Computer Technology in the Biomechanical Analysis of Bar-Bell Lifting Motion Structures

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INTRODUCTION

An improper selection of muscle-building exercises or a technically poor execution of an exercise frequently leads to an inadvertent loading of the motion system of man, to injuries, to a poorer resulting achievement, or to a deceleration of the expected performance growth, to a disturbed dynamic stereotype and —last but not least— to motivation losses.

In order to be able to cope with the problems outlined above, it was necessary to create a data collection and processing system for speed-power and technical parameters realized on a bar-bell. The information thus obtained allows for assessing a weight-lifter's performance in qualitative and quantitative terms, using a set of pre-defined criteria. Consequently, prerequisites for describing and correcting potential mistakes in an executed exercise, as well as for its optimization and economization, are provided.

MATERIAL AND METHOD

An automated system /AS/ collecting and processing data on the vertical movement of a bar-bell has been built. It makes use of a spidographic device scanning the bar-bell vertical travel and velocity, and processes the data using an on-line system implementd on a SHARP MZ-80 computer, see Fig. 1.

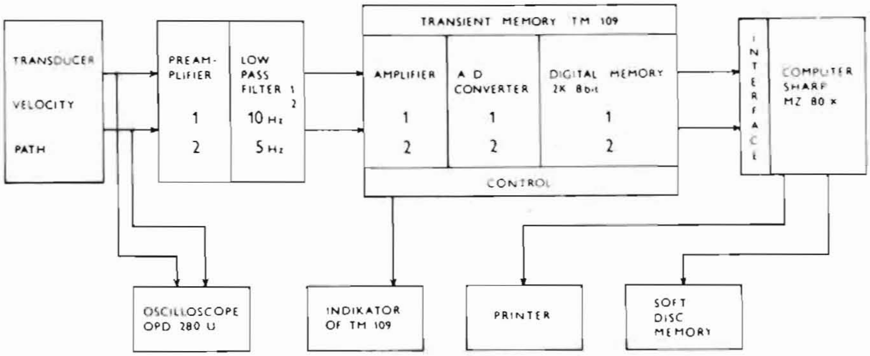

Fig. 1. Schema of AS collecting and processing data.

The computer software ensures a fast and simple attendance based on a dialogue taking place directly in real training conditions. Every attempt is processed independently and the related results printed into a table. Summarized results are available within 30 to 60 seconds after completing an attempt. In the end of the measurement cycle, the results are presented in a graphic form.

A polynomial approximation method /PAM/ is used to analyze data sets obtained through the use of the spidographic recorder or from a motion picture analysis in a detailed way, which uses the following n-th polynom for the data approximation:

$$f(x)=a_0+a_1x+\cdots+a_{nx}{}^n$$

Owing to its being expressed as a polynomial function, the PAM polynomial approximation method allows for:

a) minimizing errors in discrete data sets obtained,
b) expressing relationships of examined variables in an analytical manner, i.e. continuously,
c) using additional advantageous mathematical operations in the data-processing stage, including a suitable graphic presentation.

The AS system is employed in a clean-and-pass anaysis. Two members of the national weight-lifting team performed four to six valid attempts at 90% of their current capacities in two measurement cycles separated by four weeks. The PAM method is used to process data obtained from a motion picture analysis; a clean-and-pass analysis has been performed on three weight-lifters, each of them having two attempts with a constant weight bar-bell. The analysis concerned both vertical and horizontal motion components. Only valid attempts were used as the input.

Description

For our purposes, the clean-and-pass motion structure was divided into two basic phases:

1. From the start till the moment when the maximum vertical velocity is achieved.
2. From the moment when the weight-lifter goes below the bar-bell /his pelvis is going down/ till the bar-bell is fixed, see Fig. 2.

