
Pole.vault   1.144592e+00 35.4618611  0.7139512 14.02307063  7.005084 25.357622290
Javeline     4.446377e+00  8.1086683 29.4531777 13.42963254  5.577615 31.004964393
X1500m       4.438531e-04 33.4728757  3.8871610 24.49386930  9.878367  0.418133591
                  Dim.7      Dim.8      Dim.9      Dim.10
X100m          2.75705260  3.99520353 59.1740009  1.61756139
Long.jump      7.87159392 57.53322220  1.7146826  0.72414393
Shot.put       0.03230371  0.21618512  1.4712015 38.76768578
High.jump      0.26202607  2.59565787  8.1015517 14.62649091
X400m         27.05274658 19.87344405  4.3489667  0.95730504
X110m.hurdle  45.26163460  0.02537025 16.8579392  0.20028870
Discus         6.73226823  0.57016606  0.1150295 24.42174410
Pole.vault     0.03569883  0.39472201  0.4278065 15.43559151
Javeline       5.89573984  1.01729950  1.0543458  0.01217993
X1500m         4.09893563 13.77872941  6.7344755  3.23700871
>
> res.var$cos2 # Quality of representation
                    Dim.1        Dim.2       Dim.3        Dim.4      Dim.5        Dim.6
X100m        7.235641e-01 0.0321836641 0.090936280 0.0011271597 0.03780845 1.251375e-03
Long.jump    6.307229e-01 0.0788806285 0.036307981 0.0133147506 0.05436203 1.137570e-03
Shot.put     5.386279e-01 0.0072938636 0.267907488 0.0165041211 0.06190783 5.749878e-02
High.jump    3.722025e-01 0.2164242070 0.108956221 0.0208947375 0.16216747 8.102269e-02
X400m        4.922473e-01 0.0842034209 0.080390914 0.1856106269 0.01079698 2.429504e-03
X110m.hurdle 5.838873e-01 0.0006121077 0.201499837 0.0002854712 0.05027463 6.929502e-06
Discus       5.523596e-01 0.0024662013 0.031161138 0.1560322304 0.16665918 3.942007e-02
Pole.vault   4.720540e-02 0.6519772763 0.008846856 0.1149106765 0.04914437 1.072330e-01
Javeline     1.833781e-01 0.1490803723 0.364966189 0.1100478063 0.03912992 1.311147e-01
X1500m       1.830545e-05 0.6154091638 0.048167378 0.2007126089 0.06930197 1.768215e-03
                    Dim.7        Dim.8        Dim.9       Dim.10
X100m        0.0083423353 1.096563e-02 0.0918480768 1.972956e-03
Long.jump    0.0238179990 1.579114e-01 0.0026614779 8.832459e-04
Shot.put     0.0000977451 5.933633e-04 0.0022835540 4.728535e-02
High.jump    0.0007928428 7.124302e-03 0.0125749811 1.784008e-02
X400m        0.0818566479 5.454664e-02 0.0067503333 1.167635e-03
X110m.hurdle 0.1369534023 6.963371e-05 0.0261663784 2.442942e-04
Discus       0.0203706085 1.564935e-03 0.0001785453 2.978746e-02
Pole.vault   0.0001080181 1.083393e-03 0.0006640282 1.882695e-02
Javeline     0.0178394271 2.792182e-03 0.0016365234 1.485599e-05
X1500m       0.0124026272 3.781848e-02 0.0104530472 3.948213e-03
>
> # Results for individuals
> res.ind <- get_pca_ind(res.pca)
> res.ind$coord # Coordinates
```

```
                  Dim.1      Dim.2       Dim.3       Dim.4         Dim.5       Dim.6
SEBRLE        0.1912074  1.5541282 -0.62836882  0.08205241  1.1426139415  0.46389755
CLAY          0.7901217  2.4204156  1.35688701  1.26984296 -0.8068483724 -1.30420016
BERNARD      -1.3292592  1.6118687 -0.19614996 -1.92092203  0.0823428202  0.40062867
YURKOV       -0.8694134 -0.4328779 -2.47398223  0.69723814  0.3988584116 -0.10286344
ZSIVOCZKY    -0.1057450 -2.0233632  1.30493117 -0.09929630 -0.1970241089 -0.89554111
McMULLEN      0.1185550 -0.9916237  0.84355824  1.31215266  1.5858708644 -0.18657283
MARTINEAU    -2.3923532 -1.2849234 -0.89816842  0.37309771 -2.2433515889  0.45666350
HERNU        -1.8910497  1.1784614 -0.15641037  0.89130068 -0.1267412520 -0.43623496
