PRESENT POSSIBILITIES OF OBJECTIFIED ELECTRONIC MEASUREMENT OF EQUINE LOCOMOTIVE POTENTIAL IN THE CZECH REPUBLIC

SOUČASNÉ MOŽNOSTI OBJEKTIVNÍHO MĚŘENÍ POHYBOVÉHO POTENCIÁLU KONÍ V ČESKÉ REPUBLICE

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ABSTRACT: An electronic device has been developed which helps to substantially objectify the so-far manual method of measuring the quantitative element of locomotion in a horse until now used in the Czech Republic. The device can be used with all horse breeds. It operates on the principle of a special sensor, fixed to the sole part of a hoof. When it touches the ground, it transmits a numerical signal. The signal reaches a portable computer via a repeater station and it is processed by software there and evaluated. Reading is made on a sandy or grassy testing track exactly defined by electronic gates. It is possible to change the length of the track as needed. Special software has also been developed for the evaluation of horses tested, ranking them according to a ten-credit scale expressing the locomotive potential of the observed equine gait as compared with a set standard. The results are documented in the illustrative graphs enclosed. The device makes it possible to observe the tested gait of a horse simultaneously on all the four limbs. Besides the usual parameters of a given gait, it is also possible to observe the regularity or irregularity of the basic gaits, such as "amble", and the like. For a routine use, more large-scale testing is made in dependence on breeds, with the aim to bring standards up-to-date and to improve criteria for effective selection.

Keywords: horses; mechanics of motion; locomotion

ABSTRAKT: Bylo vyvinuto elektronické přístrojové vybavení výrazně objektivizující ruční způsob měření kvantitativní složky lokomoce koně, dosud využívaný v ČR. Zařízení je využitelné pro všechna plemena koní. Pracuje na principu speciálního čidla upevněného na chodidlové části kopyta, které při dotyku s podložkou vysílá číslicový signál přes retranslační stanici do přenosného počítače, kde je signál softwarově zpracováván a vyhodnocován. Měření je prováděno na pískové nebo travnaté zkušební dráze, přesně definované elektronickými závorami. Délka dráhy může být různě měněna. Dále byl vytvořen speciální vyhodnocovací software umožňující vyhodnocení konkrétních testovaných koní podle desetibodové stupnice vyjadřující úroveň pohybového potenciálu sledovaného chodu koně vzhledem k stanovenému standardu. Výsledky jsou dokumentovány na přiložených ilustračních grafech. Zařízení umožňuje sledování testovaného chodu koně současně na všech čtyřech končetinách. Vedle běžně sledovaných parametrů příslušného chodu je umožněno sledování pravidelnosti, ale i nepravidelnosti základních chodů, jako je „mimochod", „nákrok" apod. Pro rutinní využití je prováděno další plošné testování podle plemen s cílem aktualizace standardů a upřesnění kritérií pro efektivní selekci.

Klíčová slova: koně; mechanika pohybu; lokomoce

INTRODUCTION

The mechanics of equine locomotion plays one of the most decisive roles in its practical use. This role is even stronger in special, namely sport and racing, use of a horse, which is predominant in most breeds today.

The mechanics of locomotion can be methodically divided into two elements. The quantitative element (sway, rhythm, action, motion balance, regularity) is usually judged subjectively by an assessor (a jury) in different testing disciplines. The other element is quantitative (length of step, speed, frequency) which may be measured and evaluated by more or less exact methods.

The possibility to estimate objectively the mechanics of equine locomotion, especially its quantitative element, constitutes a precondition for estimating the locomotive potential or working abilities of horses with a genetic impact.

The mechanics of locomotion in the breeding of horses with high performance is therefore becoming one of the basic preconditions of a successful breed and plays an important role in the process of breeding.

The mechanics of equine locomotion and interrelations between the mentioned properties have been studied by a number of authors. In the Czech Republic it was above all Dušek (1973, 1974a, b, 1981) and Dušek *et al.* (1970), who give a summary of his own and foreign works related to the given issue and establishes a method of measuring the quantitative element of locomotion measured by a subject, including proposed standards for selected horse breeds.

Evaluation is based on an analysis of the locomotive potential of a horse made in a special test over a 100-m long track. The method evaluates the interrelation of all the three variables, i.e. speed, step length and its frequency. From values measured, standards were set for the usual breeds, except the English full-blooded and the trotter (Dušek, 1977). Measuring the quantitative elements of the mechanics of locomotion has become part of evaluation in performance tests of young horses before they are introduced into the breed.

