UTILIZATION OF THE BIOMECHANICAL MODEL OF THE SKI-JUMPER'S TAKE-OFF IN TRAINING

Vaverka, F.; Salinger, J.; Kráková, M.
Elite Sports Laboratory
Palacky University
Olomouc
Czechoslovakia

Utilization of biomechanical data from current measurements to correct the technique of the ski-jumper's motion offers considerable improvement of the pedagogical progress in traning. In both the theory and practice of ski-jumper's training (1, 2, 7, 12) the take-off phase is regarded as the key moment of the whole jump. The quality of the take-off is extremely difficult to diagnose, since this phase takes no longer than 0.2 - 0.4 sec., with the competitor moving at the speed of 20 - 35 m/sec. Exact information about the quality of the take-off obtained through kinematic examination has a considerable time lag and thus it is not directly applicable during the training. On the other hand dynamic analysis of the jumper's take-off caried out through the ON-LINE system provide immediate biomechanical information that can be utilized immediately to correct the take-off technique. In our paper we have described the construction of a biomechanical take-off model based on the data of dynamometrical measurements of the take-off phase of the ski-jump, which is applicable in practise.

PROBLEM

The conception of our model is based on the biomechanical theory of the take-off phase of ski-jump as described in (12). The ski-jumper's take-off is defined as a multifactorial event in which 5 specific motor tasks are solved by the ski-jumper simultaneously (take-off vigour, accuracy, aerodynamics, rotation and arm activity).

The starting point of our model is based on quantification of the two key factors of take-off, namely vigour and accuracy. Using results of dynamometrical study of the ski-jumper's take-off, as presented in our monography (12), we formulated the following hypothesis :

Hypothesis: We suppose that top performance in ski-jumping is determined by optimum combination of the factors of take-off vigour and accuracy.

The goal of our study:

- to find a mathematical model of the relation between the group of the two variables (vigour and accuracy) and the lenght of the jump achieved,
- through transformation of the model into a version applicable in practise to obtain a high quality biomechanical apparatus controlling the training process on the ski jump.

METHOD

In 1977 - 1989 a dynamometric examination method was being gradually developed and improved enabling to carry out, in natural conditions, measurements of the two important factors of take-off, namely vigour and accuracy. A 6m long and 0.9 m wide tensometric platform is built in the Frenstat p. R. ski-jump (P-72) with plastic surface (since 1989 with a ceramic track). This ski-jump is also equipped with an automatic system measuring the run-on velocity and the lenght of jump (in operation since 1982). The tensometric platform scans the resulting reaction force F_{REA} perpendicular to the take-off platform (Fig. 1). Through mathematical computer assisted calculation the two key characteristics of the take-off phase are calculated from the F_{REA} (t). Vigour is expresed by velocity increment of the centre of gravity of the body in the direction vertical to the take-off board, which is gained by the take-off at the final 6 meters from the edge of the board. Accuracy is expresed by the distance from the edge of the board where take-off was completed. Detailed clarification of the methodology of function F_{REA} (t) evaluation can be found in our monography (12) together with a number of concrete research data. In our search for mathematical model of the relation between the vigour and accuracy of the take-off on the one hand and the lenght of jump on the other hand our previous analysis of 406 ski-jumps carried out in 1987 and 1988 was used. Statistical analysis of the data was carried out by standard procedures using computer PC-AT.

DISCUSSION OF RESULTS

Lenght of jump f(vigour, accuracy)
A preliminary visual image of the shape of function in space could be seen from the histogram in Fig.2. On the basis of this orientation mathematical analysis of different variants of equations expressing non-linear regressive dependence among three variable was carried out. The most adequate approximation to reality was expresed by the following non-linear regresive equation :

$$LJ = 66.4 * e^{(-.18 * AC^2 + .018 * AC \cdot VI + .02 * VI^2)}$$

Grafic representation of this function can be seen in Fig.3. The graph implies the decrease in take-off vigour influences ski-jump performance more rapidly than deterioration in take-off accuracy. The statement of optimum combinations of the factors under investigation is not a purely mathematical problem. It is necesary to start from the multifactoral theory of ski-jumper's take-off (12) and consider the individual features of individual take-off. Mathematical solutions of the vigour and accuracy factors can be seen in Fig. 4. The areas with irregular boundaries represent theoretical combinations of the two factors necessary for the achievement of corresponding jump lenghts. Practical utilization of this model would be extremely complicated.

In our attempt at creating a model applicable in the practise we started from the theoretical model that has just been described and from the results of our study (14). Through statistical confrontation of the parameters followed in different selected sets bands were found for the values of vigour and accuracy with top ski-jumpers who take part in competitions GP Prenstat p. R. Very good correspondence with the mathematical model was achieved. The bands of optimum vigour and accuracy levels were expressed numerically and a graphic method of their representation was worked out. The graphic output of the resulting model is represented by Fig. 5. The computer input consisted of values of vigour, accuracy and lenght of the ski-jump. A different number of jumps can be analysed in one graph. The graph yields two types of information :

- individual evaluation of each ski-jump,
- statistical evaluation of a larger number of jumps (in both graphic and numerical form).