BARRAS       -1.7744575 -0.4125321  0.65817750  0.22872866 -0.2338366980 -0.09026010
NOOL         -2.7770058 -1.5726757  0.60724821 -1.55548081  1.4241839810 -0.49716399
BOURGUIGNON  -4.4137335  1.2635770 -0.01003734  0.66675478  0.4191518468  0.08200220
Sebrle        3.4514485  1.2169193 -1.67816711 -0.80870696 -0.0250530746  0.08279306
Clay          3.3162243  1.6232908 -0.61840443 -0.31679906  0.5691645854 -0.77715960
Karpov        4.0703560 -0.7983510  1.01501662  0.31336354 -0.7974259553  0.32958134
Macey         1.8484623 -2.0638828 -0.97928455  0.58469073 -0.0002157834  0.19728082
Warners       1.3873514  0.2819083  1.99969621 -1.01959817 -0.0405401497  0.55673300
Zsivoczky     0.4715533 -0.9267436 -1.72815525 -0.18483138  0.4073029909  0.11383190
Hernu         0.2763118 -1.1657260  0.17056375 -0.84869401 -0.6894795441  0.33168404
Bernard       1.3672590 -1.4780354  0.83137913  0.74531557  0.8598016482  0.32806564
Schwarzl     -0.7102777  0.6584251  1.04075176 -0.92717510 -0.2887568007  0.68891640
Pogorelov    -0.2143524  0.8610557  0.29761010  1.35560294 -0.0150531057  1.59379599
Schoenbeck   -0.4953166  1.3000530  0.10300360 -0.24927712 -0.6452257128 -0.16172381
Barras       -0.3158867 -0.8193681 -0.86169481 -0.58935985 -0.7797389436 -1.17415412
                  Dim.7       Dim.8       Dim.9      Dim.10
SEBRLE       -0.20796012  0.043460568 -0.659344137  0.03273238
CLAY         -0.21291866  0.617240611 -0.060125359 -0.31716015
BERNARD      -0.40643754  0.703856040  0.170083313 -0.09908142
YURKOV       -0.32487448  0.114996135 -0.109524039 -0.11969720
ZSIVOCZKY     0.08825624 -0.202341299 -0.523103099 -0.34842265
McMULLEN      0.47828432  0.293089967 -0.105623196 -0.39317797
MARTINEAU    -0.29975522 -0.291628488 -0.223417655 -0.61640509
HERNU        -0.56609980 -1.529404317  0.006184409  0.55368016
BARRAS        0.21594095  0.682583078 -0.669282042  0.53085420
NOOL         -0.53205687 -0.433385655 -0.115777808 -0.09622142
BOURGUIGNON  -0.59833739  0.563619921  0.525814030  0.05855882
Sebrle        0.01016177 -0.030585843 -0.847210682  0.21970353
Clay          0.25750851 -0.580638301  0.409776590 -0.61601933
Karpov       -1.36365568  0.345306381  0.193055107  0.21721852
Macey        -0.26927772 -0.363219506  0.368260269  0.21249474
Warners      -0.26739400 -0.109470797  0.180283071  0.24208420
Zsivoczky     0.03991159  0.538039776  0.585966156 -0.14271715
Hernu         0.44308686  0.247293566  0.066908586 -0.20868256
Bernard       0.36357920  0.006165316  0.279488675  0.32067773
Schwarzl      0.56568604 -0.687053339 -0.008358849 -0.30211546
Pogorelov     0.78370119 -0.037623661 -0.130531397 -0.03697576
Schoenbeck    0.85752368 -0.255850722  0.564222295  0.29680481
Barras        0.94512710  0.365550568  0.102255763  0.61186706
>
> res.ind$contrib # Contributions to the PCs
                  Dim.1      Dim.2       Dim.3       Dim.4       Dim.5       Dim.6
SEBRLE        0.03854254  5.7118249 1.385418e+00  0.03572215 8.091161e+00  2.21256620
CLAY          0.65814114 13.8541889 6.460097e+00  8.55568792 4.034555e+00 17.48801877
BERNARD       1.86273218  6.1441319 1.349983e-01 19.57827284 4.202070e-02  1.65019840
YURKOV        0.79686310  0.4431309 2.147558e+01  2.57939100 9.859373e-01  0.10878629
ZSIVOCZKY     0.01178829  9.6816398 5.974848e+00  0.05231437 2.405750e-01  8.24561722
McMULLEN      0.01481737  2.3253860 2.496789e+00  9.13531719 1.558646e+01  0.35788945
MARTINEAU     6.03367104  3.9044125 2.830527e+00  0.73858431 3.118936e+01  2.14409841
