CLUSTER ANALYSIS OF SPEED RUN, BOUNDING RUN AND SKIPPING EXERCISES.

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The purpose of this study is to find analogies and differences among 3 different skills: speed run and two special exercises (bounding run and skipping).
Three correlation patterns have been created, each for one of the 3 skills, every pattern takes origin by multivariate analysis (cluster analysis), using the same 12 variables.
All these variables (spatial, temporal and kinematic) are relative to the Center of Mass (COM).
Eight athletes were analyzed and the system used to get the data was the Vicon Motion System (3D optoelectronics system).
The analysis has shown that only few variables of the 3 patterns are correlated in the same way, these few variables must to be taken into consideration to develop the running performance through these special exercises.

KEY WORDS: speed run, special exercises, 3D analysis, center of mass, cluster analysis.

INTRODUCTION: Special exercises have some biomechanical parameters very similar to the race movement. It is very important for the coach to find special exercises to develop some basic aspects of the run, like the leg push (bounding run) or the movement frequency (skipping). The speed run is the most studied movement in the track and field; there are a lot of researches about the run, but only few of them (Mero,Komi 1994, Ciacci, Merni 2005, Coh M. et al. 2005) regard the special exercises. The special exercises, if well carried out, are very important to improve the performance and to restrict the injuries.

AIM: The purpose of this study is to find analogies and differences among 3 different skills: speed run and two special exercises (bounding run and skipping). The second target is to have a satisfactory comprehension of the biomechanics of the speed run and of the special exercises by means of multivariate analysis. For this reason a hierarchical and not-hierarchical cluster analysis will be used.

METHODS: Eight athletes were analysed: 6 male (181±7 cm hight and 77±8 kg weight) and 2 female (164±3 cm hight, and 57±3 Kg weight) of middle level performance (personal 100m 11.01±0.60 s for men, and 12.15±0.14 for women), each athlete performed nine trials. A Vicon Motion System 460 optoelectronics system with a sampling frequency of 100 Hz and a resolution of 300000 pixel has been used, the system was composed of 6-8 video-cameras. To get the data a marker set of Helen-Hayes model (Davies and others 1991, Tabakin and Vaughn 2000) has been used with 36 markers of 14 mm. Data have been recorded during 3 phases: foot strike, gathering and take off. The COM and the toe coordinates have been evaluated in these phases, as suggested from Skripko 2003, Hunter et al. 2003 and Corn et al. 2003.Two couple of horizontal distances (along the x axis) have been calculated: the distance COM-toe and the space covered from COM, respectively during the contact and the flight phases. Three height differences (along the vertical z axis) concerning the COM have been calculated during these following phases: foot strike, gathering, take off and maximal height during flight. The horizontal COM velocity (along X axis) was analysed at foot strike; instead vertical COM velocity was measured at foot strike and take off. One cycle of movement was considered from foot-strike of the first support to the same of the second one (one step). In table 1 it’s possible to see the variables analysed for each movement and their description.

Tab 1.

VARIABLE	DEFINITION	DESCRIPTION
C-TFS	Com-Toe Foot Strike (cm)	Distance between Com and Toe at foot strike
C-TTO	Com-Toe Take Off (cm)	Distance between Com and Toe at take off
CXSP	COM on X axis at Support Phase(cm)	Distance covered by Com along X axis during all support phase
CXFL	COM on X axis at Flight phase (cm)	Distance covered by Com along X axis during flight phase
ConT	Contact Time (s)	Time of support phase
FliT	Flight time (s)	Time of flight phase
VxFS	Velocity on x axis at Foot Strike (m/s)	Horizontal Velocity of Com at foot strike
VzFS	Velocity on z axis at Foot Strike (m/s)	Vertical Com Velocity of at foot strike
VzTO	Velocity on z axis at Take Off (m/s)	Vertical Com Velocity at take off
ΔFS-GA	Δ Foot Strike-Gathering (cm)	Differences of COM on vertical axis between Foot Strike and Gathering
ΔGA-TO	Δ Gathering-Take Off (cm)	Differences of COM on vertical axis between Gathering and Take Off
ΔTO-MH	Δ Take Off-Max Heigh (cm)	Diff. of COM on vertical axis between Take Off and Maximal High

CLUSTER ANALYSIS:
The clusters analysis are standardized procedures helpful to assemble in subsets (clusters) variables correlated among them, but not with the other ones, belonging to other distinguished clusters. The information got with such classification methods, hierarchical and not, can be defined with better precision and in a less equivocal way, than other methods like the factorial analysis. The non-hierarchical analysis starts from correlation matrix and therefore:

- Underline the higher correlation for every column.
- Find the row with the higher correlation and write the variable name connected with a line to other underlined row values, and then find other rows with correlated variables.
- Characterize other rows, which, if not related with the previous ones, form other clusters.
- Restart from point 2 until the exhaustion of all the variables.

