Multiple Factor Analysis as a Tool for Studying the Effect of Physical Training on the Autonomic Nervous System

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Abstract

Sports activity may modify cardio-vascular regulation through the Autonomic Nervous System, the results of the studies previously performed in athletes depend on the type of HRV analysis is subjected to, the populations studied and the physical training period. The drawback of these studies comes from an analysis parameter by parameter whereas the problem is inherently multifactorial. A method based on multiple factorial analysis is proposed in this study. Multivariate analysis results confirmed the existence of differences in the ANS in athletes depending on the training period and the sport discipline. Multiple Factorial Analysis provides a very powerful tool allowing the confrontation of² whole information, which is more rich than an examination parameter by parameter to assess autonomic nervous system.

1. Introduction

The regulation of heart rate by physical training may modify cardio-vascular regulation through the Autonomic Nervous System (ANS).

The content of the training cycles varies during the sports seasons. Schematically, during basic effort, the aerobic metabolism is mainly called in contrast with intensive effort during which the anaerobic metabolism is used. Previous numerous studies with controversial results have been carried out in athletes so as to evaluate the effect of sport discipline and the training on Heart Rate Variability (HRV)[1,2,3,4].

In the present work, an original protocol coupled with an in-depth statistical analysis has been drawn in order to assess the possible existence of modifications in the ANS in sportsmen depending both on the training period and the sport discipline. The periods analyzed were basic training and preparation prior competition and the sport discipline were swimming and judo.

A preliminary study based on the analysis parameter by parameter did not show clear differences between population neither between sport season. That's why a method based on Multiple Factorial Analysis (MFA) was studied. It was originally conceived to study a population of individuals represented by several variable's group and to characterize their inter-structure and their intra-structure. It allows to reduce the number of variables, and to detect structures in the relationships between groups of variables and between groups of subjects.

Section 2 presents materials and methods used in this study. Protocols, parameters and Multiple Factor analysis is described succinctly. Section 3 presents and discusses the results.

2. Materials and methods

2.1. Study protocol

Twenty-eight young healthy subjects (12 swimmers, 7 judokas and 9 sedentary subjects; 18men, mean age of all subjects 20 ± 2 years) gave their informed consent to participate to the study. Athletes were instructed to perform 2 stress tests. Test A was held during the basic training (endurance), and test B was held during the training period (tapering) before competition. The sedentary subjects, of course, undertook only test A.

Each test consists of six five-minutes stages performed under the following conditions:

- Rest 1 : free ventilation in supine position,
- Rest 2 : controlled ventilation in supine position,
- Rest 3 : free ventilation in standing position ;

and 3 stages during sub-maximal stress test on a bicycle, at constant heart rate :

- HR=120 bpm,
- HR=160 bpm and
- Recovery at HR=120 bpm.

2.2. Electrocardiographic variables

ECG was acquired with a 1000 Hz sampling rate. The detection of the QRS complexes was conducted using the Grizaldi's algorithm described in [5].

From each RR sequence, the classical temporal parameters, i.e. the mean, the standard deviation (SD) and the square root of the mean squared difference of successive intervals (rMSSD), were then extracted.

Prior to power spectrum density estimation, the RR sequence, which is intrinsically a non-evenly spaced data, was linearly interpolated in order to obtain a series of uniformly sampled data [6]. The retained sampling rate was set to 2 Hz. Using a sliding window of 25 seconds duration, a time varying auto-regressive modeling of the interpolated RR sequence was performed for estimating its power spectrum. The LF and HF bands were defined respectively by [0.04-0.15 Hz] and [0.15-0.4 Hz] as proposed in [6].

For each stage of the protocol, RR intervals were obtained, and 7 classical HRV parameters were determined : RR mean, SD, rMSSD, LF, HF, LF/HF and LF/(HF+LF).

2.3. Multiple Factor Analysis

Multiple Factor Analysis (MFA) deals with data in which a set of individuals is described by several sets of variables. The MFA can be represented in three spaces : subject's space, variable's space and the spaces of groups of variables [7,8].

