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A RELATIONAL DATA BASE FOR QUANTITATIVE BIOMECHANICAL DATA ANALYSIS

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INTRODUCTION

Multifactorial movement analysis is today extensively adopted, both in sports and in clinical applications. In fact the detection of human movement biomechanical variables is today well supported from a technological point of view, and a number of very sophisticated motion analysers are able to provide a complete set of data for three dimensional representation of any complex motor performance. This can lead to a kind of analyses that would have been considered unthinkable only a few years ago because of the large amount of time required by not automatic systems to obtain the data. In fact nowadays it is not so difficult to acquire data in order to study the variations in the biomechanical performances of a set of athletes after a special training period, or to perform comparisons to study the differences between various classes of athletes. Conversely the problem to face is how to manage the enormous quantity of data available for each subject, and how to perform, taking into account the motor pattern morphology, a statistical analysis that could involve for each variable a point to point comparison between different groups of data. The aim of this paper is to describe a special developed integrated software package including a relational data base manager and a signal processing algorithm for the management of quantitative and detailed statistical comparison among different kinematic and dynamic patterns.

METHODOLOGY

As mentioned above the integrated software package has been developed with the aim of allowing a point to point statistical comparison taking into account a *Multifactorial* approach. The *Multifactorial* approach involves the analysis of kinematic, dynamic and electromyographic variables that can be directly recorded (by means of motion analysers, force platforms, electromyographs etc.) or derived (as for instance velocity, acceleration, joint torque, power etc. by means of signal processing algorithm, mathematical body model etc.). The application of the statistical comparison approach can be used in two main different mode: the *Intra-individual* and *Inter-individual* mode. For each mode, two different purpose can be pointed out: the first involves directly sport performances and training, the second involves the field of medicine and in our case that of sport traumathology and sport rehabilitation.

The *Intra-individual* mode is adopted when the matter of interest is to study the single subject variations along time. For instance for the sport purpose a trial set of an athlete can be analysed before and after a special training period in order to monitoring the enhancement of a particular performance. This allow to establish quantitatively the effectiveness of the training with respect to the global results and/or the various variables of interest. The same considerations, of course, are valid for the monitoring of a particular physical therapy when a rehabilitation period after a trauma is necessary.

The *Inter-individual* mode is adopted when the matter of interest is to study a subject characteristics with respect to other subjects or classes of subjects. For instance in this mode the method allows to make comparison between top level athletes belonging to the same speciality in order to study the different motor control strategies adopted by each one. In a wider use adopting this integrated software could be very interesting to build large classes for various specialities. As an example in track and field could be considered a data base in which could be present several classes relative to sprinters, jumpers, long distance runners etc., and this could be the way to study the biomechanical difference between the various classes. After these considerations the translation and the application in the clinical field for a diagnostic point of view becomes very evident. In fact the method allows a clinician to study a subject with a certain trauma with comparison to the class of normal subject and to focus his attention only to those variables which present a statistical significant difference. Moreover once some classes of pathologies have been built the comparison could be extended also in order to classify the particular pathology that affects the subject under study.