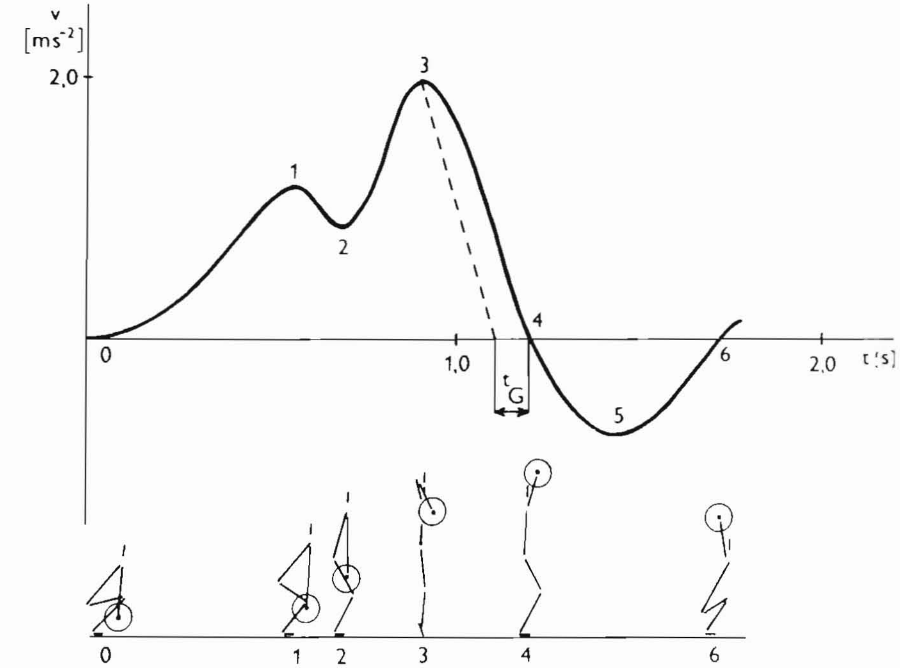

Fig. 2. Vertical velocity of bar-bell and phases of movement of weightlifter.

List of selected parameters of the first phase

s_3– bar-bell vertical travel — pertains to the maximum vertical bar-bell velocity

v_3– bar bell maximum vertical velocity

s_4– maximum vertical bar-bell travel — pertains to zero vertical bar-bell velocity

s_S – jerk-up phase acceleration /ms.$^{-1}$/ — average acceleration which the weight-lifter imparts to the bar-bell, phase 2-3

F_S – jerk-up force /N/ — average force developed by the weight-lifter on the bar-bell, phase 2-3

P_{23} – jerk-up power input /W/ — average power input by the weight-lifter to the bar-bell, phase 2-3

VPI_{03} – vertical performance index, phase 0 to 3.

List of selected parameters of the second phase

a_G – acceleration gain /ms^{-2} — the difference between the acceleration due to gravity and the actual bar-bell acceleration, phase 3-4. It represents the average vertical acceleration achieved by the weight-lifter pushing the bar-bell vertically upward, i.e. at the moment of his getting below the bar-bell, phase 3-4.

F_G – force gain /N/ — the average force defined for phase 3-4 by means of $a_G/F_G = m \cdot a_G/$, where m is the bar-bell weight. It is the force developed by the weight-lifter during the phase of getting below the bar-bell, and used to alleviate the bar-bell.

t_G – time gain /s/ — the difference between the actual time in Point 4 and the theoretical time necessary to cover the maximum travel distance, s_4, if the force, F_G, developed by the weight-lifter during phase 3-4 is zero.

Ch – characteristic of movement of second phase

$$Ch = \frac{t_G}{t_6 - t_3} \cdot 100$$

D – deep of bar-bell /m/ from position 4 to 6

Hypotheses

Hypothesis 1: If, upon examining the second stage of the technical clean-and-pass, some of the selected variables are found to have deteriorated, it is assumed that the technical execution of the first phase should be optimized, within certain individual limits and in a general manner, i.e. in terms of both horizontal and vertical components of the bar-bell motion.

Hypothesis 2: If there is a general deterioration of the technical execution of phase I, i.e. of vertical and horizontal parameters of the bar-bell motion, there will be no deterioration of some selected variables of phase II within certain individual limits.

RESULTS

a) Applying the PAM method on data from a motion picture record, calculations of VPI, HPI and EI were carried out for three weight-lifters, in accordance with Garhammer (1979).

TABLE 1

Test person	Attempt No.	Category	Weight	Height	VPI	HPI	EI
P.Š.	1.	over 110 kg	113 kg	1.825 m	0.95	0.023	0.977
P.Š.	2.	over 110 kg	113 kg	1.825 m	0.94	0.025	0.974
J.K.	8.	over 110 kg	126 kg	1.893 m	0.88	0.013	0.986
J.K.	12.	over 110 kg	126 kg	1.893 m	0.90	0.019	0.979
L.B.	10.	up to 110 kg	105 kg	1.781 m	1.02	0.039	0.963
L.B.	11.	up to 110 kg	105 kg	1.781 m	1.05	0.044	0.959

Index values of Czechoslovak weight-lifters in comparison with American ones:

	CZECHOSLOVAKIA	USA
VPI	0.88-1.05	0.58-1.10
HPI	0.01-0.04	0.01-0.06
EI	0.96-0.99	0.90-0.99

b) During a training period of four weeks, the selected parameters obtained by the AS system with test persons, A.B. and S.J., manifested the following changes (see Table 2).