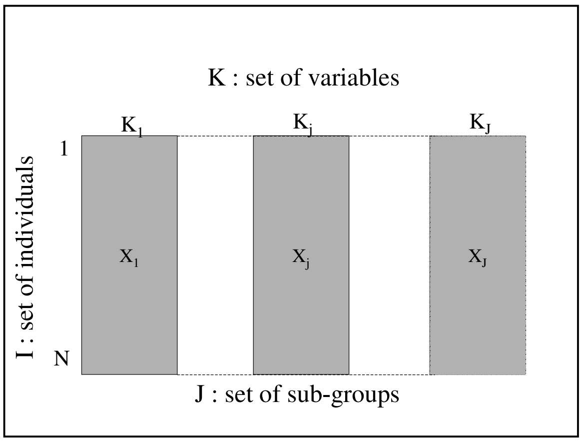

Figure 1. Data representation

We denote X the whole matrix, I the set of individuals, K set of the variables (all together), J the set of sub-groups such that $K = \bigcup_j K_j$ and X_j is the sub-matrix associated with group j (figure 1). More precisely, the symbols I , J , K denote the set and their ordinal at once.

The principle of the MFA is based on the Principal Components Analysis (PCA) of the whole table. This analysis makes possible to balance the role of the groups of variables and provides a representation of the individuals and variables which are interpreted according to the usual rules of PCA.

In a summarized form, the MFA on a series of groups of quantitative nature consists in performing :

1. A PCA on the partial table X_j with the objective to balance the influence between the groups ;
2. A PCA of all the juxtaposed groups where each one of them has been previously weighted by the inverse of the root of the first eigenvalue coming from the partials PCA, such that :

$$X = \left[\frac{1}{\sqrt{\lambda_1^1}} X_1 \ \frac{1}{\sqrt{\lambda_1^2}} X_2 \ \cdots \frac{1}{\sqrt{\lambda_1^J}} X_J \ \right]. \qquad (1)$$

Later, the coordinates of the variables of each group are calculated with respect to the factors and a global representation is obtained.

In our study, the data arise in the following form : I=47 recordings , J = 6 stages, K= 7 variables, as explained in section 2.1 and 2.2.

Finally, the comparisons were carried out using the test of Wilcoxon signed rank (test of equality of medians). The significant threshold was fixed at $p<0.05$.

3. Results

3.1. Eigenvalues

Table 1 presents the decomposition of the inertia of the first four principal components of the AFM according to the six stages. Since the inertia explained by the first four axes being equal to 55.35% of total inertia, we will limit to the examination of these four axes.

Table 1 : inertia's decomposition of the first four components.

	λ_1	λ_2	λ_3	λ_4
REST 1	0.68	0.14	0.23	0.10
REST 2	0.60	0.09	0.07	0.02
REST 3	0.55	0.10	0.19	0.15
HR=120	0.21	0.57	0.10	0.11
HR=160	0.08	0.14	0.56	0.72
Recovery	0.27	0.62	0.16	0.14
Total inertia	2.39	1.66	1.31	1.22
%	20.08	13.95	11.02	10.29
% cumulates	20.08	34.03	45.05	55.35

3.2. Relations between stages and axis's interpretation

In Figure 2, we observed that the strong coordinate of the first three stages indicates that the first factor corresponds to a direction of significant inertia of these stages and under groups of variables. Concretely, this factor is dependent to a great number of variables at rest. The weak coordinates of stages 1, 2, 3 shows that the variables at rest are not very related to the second factor. The coordinates along the second axis show that the second factor is due mainly to the moderate effort: HR=120 and recovery, whereas HR=160 is not dependent neither by the first axis, nor by the second.

An in depth analysis of the contribution of the different groups of variables show that the four components may represent :

- F1 : global variability at rest,
- F2 : parasympathetic activity at sub-maximal effort
- F3 : sympathetic profile during peak exercise.
- F4 : ANS's balance where positive and negative axis represent respectively sympathetic and parasympathetic profile during peak exercise.