HERNU         3.76996156  3.2842176 8.583863e-02  4.21505626 9.955149e-02  1.95655942
BARRAS        3.31942012  0.4024544 1.519980e+00  0.27758505 3.388731e-01  0.08376135
NOOL          8.12988880  5.8489726 1.293851e+00 12.83761115 1.257025e+01  2.54127369
BOURGUIGNON  20.53729577  3.7757623 3.534995e-04  2.35877858 1.088816e+00  0.06913582
Sebrle       12.55838616  3.5020697 9.881482e+00  3.47006223 3.889859e-03  0.07047579
Clay         11.59361384  6.2315181 1.341828e+00  0.53250375 2.007648e+00  6.20972751
Karpov       17.46609555  1.5072627 3.614914e+00  0.52101693 3.940874e+00  1.11680500
Macey         3.60207087 10.0732890 3.364879e+00  1.81387486 2.885677e-07  0.40014909
Warners       2.02910262  0.1879390 1.403071e+01  5.51585696 1.018550e-02  3.18673563
Zsivoczky     0.23441891  2.0310492 1.047894e+01  0.18126182 1.028128e+00  0.13322327
Hernu         0.08048777  3.2136178 1.020764e-01  3.82170515 2.946148e+00  1.13110069
Bernard       1.97075488  5.1661961 2.425213e+00  2.94737426 4.581507e+00  1.10655655
Schwarzl      0.53184785  1.0252129 3.800546e+00  4.56119277 5.167449e-01  4.87961053
Pogorelov     0.04843819  1.7533304 3.107757e-01  9.75034337 1.404313e-03 26.11665608
Schoenbeck    0.25864068  3.9969003 3.722687e-02  0.32970059 2.580092e+00  0.26890572
Barras        0.10519467  1.5876667 2.605305e+00  1.84296038 3.767994e+00 14.17432302
```

```
                  Dim.7        Dim.8        Dim.9       Dim.10
SEBRLE       0.621426384 2.992045e-02 12.177477305  0.03819185
CLAY         0.651413899 6.035125e+00  0.101262442  3.58568943
BERNARD      2.373652810 7.847747e+00  0.810319793  0.34994507
YURKOV       1.516564073 2.094806e-01  0.336009790  0.51072064
ZSIVOCZKY    0.111923276 6.485544e-01  7.664919832  4.32741147
McMULLEN     3.287016354 1.360753e+00  0.312501167  5.51053518
MARTINEAU    1.291109482 1.347216e+00  1.398195851 13.54402896
HERNU        4.604850849 3.705288e+01  0.001071345 10.92781554
BARRAS       0.670038259 7.380544e+00 12.547331617 10.04537028
NOOL         4.067669683 2.975270e+00  0.375477289  0.33003418
BOURGUIGNON  5.144247534 5.032108e+00  7.744571086  0.12223626
Sebrle       0.001483775 1.481898e-02 20.105546253  1.72063803
Clay         0.952824148 5.340583e+00  4.703566841 13.52708188
Karpov      26.720158115 1.888802e+00  1.043988269  1.68193477
Macey        1.041910483 2.089853e+00  3.798767930  1.60957713
Warners      1.027384225 1.898339e-01  0.910422384  2.08904756
Zsivoczky    0.022889042 4.585705e+00  9.617852173  0.72605208
Hernu        2.821027418 9.687304e-01  0.125399768  1.55234328
Bernard      1.899449022 6.021268e-04  2.188071254  3.66566729
Schwarzl     4.598122119 7.477531e+00  0.001957159  3.25357879
Pogorelov    8.825322559 2.242329e-02  0.477268755  0.04873597
Schoenbeck  10.566272800 1.036933e+00  8.917302863  3.14020004
Barras      12.835417603 2.116763e+00  0.292892746 13.34533825
>
> res.ind$cos2 # Quality of representation
                  Dim.1       Dim.2        Dim.3       Dim.4        Dim.5        Dim.6
SEBRLE       0.007530179 0.49747323 8.132523e-02 0.001386688 2.689027e-01 0.0443241299
CLAY         0.048701249 0.45701660 1.436281e-01 0.125791741 5.078506e-02 0.1326907339
BERNARD      0.197199804 0.28996555 4.294015e-03 0.411819183 7.567259e-04 0.0179131165
YURKOV       0.096109800 0.02382571 7.782303e-01 0.061812637 2.022798e-02 0.0013453555
ZSIVOCZKY    0.001574385 0.57641944 2.397542e-01 0.001388216 5.465497e-03 0.1129176906
McMULLEN     0.002175437 0.15219499 1.101379e-01 0.266486530 3.892621e-01 0.0053876990
