THE JUMPING CAPACITY OF YOUNG HORSES PREDICTED BY STIFLE-HOCK-FETLOCK ANGULATION IN FREE-JUMPING

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SUMMARY

The aim of this study was the objective measurement and evaluation of one of the most important part of the jump the stifle-hock-fetlock angulation.

Movement analyses on twelve one-year-old foals were conducted of the same breed grown up at the same location with repeating the tests at the age of three. The foals worked individually each in a hall measuring 22 x 42 m where there was a 12 m long free-jumping corridor formed without a sidewall along the longer wall of the hall with one oxer jump in the corridor. The digital camera used to do the recordings (29 photos/sec) was set up 12 m from and in line with the first element of the oxer jump. The recordings were evaluated by using a Szelektor HDPG 02 program developed by ourselves. For the purposes of mathematical analyses and diagrammatic presentation the movement sequences were subdivided into their elements and the key movement elements were given coordinate values, i.e., value scores by making use of so called marker scores.

The stifle-hock-fetlock angulation above the hurdle of the hind limbs pushing off depends on the intensity of the push off. At the age of three the changes in the angles of the more outstretched stifle-hock-fetlock during the time period between the peak of the trajectory and the landing of the forelimbs are smaller and the further closing of the closed stifle-hock-fetlock angle with weaker jumpers is more significant.

ÖSSZEFOGLALÁS

Jónás, S. – Komlósi, I. – Posta, J. – Mihók, S.: CSIKÓK SZABADON UGRATÓBAN MÉRT CSÁNKHAJLÍTOTTSÁGI ÉRTÉKEI ÉS EZEK ÖSSZEFÜGGÉSE AZ EGYEDEK UGRÓ KÉPESSÉGÉVEL

A szerzők célja a csánk hajlítottságának, mint az ugrás egyik legfontosabb összetevőjének mérése, és értékelése.

Mozgáselemzést végeztek 12 azonos fajtához tartozó egy helyen nevelt csikókkal 1 éves korban, majd megismételték a méréseket a csikók 3 éves korában. A csikók egyenként dolgoztak egy 22x42 m-es csarnokban, ahol az egyik hosszúfal mellett a 12 m hosszú, oldalfal nélküli mérőfolyosót alakítottak ki. A mérőfolyosóban 1 db oxer ugrás található. Az oxer ugrás első elemével egy vonalban, attól 12 m-re állították fel a digitális kamerát, amellyel a felvételeket készítettek (29 kép/sec sebességgel). A felvételek értékeléséhez a saját fejlesztésű Szelektor HDPG 02-es programot használták. A matematikai elemzés és a grafikonos ábrázolás érdekében a mozgássorokat elemeire bontották, és a markerpontok felhasználásával a kulcsmozzanatokhoz koordinátákat, ezen keresztül értékeket rendeltek.

Az elrugaszkodó hátsó lábpár akadály fölötti csánk hajlítottsága függ az elrugaszkodás intenzitásától. Háromévesen a pályagörbe csúcsa és a mellső láb talajfogása közötti időszakban, a jobban ugró csikók nyújtottabban tartott csánkjának szögváltozása kisebb, így a rosszabbul ugró csikók zártabb csánkjának jelentősebb a további záródása.

INTRODUCTION

The making of international-level is an extremely time- and money objective of riding-horse selection has been the selection of sport horses breeders have been trying to find ways that make this work more efficient. A major difficulty in this work is the long generation period of horse breeding, which results in long periods of financial return and so breeder decision-making is made extremely difficult. Rightly performed free-jumping performance tests of horses at young foal ages and thorough evaluations of their results, however, may closely correlate with sport performance at later ages. This is how it may become possible to obtain information on participating horses at early stages in their lives that will help selection objectively. Serving this objective, our research would like to call breeders' attention to a vital assessment aspect of the jumping abilities of foals.

Leading horse-breeding countries are ever more consciously trying to make use of their methods for analysing the quality of movement in their tests for riding horses and even if the basic gaits are not always evaluated the performance of free jumping exercises is more and more often assessed by using some kind of recording process. As early as 1979 *Bekedam and Koops* (1979) call attention with their experiments to the fact that the picture about the jumper is primarily determined by free jumping. In a study *Thorén Hellsten et al.* (2006) claim that among the qualities analysed in different stallion tests it was the jumping capacity that correlated most closely with the results in jumping events later on. According to *Thorén Hellsten et al.* (2006) performance tests at young ages are most applicable to objectively predict the qualities of an individual in a later sport career. *Brockmann* (1998) obtained a correlation figure of r=0.95 between the performance in the free jumping facility and that in a show jumping event. *Ducro et al.* (2007) obtained a correlation value of r=0.80 between the free jumping results of Dutch stallions designated to become sport horses and their later performances in jumping events.

On the basis of analyses of the trajectory of the centre of mass *Preuschoft and Hüllen-Kluge* (1987) and *Preuschoft et al.* (1987) says that in kinematic analyses of the characteristics determining the qualities of different forms of movement the major role belongs to the fore- and hind limbs in the lifting of the centre of mass and adjusting the inclination of the trunk. According to *Clayton* (2001) in jumping over hurdles of over 1.1 m there is no difference in the position and positioning of the limbs regardless whether the fences are steep or wide.

The opinions concerning the determining characteristics of the jumping capacity of the successful jumping horse and how early they can be recognised in the life performance of the individual, however, are not so unanimous. It seems proved though that the positioning of the limbs in time scale and their role in supporting is quite similar in foals and adults (*Santamaria et al.*, 2002). Foals classified and considered to be talented jumpers at the age of one retained the characteristics of their advantageous jumping techniques at the age of four too. *Bobbert et al.* (2005) says that colts possess characteristic features of the jumping technique, from the evaluation of which the jumping ability of the individual may be inferred. These are the positions of the fore- and hind limbs after push off and before landing. The forelimbs of talented horses are more inflexed at the tarsus and its region than those of the less talented ones and the same foals close and flex their hind limbs to a lesser extent over the fence *Bobbert et al.* (2005).