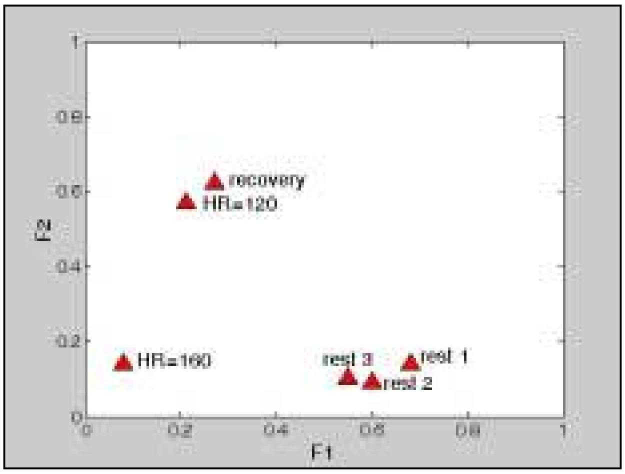

Figure 2. The six stages on first factorial plan.

3.3 Averaged subjects projected

Figure 3 shows the averaged subjects (over the six stages) on first factorial plan. Among sedentary subjects (sed), the first factor is less significant and in general more significant for the swimmers (higher HRV). Judokas do not present a special distribution.

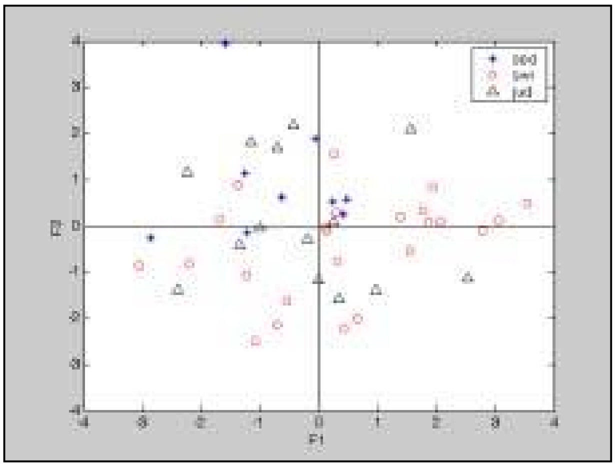

Figure 3. Averaged subject on first factorial plan

The second component (F2) related to the non-maximal effort is more significant among sedentary. We see that coordinates on axes F1 and F2 are respectively negative and positive for the sedentary subjects. Since factor 1 is related to total heart rate variability, it is concluded that the sedentary subjects have less HRV than swimmers at rest ($p<0.05$). Otherwise there's no significant difference between sedentary subjects and judokas.

Figure 4 shows the averaged subject on the second factorial plan (F3 and F4). As it is mentioned above, axis F3 is interpreted as a sympathetic axis during the maximum effort and axis F4 as a sympathovagal balance. It is clear that the sedentary subjects present a more sympathetic profile and for this reason, we find them in the high right corner. Sedentary subjects coordinates on axis F3 are greater than those for swimmers and judokas ($p<0.01$).

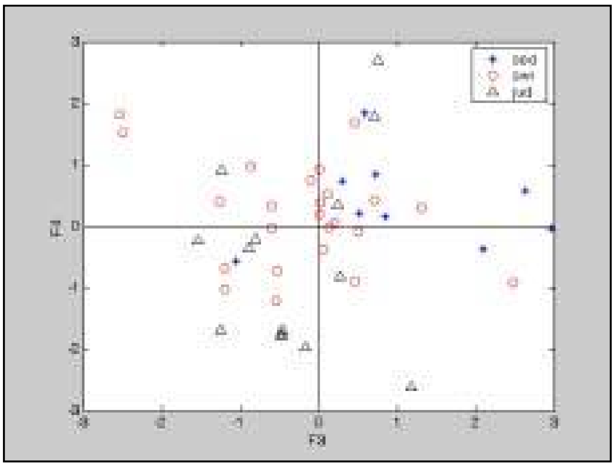

Figure 4. Averaged subject on factorial plan composed by axis 3 and axis 4.

3.4. Differences between physical training periods and between sport disciplines

The study of the positions of the partial individuals makes possible to specify the analysis and to characterize the significant modifications seen with the tapering and the differences between disciplines.