MARTINEAU    0.404013915 0.11654676 5.694575e-02 0.009826320 3.552552e-01 0.0147210347
HERNU        0.399282749 0.15506199 2.731529e-03 0.088699901 1.793538e-03 0.0212478795
BARRAS       0.616241975 0.03330700 8.478249e-02 0.010239088 1.070152e-02 0.0015944528
NOOL         0.489872515 0.15711146 2.342405e-02 0.153694675 1.288433e-01 0.0157010551
BOURGUIGNON  0.859698130 0.07045912 4.446015e-06 0.019618511 7.753120e-03 0.0002967459
Sebrle       0.675380606 0.08395940 1.596674e-01 0.037079012 3.558507e-05 0.0003886276
Clay         0.687592867 0.16475409 2.391051e-02 0.006274965 2.025440e-02 0.0377627839
Karpov       0.783666922 0.03014772 4.873187e-02 0.004644764 3.007790e-02 0.0051379747
Macey        0.363436037 0.45308203 1.020057e-01 0.036362957 4.952707e-09 0.0041397727
Warners      0.255651956 0.01055582 5.311341e-01 0.138081100 2.182965e-04 0.0411689767
Zsivoczky    0.045053176 0.17401353 6.051030e-01 0.006921739 3.361236e-02 0.0026253777
Hernu        0.024824321 0.44184663 9.459148e-03 0.234196727 1.545686e-01 0.0357707217
Bernard      0.289347476 0.33813318 1.069834e-01 0.085980212 1.144234e-01 0.0166586433
Schwarzl     0.116721435 0.10030142 2.506043e-01 0.198892209 1.929118e-02 0.1098063093
Pogorelov    0.007803472 0.12591966 1.504272e-02 0.312101619 3.848427e-05 0.4314162233
Schoenbeck   0.067070098 0.46204603 2.900467e-03 0.016987442 1.138116e-01 0.0071500829
Barras       0.018972684 0.12765099 1.411800e-01 0.066043061 1.156018e-01 0.2621297474
                  Dim.7        Dim.8        Dim.9       Dim.10
SEBRLE       8.907507e-03 3.890334e-04 8.954067e-02 0.0002206741
CLAY         3.536548e-03 2.972084e-02 2.820119e-04 0.0078471026
BERNARD      1.843634e-02 5.529104e-02 3.228572e-03 0.0010956493
YURKOV       1.341980e-02 1.681440e-03 1.525225e-03 0.0018217256
ZSIVOCZKY    1.096685e-03 5.764478e-03 3.852703e-02 0.0170924251
McMULLEN     3.540616e-02 1.329562e-02 1.726733e-03 0.0239268142
MARTINEAU    6.342774e-03 6.003515e-03 3.523552e-03 0.0268211980
HERNU        3.578167e-02 2.611676e-01 4.270425e-06 0.0342288717
BARRAS       9.126203e-03 9.118662e-02 8.766746e-02 0.0551531863
NOOL         1.798232e-02 1.193105e-02 8.514912e-04 0.0005881295
BOURGUIGNON  1.579887e-02 1.401866e-02 1.220108e-02 0.0001513277
Sebrle       5.854423e-06 5.303795e-05 4.069384e-02 0.0027366539
Clay         4.145976e-03 2.107924e-02 1.049876e-02 0.0237264222
Karpov       8.795817e-02 5.639959e-03 1.762907e-03 0.0022318265
Macey        7.712721e-03 1.403282e-02 1.442502e-02 0.0048028954
Warners      9.496848e-03 1.591742e-03 4.317040e-03 0.0077841113
Zsivoczky    3.227467e-04 5.865332e-02 6.956790e-02 0.0041268259
Hernu        6.383462e-02 1.988402e-02 1.455601e-03 0.0141595965
Bernard      2.046050e-02 5.883405e-06 1.209056e-02 0.0159167991
Schwarzl     7.403638e-02 1.092132e-01 1.616543e-05 0.0211173850
Pogorelov    1.043115e-01 2.404103e-04 2.893750e-03 0.0002322016
Schoenbeck   2.010275e-01 1.789520e-02 8.702893e-02 0.0240826922
Barras       1.698426e-01 2.540745e-02 1.988116e-03 0.0711836486
>
```

Hasil Analisis Singkat

Di atas adalah hasil dari tiap variabel jika ingin melihat kontribusi, koordinat, dari masing-masing personal atau individu yang mendominasi dari tiap tiap dimensi. Dimensi 1 nanti merupakan visual vektor. Untuk insightnya yang bisa ditarik dari

informasi di atas untuk pengambilan keputusan dari tiap komponen utama yang diambil
KARPOV memiliki skor PC1 dan PC3 yang tinggi, menunjukkan performa yang baik pada "kecepatan keseluruhan" dan "kekuatan keseluruhan".
