Multidimensional Analyses to Detect Sport Talent in Athletes with Down Syndrome

Sergio Camiz[1], Willy Rivero[2]
[1] *Dipartimento di Matematica - Sapienza Università di Roma - Italia, Instituto de Matemáticas y Ciencias Afines - IMCA - Lima - Perú*
[2] *Universidad Nacional de Ingeniería de Lima - Perú*

Recibido el 4 de Agosto del 2015; aceptado 18 de Agosto del 2015

In this paper we propose a methodology alternate to the somatotype to classify Down athletes in Peru, since they appear most alike in respect to this classification. A tandem analysis was performed, consisting in Principal Component Analysis of the ten body measures used for the somatotype, and Hierarchical Classification was run on the distances between athletes on the first two principal components through minimum variance clustering. A K-means partitioning was run further to optimize the classification. Three groups of measures resulted and six classes of athletes, whose differences could be checked via statistics. The results, compared to the somatotype revealed more useful to identify a suitable training for the athletes to improve both their health conditions and sport performance.

Keywords Down athletes; Somatotype; Principal component analysis; Hierarchical classification.

1 Introduction

The aim of this work is to study an alternative methodology to detect potential sport talents based on their somatotype, to be used in Peru. The somatotype is based on a set of anthropometric measures(*ISAK*, 2001), according to specific formulas. On the opposite, the Sport Peruvian Institute (*IPD*, Instituto Peruano del Deporte) recommends measures different from those internationally used to define the somatotype. Here, we are interested in checking the ability of the somatotype to estimate the conditions of a specific group of athletes, those affected by Down syndrome, whose somatotype is highly homogeneous. Thus, we propose an exploratory methodology suitable to integrate the somatotype in a case in which the homogeneity of the sampled individuals does not allow to clearly distinguish among them through it.

The proposed methodology, representing the relations within measures, athletes, and between them, allows an interesting interpretation of the groups of athletes, obtained by classifying them according to their measures. In addition, supposing known the performances of (at least some of) the sampled athletes, the method may help in the estimation of their potentials, based on their measures, both physical and psychological performance, and their nutritional condition.

The selection of talents is a very promising field within sport sciences, receiving very favorable opinions more than critics. Nowadays sport tendencies are based on an early specialization of athletes, whose effectiveness in contrast with natural selection may allow a long term quality of results in the chosen specialty (Leyva, 2003). It is known that the detection and selection of sport talents in soccer resulted in a high profitable international business, so that the mayor clubs opened affiliates in different world sides: for Peru, we may quote, e.g., Boca Juniors, River Plate, FC Barcelona, Chelsea, Manchester City, etc.. In Argentina, the Asociación de Fútbol Argentina registers all youngsters nationwide, just to avoid their emigration.

It is known that morphological characters may be relevant indicators to select the most suitable specialty for a youngster, whose physical development may be further favored by the training, e.g. the relevant height may favor a good achievement in basketball. Thus, it is necessary to define, for the sports, directives to select athletes at very early ages, so that they may enter the sport elite after an adequate training. Several authors proved that the study of body composition and proportions and its application in the sport practice allow a very deep knowledge of the athlete and his/her leading towards a specific sport specialty, since to each specialty a different anthropometric profile corresponds (Rodríguez, 1999).

Anthropometric measures provide valid information to diagnose both physical and morphological conditions of people. They allow to plan physical activities related to their requirements and to establish a follow-up to check the produced changes. Both aspects are particularly relevant for sport trainers, since they may use these instruments to improve individual training and development. The identification of biophysical potentials is fundamental for the adequate start of formation process in physical and sport activity of kids. Thus, scientific parameters are suitable to describe the physical development and forecast the neuromotor performance, in order to ease an appropriate training and learning in the early ages. To identify and select sport talents, several mathematical models exist. Among those developed in South-America, we may quote (*IPD*, 2013):

- The Venezuela model, developed by Alexander (1995) on 7,063 youngsters. This study was used to implement programs of physical and health activity, as well as to early detect sport talents.
- The Colombia model, developed by Instituto Colombiano de la Juventud y el Deporte (quoted by *IPD*, 2013) on a sample of 10,258 youngsters, allowed the implementation of a method for the beginning of sport formation based on the Colombian population conditions, as well as detect the skills of future athletes.
- The Argentina model, based on 20,899 11-years old kids, that aimed at knowing the general health state of youngsters, their posture, development, psycho-social condition.