For this purpose, we studied the inertia of the individuals stage by stage on the first four principal components, by making two analyses: i) between physical training periods, where we compared the coordinates of swimmers and judokas during test A and test B, and ii) between sport disciplines: where the comparison was done between populations in each training period (test A and test B).

Differences between physical training periods :

At rest, during test B, the profile of the athletes ($p<0.04$) seems less parasympathetic because it have a smaller variability (coordinate smaller on F1) (Figure 5).

During sub-maximal exercise, only the profile of swimmers ($p<0.04$) is modified with the training. It is observed that their profile seem less parasympathetic (smaller coordinate on F2). We did not observe these differences in judokas' group.

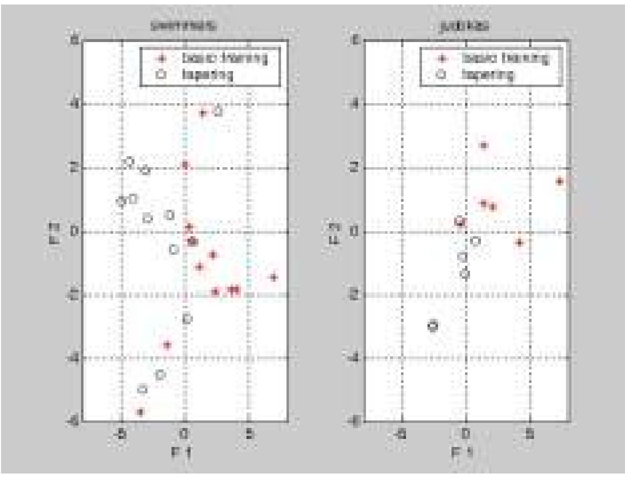

Figure 5. Differences between sports periods at stage 2

Differences between swimmers and judokas:

We observed differences between judokas and swimmers during the basic training period, which disappear during the tapering period. These differences were particularly noted at stages 4 and 6 of test A. This result indicates that swimmers' profile is more parasympathetic and less sympathetic than judokas' profile. More precisely, stages 4 and 6 are very well represented on F2 axis with a contribution of 34.5%. and 37.5 % respectively. Figure 6 shows that the F2 components of the swimmers are greater than judokas and sedentary subjects ($p<0.02$) during test A. This may indicate that swimmers' profile is more parasympathetic than judokas and sedentary one's.

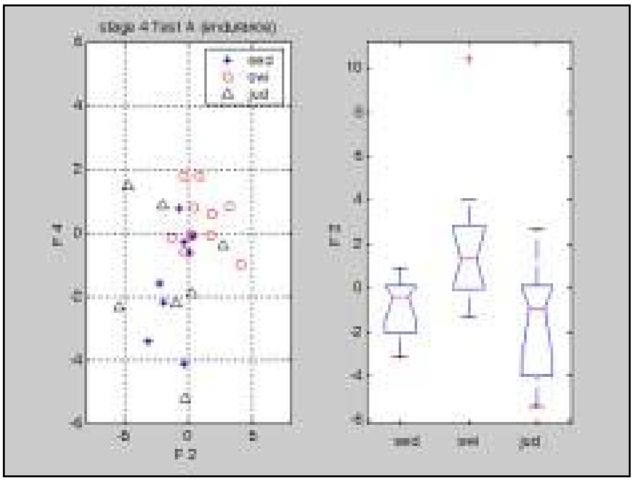

Figure 6. Differences between sports disciplines

4. Discussion

The multiple factorial analysis made it possible to draw the following conclusions :

It is possible to resume 42 variables into 4 synthetic variables which explain more than half of the original variance.

MFA analysis confirmed the existence of differences in the ANS in athletes depending on the training period and the sport discipline :

- aerobics' profile are less sympathetic than anaerobic's one (basic training) ;
- only swimmers's profiles are modified in tapering period at sub-maximal exercise.

These results indicate that endurance training results in the enhanced vagal activities in athletes, which may contribute in part to the resting bradycardia.

It is possible to make a satisfactory classification between sedentary and sporting means with the first three factors, whereas for a given stage these differences are not spontaneously observed.

Therefore, multiple factorial analysis provides a very powerful tool allowing the confrontation of whole information rather than an examination parameter by parameter to assess autonomic nervous activity.

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