For the hierarchical cluster analysis were used SPSS 14.0 procedure. This was adapted to identify relatively homogeneous groups of variables based on selected characteristics, using an algorithm that starts with each variable in a separate cluster and combines them.

RESULTS: For each variables the Average (AV), the Standard Deviation (DS), the Maximum (MAX) and Minimum (MIN) value have been calculated (Tab. 2):

Tab 2.

VAR	SPEED RUN				SKIP				BOUNDING RUN			
	AV	DS	MAX	MIN	AV	DS	MAX	MIN	AV	DS	MAX	MIN
C-TFS	21,66	6,10	29,13	11,11	4,74	4,12	13,39	0,38	20,78	8,36	34,05	10,06
C-TTO	54,31	6,44	62,39	44,09	15,31	3,88	19,92	9,01	51,65	10,62	66,64	37,64
CXSP	78,03	9,23	89,60	65,78	19,94	9,05	27,24	0,88	74,98	18,54	95,97	48,98
CXFL	126,72	22,36	155,27	102,55	28,33	8,60	44,35	15,13	152,41	36,69	212,72	103,45
ConT	0,10	0,01	0,11	0,08	0,13	0,01	0,15	0,11	0,14	0,02	0,17	0,12
FliT	0,15	0,02	0,18	0,13	0,16	0,02	0,19	0,14	0,26	0,04	0,34	0,20
VxFS	8,18	0,83	9,82	7,07	1,75	0,37	2,37	1,29	5,28	0,99	6,73	4,09
VzFS	-0,65	0,21	-0,41	-0,99	-0,64	0,17	-0,39	-0,87	-1,24	0,39	-0,77	-1,99
VzTO	0,77	0,10	0,92	0,62	0,55	0,12	0,81	0,41	1,39	0,38	2,10	0,95
ΔFS-GA	1,55	1,18	3,20	0,37	2,37	0,84	3,36	0,98	3,92	2,18	9,09	2,02
ΔGA-TO	3,94	1,37	6,95	2,74	4,00	0,95	5,45	2,80	9,88	4,01	15,70	4,32
ΔTO-MH	3,63	3,08	10,80	1,29	2,20	1,29	5,23	1,34	8,74	3,41	14,80	4,80

In the average data of the horizontal distances (C-TFS, C-TTO, CXSP and CXFL), the speed run is more similar to bounding run than skipping. On the contrary the skipping is more similar to speed run relatively to velocity data, except for the VxFS (these data are very different in all exercises).

Data values concerning the COM movement along the vertical axis (ΔFS-GA, ΔGA-TO, ΔTO-MH) are similar between skipping and speed run, except in ΔGA-TO. Skipping and speed run are similar relatively the flight time, instead the skipping and the bounding run are similar for the contact time.

DISCUSSION: There are 2 cluster in the not hierarchical analysis for the speed run. The first one include 2 variables: VzFS and ΔFS-GA. The correlationship between these variables is very high (0.93).

The second cluster is more articulate than the first: the relationship higher is between C-TTO and FliT (0.80). The flight's variables are grouped on the right side of the cluster; on the contrary, the support's variables are placed on the left side

The hierarchical cluster analysis confirm the same clusters.

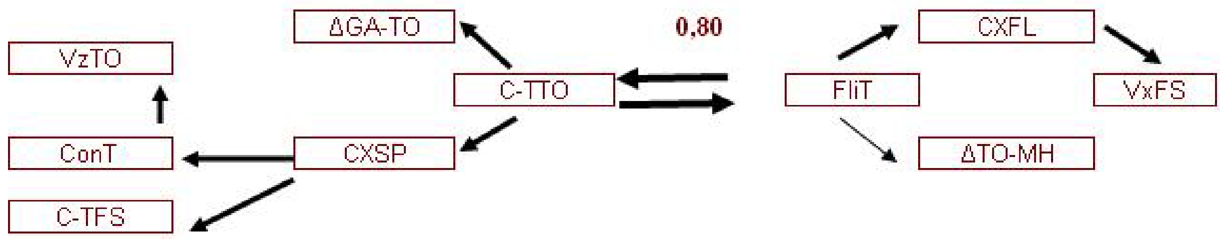

Fig 1.