Systematic and non-systematic faults occur when performing measurements. Namely Dušek *et al.* (1970) and Dušek (1973) tried to alleviate these faults and proposed some corrections to be made at the start and end of the measured track. However, not even after the alternations the methods are quite satisfactory.

In our approach we have concentrated mainly at eliminating the shortcomings of the presently used method of measuring the quantitative element of the mechanics of equine locomotion as an auxiliary selection criterion. In the framework of a research solution, co-financed by the Czech Ministry of Agriculture, development was started of a device which would minimize the subjective element in measuring horses and gradually enable to consider other, so far unmeasured, components or signs of equine locomotion.

The presented state is the result of research of a number of years in different concepts of apparatuses. The following procedure indicates the essence of our latest proposed variant.

MATERIAL AND METHOD

The aim of the task was to increase precision in time measuring, bring to minimum any systematic or non-systematic faults, minimize the influence of a subjective factor in measuring and to make possible consideration of some other effects, such as regularity of gaits (which belongs to the qualitative element), the length of steps, etc. This concerns mainly signs and properties which cannot be evaluated in the manual measuring method. The solution is also to provide computer processed measured values and their evaluation.

In its next stage, the research will concentrate on standardisation of curves of data measured for the basic equine gaits using an objectified method. The aim is to make use of the results in breeding and selective work in horse breeds included in a research project.

In the first stage of our research, dealt with here, our efforts were concentrated in three spheres and were to result in:

1. Electronic reading of a signal from the direct impact of one and/or all four limbs simultaneously in all basic equine gaits and its telemetric reception in a computer.
2. Electronic reading of the measured time of the length of the course of the observed limb impact, and/or of all the four limbs, including an objective determination of the start and the finish of the test track.
3. Development of software which would enable processing the transmitted signal, later standardisation and classification of measurement results from a specific individual as compared with a standard value. The result thus obtained should be defined simply and it should be possible to use it in the selective and breeding process of observed horse breeds.

The results obtained from the device developed have so far been verified on horses of warm-blooded breeds and the English full-blooded horse. Development and verification took place in the Research Institute of Horse Breeding in Slatiňany and on the Research Grounds of the Czech Association of Steeplechase, the Race Course in Pardubice. First results of the new method of measurement were presented by Jelínek *et al.* (1995a).

RESULTS AND DISCUSSION

The method of present-day measurement of the quantitative element of the mechanics is based in principle on counting by sight the horse's steps over a 100-m long direct track in relation to increasing speed of gait under observation. This calculation results in credits given on the basis of a set evaluating scale with regard to the standardised curve of the gait of a horse under observation.

The mentioned procedure, used traditionally in testing systems also in other countries, is not quite satisfactory even after the above mentioned additional corrections. One of the shortcomings being inaccuracy, in some cases even faults without any possibility to judge objectively the regularity of gaits, the lengths of individual steps, etc.

With regard to the above facts we have started to develop and design a new equipment for the already mentioned three spheres.

Device for reading a signal from limb impact and its transmission into a computer

Electronic sensors of different structures were tested and developed; they worked on different principles and at different places during work on a horse. Their detailed description is given by Jelínek and Volenec

(1990). We do not consider effective to give a detailed description in this study because none of the structures tested showed sufficient reliability during tests and precision in practical measuring. The final solution is described by Jelínek *et al.* (1994, 1995b).

The final sensor structure, designed by us, works in direct contact of the sole area of a horse's hoof with the surface of the testing track. The sensor is fixed by a special system which keeps it in a constant position even at the top speeds of race gallop.

Signal is recorded when a tensometric unit reacts to the load of hoof pressure onto the base. The sensor consists of a power supply unit and a miniature transmitter which sends the signal over an aerial into a repeater station which amplifies it and transmits it into a computer placed at a control post close to the testing track.

Signals from sensors are transferred in the form of a numerical code and sent, all together, through a single high-frequency channel to a stationary receiver in a small portable computer.

The repeater station, which was developed together with the sensor, is placed in the seat pad and the force of the signal transmitted guarantees to cover the necessary distance. The station can simultaneously receive independent signals from all four limbs.