It is the difference in the push off intensity of the fore- and hind limbs influencing the trajectory of the centre of mass that determines the jumping styles and capacities of individual horses. With weak jumpers the trajectory of the centre of mass forms a flatter curve over the fence (*Cassiat et al.*, 2004). This observation may result from the push off intensity of the limbs.

In analysing the jumping kinematics of elite jumping horses *Van den Bogert* (1994) came to the conclusion that it is the push off intensity of the hind limbs that most determines the jumping performance of the horse. According to *Galloux and Barrey* (1997ab) after take off in the airborne phase, correction movements of the different body parts influencing the angle acceleration of rotation can be observed. During the airborne phase all parts of the body contribute to enabling the centre of mass to fly the smallest possible curve and prepare the body of the horse for landing without breaking the rotation of the trunk. Naturally, side by side with the hind limbs, it is the trunk, the neck and the head that have the greatest influence the rotation. The corrective positioning of these parts of the body in the airborne phase of the jump could be typical for the individual.

According to the measurements conducted by *Galloux and Barrey* (1997ab) it can be assumed that the differences in style and ability between the individuals result from different magnitudes of push off intensities at the forelimbs and hind limbs.

MATERIALS AND METHODS

Movement analyses on twelve one-year-old foals were conducted of the same breed grown up at the same location with repeating the tests at the age of three.

The foals worked individually each in a hall measuring 22x42 m where there was a 12 m long free-jumping corridor formed without a sidewall along the longer wall of the hall with one oxer jump in the corridor. Due to the special measuring setups, the oxer jump had no going in cross (small helping fence for jumps), in front of the oxer so that the constant, typical style elements in the different jumping situations could be seen. The horses were "left alone" and were helped to achieve the correct speed and rhythm only.

The digital camera used to do the recordings (29 photos/sec) was set up 12 m from and in line with the first element of the oxer jump. The recordings were evaluated by using a Szelektor HDPG 02 program developed by ourselves.

Despite the more difficult than usual conditions the horses carried out the jumps of 0.90 m (maximum 1.1 m) at the age of one and jumps of 1.3 m (maximum 1.6 m) at the age of three without difficulties following the standard training before the measurements started. Based on our experiences of many years, which are in line with *Preuschoft and Hüllen-Kluge* (1987) and *Preuschoft et al.* (1987) claims, that with adult horses there seems to be a difference in the style and technique of jumping over smaller and higher than 1.1 m fences we tried to set testing heights that could be managed by weaker horses too, but due to the height itself, at the same time revealed the jumping styles of the foals. Jumps of 0.50 m performed at one year of age are partly usable to test the skill but are by no means useful to test the ability. Experience shows the same picture in the case of 1.0–1.1 m jumps for horses aged three. Due to this fact photos of the 0.8-1.0 fences of the first measurement round and (five photos/height/foal) and photos of the 1.2–1–3 m fences of the second measurement round (ten photos/height/colt) were selected for analyses (*Table 1.*). The changes in the height of the jumps were as follows: After the warming-up jumps of 0.5 m in the first round of measurements the bar was raised by 0.1 m following every two successful jumps. In the second round the same principle was observed and after the warming-up jumps of 0.9 m the bar was raised by 0.1 m following every two successful jumps. If, after a concentrated and calm approach the horse was unable to jump a certain height on three occasions, the bar was not raised any further (*Table 1.*).

Table 1.

The more important characteristics of the horses taking part in the test

Age(1)	Pre-training in days(2)	Time of measurement, day(3)	Maximum fence height, m(4)	n	Jumps repeated/individual(5)
1 year(6)	4	4	1.1	15	15
3 years(7)	18–21	18–21	1.6	12	20

1. táblázat: A vizsgálatban résztvevő csikók tesztjének fontosabb jellemzői
életkor(1), előtréning ideje napban(2), mérés ideje, nap(3), akadálymagasság maximuma(4), ismétlésugrás/egyed(5), egyéves(6), hároméves(7)

As regards each measurement round and individual there were 15 photos taken of each individual of one year of age while the three-year-old ones were taken 20 photos of in jumping. Out of these ones there were four photos selected, namely the ones that were the most characteristic of the individual in question, that is where the foal made the jump at a quet pace, from an ideal push off location while concentrating on the fence itself. Thus, jump analyses for a total of 12 foals were made on the basis of a total of 96 photos.

The horses taking part in the tests were divided into groups: those making fewer mistakes and that of those making several (subsequently, considering the rules of the equestrian sport, those making few mistakes can be considered as good jumpers and those making several mistakes can be considered as weak jumpers, respectively and so will be labelled as g and w in future). This classification was done in a way that the jumps of three-year-old horses were recorded daily and the numbers of good and wrong jumps were recorded.

During the 21 day-long period of tests the jumps performed by the horses were given scores on days 3–7, 10–15 and 18–20 with the remaining days allocated to training, relaxing and camera recordings.

On the days of training and jumping (i.e., not on the days for relaxing and camera recordings) records were taken. All the successful and unsuccessful jumps between heights 0.9 and 1.6 were taken into account. The successful jumps were given positively while the unsuccessful ones were given negatively weighed scores (*Table 2.*). If a given colt managed all the jumps successfully without errors, he had to perform a total of 13 jumps. If he made mistakes, but did not make three mistakes on any of the heights, he colt still managed to reach the height of 1.6 by having a maximum of 23 jumps with a total of ten jumps performed unsuccessfully. In theory, in an extreme case, a colt might have closed a day with only three failed jumps without having performed any successful ones on that day. Fortunately, however, this did not occur. At each one of the heights of 1.4–1.5-1.6 m the horses could only have one attempt and were stopped following the first unsuccessful jump. On the days of recording there were no records taken of the jumps and even after a series of wrong jumps each horse was made to perform 10 jumps at the heights of 1.2 and 1.3 m, respectively.