WARNERS memiliki skor PC1 dan PC3 yang positif, menunjukkan performa yang baik pada "kecepatan keseluruhan" dan "kekuatan keseluruhan".
Nool memiliki skor PC1 yang negatif dan skor PC4 yang sangat negatif, menunjukkan performa yang kurang baik pada "kecepatan keseluruhan" dan "kemampuan atletik secara keseluruhan".
Drews memiliki skor PC1 dan PC3 yang positif, menunjukkan performa yang baik pada "kecepatan keseluruhan" dan "kekuatan keseluruhan".

6. Prediksi menggunakan PCA

Coding dan Output

```
> # Data for the supplementary individuals
> ind.sup <- decathlon2[24:27, 1:10]
> ind.sup[, 1:6]
        X100m Long.jump Shot.put High.jump X400m X110m.hurdle
KARPOV  11.02      7.30    14.77      2.04 48.37        14.09
WARNERS 11.11      7.60    14.31      1.98 48.68        14.23
Nool    10.80      7.53    14.26      1.88 48.81        14.80
Drews   10.87      7.38    13.07      1.88 48.51        14.01
> ind.sup.coord <- predict(res.pca, newdata = ind.sup)
> ind.sup.coord[, 1:4]
                PC1         PC2       PC3         PC4
KARPOV    0.7772521  0.76237804 1.5971253  1.6863286
WARNERS -0.3779697 -0.11891968 1.7005146 -0.6908084
Nool    -0.5468405  1.93402211 0.4724184 -2.2283706
Drews   -1.0848227  0.01703198 2.9818031 -1.5006207
```

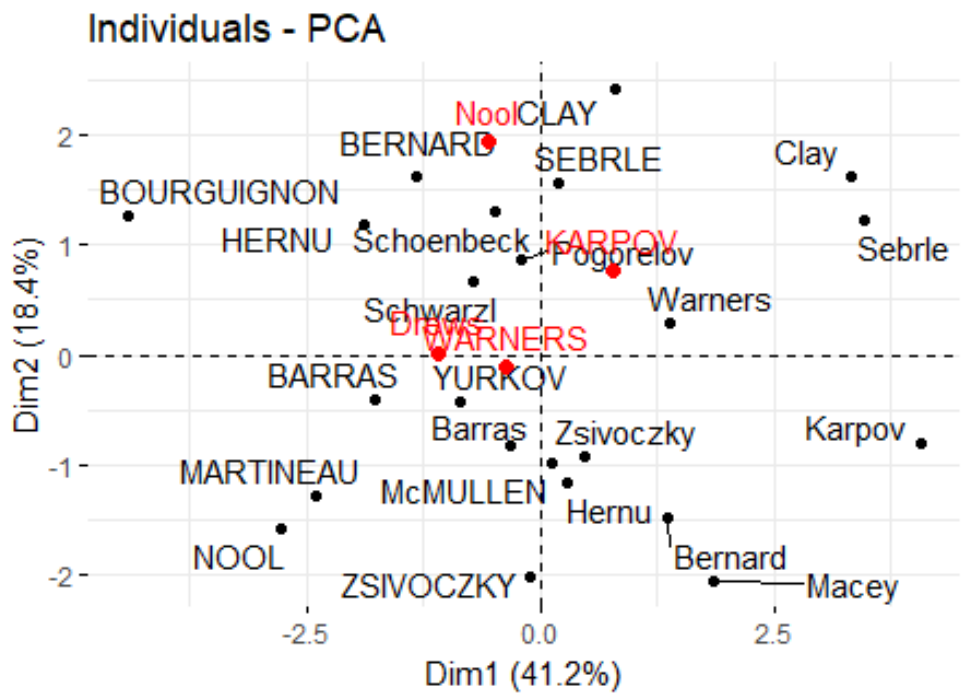
Hasil Analisis Singkat

Kode di tas merupakan kode untuk memprediksi menggunakan PCA. Hasil prediksi menunjukkan bahwa KARPOV dan WARNERS memiliki performa yang lebih baik dibandingkan dengan Nool dan Drews.