The device of the said configuration makes it possible to follow on a computer screen the course of hoof load in real time. Data measured are immediately stored into the memory. After field measuring is completed, data may be analysed independently and evaluated. The analysis results in objective parameters describing the mechanics of a given horse.

When measuring the contact of limbs with the track surface, there are, understandably, quite marked pressures, especially during gallop impacts when the total weight of the horse is borne by a single front leg, depending which leg the horse uses in gallop. Our present experience from practical tests with some 30 horses in principle only allows measuring on a sandy testing track. This fact limits, to a certain degree, the use of the developed sensor for some breeds that cannot be measured under the saddle, without some distortion, or measured free, e.g. cold-blooded breeds in which this is still required under the amended standard. Measuring in sulky would thus result in a significant systematic fault which would distort and undermine the measured parameters.

The mentioned restrictions make us work even more at technically improving the sensor structure and the manner of reading the signal in order to overcome the problems. Today, the development is in a stage of practical verification. The first results (from about 20 horses) indicate the possibility of recording on a grassy surface. However, not even will such an adjusted manner of reading the signal most likely make it possible to determine the specific objective distribution of load of the different limbs during a horse's motion. It is however a guarantee of the possibility of measuring shoed horses of all breeds and does not have any other specific requirements as to the structure of the surface of the testing track.

The original intent of the task was, inter alia, to make it possible to judge the relative load per specific limbs. This was to help study the distribution of weight and the movement of the centre of gravity at the different stages of somatic development, in natural and artificial balance, during different stages of training and practical use of horses. Results of the study of data obtained from different surfaces of testing tracks showed however showed that the course of measured load of a localised impact onto the base displayed such a high variability that the load cannot be objectively and without any significant faults calibrated. The bases of these faults are the significantly changing conditions of the testing track during the individual impacts of limbs and the physiological reaction of the horse, caused by the influence of the level of artificial balance achieved, as well as the reaction of the higher nerve activity to the external environment.

As regards the structure of our solution itself, we can say that this is a unique principle of measuring. In international literature we can only find indirect methods of measuring, utilising an accelerometric device, or a camera or a video-camera. The first mentioned principle is based on recording and analysing inertial forces at two levels; cranio-caudal and dorso-ventral. This method is namely practised in France and is utilised mainly for analysing the quality of locomotion in people and, lately, in horses. Besides studying and analysing locomotion, it is directed to predicting the suitability of horses for sport (jump, training, trotters) or to pin-pointing limping in horses. The method and results of accelerometry in the last years were namely presented by Barrey *et al.* (1994, 1995), Barrey (1995), as well as Kennedy *et al.* (1995).

Electronic reading of the measured time of the length of the course of the observed limb impact, and/or of all the four limbs, including determination of the start and the finish of the test track

A necessary requirement for an objective measuring of time and length of step of individual limbs is an independent, electronic measuring of start and finish bound to data obtaining. For this purpose, two modified infra-sensors with special lenses are used. They are placed along the sides of the testing track and they register motion only in a narrow sector around the starting and finishing lines. The passage of a horse is indicated to the nearest ca. 10 cm.

The signal travelling by air is intercepted, by means of a specially designed device, directly by a portable computer and processed as part of the software evaluation of the measured data. The result is then displayed and impacts of the different limbs are also represented. An example of such representation can be seen in graphical examples Nos. 1 to 3.

Software for reading and evaluating results

We have developed special software for evaluation – it enables numerical and graphical processing of the data of motion and impact of the different limbs of a horse. The software makes it possible to evaluate specific steps or jumps of a horse.

Besides a colour display of motion, it also shows the following basic parameters for each limb under measurement:

1. The number of measurements
2. Total time in seconds for measured steps between start and finish
3. Speed of horse motion in the measured gait
4. Average step length in the measured gait in seconds and also converted into meters
5. Average limb frequency over the measured track per minute
6. Decisive deviation of tested step lengths for estimating the regularity of manner of movement of the limb under observation
7. Numbers of identical steps in length made by a given limb over the track under observation in seconds of a time interval and also converted into meters.