Table 2.

The scoring system used on the days of training

Hurdle height(1)	0.9 m	1.0 m	1.1 m	1.2 m	1.3 m	1.4 m	1.5 m	1.6 m
Possibilities of successful jumps(2)	2	2	2	2	2	1	1	1
Possibilities of unsuccessful jumps(3)	3	3	3	3	3	1	1	1
Multiplication factors of successful jumps(4)	1.0	1.0	1.1	1.2	1.3	1.4	1.5	1.6
Multiplication factors of unsuccessful jumps(5)	–1.3	–1.2	–1.1	–1.0	–1.0	–1.0	–1.0	–1.0

2. táblázat: A tréning napok pontrendszere
akadály magassága(1), sikeres ugrások lehetőségei(2), rontott ugrások lehetséges száma(3), sikeres ugrások szorzótényezői(4), rontott ugrások szorzótényezői(5)

The twelve colts were split into two groups of 6 on the basis of their successful and wrong jumps and the numbers of the points they had scored. The 6 horses making the fewest number of mistakes were put into the good group while the ones making the most number of mistakes were put in the weak group. Any classification done in this way has some inherent dangers at the same time with nearing the results to one another and thus only the really marked group differences can be felt during the subsequent analyses.
Table 3. contains some important data.

Table 3.

The most important numerical data of the statistics for the jumps

More important statistics(1)	Their values, points(2)
Theoretical maximum score(3)	219.8
Theoretical minimum score(4)	–42.0
Average of the weak group(5)	75.6
Average of the strong group(6)	162.4
The weak score of the best horse(7)	107.8
The high score of the worst horse(8)	93.8
The high score of the best horse(9)	183.4
The weak score of the worst horse(10)	–4.2

3. táblázat: Az ugrás statisztikák fontosabb számai
fontosabb statisztikák(1), ezek értékei, pont(2), elviekben elérhető maximum pont(3), elviekben lehetséges minimum pont(4), rossz csoport átlaga(5), jó csoport átlaga(6), legrosszabb jó értéke(7), legjobb rossz értéke(8), legjobb jó értéke(9), legrosszabb rossz értéke(10)

The data obtained were also compared with the opinions on the 12 three-year-old foals of the riding and breeding specialists with international backgrounds taking part in the experiment.

For the purposes of mathematical analyses and diagrammatic presentation the movement sequences were subdivided into their elements and the key movement elements were given coordinate values, i.e., value scores by making use of so called marker scores. The changes in the stifle-hock-fetlock angulation were measured in the jumps from moment of support by the forelimbs before the push off till the landing of the forelimbs after the jump had been completed.

Lateral marker points were painted on the lateral condulys, the area of the inner, rear hock articulation, the lateral middle of the os tali and at the end of the metatarsis distalis III in the area of the inner hind hock articulation of the right-hand part (the one near the side of the test corridor) of the foals.

The moment of support by the pushing up forelimb was always taken as the point of reference in carrying out the evaluations (*Phase 1, Photo 1.*).

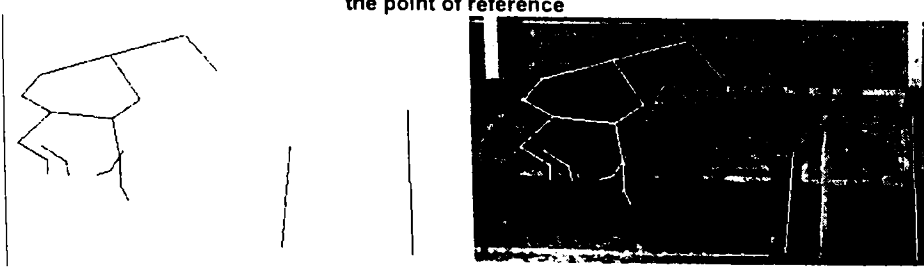
The jump, as a sequence of movement, was divided into two phases. Phase I lasted from the landing (which is at the same time the reference point as well) of the single leg of the last galloping jump till the moment of the pushing off of the hind limbs (*Photos 1–3.*) while phase II lasts from this latter moment till landing (*Photos 4–6.*). Either phase contains important elements (see serial pictures).

Phase I: the active setup of the trajectory

Phase II: passive flight, adjusting to the trajectory with minor corrections (legs, neck).

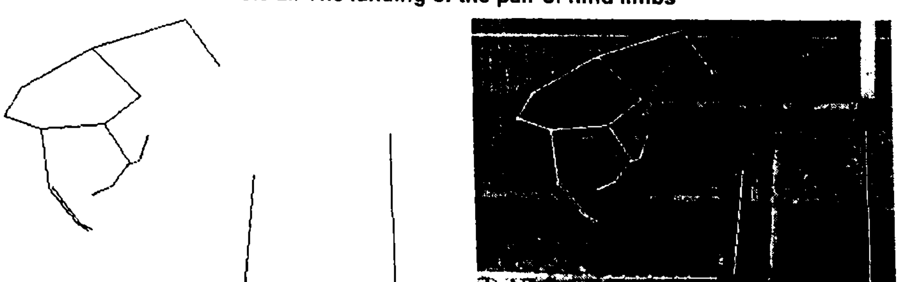
Phase I.