All these models are based on the identification and the analysis of the somatotype of the population under study. These matters are new for Peru, where no methodology has been developed so far to detect sport talents among people, in particular among those affected by some specific disease, not even known models have been adapted to Peruvian reality.

The Down syndrome (Ortega, 2001) is a genetic anomaly, also known as *21 trisomy*: it is due to the disjunction of the pair 21 of chromosomes during meiosis (Patterson, 2009). This presence slightly modifies the development of both individual's body and brain, thus causing both physical and mental problems in the child. According to Federación Española de Instituciones para el Síndrome de Down (*FEISD*), this is the first cause of mental retardation in the population (Lip, 2004). The anomaly is responsible of the characteristic phenotype, it conditions both brain and nervous system's structure and function of affected individuals, their socio-affective needs, and the role that they occupy in the society (*FEISD*, 2000). Albeit the effects of the syndrome may have different intensity, in general Down people development is slower than others. Some of them may be affected by medical problems and present physical and/or mental handicaps. This does not prevent many of them to carry out a happy and productive adult life (Lip, 2004). Both *UNESCO* and *OMS* state that around one out of a thousand living newborn are affected by Down Syndrome and that it results in 90-95% of total handicapped people (Lip, 2004). Presently, Down people are around 5 millions worldwide, around 600,000 in Europe, and 35,727 in Peru, according to 1993 National Census (*INEI*, 1996; Lip, 2004). It is to be noted that Down people improve their physical state with usual sport activity. Moreover, such routine activity may transform attitudes of rejection in kindness and sociability (López and Sánchez, 2014).

This work was developed with the aim to help Down people to improve their quality of life through sport activity. For this task, we started by trying to identify the Carter and Heath (1980) somatotype of athletes affected by Down syndrome, in order to classify them and to identify those that may be suited for some specific sport activity, that is those with greatest skills and sport qualities.

2 The somatotype

The determination of individual *somatotype*, as well as its distribution among a specific population, may be used for different purposes, given the known relations between somatotypes and sport specialties. As well, the follow-up of body evolution of school pupils along time allows a better planning of the sport activities, a better attribution of kids to different specialties, a better selection of most skilled athletes, and a better forecast of the results they may be expected to achieve (Bustamante, 2003). Once based on intuition, body measures were introduced in *XIX* century, starting *somatometry* and its different *biotypological schools*, that distinguished according to the used measures. We remind the following (Bustamante, 2003):

- Italian school (De Giovanni, Viola, and Pende), based on two rules: the body mass, based on the torso, and the form evolution, measured by the limbs. Three types are distinguished: normotype, long-limbed, and short-limbed.
- French school (Sigaud, Chaillon, and Mac Auliffe), based on the morphological development, that distinguishes between center, the source of energy, and periphery, interacting with the environment. Consequently, four constitutional types are recognized: muscular, breathing, cerebral, and digestive.
- German school (Kretschmer), based on the body architecture of mentally affected persons. The relation between morphological types and psychic temperament was argued, distinguishing four types: athletic, astenic, athletic, and pyknic.
- American school (Sheldon) based on a continuous scale. Sheldon (1940, 1954) introduced the indirect measure of the three body primary components (endo- meso- and ectomorphy), aiming at guessing the human character based on body shape, something similar to Jung's (Bustamante, 2003) classification according to the kind of thinking, feeling, and perceiving, and to popular stereotypes of men "delicate and fairfull, fat and merry, tough and rough". Through his photoscopic method, he took systematically 17 measures from three pictures of every individual, that allowed attribute values to the three components.

The Sheldon approach revealed most useful for the analysis of the variation of body shape in human groups, as it takes into account both biological and environmental factors (Bustamante, 2003). It was further modified by Heath, Hooton, and Parnell (Bustamante, 2003) by taking body measures, again modified by Carter (1980) who introduced the direct measurements in place of those taken on photographs. Presently, Carter's method is included in the protocols indicated by the International Society for the Advancement of Kinanthropometry (*ISAK*, 2001). It is applied to persons with or without sport activity, albeit preferably to people with systematic activity and qualified athletes.

The somatotype is currently expressed by a three-dimensional scale and it is computed based on ten measures, officially stated by the International Society for the Advancement of Kinanthropometry (*ISAK*, 2001; Carter, 2002) for the purpose, subdivided as:

1. *sizes*: height and weight;
2. *skinfolds*: they are a double layer of skin and underlying adipose tissue, excluding muscles;
3. *perimeters*: they are the contour of a body segment;
4. *diameters*: they measure the thickness of a body segment.