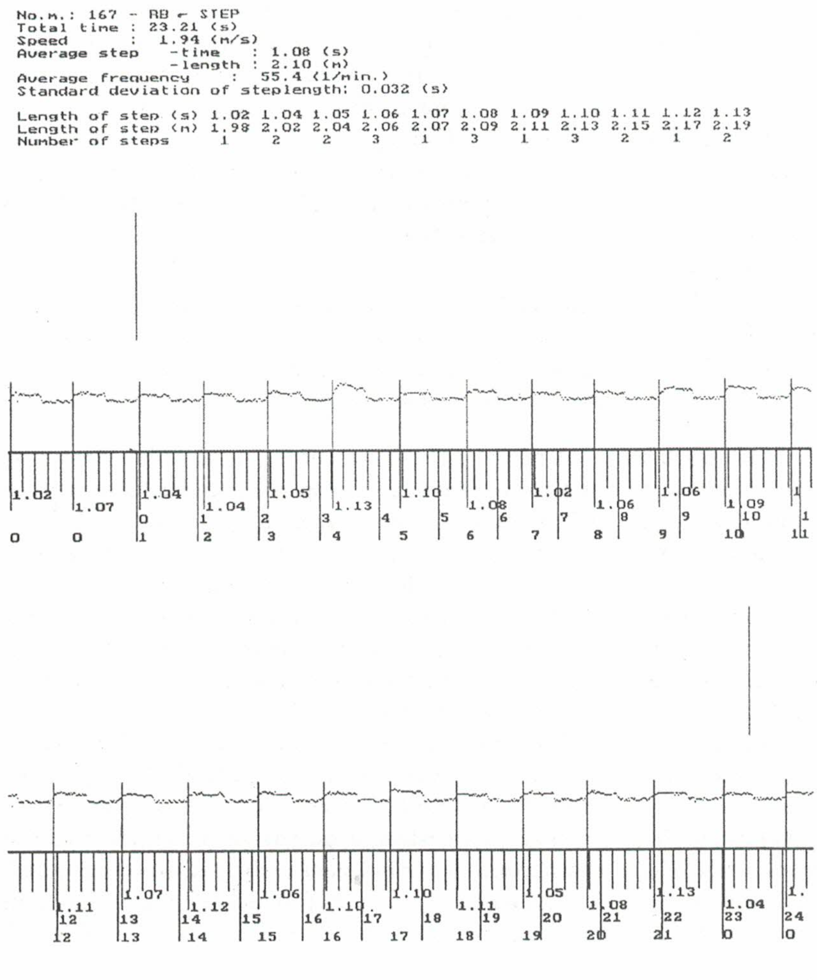
Practical illustration can be seen in Figs. 1–3.

For each basic kind of horse gait software graphical illustration is made for all the four limbs, or rather sensors, together. This makes it possible to consider if the succession of legs is correct and to judge the overall regularity of succession of limb impacts. An example can be seen in Fig. 4.

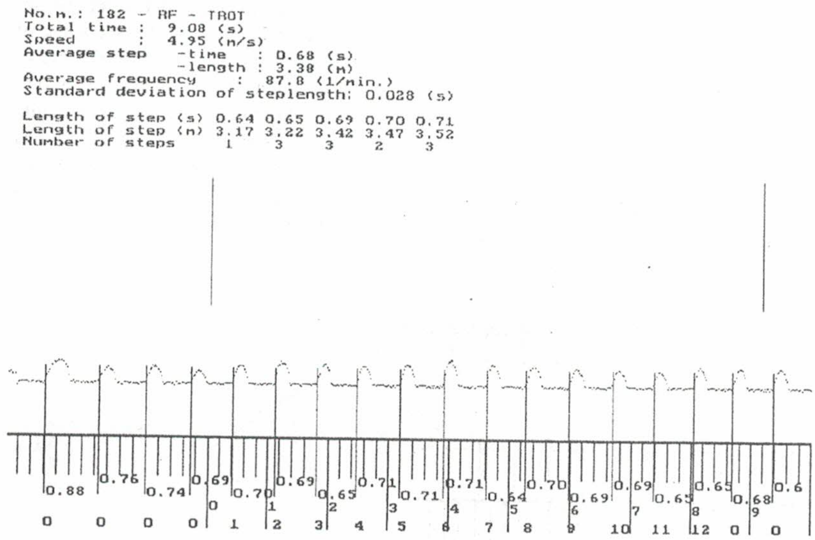
We have developed special software for evaluating and standardising gait measurements in specific horses. The software enables us to speedily obtain results with the help of a computer. Its weak point is that it has so far worked with a single-channel reception only, i.e. for a single horse limb.