TABLE 2

Percentage values of average changes of selected parameters of phases I and II within the examined four-week cycle, including intervals of changes and absolute values of change intervals

Test persons	Clean-and-pass phase	I.	II.
A.B.	Average of changes	+0.2%	−50.4%
	Interval of changes	−3.3 up to 4.6%	−42.0 up to −61.5%
	Absolute value of change interval	7.9	19.5
S.J.	Average of changes	−11.8%	+1.4%
	Interval of changes	−9.2 up to −13.6%	−2.1 up to 6.0%
	Absolute value of change interval	4.4	8.1

Note: Owing to their specific character, the parameters v_3, A_S, D have not been included in the table.

CONCLUSION

As far as the test person A.B. is concerned, the performance has improved by +10 kg. There is a significant decrease of the selected parameters of phase II (by as much as −50.4%), while those of phase I remain relatively constant (an increase of +0.2%), see Table 2, Fig. 3.

The performance of the second test person, S.J., has remained on the same level as before. While there is a significant decrease of the first phase parameters (−11.8%), those of the second phase remain relatively constant (an increase of +1.4%). Consequently, it is possible to conclude

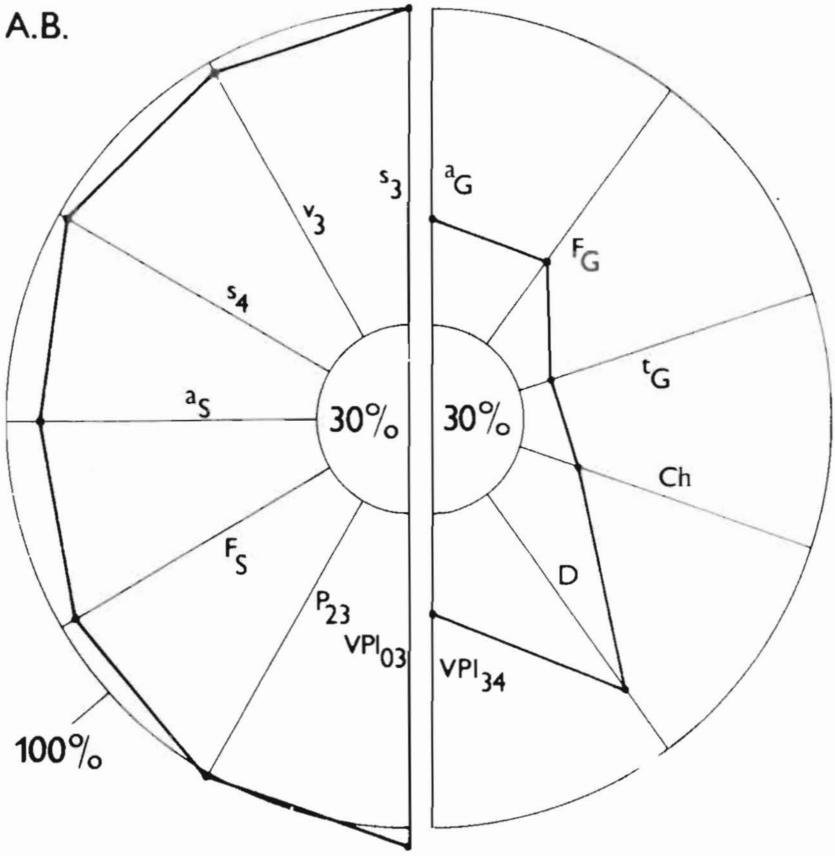

Fig. 3. Graphic presentation of the dynamics of some selected parameters of the technical clean-and-pass within the four-week cycle under examination, test person A.B.

Explanatory notes: Values of parameters at the circle circumference are initially taken for 100%.
Values of parameters connected by a broken line are values obtained after the four-week training cycle.
The left hemisphere shows phase I. parameters.
The right hemisphere shows phase II. parameters.

that the second phase parameters of the second test person, S.J., were at the relatively maximum level during the observations, see Fig. 4.