The ten measures are not invasive and must be taken observing the stated *ISAK* protocols, so that their average error is usually no larger than 2%. They are the following:

1. *Height*
2. *Weight*
3. *Upper arm girth*
4. *Calf girth*
5. *Breadth of the femur*
6. *Breadth of the humerus*
7. *Triceps skinfold*
8. *Subscapular skinfold*
9. *Supraspinale skinfold*
10. *Medial calf skinfold*

The three somatotype components and the relative models to compute them are the following:

- *Endomorphy* (relative adiposity). It indicates predominance of the vegetative system and tendency to obesity. Endomorphic individuals have flabby body with rounded shapes, with low specific weight. The endomorphy measure is given by:

$$Endo = 0.7182 + 0.1451 * F - 0.00068 * F^2 + 0.0000014 * F^3 * \frac{170.18}{T},$$

  where:

  $F = \sum PC$: sum of skinfolds (tricipital, subscapular, and super-iliac),
  T : height

- *Mesomorphy* (muscular-skeletal development). It indicates predominance of mesodermic tissues: bones, muscles, and connective tissue. Mesomorphic individuals in respect to the previous have more muscle and bones mass and higher specific weight. Mesomorphy measure is given by:

$$Meso = 0.858 * dh + 0.601 * df + 0.188 * pbc + 0.161 * ppc - h * 0.131 + 4.5,$$

  with:

  dh : Humerus diameter,
  df : Femur diameter,
  pbc : Corrected arm perimeter, pbc = arm perimeter - tricipital fold/10
  ppc : Corrected calf perimeter, ppc = calf perimeter - calf fold/10.

- *Ectomorphy* (linearity or relative lightness). It indicates predominance of linear and frail forms due to the ectodermic layer origin of the tissues and a highest specific weight. The ectomorphy measure is given according to the following:
  Given $I.P. = \text{height}/(\text{weight})^{1/3}$:
  - if $I.P. \geq 40.75$ then $Ecto = (0.732 * I.P) - 25.58$
  - if $38.25 < I.P. < 40.75$, then $Ecto = (0.463 * I.P) - 17.63$
  - if $I.P. \leq 38.25$, then $Ecto = 0.1$

Each individual is measured and evaluated according to these algorithms. Then orthogonal coordinates are computed as follows:

$$X = Ecto - Endo$$
$$Y = 2 * Meso - (Endo + Ecto)$$

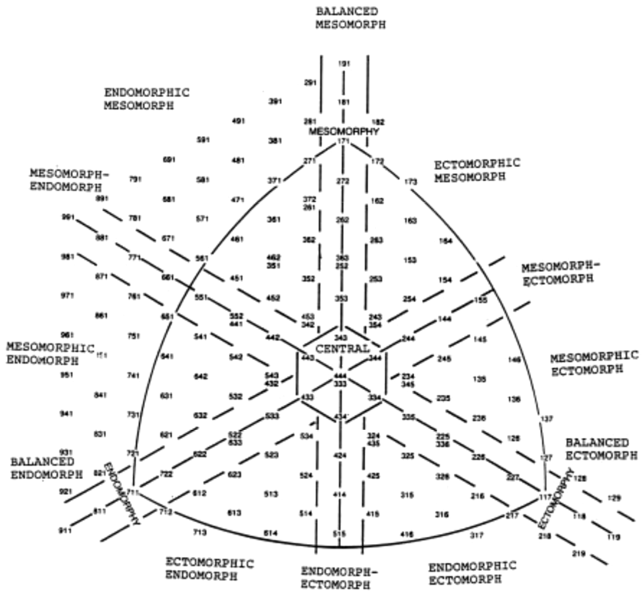

Figura 1: *The somatochart, according to Sheldon (1954). The 13 classes are indicated along the border of the Reauleaux triangle.*

and are plotted on the *somatotype chart* (see Fig. 1). This is a graphic formed by a *Reauleaux triangle*, a triangle with curve edges (Alsina and Nelsen, 2011), adopted by Sheldon (1954). The triangle is partitioned according to three axes crossing in the center and forming an angle of 120° among each other: every axis represents one of the three somatotype components, so that each type is represented by one of the triangle vertexes: the mesomorphy is situated on the upper side, the endomorphy on the left, and the ectomorphy on the right. Indeed, the set of measures taken on individuals contribute to all three components, so that 13 classes result based on them, according to the predominance of one component with respect to the others and to the differences between the latter. In Fig. 1 the dashed lines separate the 13 classes.

For specific references, see Carter and Heath (1980). This way, each individual somatotype may be easily identified according to its position in the somatotype chart.