An example of a step evaluation can be seen in Fig. 5, Fig. 6 for trotting and 7 for gallop. The heavy central line represents the course of the calculated standard. When evaluating the quantitative element of the mechanics of motion, length of step was considered, i.e. from one single impact of a limb to the next one. The length depends on the speed of the motion of the horse, or rather of the limb observed. Earlier experience from observing the results justifies us to state that the dependence is linear in the case of step and trot while that of gallop is quadratic.

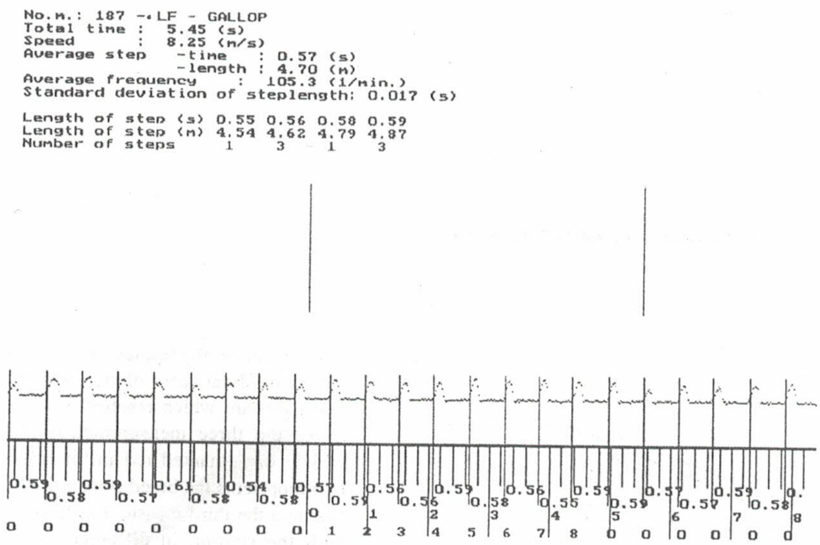
Each horse and kind of step were measured in different speeds. The values were used to construct the function (linear or quadratic) which expresses the de-



1. An example of graphical representation of step for set of measurements No. 167. Parameters can be seen in the graph legend and description. Vertical lines over step course indicate the start and finish



2. An example of graphical representation of trot for set of measurements No. 182. Parameters can be seen in the graph legend and description. Vertical lines over step course indicate the start and finish



3. An example of graphical representation of gallop for set of measurements No. 187. Parameters can be seen in the graph legend and description. Vertical lines over step course indicate the start and finish

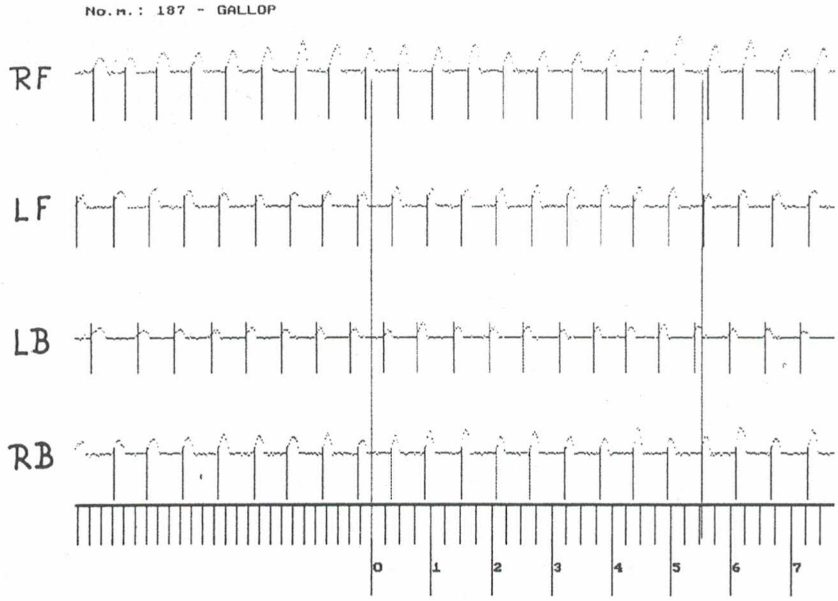
pendence of step length on horse speed and the frequency of the observed limb. The method of the least squares was used. From this function, "theoretical values" are deduced in speeds we have selected.

