BIOMECHANICAL CONTROL OF SPORT TECHNIQUE WITH THE APPLICATION OF VIDEO-COMPUTER MODELS

Alexander Arkhipov, Anatoly Laputin, Nickolai Nosko, Vladimir Bobrovnik, R. Launi,
Ukrayinsky Gosudarstvenny Universitet Fizicheskogo Vospitaniya i Sporta, Kiev, Ukraine

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INTRODUCTION: The development of personal computers and video-technique in the 90s gave a new impulse for improving the automation of training process control. By this time, in biomechanics, the wide experiences in the analysis of human movements in sport have been yet cumulated. However, its large scale usage, based mainly on the traditional cinematography & photography technologies of movements registration, has been slowed by a complexity and capacity of digital operations during kinograms processing in practice. So a well-turned conjunction of video-technology for movement registration and very effective technology for results processing based on biomechanical analysis algorithms, already tested in multiple experiments, have had impressive results.

This direction of sport training was mostly expanded in civilized states where just from the beginning of the 80s the technological base was exchanged in the athlete's movement measuring sphere to «on-line» (real time) mode.

The advanced biomechanical achievements employment in sport practice resulted in a research technology exchange that was a major computerization at all levels, designing and manufacturing the highly productive and inexpensive micro-computers. That is why a more effective measuring technology and complicated precise measuring equipment which is available to register any necessary parameter, are important characteristics of this exchanging. Among the advanced technologies, the remote and non-contact researching technologies are in first place. The above statements identify three basic directions of measuring system development in sport biomechanics today:

- high-speed video-cameras connected with video-film converter for personal computer;
- stationary mounted dynamographic platforms operated in natural conditions of sport training and providing data output through analog-to-digital converters with personal computers;
- automated videogram processing systems including personal computers.

In of three cases, data fixation & processing technology while personal computer is used in «real time» mode, gives a possibility to operate with large data dimensions. At that, the accent of the research is directed to the studying of the technique model for highly skilled athletes. It became the ground for mobile laboratories with compact measuring systems which gave a possibility to control the athlete's motor action during the training process under natural conditions and to give close solutions to sport technique simulation problems.

The main goal of the given research is to solve the problem of how to improve training process quality by means of skill technique improvement with elite athletes on the base of application of group and individual biomechanical models of their technique (Augulo & Dapena 1992, Haliand, Tamp & Soosar, 1988). The following main tasks were solved:

- process design for biomechanical criteria control in the technique of studied actions;
- identification of quantitative (kinematical) technique model for highly skilled athletes;
- forecasting different variants and possibilities for element correction of studied motor action technique on the basis of video-computer animation with designed models.

METHODS AND PROCEDURES: A video-computer set, where a standard video-television unit is connected with a personal computer and analogue-digital transformation video-adapters 'Aver' and 'Aver Pro 2000', was used to carry out a quantitative biomechanical analysis in this work. Data reading out tested object was performed in a semi-automatic regime with a video-segment having been demonstrated in a 'still' position on a monitor. A 14-segment model was used (N.A. Bernshtein, 1947) of human skeleton-muscle structure. Computer-video-analyzer software allowed us to calculate kinematics parameters for the movement of any memory point located in the computer, both in movable somatic and any inertial coordinate system. Registration of coordinates of points of the moving object was done by use of 'mouse' type transformer when the video tape was in a 'still' position. As a model of a moving person we used branched kinematics chains, whose elements correspond to the major segments of the human body, and the main points of the coordinates - to the main joints. Computer software allowed us to analyze all kinematics parameters of any point (located in memory) both in the somatic and inertial coordinate system. Registration of the positions of a moving body was done by video-cameras JVC GF-500 with the standard recording speed for the VHS system. All metrological demands, allowing to minimize systematic and occasional mistakes were taken in to consideration. For minimizing mistakes during measurements of athletes' movements we used the high speed electronic regimen, allowing us to expose at 0.001 sec. Minimizing errors in time and space-time characteristics due to the speed of tracking and occasional mistakes of the operator during the 'listing' of the picture on the video-computer complex was done by coding the video-signal and further scanning it by video-computer.

The members of the Ukrainian national and junior selected teams were tested in the experiment.

RESULTS AND DISCUSSION: For the 1990-1997 period of research the authors elaborated individual and group biomechanical models for the technique of complex motor actions in different sport: diving, athletics, ski racing, biathlon, etc.

Technology for creating the model included: gathering information on technique and its biomechanical characteristics; evaluation of their variability on the PC, looking for interrelations (correlation and factor) between characteristics and the level of their influence on general criteria. As a systematic approach used in this study to determine the most important features of the object of study which can describe it as a whole, many authors recommend using the speed of the general center of masses (GCM). But the exact measurements of it is rather difficult and is not always exact. That is why in skiing scientists are recommended to use measurements based on the movements of the feet (X.X. Gross, 1980) or hip joint (A.V. Kondrashov, 1986; V.V. Ermakov, 1988). We used both of these approaches in complex. As a result of analyzing 5000 parameters we have regressive models in which the average value and standard deviation were considered. Models were described by equalities of the first and second order with calculations of coefficients of pair correlation. A model was considered correct (efficient) if the value of the reply described the initial data properly, the coefficient of group correlation was over 0.9 and the error of the model did not exceed 3%. As an example we can use the model of the alternate two-step move of a female elite athlete (Arkhipov & Zubrilov,1993).The error of model was 1.8%. Coefficient of group correlation - 0.94.

$$Y = 3.09+0.02X_1-7.12X_2- 0.26X_3- 0.13X_4-0.2X_5+2.75X_6- 0.029X_7+0.33X_8+0.03X_9$$
$$0.00004X_1^2+7X_2^2-0.09X_3^2+0.08X_4^2+0.02X_5^2+2X_6^2+0.009X_7^2- 0.02X_8^2- 0.0003X_9^2$$

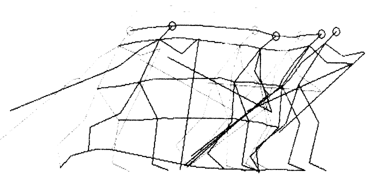

Figure 1. Example of the video-computer's model of the alternate two-step move.