3 Data and somatotype

In order to get possible the comparison of the proposed method with the somatotype, we took for each sampled athlete the ten measures necessary to compute the somatotype, by adopting the protocols officially stated by the International Society for the Advancement of Kinanthropometry (*ISAK*, 2001; Carter, 2002) for the purpose. Thus, all measures were taken on the right side of the individuals.

The individuals that formed our sample are all affected by Down syndrome, men and women at that time within 12 and 36 years age (limits defined by the Asociación de Olimpiadas Nacionales Especiales del Perú) and were nearly all those present in some institution, say clubs and schools, that participated to the sport competitions organized for the *Olimpiadas Especiales* (Special Olympic Games) held in Lima metropolis in the period January-August 2004. Indeed, people out of the age range or with evident functional of health problems, preventing physical activity, were excluded. A total of 103 individuals was observed during six months, thus obtaining our 103×10 data matrix.

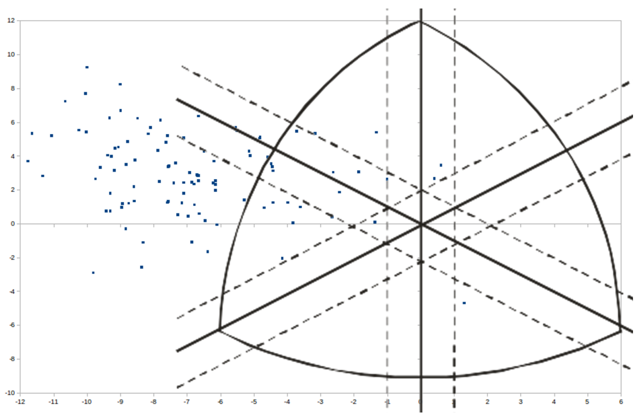

Figura 2: *Somatochart reporting the somatotype of Down athletes. Most athletes are situated in the Endomorph-Mesomorphic sector.*

Through these anthropometric measures, the athletes' somatotype could be estimated and they could be plotted on a somatochart (Figure 2). It is evident from the figure that the Down athletes do not spread the whole somatochart but concentrate in a quite reduced region, namely in its *mesomorphic-endomorphic* side. This pattern reflects the correlation between the two somatochart coordinates (-.26) as a consequence of the high one between the three indexes: negative (-.705 and -.590, respectively) of *Ectomorphy* with both *Endomorphy* and *Mesomorphy* and positive (.576) of the latter with *Endomorphy*. As a result, 82 athletes were attributed an *Endomorph-Mesomorphic* somatotype, 12 an *Endo-Mesomorph*, 5 a *Mesomorph-Endo-morphic*, and only 4 other somatotypes: *Mesomorph, Ecto-Endomorph, Ecto-Endomorphic*, and *Meso-Ectomorphic*. The high concentration of athletes in the *Endomorph-Mesomorphic* somatotype justifies the need to apply some other classification method to distinguish the structure of this particular athletes.

4 Data analysis methods

Unlike the somatochart, that is based on the quoted models that identify the three body components, our purpose is to develop an independent methodology able to distinguish the athletes according to the same measures, but model free. This is particularly interesting in this specific case. Thus, we set in the *exploratory analysis* framework, in which the geometric representation of both the individuals and the observed characters "lets the data speak by themselves" individually (Benzécri et coll., 1982), instead of being studied as misfitting a predefined statistical model. On the contrary, the study of exploratory analysis results may lead, after due confirmation of some hypotheses that deserves being tested, to a more realistic identification of a model able to explain most of the observed data.

Our aim is to partition the observed sample of athletes in homogeneous classes, according to their measures. Thus, we propose the so-called *Tandem analysis* (Arabie and Hubert, 1994), largely adopted in exploratory frameworks in which a partition is sought to better understand and describe the data structure. Tandem analysis is composed by an exploratory factor analysis, aiming at reducing the *noise* contained in the data, followed by a classification of units based on the units coordinates on the components selected among those issued by the factor analysis. Its commented drawback (not always to be able to detect "natural" classes, Arabie and Hubert, 1994) does not apply to our case, since we expect that athletes may form a nearly continuous population, in which tendencies may be identified, but not subpopulations. Thus, the partition may not be natural, in the sense that we do not seek discontinuities in the pattern itself that suggest the existence of isolated natural classes. These exploratory techniques are essentially based on unit's inertia, that is the sum of weighed squared distances among units, that in exploratory framework is considered a measure of information contained in the data.