Statistical analysis of a larger number of jumps provides valuable information about the stability of take-off performance. All of the data undergo graphic confrontation with the optimum model provide a rich combination variety of the factors followed. From the didactic point of view these deviations can be defined with considerable accuracy. When transformed into concrete instructions they express the strong or weak points of the take-off performance. The clarity of arrangement and practical usefulness characteristic of the graphic variant of the take-off model are features which recommend the procedure describe above as a high standart and fully applicable tool of biomechanical approach to controlled training. Utilization of this method is conditioned by built in measuring apparatus in the ski-jump.

The following two examples were chosen to demonstrate the practical usefulness of this approach to biomechanical investigation of take-off. Fig. 6. shows statistical characteristics of the two parameters followed in competitors of different level of performance and of different age. Both competitors, Ploc and Svagerko, are found to be in optimum band, they are characterized by high vigour stability as well as take-off accuracy, and their conception of take-off is rather unique. Both competitors ranked in the competition up to the third place. In ski-jumper low level of vigour and low accuracy of take-off can be observed. The example of two junior ski-jumpers exhibits considerable differences in the conception of take-off. No. 1 has a highly accurate and stable take-off, even though his vigour has not yet reached the desirable optimum value. This competitor has already scored several points in this year's Wold Cup competitions. On the other hand junior No. 2 is characterized by a number of take-off mistakes (systematic premature take-off as well as very low vigour).

Fig. 7 represents statistical characteristics of various selective sets. Confrontation of three selective sets of Yugoslavian ski-jumpers with a set of best competitors enables estimation of the quality of take-off within the whole group of sportsmen.

CONCLUSIONS

The proposed model of the take-off phase of ski-jump has undergone long-term practical verification during the training of Czechoslovak jumpers as well as during competitions at G.P. Prenstat p. R. The model has proved useful not only for training practice, but also for investigation. Connecting dynamometric measurements of the take-off phase with other measuring systems built in ski-jump at Prenstat p. R. (measuring run-on velocity and lenght of jump) has created favourable material and methodological conditions for the utilization of exact biomechanical procedures in the natural conditions of the ski-jump training .