Photo 1.: **The beginning of the lifting of the body by the supporting forelimb, the point of reference**



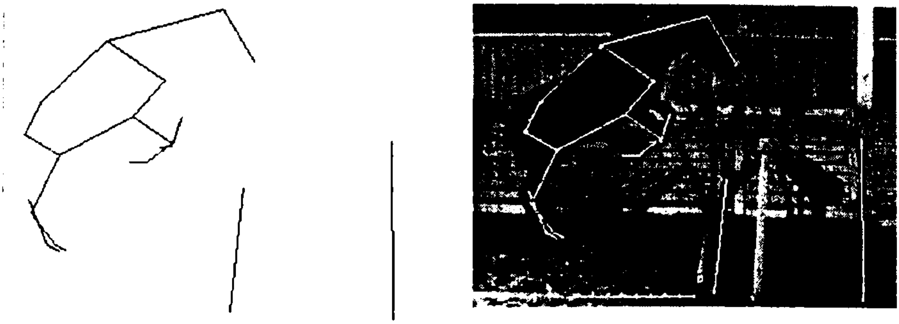
1. kép: Az alátámasztó mellső láb törzs emelésének kezdete, a referencia pont

Photo 2.: **The landing of the pair of hind limbs**



2. kép: A hátsó lábpár talajfogása

Photo 3.: **The ending of the flexing sub phase of the hind limbs, the beginning of the pushing sub phase**



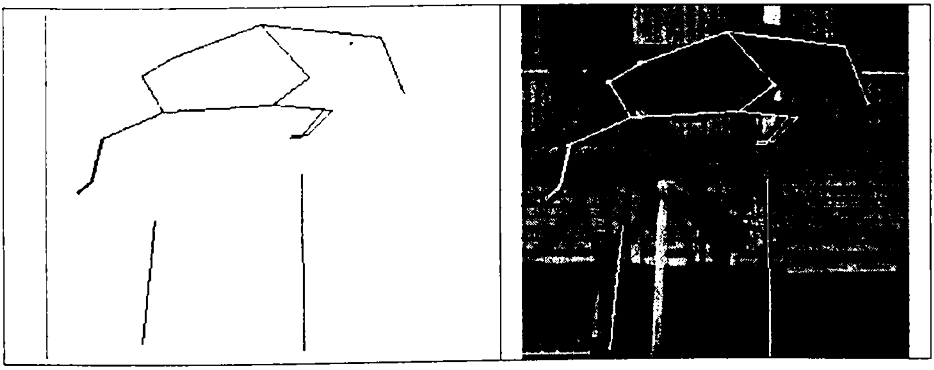
3. kép: A hátsó lábpár hajlító alfázisának vége, a toló alfázis kezdete

Phase II.

Photo 4.: **The ending of the push off, at the same time the beginning of the airborne phase**

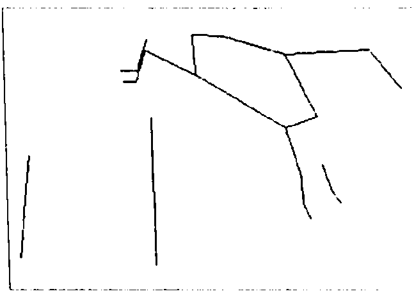
4. kép: Az elrugaszkodás befejezése, egyben a lebegés kezdete

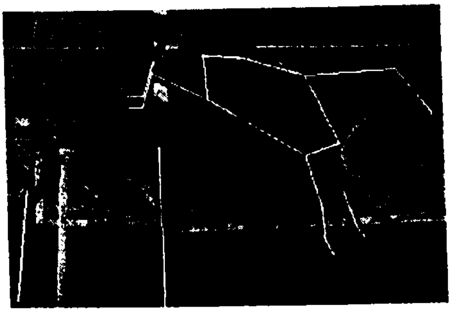
Photo 5.: **The airborne phase at the peak of the trajectory**



5. kép: Lebegés a pályagörbe csúcsánál

Photo 6.: **Landing, landing by the two forelimbs**





6. kép: Landolás, mellső láb talajfogása

When interpreting the graphs it is vital to be familiar with the key photos of the given recording, the point where the values for the 4 characteristics listed above were taken and compared (see, serial photos).

They are as follows in each case:

— The support by the forelimb before push off, the point of reference.

— The simultaneous landing of the hind legs before push off which is at the same time the beginning of the flexing sub phase.

— The beginning of the pushing sub phase by the hind legs (which is at the same time the ending of the flexing sub phase).

— The ending of the pushing sub phase by the hind limbs, the push off (which is at the same time the beginning of the airborne phase and phase II).

— The airborne phase at the peak of the trajectory.

— The landing of the forelimb after the jump, the beginning of the landing phase.

To conduct the analysis of variance of the data obtained SAS PROC GLM (2001) (general linear model procedure) was used. The height of the hurdle was taken into consideration within the age group as it was different from age group to age group. Besides, the model included the random effect of the quality of the jump (weak and good) also considered within the age group. The structure of the model was as follows:

$$Y_{ijk}=\mu+A_i+B_j(A_i)+O_k(A_j)+e_{ijk}$$

where:

Y_{ijk} = angle variable;

A_i = the constant effect of age (1, 3 years);

B_j = the random effect of the quality of the jump within the age group

O_k = the constant effect of the height of the hurdle within the age group (0.9, 1.0 and 1.1 m at the age of one, and 1.1, 1.2 and 1.3 m at the age of three)

e_{ijk} = the effect of the error.

The components of variance were assessed as regards age, horse and horse x age interaction by using SAS VARCOMP procedure (2001). Repeatability and reproducibility were calculated by using the formula below suggested by *Jansen et al.* (1985):

repeatability (r1) $= \sigma^2_{HORSE}+\sigma^2_{AGExHORSE}/\sigma^2_{TOTAL}$

reproducibility (r2) $= \sigma^2_{HORSE}/\sigma^2_{TOTAL}$

where:

σ^2_{HORSE}=horse variance component;

$\sigma^2_{AGExHORSE}$=horse x age variance component;

$\sigma^2_{TOTAL}= \sigma^2_{HORSE}+\sigma^2_{AGExHORSE}+\sigma^2_{ERROR}$,

where σ^2_{ERROR} the error variance component.