As factor method, we used *Principal Component Analysis* (*PCA*, Benzécri et coll., 1982; Jolliffe, 2002; Langrand and Pinzón, 2009), based on the eigenanalysis of the correlation matrix between original characters, a technique that produces, unlike the observed characters, uncorrelated principal components. They are linear combinations of the original characters, corresponding to the directions of maximum inertia of the units in the plane spanned by the observed characters. Thus, the first ones summarize most of the data table inertia and one may hope to reduce to the last, least important components, the residual data noise: this way, by dropping them, the noise would not be taken into account. To choose which components to retain, the *brokenstick* method was adopted, consisting to keep those components whose share of the total inertia is larger than the supposed length share of a corresponding piece of a randomly broken stick (Frontier, 1976).

After *PCA*, a classification, based on the Euclidean distances among individuals in the reduced-dimensional space spanned by the principal components is performed through a *Hierarchical Ascendant Classification* (*HAC*, Benzécri et coll., 1982; Gordon, 1999; Langrand and Pinzón, 2009): at each step, those two classes are merged that, by merging, least increase the within class inertia (minimum variance clustering method; Ward, 1963). Thus, a complete set of partitions results, with the within classes inertia acting at each step as hierarchy index. To select the more suitable partition, the one was chosen such that the difference between its index and the following one was much higher than the difference with its previous one. Once chosen the partition, an iterative K-means classification was applied, in order to improve the partition consistency: all units are iteratively aggregated to the class whose centroid is closest and within inertia is recalculated, until no improvement is possible (MacQueen, 1967; Gordon, 1999).

For each built class, statistics are computed, namely means and standard deviations, that were compared to the total ones, through a Student's t statistics. This way, the difference between the means could be checked at a pre-defined threshold value (in our case 5%, Langrand and Pinzón, 2009). This allowed to put in evidence, for each class, those characters whose means were significantly larger or smaller than the pooled ones, to be consider characteristic for the class itself.

5 Results

The *PCA* was done considering only 102 athletes, because one was exceptional in size (height 1.97m, weight 122.60 kg) and as such heavily modified the data structure. He was then added as supplemental unit and as such projected onto the factors and classified with the others.

The *PCA* gave two factors whose eigenvalues are larger than 0.7 and significant according to the Brokenstick test. They summarize over 75% of the total inertia, a relevant amount. In Figure 3 the characters are represented on the circle of correlations on the two factors: all characters are situated on the right side of the circle, thus are positively correlated with the first (horizontal) factor, that may be interpreted as *size*. Then, three groups may be clearly identified: *i)* the four *skinfolds* in the negative side of the second (vertical) factor, opposed to all others, *ii)* the group formed by *Weight, Femur breadth, Upper arm girth,* and *Calf girth* more horizontal, and *iii)* the one formed by *Height* and *Humerus breadth* on the positive side of the second factor. The opposition of the groups *i)* and *iii)* may be interpreted as that between high and slim athletes with short and fat ones. Indeed, the first factor is positively correlated with both *Endo-* and *Mesomorphy* indexes and negatively with the *Ectomorphy* one; as well, it is negatively correlated with the x coordinate of the somatochart and negatively with the y, whereas the x is positively correlated with the second factor. The consistence of the three groups may be ascertained by the stronger inner correlation between the characters within the groups than that between characters of different groups. This is particularly relevant for what concerns in particular the four *skinfolds*.

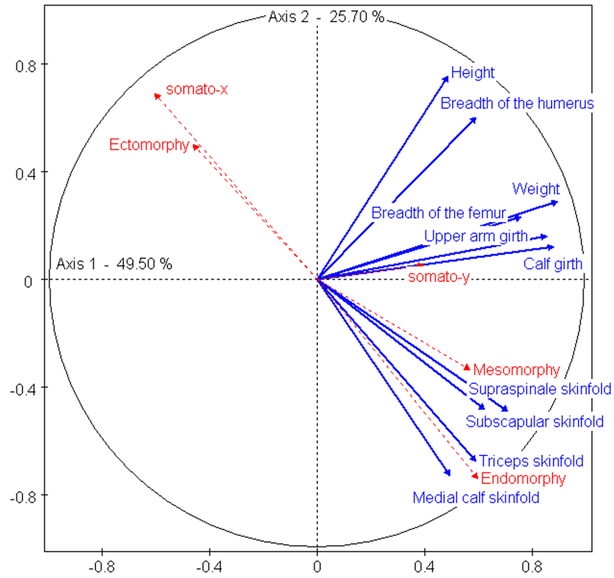

Figura 3: *The ten measures for the somatotype on the circle of correlations on the first two factors of PCA of Down athletes (in blue) together with the indexes of somatotype and the somatochart coordinates, projected as supplemental characters (in red).*