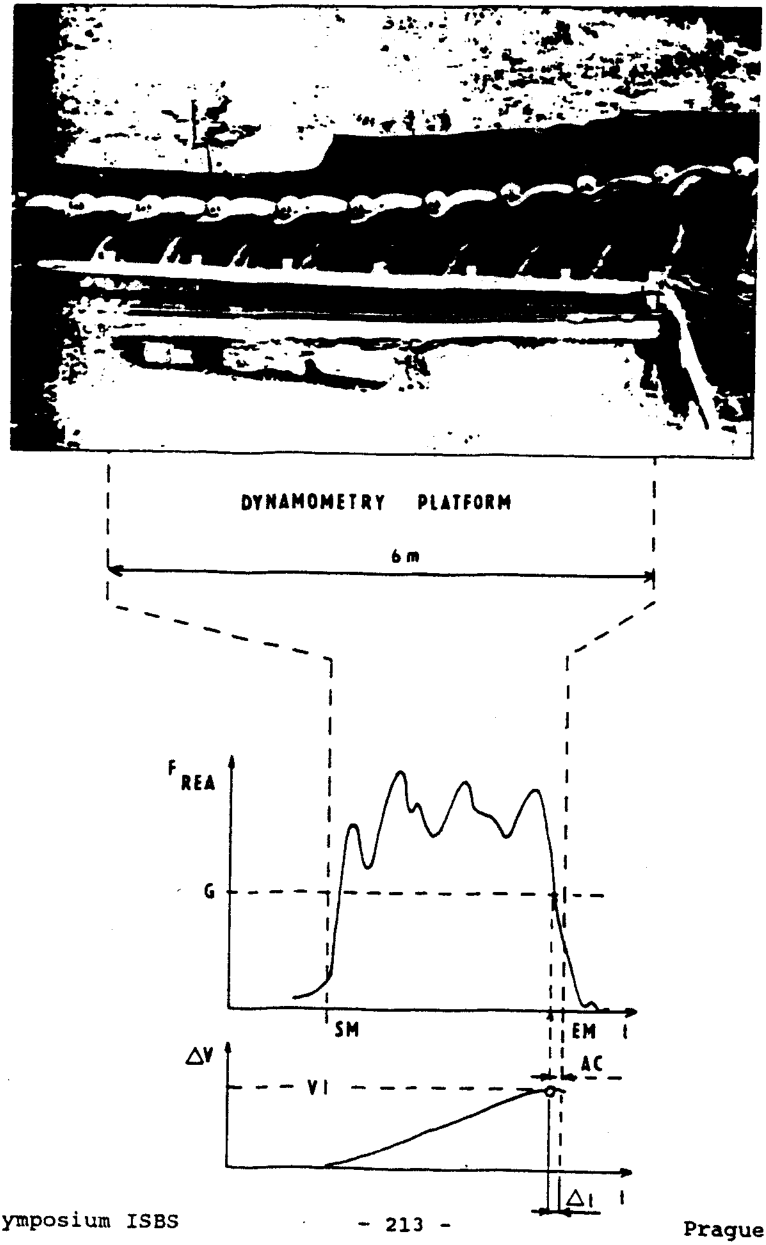


Figure 1:

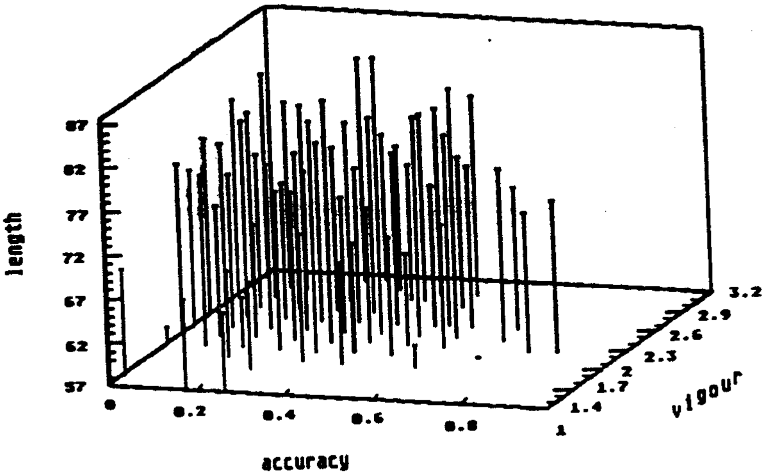
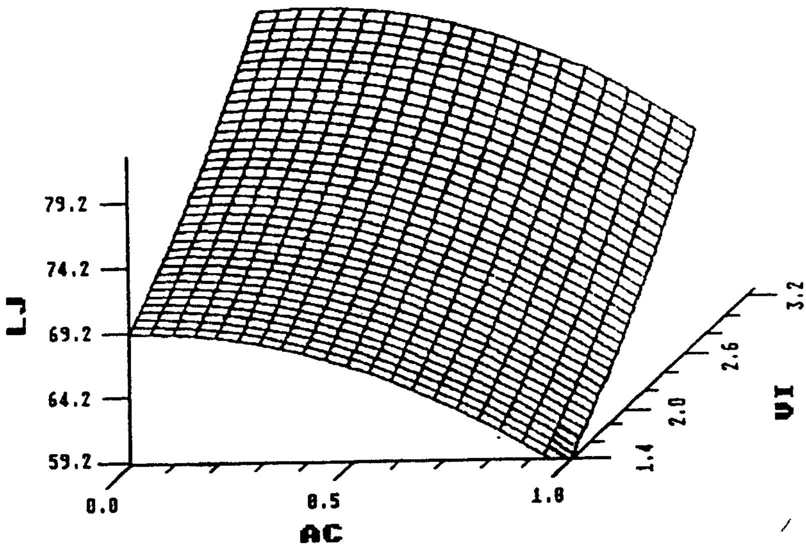


Figure 2:

LJ = 66.4 * exp(-0.18 * AC * AC + 0.18 * AC * VI + 0.12 * VI * VI)