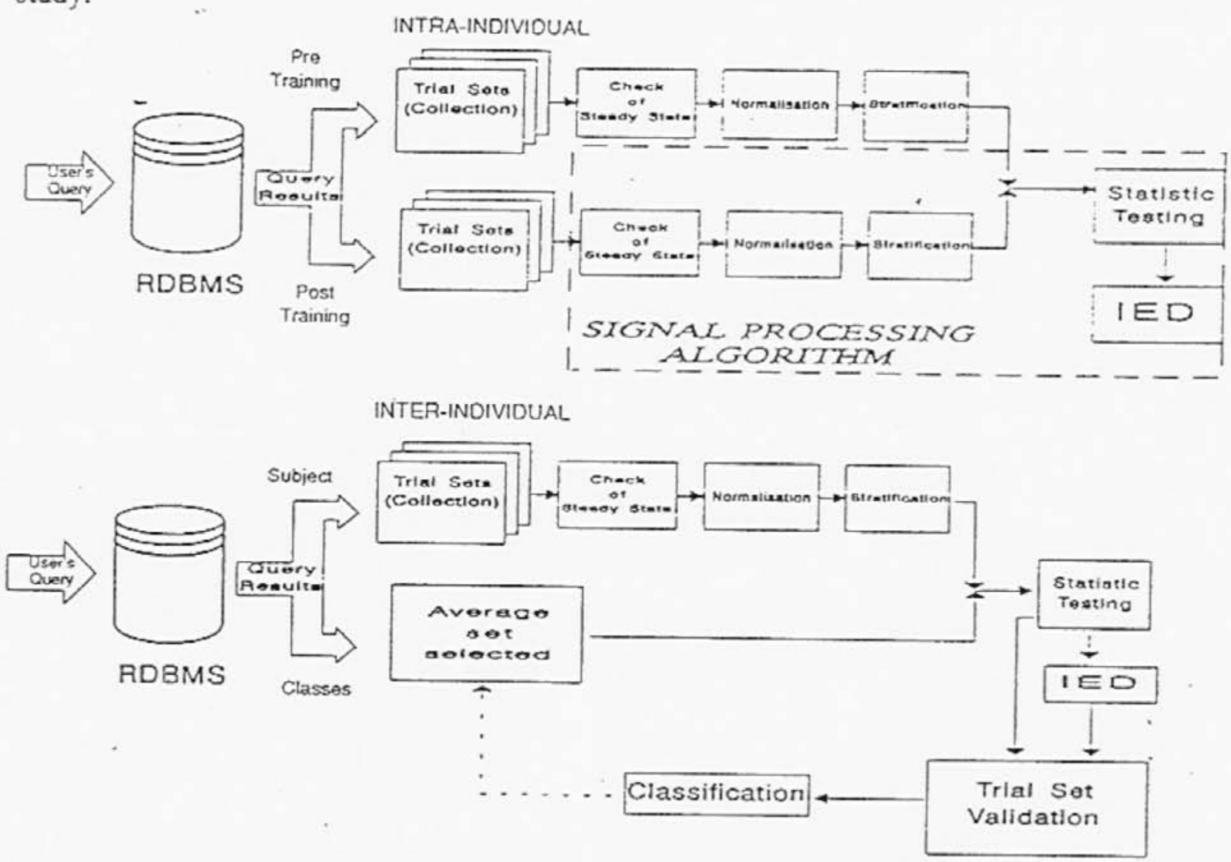

Fig. 1 Data Flow and Processing for the two considered modes

In order to obtain such characteristics the software implementation has been subdivided. from a functional point of view, into two main parts that is the specially developed signal processing algorithm and the Relational Data Base Management System (**RDBMS**) engine. Figure 1 illustrates the global procedure block-scheme describing the various steps the algorithm passes through for both the *Intra-individual* and the *Inter-individual* modes. The dashed box enlighten the signal processing algorithm role, i.e. it is devoted to treat the data and to perform all the computations necessary to allow the statistical comparison, while the **RDBMS** engine is devoted to the data file organisation and management in order to allow the data collection, that is the data arrangement into homogeneous groups containing all those typical series provided by individuals with similar anthropometric features, age, sex kind of performance etc. associated with a given locomotor state. The detailed description of the mathematical procedure has been presented in the previous symposium and can be found in D'Amico et al. 1991, anyway in order to better understand the way in which the global procedure acts the meaning of each step will be herein briefly summarised.

RDBMS engine and Signal Processing

The integrated software package for the **RDBMS** engine and the **Signal Processing** is PC based (386-486 CPU) and it presents the following features: it has been developed in the Microsoft Windows environment release 3.1 with standard (SAA & CUA) graphic interface . the language adopted has been the C++, with Local Area Network capabilities, it allows images compression (J-PEG standard) and it is dBIII - dBIV - Fox Base - Clipper compatible. The **RDBMS** model has been chosen because it permits a high level of flexibility for the kind of queries that the user can define in order to select the various set of trials. The query is the tool given to the user to make an interrogation to the **RDBMS** in order to obtain files of data with a particular characteristic or more characteristics linked with a relationship defined by the user. The RDBMS answers to a query selecting all the files present in the Data Base belonging to that class defined by that query.

Each kind of performance must be characterised by a data input fixed protocol, in order to allow the correct data collection and a consistent statistical comparison. Anyway all the protocols must consider the following steps.

a) **Data Acquisition:** in this section are considered the data acquired (when the *Multifactorial* approach is adopted) by using a system for motion analysis involving kinematic (3D co-ordinates of a number of body landmarks) , dynamic (the three orthogonal components of the ground reaction force generated by a force platform during the stance-phase of a generic sport gesture) and electromyographic measurement giving information about the activities of the muscles contraction and motor-control performance.

b) **Pretreatment:** given the above variables a signal processing is performed in order to obtain other variables of interest such as velocities and acceleration of each body landmarks; angles, angular velocities, angular accelerations between body segments; joint moments etc.

To all these numerical data other kind of information are added such as: antrhopometric measurements (body weight, bone measurements etc.); personal data (age, sex , address etc.); images (picture, x-ray measurements when necessary etc.); kind of performance recorded (sprint, jump, run etc.). This additional data can be subsequently used to define a query (i.e. find all the male subject between 15-20 years old, 65-75 Kg. of body weight, 160-170 cm. tall , performing the long jump).

Taking into account the enormous amount of data involved in each set of trials, it is evident how the **RDBMS** engine plays a fundamental role in order to manage the heterogeneous set of data and to allow the selection of the trial sets of interest for each subject by allowing user's queries.

c) Check of Steady State: after the user's query and the Trial Set collection, a way to guarantee a constant experimental uniformity of the various trials is mandatory to perform a reliable and consistent comparison. The criteria for evaluating such uniformity depend in general on the movement to be analysed. A Steady State criterion requires that the analysed performance can reasonably be supposed in a range defined as stationary condition (Santambrogio 1989). It is accomplished both on ground reaction forces and on acceleration (of near baricentric body landmark) in the advancing direction.

d)Normalisation: in order to compare data sets relative to different trials, a normalisation both in time and in amplitude is mandatory. A particular attention must be dedicated to this procedures. In fact they could be heavily affected by the filtering technique used, especially on the derivatives. To this aim as described in D'Amico et al. 1991, has been used the *LAMBDA* procedure (D'Amico and Ferrigno 1990), that has demonstrated to be a very accurate and powerful tools.

d) Data stratification and Testing: after having obtained the normalised series the data stratification (i.e. the stratified averaging of the original data) is performed by computing for each i-th element of the series the stratified mean values (μ) and the related standard deviation (σ) (D'Amico et al. 1991). The difference occurring between two typical groups of data can be estimated by applying a two-tailed t-test, at 0.01 and 0.05 level of significance, to each element of the series (Santambrogio 1989). The statistical results are synthetised by a merit parameter named IED (D'Amico et al. 1991)

CONCLUSIONS

To present examples of results is beyond the aim of this paper in which only the method and the software characteristics are presented. The proposed procedure has been developed in order to offer a wide possibilty of use both in sports and in the clinical field as described above. With this procedure we claim the adoption of a point to point comparison for each considered variables, contrarily the purely visual interpretation of the pattern morphology of the biomechanical variables or the statistical analysis of just a limited number of parameters for each variables. It is in fact in our opinion the proper method to provide a complete description of the motor performance and of the differences occurring between either a single subject or groups of subjects.

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