In bounding run the cluster are 3: in the first one the higher correlation is between CXSP and C-TTO (0.97). Both the cluster analysis show the same results: the first cluster groups the support's variables with also horizontal and vertical velocity at foot strike.

The second cluster assembles the differences of the COM movement along the vertical axis (z) in the three moments of the support phase and the vertical velocity at take off too.

The third cluster groups the variables of the flight phase. In the hierarchical analysis this cluster is connected with the second one (Fig.2).

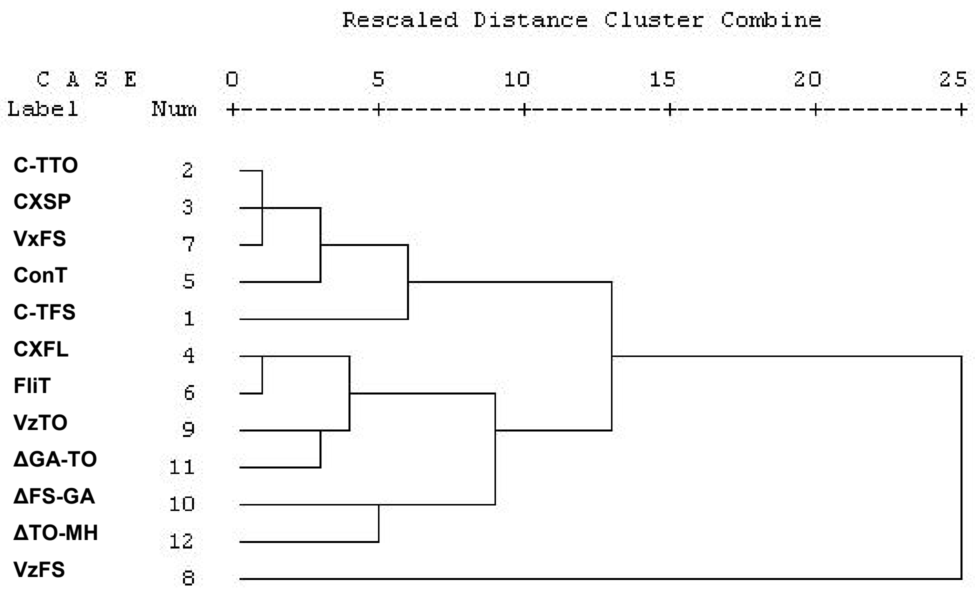

Fig 2.

Skip:
In the skipping exercise there are four clusters with following variables:

- The horizontal variables (space and velocity) during the flight and support phase with vertical COM displacement during push off.
- Vertical velocity at foot strike and vertical COM movement at gathering time. This cluster is the same of the one found firstly relatively the speed run.
- The flight's variables (time and high) with vertical velocity at take off. In hierarchical analysis, this cluster is connected with the number one.
- Contact time and distance COM-TOE at take off.

CONCLUSIONS: The descriptive statistics shows some variables with similar average values, in the speed run and in the bounding run (spatial horizontal variables).
The skipping instead has analogy with the spatial vertical variables of running.
The very different values in the 3 skills are: contact and flight times and horizontal speed.
The cluster analysis shows some analogies regarding the variable relationships of speed run and skipping. The most important cluster includes Vertical COM Velocity at foot Strike (VzFS) and Differences ΔFS-GA. Others interesting relationships are: between FliT and ΔTO-MH and between ΔGA-TO and CXSP. Except these cases, the speed run clusters are different from the skipping clusters.
In the running there is only one cluster with two polarities; the first one with flight variables, the second one with support variables. On the contrary, in the skipping there are three distinct clusters that show different relationships among the variables.
There are different clusters numbers: 3 for bounding run and 2 for running. These clusters show only little analogies; in particular there are few common high correlations; C-TFS with CXSP and FliT with CXFL.
The bounding run and the skipping show a similar relationship only between ConT and C-TTO (0.91 in bounding run, 0.82 in skip exercise).
The analysis has shown that only few variables of the 3 patterns are correlated in the same way, these few variables must to be taken into consideration to develop the running performance through these special exercises.
This study show that these special exercises appear very different to speed run: only few couples of variables show similar correlations.

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