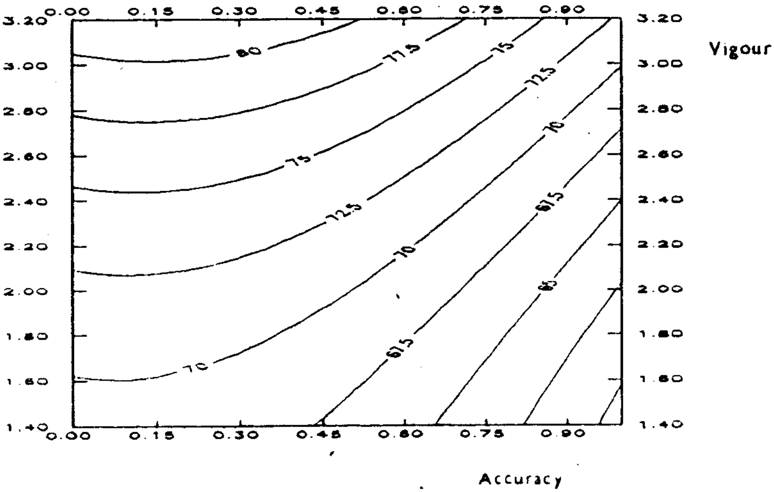
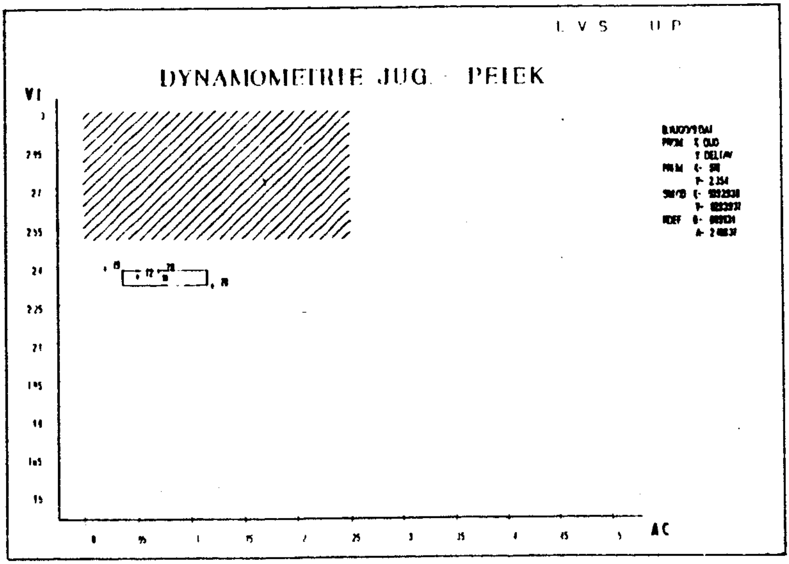


Figure 4:



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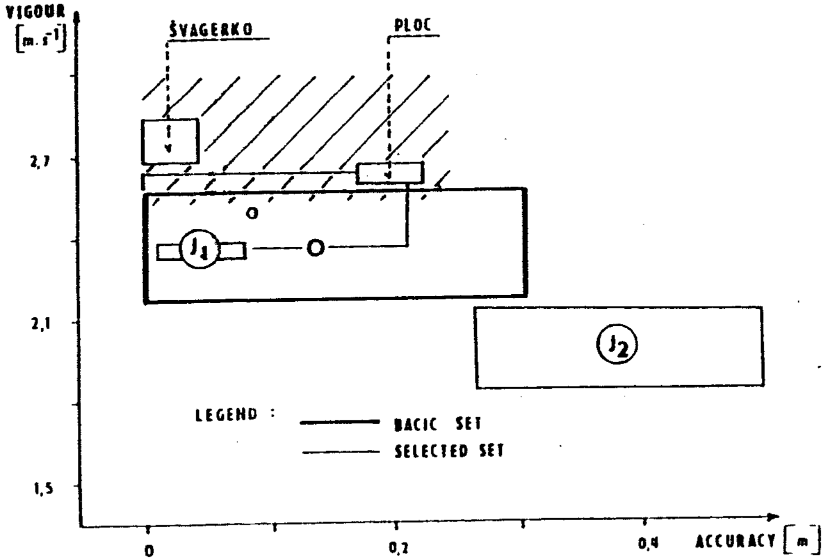

Figure 6:

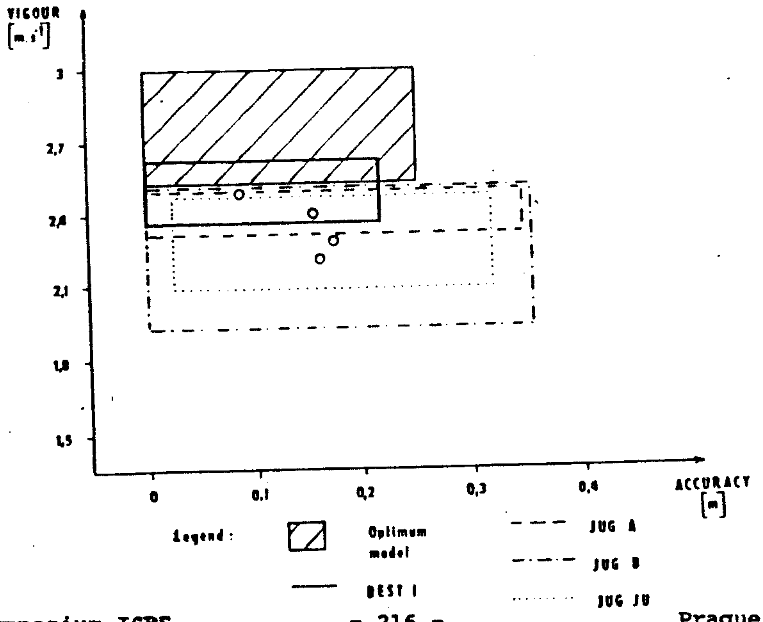

Figure 7:

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