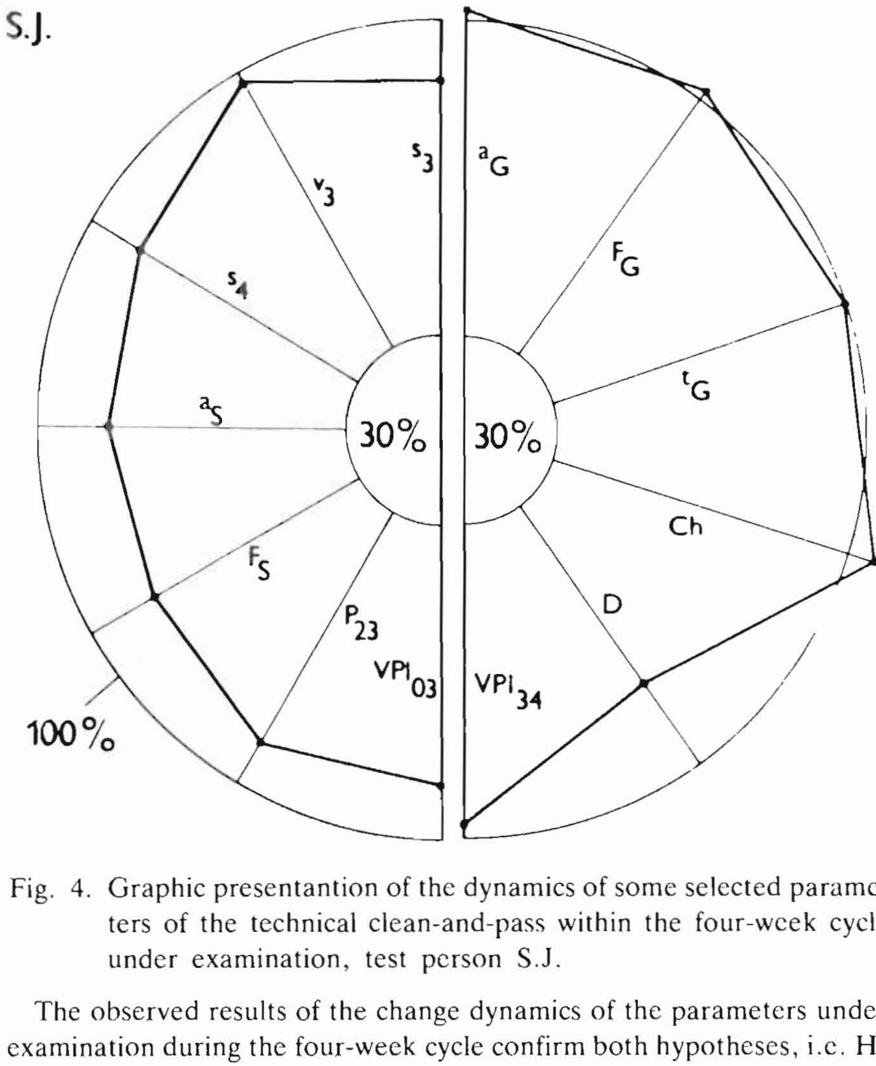

Fig. 4. Graphic presentantion of the dynamics of some selected parameters of the technical clean-and-pass within the four-week cycle under examination, test person S.J.

The observed results of the change dynamics of the parameters under examination during the four-week cycle confirm both hypotheses, i.e. H_1 and H_2.

With the two hypotheses confirmed, it is possible to conclude that the first test person, A.B., has improved both his performance and the clean-and-pass technique within the four-week training cycle under examination. On the other hand, the second test person, S.J., has not only stagnated in his performance, but there has also been a relative deterioration in the clean-and-pass technique.

The present set of criteria and he automated AS system are used both for immediate evaluations of preceding measured attempts and for comparisons of whole training batches. Thus, the training process can be objectively evaluated in quantitative terms and the weight-lifting technique learning process improved. A fast feedback of information is now provided for sportsmen as well as trainers and experts. The results in a tabular form are available within approximately 60 seconds after an attempt is completed, the graphic presentation can be obtained after some 3 to 4 minutes.

Apart from the application described above, the AS system and PAM method are used in a number of biomechanical analyses in many other human sporting activities, such as in a biomechanical analysis of javelin throws, European Championship, Athens 1984, in a ball-kicking technique analysis etc.

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