Repeatability represents the proportion of the total variance attributable to the horses and the differences between horses at various ages. *The British Standards Institution* (1979) describes repeatability as the index-number of the difference between two measurements conducted under identical conditions. In our case this is the similarity between two angles for one and the same individual in two subsequent jumps. Reproducibility measures the proportion of the total variation attributable to horses only. *The British Standards Institution* (1979) defines reproducibility as the index number between the performances of one and the same individual under different conditions. In our case this is the similarity between the angles of one and the same individual at different ages.

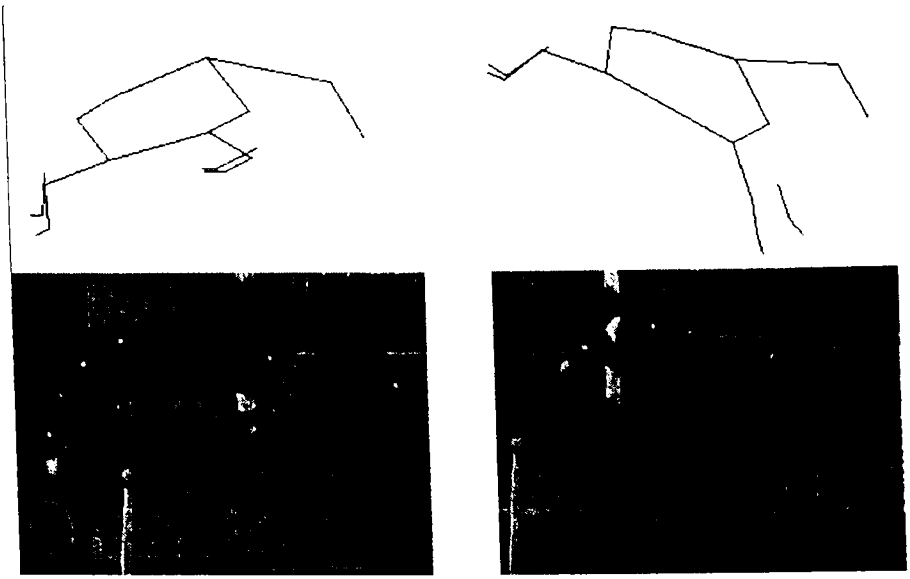
RESULTS

As is supported by the results of *Van den Bogert* (1994) this movement is the expression of the push off intensity of the hind limbs. Our claim is that by all means the push off by the hind limbs is the most important factor in manifesting the jumping ability of the horse. We have found that each foal makes efforts to find the ideal position between the hind limbs pushing off and its centre of mass that corresponds to the volume of the obstacle, the speed and the break away distance.

On the basis of our research we suggest that the horse trunk that has pushed off and is flying helplessly, follows the trajectory that depends on take off distance, the volume of the obstacle and the momentum with constant, gentle corrections, i.e. the success of the jump is primarily determined by the intensity of the push off of the hind limbs. In the second phase a clockwise turn of the body of the horse is observed. The speed of the turn of the angle formed with the horizontal line depends on the position of the hind limbs in relation to the centre of mass and the intensity of the push off as it is not under the lifting centre of mass that the hind limbs support the horse. Our research suggests that horses stretch their pasterns back and downwards or pull them under themselves and thus influence their stifle-hock-fetlock angles so as to correct the push off force and regulate the speed of the rotation of their bodies while in the air. *Galloux and Barrey* (1997ab) also claims that it is after push off, in the airborne phase of the jump that the corrective movements of the various parts of the body to influence the acceleration angle can be observed. The trajectory of the hind legs in relation to the pastern joint and the angulation of the stifle-hock-fetlock depend on the quality of the push off, which at the same time may establish a ranking order among the colts.

The angulation of the stifle-hock-fetlock and thus the effect on the acceleration angle of the rotation is illustrated by the horse Gidrán Rasbeg I-4 (Nepomuk), who made only few mistakes. The jump of three-year-old Gidrán Rasbeg I-4 (Nepomuk), jumping off vigorously and moderating the rotation taken at the peak of the trajectory and at the landing of the forelimbs (*Photo 7., Table 4., Figure 1.*).

Photo 7.: **The jump of three-year-old Gidrán Rasbeg I-4 (Nepomuk) (Jump No. 474)**



7. kép: A hároméves Gidrán Rasbeg I–4 (Nepomuk) ugrása (474-es kép)

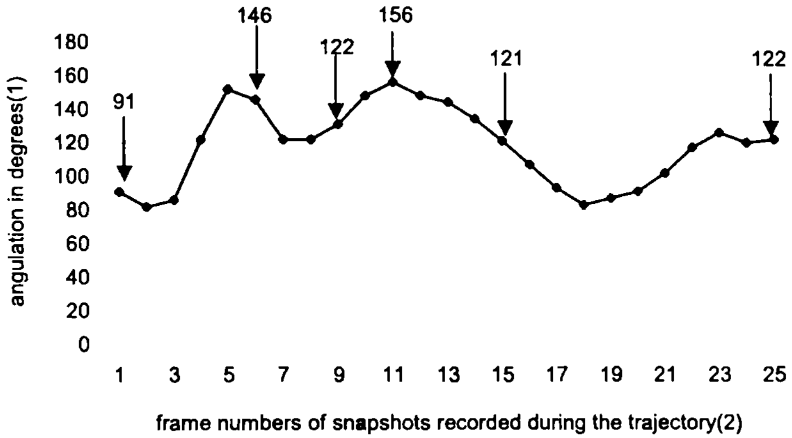
Table 4.