7. Individuals PCA

Coding dan Output

```
> # Plot of active individuals
> p <- fviz_pca_ind(res.pca, repel = TRUE)
> # Add supplementary individuals
> fviz_add(p, ind.sup.coord, color ="red")
```



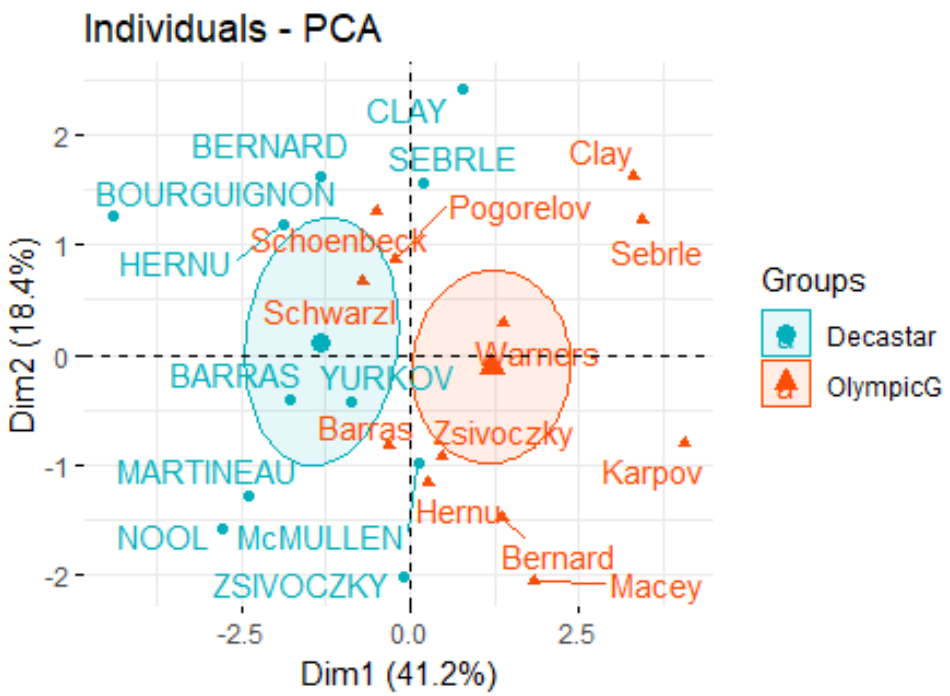
Hasil Analisis Singkat

Diatas adalah hasil grafik untuk individual tiap individu, merupakan visual dari vektor sebelumnya dan merah adalah hasil prediksi dari individu.

8. Variabel Pelengkap Individuals PCA

Coding dan Output

```
> ind.scaled <- scale(ind.sup,
+                     center = res.pca$center,
+                     scale = res.pca$scale)
> # Coordinates of the individividuals
> coord_func <- function(ind, loadings){
+   r <- loadings*ind
+   apply(r, 2, sum)
+ }
> pca.loadings <- res.pca$rotation
> ind.sup.coord <- t(apply(ind.scaled, 1, coord_func, pca.loadings ))
> ind.sup.coord[, 1:4]
               PC1         PC2       PC3        PC4
KARPOV   0.7772521  0.76237804 1.5971253  1.6863286
WARNERS -0.3779697 -0.11891968 1.7005146 -0.6908084
Nool    -0.5468405  1.93402211 0.4724184 -2.2283706
Drews   -1.0848227  0.01703198 2.9818031 -1.5006207
> #VARIABEL PELENGKAP
> groups <- as.factor(decathlon2$Competition[1:23])
> fviz_pca_ind(res.pca,
+              col.ind = groups, # color by groups
+              palette = c("#00AFBB", "#FC4E07"),
+              addEllipses = TRUE, # Concentration ellipses
+              ellipse.type = "confidence",
+              legend.title = "Groups",
+              repel = TRUE
+ )
```



Hasil Analisis Singkat

Kode di atas melakukan Pemusatan (dengan parameter center) dan penskalaan individu (dengan parameter scale).
Tabel menunjukkan skor individu tambahan pada masing-masing komponen utama. Nilai yang lebih tinggi menunjukkan kontribusi yang lebih besar terhadap komponen tersebut. Nilai positif menunjukkan hubungan positif dengan komponen, sedangkan nilai negatif menunjukkan hubungan negatif.
Grafik di atas adalah visual untuk pengelompokkan, disana terdapat pengrupan menjadi 2 yaitu Decastar dan OlympicG ada warna yaitu hijau ke biruan dan orange.