From the theoretical values, basic statistic values were calculated for each speed, i.e. mean value and standard deviation which we made use of the calculation of decile zones for each appropriate theoretical speed.

From the limits of these calculated zones, functions were obtained again by means of the least squares method. These functions determine appropriate decile zones in the full extent of speeds in each equine gait. The zones served as a limit for awarding credits to specific horses within a ten-credit scale. Decile zones were created on the basis of normal division quantiles. Kolmogorov-Smirnov test was used to verify normality in selected speeds.

It is evident from the results that we have managed to find a satisfactory technical electronic device as well as processing software. This significantly improves objectification of the method and manner of measuring used until now for the quantitative element of the mechanics of equine motion as used in our conditions and to expand evaluation of some other characteristics of horse locomotion, which was the target of the first stage of our research.

The equipment enables to determine the length of each single step over the test track in a relatively accurate and simple way as compared to manual measuring. It allows to characterise the regularity of gaits in the form of standard deviations in measured horses, which are automatically calculated for each tested individual together with other gait characteristics and classifies it into a ten-credit scale depending on its motion potential for the given gait in comparison with the breed



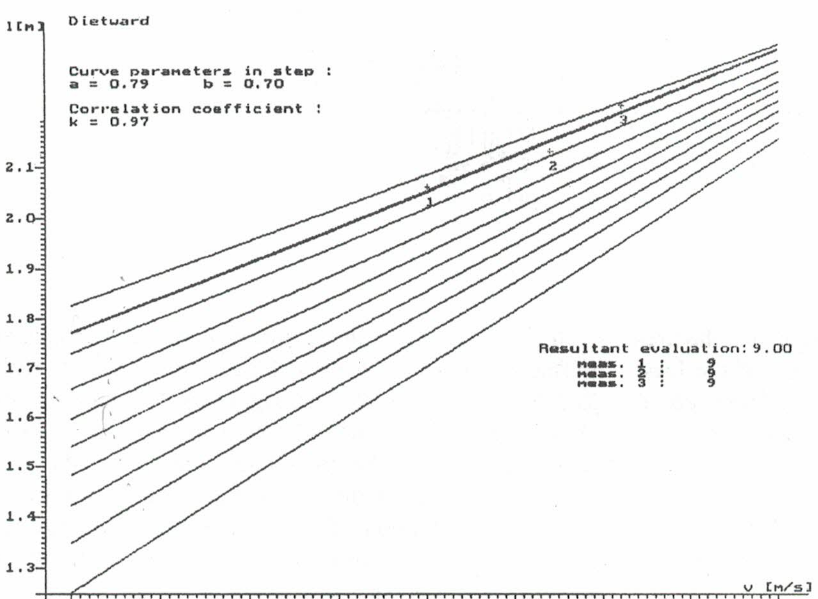
4. An example of graphical representation of regularity of the sequence of the impact of all four legs of a horse, while taking measurements of a specific horse-set of measurements No. 187. The impacts of specific limbs can be seen in the time behaviour between the start and the finish, marked by vertical lines

Graphic exhibit of measure of all four legs at the same time.

Legend:

RF - right front leg
LF - left front leg
LB - left back leg
RB - right back leg

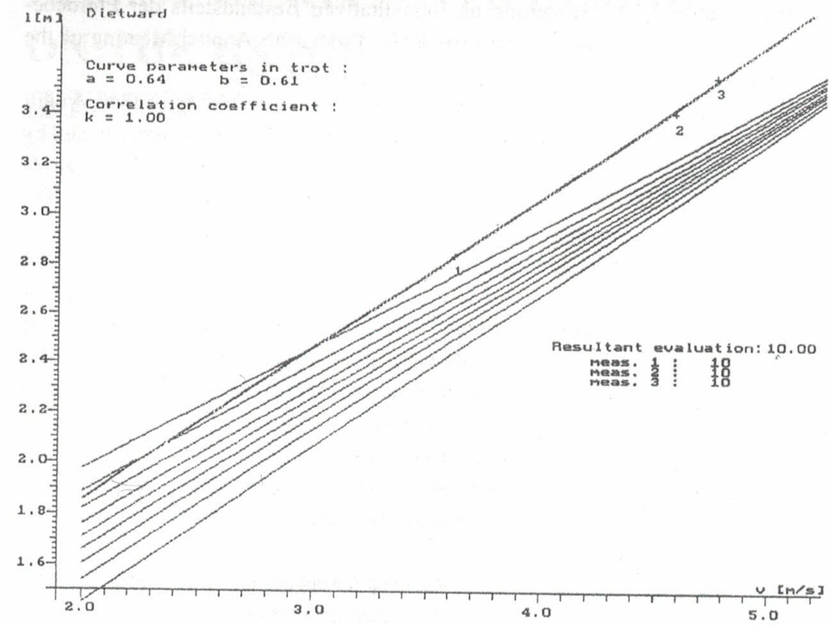
The vertical long lines mean start and goal of the measured part of the track.