The development of the stifle-hock-fetlock angulation at the key moments of jump No. 474

The key moments of the jump(1)	Ref. point. The support of the fore-limb(2)	Landing of the hind limbs (the beginning of the flexing sub phase)(3)	The beginning of the pushing sub phase(4)	Push off(5)	The peak of the trajec-tory(6)	Forelimb lands(7)
Stifle-hock-fetlock angulation in degrees(8)	91	146	122	156	121	122
Number of picture(9)	1	6	8	11	15	25

4. táblázat: A 474-es ugrás szögváltozásának mért értékei fokokban
az ugrás kulcsmozzanatai(1), referenciapont, mellső láb alátámasztása(2), hátulsó lábak földet érése (hajl. alf. kezd.)(3), toló alfázis kezdete(4), elrugaszkodás(5) pályagörbe csúcsa(6), mellső láb földet ér(7), az ugrás csánk hajlítottsága fokokban(8), képkocka sorszáma(9)

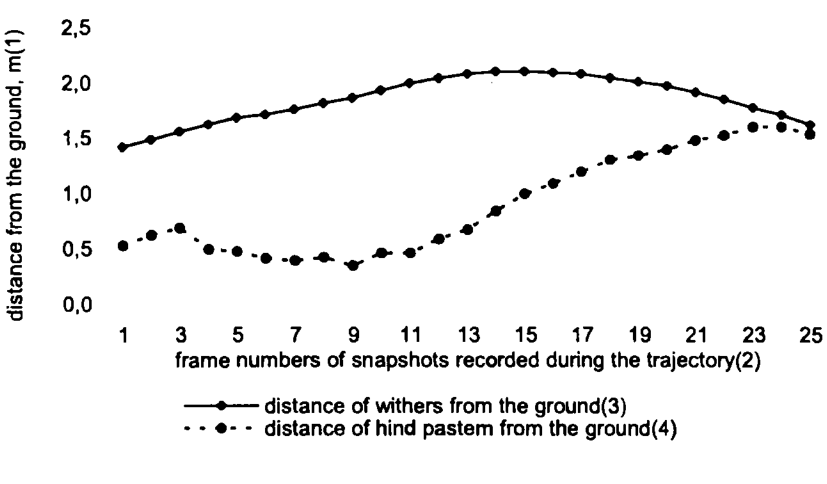
Fig. 1.: **Illustration of the jump off intensity of Gidrán Rasbeg I–4 (Nepomuk) through the stifle-hock-fetlock angulation (jump No. 474)**



1. ábra: Gidrán Rasbeg I–4 (Nepomuk) elugrási intenzitása fokokban (474-es ugrás)
hajlítottság fokokban(1), a röppálya pillanatfelvételeinek sorszáma(2)

Gidrán Rasbeg Nepomuk a stallion with excellent jumping abilities flies at 121° knee-hock-pastern angulation at the peak of the trajectory after push off (*Fig. 1.*). From this moment onwards this value increases till the moment the forelimbs land. When analysing the trajectories of the withers and the hind pastern side by side, we can see that the distance of the hind pastern from the ground at the moment of landing is very near to that of the withers (1.62 m and 1.54 m).

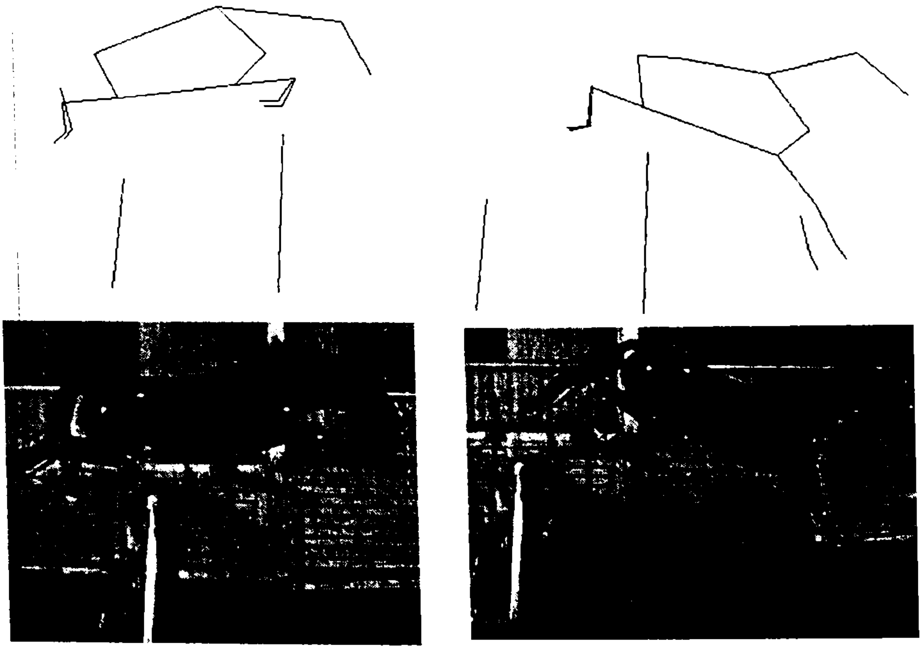
Fig. 2.: **Illustration of the jump off intensity of Gidrán Rasbeg I–4 (Nepomuk) (jump No. 474)**



2. ábra: Gidrán Rasbeg I–4 (Nepomuk) mar hátsó csüd pályagörbéje (474-es ugrás)
hajlítottság fokokban(1), a röppálya pillanatfelvételeinek sorszáma(2), mar távolsága a földtől, m(3), hátsó csüd távolsága a földtől, m(4)

Out of the poorly jumping (weakly pushing off) group, the group trying to ac celerate the rotation, it is jump 496 performed by Gidran Rasberg I-10 Sirán that is presented through the stifle-hock-fetlock angulation at the peak of th trajectory and at the moment of the landing of the forelimbs (*Photo 8., Table 5. Figure 3.*).