The present models are elaborated in consideration of optimal relations on the basis of the sensory and motor sides of complex movement systems. At the same time, such models are optimal and quantitatively substantiated movement variants with a particular range of such biomechanical characteristics that could be used as reference points during the teaching process and as a criteria for operative control during movement. All parameters included in the model can be easily used in the pedagogical process and are clear to coaches and athletes. Next the individual athlete's technique was evaluated. In the first turn, an evaluation was done in a qualitative way that was a visual review of multifiles with movement in concordance with trajectories and formal kinematic marks (Fig. 1) and after—in a quantitative way that was a multiple regression analysis (Table 1). This gave a possibility for concrete and objective estimation of which elements are developed properly and which need correction. However, before starting any practical corrections in technique the coach and athlete must be sure that the process will help them gain a desired result. So they must know what to change and to what extent. The model allows one to do this, predicting the result. If after the estimation of those technique elements which a trainee is skilled in, their improvement would be started as Table 1 presents; we see that when the parameters 1-9 change by a definite value, then the sport result (**Y**—«Velocity in cycle» as a competition activity criterion in this case) will increase from 4.07 m/s to 4.83 m/s. In first case, coach, professional and athlete discuss either the technique variant and decide what should be changed in the technique and to what extent. Then the result: **Y**—«Velocity in cycle» as a competition activity criterion, caused by these planned changes in the biomechanical structure of technique should be calculated with computer software. Another way is to input the desirable result:

Y—«Velocity in cycle» into the computer and using the previous technique parameters to calculate with model the new technique parameters which will allow one to reach a desirable criterion. In both cases, besides figures, coach and athlete have a possibility to view on the computer monitor the changed kinematic model, which is moving about the previous videogram frame by frame and may be stopped at any moment for discussion. So one can choose any type of basic technique parameter simulation and start the training process, dedicated to the perfection of technique with constant control of its efficiency.

Table. *Example of the model of the alternate two-step move*

№	Parameter	Mean	Change	Model
Y	Velocity in cycle (m/s)	4,07	Incr.	4,83
X_1	Angle of trunk incline at the first phase (degree)	54,5	Incr.	60,7
X_2	Length of thigh joint projection on support leg along OX axis at	0,59	Incr.	0,64
X_3	the 1 phase(m)	0,27	Decr.	0,10
X_4	Distance between pole and support leg during the second	3,67	Incr.	4,24
X_5	phase (m)	5,97	Incr.	6,80
X_6	Support leg velocity during the second phase (m/s)	-0,61	Incr.	-0.44
X_7	Swinging hand wrist velocity during the second phase (m/s)	7,36	Incr.	8,20
X_8	Distance between swinging and support legs during the third	7,92	Incr.	8,68
X_9	phase (m)	492	Incr.	610
	Swinging leg velocity during the fourth phase (m/s)			
	Swinging wrist velocity during the fourth phase (m/s)			
	Angle of heel break away during fifth phase (degree)			

CONCLUSIONS: Received results testify that the given approach in biomechanical modeling and video-computer analysis of technique are effective for all kinds of Olympic sport program. The practice reveals that the received data may be used for: creation of sport center on training in the most complicated elements of technique with individual kinematic models which are recognized visually; development of all data banks with models of technique of highly skilled athletes; carrying out operative control of athletes' technical skill level during various stages of their training before major competitions; forecasting and designing perspective models of the most perfect technique for future Olympic Games; issuing for coaches and athletes the video-production and printed documents with the most significant ways and approaches for recording results which are achieved in different kinds of sport. Video-computer complex hardware has been further improved by the extension of technical and methodological possibilities in the following directions: one-two-three plane video-recording from 25 to 240 frames per second; video-recording for non-linear montage systems, video recording-playing and animation from hard disk in real time mode (CCIR-601 4:2:2 processing, PCI, SCSI drives; instantaneously viewing the video-materials at any moment; processing and digitalizing until 10 minutes of real video, videogram designing in on/in line modes with special video-camera (CCD-TVC) and «Pentium-2 Pro» computer with K6 233 MMX processor; identification and tracing from the first digitalized frame by marker coordinates on athlete body's joint centers during entire studied motor exercise with Digital Fusion «eyeonline» software; designing multi-factor biomechanical models of technique with statistical software.
Compared with similar systems («Ariel», USA; «TAKEL 2D, 3D», Japan; «VICON-370», United Kingdom; «PEAK-3D», Canada-USA-Germany; «ELITE», Spain etc.), the present complex is considerably cheaper. Moreover, the proposed system has original software and may be further expanded and consequently by enlarging its application range, it will satisfy more and more users.

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