The hierarchical classification procedure suggested a partition in six groups, that were further consolidated by the iterative K-means algorithm: this way, the six groups explain over 78% of the inertia on the first factor plane. In Figure 4 the pattern of the athletes on the *PCA* plane spanned by the first two factors is shown, grouped in the corresponding classes. In Table 1 the means of all measures, as well as of indexes and of somatochart coordinates are reported, in comparison with the total one. The $+$ and $-$ signs close to the means indicate that the class mean is significantly larger or smaller, respectively, than the total mean at the 5% probability level. To ease the comprehension, the classes are arranged according to the descending average size. In the bottom is also reported the contingency table crossing the classes with the attributed somatotypes. Here too $+$ and $-$ signs close to the frequencies indicate that they are significantly larger or smaller, respectively, than the expected.

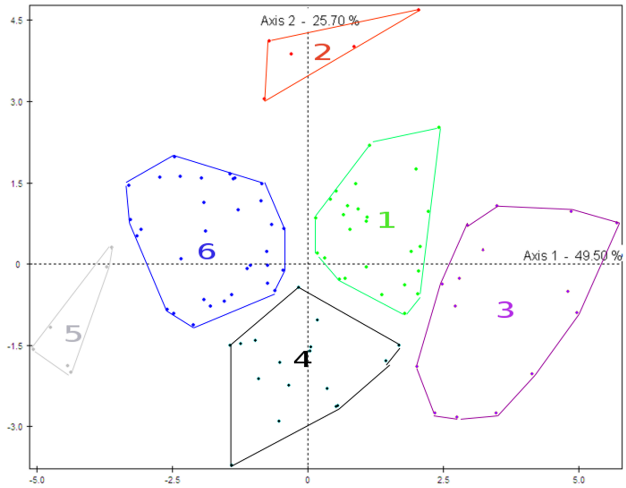

Figura 4: *The cloud of the 103 Down athletes on the plane spanned by the first two factors of PCA. The six colors correspond to the six classes obtained by the classification process.*

The interpretation of the classes is as follows:

Class 2: this group is that whose 5 athletes have the best conditions; indeed, they are significantly the tallest with the highest *breaths* and the lowest *skinfolds*; their *Ectomorphy* index is larger than the mean, while both *Endomorphy* and *Mesomorphy* are smaller. All of them have a distinct somatotype: *Mesomorph, Meso-endomorphic, Endo-mesomorph, Endo-mesomorphic*, and *Meso-ectomorphic*.

Class 1: the class contains 26 athletes characterized by *Weight, Height, Upper arm girth, Breadth of the humerus, Calf girth*, and *Supraspinale skinfold* significantly larger than the mean; thus, they are more robust than the mean. Most athletes in this class are *Endo-mesomorphic*, but 3 are *Endo-mesomorph* and one *Ecto-endomorph*.

Class 3: this group of 16 athletes is characterized by all measures significantly higher than the average, but height; for them both *Endomorphy* and *Mesomorphy* indexes are larger than the mean, while *Ectomorphy* index is smaller. All athletes are *Endo-mesomorphic*, but two are *Endo-mesomorph*.

Class 4: this group of 17 athletes is characterized by the four *skinfolds* larger than the mean; indeed, for them the *Endomorphy* index is significantly larger too. All athletes here are *Endo-mesomorphic*.

Class 6: this group of 33 athletes is characterized by all measures significantly smaller than the mean, but the *Height*; their *Ectomorphy* index is larger, while both *Endomorphy* and *Mesomorphy* indexes are smaller than the mean. The 22 athletes *Endo-mesomorphic* are in this class significantly less than expected, whereas 4 are *Meso-endomorphic*, a value significantly higher than expected, six are *Endo-mesomorph*, and one is *Ecto-endomorphic*.

Class 5: this group gathers the 6 smallest athletes: their measures are all significantly lower than the mean, but *Medial calf skinfold*. All athletes here are *Endo-mesomorphic*.