Photo 8.: **The jump of three-year-old Gidran Rasberg I-10 (Sirám) (Jump No. 496)**



8. kép: A hároméves Gidrán Rasbeg I–10 (Sirám) ugrása (496-os kép)

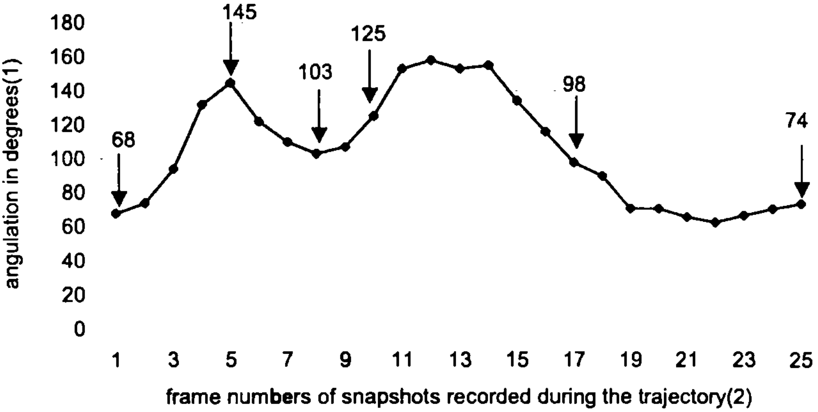
Table

The development of the stifle-hock-fetlock angulation at the key moments of jump No. 496

The key moments of the jump(1)	Ref point, the support of the fore-limb(2)	Landing of the hind limbs (the beginning of the flexing sub phase)(3)	The beginning of the pushing sub phase(4)	Push off(5)	The peak of the trajec-tory(6)	Forelin lands(
Stifle-hock-fetlock angulation in de-grees(8)	68	145	103	125	98	74
Number of pic-ture(9)	1	5	8	10	17	25

5. táblázat: A 496-os ugrás szögváltozásainak mért értékei fokokban
lásd 4. táblázat(1–9)

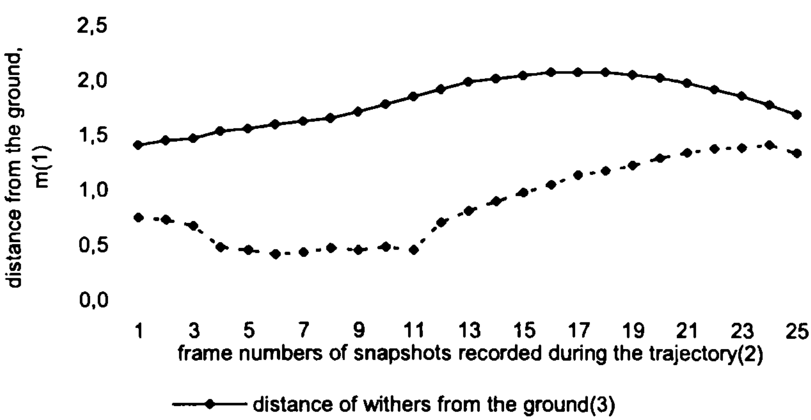
Fig. 3.: **Illustration of the jump off intensity of Gidrán Rasbeg I-10 (Sirám) through the stifle-hock-fetlock angulation (jump No. 496)**



3. ábra: Gidrán Rasbeg I-10 (Sirám) elugrási intenzitása fokokban (496-os ugrás)
hajlítottság fokokban(1), a röppálya pillanatfelvételeinek sorszáma(2)

Gidran Rasberg I-10 (Sirám)(w group) is forced to pull his hind limbs nearer his centre of mass so as to maintain the ideal body position for the trajectory of his jump and so has a rather more angulated hock in phase II of the jump than the colt performing jump 474, which was analysed earlier. The angle of 98° measured at the peak of the trajectory decreases further to 74° until the fore-limbs land. In analysing the trajectories of the withers and the rear pastern it is revealed that at the moment the forelimbs land the withers are in the air at 1.69 m, while the hind pastern is airborne, showing a much bigger difference in relation to the withers, at 1.34 m.

Fig. 4.: **Illustration of the jump off intensity of Gidrán Rasbeg I-10 (Sirám) (jump No. 496)**



4. ábra: Gidrán Rasbeg I-10 (Sirám) mar hátsó csüd pályagörbéje (496-os ugrás)
hajlítottság fokokban(1), a röppálya pillanatfelvételeinek sorszáma(2), mar távolsága a földtől, m(3), hátsó csüd távolsága a földtől, m(4)

In order to land in an ideal position after a vigorous push off Gidran Razbeg I-4 (Nepomuk) has to brake (and not to accelerate) his clockwise rotation in phase II of the jump. This is why he does not have to pull his hind legs under himself and so at the peak of the trajectory he can fly at a stifle-hock-fetlock angulation of 121° in comparison to that of 98 degrees seen in the case of Sirám. Due to the balancing corrections prior to landing the stifle-hock-fetlock angulation not only fails to increase further (as is the case with Sirám) but it actually decreases (i.e. the stifle-hock-fetlock angle opens up) so it reaches a value of about 122° before landing. The maintenance of stifle-hock-fetlock angulation before landing at the end of phase II is only characteristic of jumping colts with good jumping abilities and high push off intensity.

Based on statistical analyses it was concluded that at the action points considered the most important in this paper the stifle-hock-fetlock angulation occurred as is described below.

In the case of either age group significant differences were observed at the moment of support by the forelimbs before jumping off. It was interesting to observe that the individuals in the good jumpers' group arrived in phase I at smaller stifle-hock-fetlock angulations (more active hocks). Although not significantly this trend was continued until lumping off. At the age of one this difference disappears at the peak of the trajectory and in comparison to weaker jumpers a slower closing of the hock can be discerned until the point of landing. This feature tends to become more marked with age and at the age of three significant differences can be measured as regards stifle-hock-fetlock angulation at the moment of landing. With the individuals in group 2 there were significant differences in stifle-hock-fetlock angulation measured at the peak of the trajectory at the age of three. The fact that the data do not differ significantly may be the result of the large variation due to the small number of individuals.