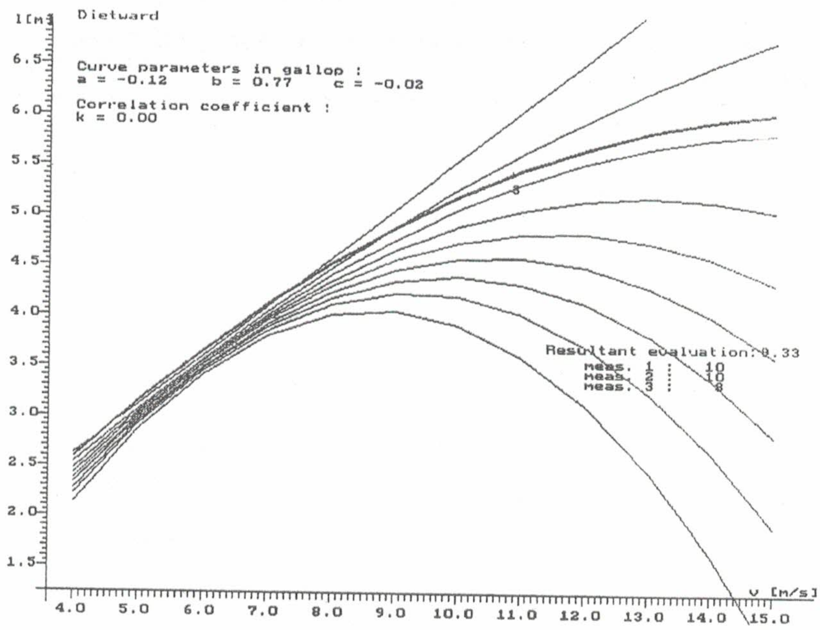
5. An example of graphical representation of the final score of step for stallion Dietward which reached 9 points in all the three measurements. The middle line (marked red in the original) represents the breed standard. The first and the third measurements made with the stallion in different speeds (marked by numbers with interpolated regression) show the position of the stallion under evaluation as compared with the standard. Parameters can be seen in the graph legend and description.

standard (see illustrative Figs. 5 to 7). The already mentioned shortcomings are that the software has so far worked only over a single channel, a problem we shall tackle in the next period.

Using the contemporary manner of recording four channels, it is possible to identify inborn irregularities of gait, such as partial or complete "amble" etc. It is not always necessary to make the measuring over an



6. An example of graphical representation of the final score of trot for stallion Dietward which reached 10 points in all the three measurements. The middle line (marked red in the original) represents the breed standard. The first and the third measurements made with the stallion in different speeds (marked by numbers with interpolated regression) show the excellent position of the stallion under evaluation as compared with the standard. Parameters can be seen in the graph legend and description.



7. An example of graphical representation of the final score of gallop for stallion Dietward which reached 9.33 points in all the three measurements. The middle line (marked red in the original) represents the breed standard. The first and the third measurements made with the stallion in different speeds (marked by numbers with interpolated regression) show the very good position of the stallion under evaluation as compared with the standard. Parameters can be seen in the graph legend and description.

identical 100-m long track. It is also possible to exclude poor-quality riders from the test, incorrect sets of horse measurements, etc.

We have started a large-scale measurement of an adequate number of horses of appropriate breeds for later routine utilisation of the device in selective and breeding practice. After data are obtained, standards may be amended and criteria set for an effective selection, which is the subject of further research. Selection strategy should be based on the updating of the basic genetic parameters re-evaluated according to this method of measuring.

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Received for publication on November 23, 1998
Accepted for publication on May 4, 1999

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Czech Journal of ANIMAL SCIENCE

ŽIVOČIŠNÁ VÝROBA

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7

VOLUME 44
PRAGUE
JULY 1999
ISSN 1212-1819