6 Discussion and Conclusion

Unlike the somatotype, that does not sufficiently distinguish among Down athletes, the tandem analysis proved effective in giving a finer description of the studied athletes, complementary to it. For them, whose predominant somatotype is by far *Endo-mesomorphic* (80%) or *Endo-mesomorph* (11%), the body structure that we could classify is mostly described by two factors, one of *size* and one *body structure* represented by the alternative *lank*, that is high and slim, with *stocky*, that is small and fat. Thus, the resulting classification may be rather interpreted considering these two factors and the *Body Mass Index* (*BMI*) and accordingly some recommendation may be suggested, in order to improve the athlete's conditions. Indeed, on this basis, we may draw the following conclusions:

Class 2: it is composed by the most representative athletes of Peru in international competitions. As a consequence their physical conditions are the best possible, maybe better than many no-Down persons. Indeed, this resulted by a long-lasting training, as we could ascertain through interviews. Their ($BMI = 20.88$) shows their very good conditions. Thus, they are suggested to keep on with their current training activity and motor exercises.

Class 1: it is composed by athletes with larger body measures but non particularly fat, as it may be detected by the non-significant *skinfolds* measures. Their average $BMI = 25.76$ shows little overweight conditions in respect to the previous class, but without particular relevance. They may be suggested to enhance the aerobic training to reduce weight and improve their performance.

Class 3: it is composed by all athletes with all measures larger than average, but *Height*. Their $BMI = 29.69$ gets them as highly overweight, close to the obese people. Thus, they should urgently observe a nutritional program to reduce their overweight joint with an intense aerobic training.

Class 4: it is composed by *slow* athletes, since they have significantly large *skinfolds*, but small size. Their $BMI = 25.33$ shows their good conditions, albeit a little overweight. For them, a

Table 1: *Mean values of the measures, the indexes, and the somatochart coordinates broken down for the six classes and total. The signs + and - indicate that the mean is significantly above or below the pooled mean at the 5% significance level.*

	Class 2	*Class 1*	*Class 3*	*Class 4*	*Class 6*	*Class 5*	*Total*
Number of athletes	5	26	16	17	33	6	103
Height	172.820+	156.581+	153.667	139.847-	147.764	131.117-	149.809
Weight	62.360	63.154+	70.113+	49.535-	48.267-	33.600-	55.314
Upper arm girth	27.480	29.281+	32.340+	25.794-	25.327-	21.433-	27.321
Calf girth	34.100	34.539+	37.293+	32.818	30.955-	26.433-	32.999
Breadth of the femur	9.980+	9.419	10.007+	9.171	8.870-	7.917-	9.225
Breadth of the humerus	7.160+	6.488+	6.587+	5.735-	6.039-	5.500-	6.207
Triceps skinfold	5.500-	16.373	24.133+	19.912+	11.930-	11.083-	15.823
Subscapular skinfold	9.960-	22.750	30.900+	24.500+	15.249-	11.500-	20.525
Supraspinale skinfold	12.400-	27.462+	36.733+	28.559+	16.046-	16.350-	23.923
Medial calf skinfold	5.440-	12.808	20.567+	20.206+	10.318-	10.500	13.879
Endomorphy	3.885-	8.081	9.851+	9.193+	6.308-	6.497	7.654
Mesomorphy	4.467-	5.767	7.334+	6.046	5.010-	4.708-	5.673
Ectomorphy	2.307+	0.723	0.278-	0.374-	1.357+	1.367	0.920
somato-x	-1.920	-7.409	-9.572-	-8.818-	-4.976+	-5.129	-6.772
somato-y	3.497	3.042	4.540+	2.525	2.386	1.553	2.898
Mesomorph	1	0	0	0	0	0	1
Meso-endomorphic	1	0	0	0	4+	0	5
Endo-mesomorph	1	3	2	0	6	0	12
Endo-mesomorphic	1	22	14	17+	22-	6	82
Ecto-endomorph	0	1	0	0	0	0	1
Ecto-endomorphic	0	0	0	0	1	0	1
Meso-ectomorphic	1	0	0	0	0	0	1

local weight training exercise is recommended to increase their muscular mass and to reduce their body fat. A diet is also advisable.

Class 6: it is composed by the athletes with all measures significantly lower than the average. Their $BMI = 22.11$ shows their good conditions, albeit small in size. As they should be recommended to transform their fat into muscles, a protein diet and a power training are advisable.

Class 5: it is composed by the few athletes with least measures: their $BMI = 19.54$ gets them close to the lower limit of the normal conditions. For this reason a power training is suggested, in order to reinforce them and become more competitive.

Acknowledgements

For this work, the first author was supported by the bilateral agreement of Dipartimento di Matematica of Sapienza Università di Roma and Instituto de Matemáticas y Ciencias Afines of Universidad Nacional de Ingeniería of Lima.