9. Hitung Koordinat Variabel Pengelompokkan

Coding dan Output

```
> #koordinat group
> library(magrittr) # for pipe %>%
> library(dplyr) # everything else
> # 1. Individual coordinates
> res.ind <- get_pca_ind(res.pca)
> # 2. Coordinate of groups
> coord.groups <- res.ind$coord %>%
+   as_data_frame() %>%
+   select(Dim.1, Dim.2) %>%
+   mutate(competition = groups) %>%
+   group_by(competition) %>%
+   summarise(
+     Dim.1 = mean(Dim.1),
+     Dim.2 = mean(Dim.2)
+   )
> coord.groups
# A tibble: 2 × 3
  competition Dim.1  Dim.2
  <fct>       <dbl>  <dbl>
1 Decastar    -1.31  0.119
2 OlympicG     1.20 -0.109
```

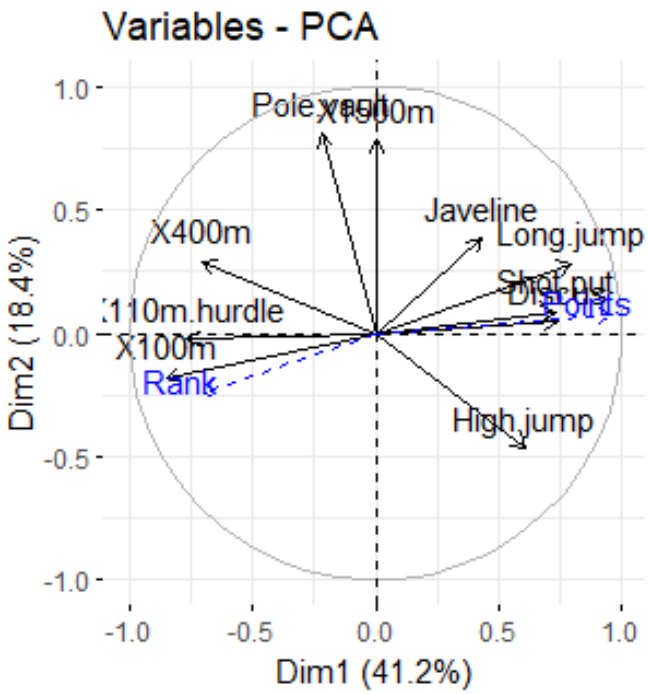
Hasil Analisis Singkat

Berdasarkan output, grup "OlympicG" memiliki centroid di posisi (1.204428, 0.1092046). Ini menunjukkan bahwa rata-rata atlet dalam grup tersebut memiliki skor tinggi pada PCA1 dan skor sedikit di atas rata-rata pada PCA 2.

10. Variable – PCA

Coding dan Output

```
> #variabel kuantitatif
> quanti.sup <- decathlon2[1:23, 11:12, drop = FALSE]
> head(quanti.sup)
          Rank Points
SEBRLE       1   8217
CLAY         2   8122
BERNARD      4   8067
YURKOV       5   8036
ZSIVOCZKY    7   8004
McMULLEN     8   7995
> # Koordinat variabel kuantitatif
> # Predict coordinates and compute cos2
> quanti.coord <- cor(quanti.sup, res.pca$x)
> quanti.cos2 <- quanti.coord^2
> # Graph of variables including supplementary variables
> p <- fviz_pca_var(res.pca)
> fviz_add(p, quanti.coord, color ="blue", geom="arrow")
```



Hasil Analisis Singkat

Kode di atas menampilkan ranking untuk tiap individu. Dan grafik di atas merupakan gabungan dari hasil visualisasi sebelumnya. Untuk warna biru di atas merupakan gambaran arah vektor untuk pengukuran ranking dan point.