Although the differences are not always significant and the repeatability of the results is low it is clear that the change in the stifle-hock-fetlock angulation with good jumpers is smaller in phase II of the jump, i.e., from pushing off onwards, than it is with weak jumpers. With good jumpers the change in the stifle-hock-fetlock angulation between pushing off and the landing of the forelimbs is 69.6°. In the same situation the change in the correction angle made by the weak jumpers is 74°. This trend increases with age significantly. With the good jumpers the change in stifle-hock-fetlock angulation between pushing off and the landing of the forelimbs is 62.2° at the age of three while with the ones jumping weakly at the age of three it is 84.4°. From these findings it follows that at the age of three the change in the angulation of the more outstretched stifle-hock-fetlock between the peak of the trajectory and the landing of the forelimbs is smaller with the better jumpers and the further closing of the otherwise closed stifle-hock-fetlock angle with weaker jumpers becomes more significant. No final conclusions can be drawn at this stage but it is a fact that according to our measurements at both ages there were even more significant differences in the stifle-hock-fetlock angulation found between the two groups in the differences measured at the push off of the forelimbs in phase I and the landing of the forelimbs in phase II. With one-year-old good jumpers the value was 17.3°, which went down to 5.8° at the age of three. With weak jumpers it was 33.6° at the age of one increasing to 35.9° at the age of three. (*Table 6.*)

Table 6.

The trends in the stifle-hock-fetlock angulation in the two groups

Characteristic/age(1)	One-year-old(2)		Three-year-old(3)	
	Good jumper(4)	Weak jumper(5)	Good jumper(4)	Weak jumper(5)
	$\bar{x} \pm s$			
Before hindlimb take off phase(6)	102.5±3.59[a]	116.7±3.49[b]	97.5±3.05[a]	105.5±2.99[b]
Hindlimb landing of the take off phase(7)	144.9±1.81	146.1±1.76	142.3±1.84	145.1±1.82
End of the hindlimb take off phase(8)	125.6±2.61	131.8±2.57	121.6±2.64	126.5±2.62
Beginning of airborne phase(9)	154.8±1.03	157.1±0.99	153.9±1.06	154.0±1.03
Airborne intermediate phase(10)	125.9±4.88	126.7±4.76	122.1±4.95	114.4±4.89
Forelimb landing phase(11)	85.2±4.74	83.1±4.67	91.7±4.79[a]	69.6±4.75[b]

[ab]: within the age groups the items indicated with different letters differ significantly at P<0.05(12)

6. táblázat: A térd-csánk-csüd hajlítottság legkisebb négyzetes átlaga és a középérték szórása korcsoportonként és ugrás minőségi csoportonként

tulajdonság/kor(1), 1 éves(2), 3 éves(3), jó ugró(4), rossz ugró(5), a mellső láb elrugaszkodás előtti alátámasztásakor(6), a hátulsó lábak elrugaszkodás előtti talajfogásakor(7), a hátulsó lábal toló alfázisának kezdetekor(8), a hátulsó lábak elrugaszkodásakor(9), lebegés a pályagörbe csúcsánál(10), mellső láb ugrás utáni talajfogásakor(11), [ab]:korcsoporton belül a különböző betűvel jelzettek P<0,05 szinten szignifikánsan különböznek egymástól(12)

The projected components of variance together with the values for repeatability and reproducibility are found in *Table 7.*

Table 7.

Components of variance in stifle-hock-fetlock angulation, values for repeatability and reproducibility

Characteristic(1)	Components of variance(2)				
	Horse(3)	Horse x age(4)	Error(5)	Repeat-ability(6)	Reproduci-bility(7)
Before hindlimb take off phase(8)	46.48	32.79	148.83	0.35	0.20
Hindlimb landing of the take off phase(9)	6.39	0.00	48.03	0.12	0.11
End of the hindlimb take off phase(10)	30.07	4.21	48.69	0.41	0.36
Beginning of airborne phase(11)	0.27	0.54	21.29	0.04	0.01
Airborne intermediate phase(12)	61.08	0.00	275.12	0.18	0.18
Forelimb landing phase(13)	78.61	85.28	150.65	0.52	0.25

7. táblázat: Az egyes szögekre számított variancia komponensek, ismételhetősége és megismételhetősége

tulajdonság(1), variancia komponensek(2), ló(3), ló x életkor(4),hiba(5), ismételhetőség(6), megismételhetőség(7), a mellső láb elrugaszkodás előtti alátámasztásakor(8), a hátulsó lábak elrugaszkodás előtti talajfogásakor(9), a hátulsó lábal toló alfázisának kezdetekor(10), a hátulsó lábak elrugaszkodásakor(11), lebegés a pályagörbe csúcsánál(12), mellső láb ugrás utáni talajfogásakor(13)

CONCLUSIONS

The free jump without pre-measured scaling jumps in front is suitable for assessing the jumping ability of colts.

The stifle-hock-fetlock angulation above the hurdle of the hind limbs pushing off depends on the intensity of the push off. There were significant differences obtained between the groups of good and weak jumpers as regards the moment of support of the forelimbs in phase I of the jump at ages of 1 and 3 respectively. As regards changes in the stifle-hock-fetlock angulation differences were measured between good and weak jumpers from pushing off in phase I till the landing of the forelimbs in phase II. At the age of one there was only a tendency towards but at three years of age there were significant differences measured between good and weak jumpers in stifle-hock-fetlock angulation at the moment of the landing of the forelimbs in phase II. At the age of three the changes in the angles of the more outstretched stifle-hock-fetlock during the time period between the peak of the trajectory and the landing of the forelimbs are smaller and the further closing of the closed stifle-hock-fetlock angle with weaker jumpers is more significant.

We think that the above standard may be applicable for projecting jumping capacity in the selection of equine populations.

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