References

Alexander, P. (1995). Aptitud Física, características morfológicas y composición corporal pruebas estandarizadas en Venezuela.Caracas, Instituto Nacional de Deportes. *ISBN* 980-240-083-1.

Alsina, C., Nelsen, R.B. (2011). Icons of Mathematics: An Exploration of Twenty Key Images, *Dolciani Mathematical Expositions* 45, Mathematical Association of America.

Arabie, P., Hubert, L. (1994). Cluster analysis in marketing research. In Bagozzi R.J. (Ed.), *Advanced methods of marketing research.* London, Blackwell, pp. 160-189.

Benzécri, J.P. (1982). *L'analyse des données.* Paris, Dunod.

Bustamante, A. (2003). *Estudio del crecimiento somático, somatotipo, composición corporal, edad morfológica y estado nutricional del escolar, entre 5,5 y 11,4 años, del Centro de Experimentación Pedagógica de la UNE.* Lima, Ed. Lerma Gómez *EIRL.*

Carter, JL. (1980). *The Heath-Carter Somatotype Method.* California, San Diego State University.

Carter, J.E.L. (2002). *The Heath-Carter Anthropometric Somatotype-Instruction Manual.* San Diego (California), Department of Exercise and Nutritional Sciences, San Diego State University. http://www.somatotype.org/Heath-CarterManual.pdf

Carter, J.L., Heath, B.H. (1990). *Somatotyping Development and Applications.* Cambridge: Cambridge University Press.

Federación Española de Instituciones para el Síndrome de Down (*FEISD*) (2000). *Bases y sustentos filosófico-teóricos.* Madrid. http://www.sindromedown.net.es

Frontier S. (1976). Étude de la décroissance des valeurs propres dans une analyse en composantes principales: comparaison avec le modèle du bâton brisé. *Journal of Experimental Marine Biology and Ecology*, 25: 67-75.

Gordon, A.D. (1999). *Classification.* London, Chapman and Hall.

Instituto Nacional de Estadísticas e Informática del Perú (2006). *Censos Nacionales 1993.*

Instituto Peruano del Deporte (2013). *Estudio antropométrico de los escolares del nivel secundario en las edades de 12 a 14 años.* Perú. Deposito legal en la Biblioteca Nacional del Perú N. 2112-10163.

ISAK (2001). *International Standards for Anthropometric Assessment.* The International Society for the Advancement of Kinanthropometry. http://www.ceap.br/material/MAT17032011184632.pdf

Jolliffe, I.T. 2002. *Principal Component Analysis.* New York, Springer, Springer Series in Statistics, 2nd ed.

Lagrand, C., Pinzón, L.M. (2009). *Análisis de datos: métodos y ejemplos.* Editorial: Escuela Colombiana de Ingeniería.

Leyva, R. (2003). La selección de talentos deportivos. Criterios para asegurar su eficacia. Buenos Aires. www.efedeportes.com

Lip, A. (2004). Influencia del entrenamiento deportivo en el somatotipo, distribución de adiposidad, índice de masa corporal y razón cintura - cadera de personas con síndrome de Down. Lima, *EUPGUNFV*, Escuela universitaria de postgrado de la Universidad Nacional Federico Villarreal.

López, G.S., Sánchez A.A. (2014). El ejercicio físico como estrategia de salud para la persona con síndrome de Down. *Canal Down 21.* Santander (España), Fundación Iberoamericana Down 21. http://www.down21.org

MacQueen, J.B. (1967). Some Methods for Classification and Analysis of Multivariate Observations. *Proceedings of 5th Berkeley Symposium on Mathematical Statistics and Probability.* Berkley, University of California Press: pp. 281-297.

Ortega,T.L. (2001). *El síndrome de Down - Guia para padre, maestros y médicos.* Editorial Trillas México.

Patterson, D. (2009). Molecular genetic analysis of Down syndrome. *Human Genetics* 126 (1): 195-214.

Rodríguez, J. (1999). *Diccionario enciclopédico de ciencias y técnicas deportivas.* Lima, *UNE*, La Cantuta.

Sheldon, W.H. (1940). *The Varieties of Human Physique (An Introduction to Constitutional Psychology).* New York, Harper and Brothers.

Sheldon, W.H. (1954). *Atlas of Men: A Guide for Somatotyping the Adult Male at All Ages.* New York, Harper.

Ward, J.H.Jr. (1963). Hierarchical Grouping to Optimize an Objective Function. *JASA*, 58(301): 236-244.