11. Menghitung Hasil PCA

Coding dan Output

```
> # Helper function
> #:::::::::::::::::::::::::::::::::::::
> var_coord_func <- function(loadings, comp.sdev){
+   loadings*comp.sdev
+ }
> # Compute Coordinates
> #:::::::::::::::::::::::::::::::::::::::
> loadings <- res.pca$rotation
> sdev <- res.pca$sdev
> var.coord <- t(apply(loadings, 1, var_coord_func, sdev))
> head(var.coord[, 1:4])
                    PC1         PC2        PC3         PC4
X100m        -0.8506257 -0.17939806 -0.3015564  0.03357320
Long.jump     0.7941806  0.28085695  0.1905465 -0.11538956
Shot.put      0.7339127  0.08540412 -0.5175978  0.12846837
High.jump     0.6100840 -0.46521415 -0.3300852  0.14455012
X400m        -0.7016034  0.29017826 -0.2835329  0.43082552
X110m.hurdle -0.7641252 -0.02474081 -0.4488873 -0.01689589
> # Compute Cos2
> #:::::::::::::::::::::::::::::::::::::::
> var.cos2 <- var.coord^2
> head(var.cos2[, 1:4])
                    PC1           PC2        PC3           PC4
X100m        0.7235641 0.0321836641 0.09093628 0.0011271597
Long.jump    0.6307229 0.0788806285 0.03630798 0.0133147506
Shot.put     0.5386279 0.0072938636 0.26790749 0.0165041211
High.jump    0.3722025 0.2164242070 0.10895622 0.0208947375
X400m        0.4922473 0.0842034209 0.08039091 0.1856106269
X110m.hurdle 0.5838873 0.0006121077 0.20149984 0.0002854712
> # Compute contributions
> #:::::::::::::::::::::::::::::::::::::::
> comp.cos2 <- apply(var.cos2, 2, sum)
> contrib <- function(var.cos2, comp.cos2){var.cos2*100/comp.cos2}
> var.contrib <- t(apply(var.cos2,1, contrib, comp.cos2))
> head(var.contrib[, 1:4])
                   PC1        PC2       PC3         PC4
X100m        17.544293  1.7505098  7.338659  0.13755240
Long.jump    15.293168  4.2904162  2.930094  1.62485936
Shot.put     13.060137  0.3967224 21.620432  2.01407269
High.jump     9.024811 11.7715838  8.792888  2.54987951
X400m        11.935544  4.5799296  6.487636 22.65090599
X110m.hurdle 14.157544  0.0332933 16.261261  0.03483735
> # Coordinates of individuals
> #:::::::::::::::::::::::::::::::::
> ind.coord <- res.pca$x
> head(ind.coord[, 1:4])
                PC1        PC2        PC3         PC4
SEBRLE     0.1912074  1.5541282 -0.6283688  0.08205241
CLAY       0.7901217  2.4204156  1.3568870  1.26984296
BERNARD   -1.3292592  1.6118687 -0.1961500 -1.92092203
YURKOV    -0.8694134 -0.4328779 -2.4739822  0.69723814
ZSIVOCZKY -0.1057450 -2.0233632  1.3049312 -0.09929630
McMULLEN   0.1185550 -0.9916237  0.8435582  1.31215266
```

```
> # Cos2 of individuals
> #:::::::::::::::::::::::::::::::::
> # 1. square of the distance between an individual and the
> # PCA center of gravity
> center <- res.pca$center
> scale<- res.pca$scale
> getdistance <- function(ind_row, center, scale){
+   return(sum(((ind_row-center)/scale)^2))
+ }
> d2 <- apply(decathlon2.active,1,getdistance, center, scale)
> # 2. Compute the cos2. The sum of each row is 1
> cos2 <- function(ind.coord, d2){return(ind.coord^2/d2)}
> ind.cos2 <- apply(ind.coord, 2, cos2, d2)
> head(ind.cos2[, 1:4])
                 PC1        PC2         PC3         PC4
SEBRLE     0.007530179 0.49747323 0.081325232 0.001386688
CLAY       0.048701249 0.45701660 0.143628117 0.125791741
BERNARD    0.197199804 0.28996555 0.004294015 0.411819183
YURKOV     0.096109800 0.02382571 0.778230322 0.061812637
ZSIVOCZKY 0.001574385 0.57641944 0.239754152 0.001388216
McMULLEN   0.002175437 0.15219499 0.110137872 0.266486530
> # Contributions of individuals
> #:::::::::::::::::::::::::::::::::
> contrib <- function(ind.coord, comp.sdev, n.ind){
+   100*(1/n.ind)*ind.coord^2/comp.sdev^2
+ }
> ind.contrib <- t(apply(ind.coord, 1, contrib,
+                        res.pca$sdev, nrow(ind.coord)))
> head(ind.contrib[,1:4])
                 PC1         PC2         PC3          PC4
SEBRLE     0.03854254  5.7118249  1.3854184  0.03572215
CLAY       0.65814114 13.8541889  6.4600973  8.55568792
BERNARD    1.86273218  6.1441319  0.1349983 19.57827284
YURKOV     0.79686310  0.4431309 21.4755770  2.57939100
ZSIVOCZKY 0.01178829  9.6816398  5.9748485  0.05231437
McMULLEN   0.01481737  2.3253860  2.4967890  9.13531719
```

Hasil Analisis Singkat

Lalu diatas terdapat perhitungan untuk tiap komponen utama. Dengan pertimbangan pembobotan, didapat kesimpulan baik dari tiap individu dan tiap jenis olahraga untuk mencari komponen utama. Cos2 adalah kualitas representasi variabel dengan pembobotan untuk menghitung kontribusi dalam olahraga dan koordinat dari tiap individu