Studies in the Relationship between Some Morphological Characters and Jumping Parameters in Sport Horses (Part I - Vertical Fence)

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Abstract
The multiliniar regression model introduced the variables control and estimated the contribution of every independent variable in the explication of the dependent variable variance, in a standard situation, when all independent had constant values. The taken into study independent variables were 12 morphological characters. The dependent value was represented by the entire length of the jump over the vertical fence and the bar-limbs distance in the same obstacle. The obtained value, for the multiple determination coefficients, nearby 1.00, in most of the cases in the high performance levels (B and C) showed the efficiency of the model and a good selection for the included factors. The obtained result focusing on the ensemble reports, in fact a result which can lead us to think that this kind of modeling can be applied freely to the horse height.

Keywords: sport horses, morphological characters, vertical fence

1. Introduction

Starting from the form-function principle, the present paper, proposed to analyse the relation between the morphological characters' of the equine jumpers and the jumping over obstacles parameters, respectively the entire length of the jump and the bar-limbs distance in a vertical fence. However, a morphological trait that would be able to stand as a mark in choosing a sport horse should be found. Although the established mark cannot ensure future competition results, which involve numerous elements, fact acknowledged by some authors [1, 2, 3, 4, 5]. But, it can function as a starting point in a competition horse career. It is well-known that a horse will not be able to become at least an average competition horse unless it has the biometric and biomechanical required trials, even if it is trained and led by a really valuable trainer and rider. In most cases when horses will not cooperate during the training, this refuse is considered due to their temperament, but it can also be a pain that prevents them to perform an exercise, or even a problem concerning their body structure or balance and equilibrium.

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2. Materials and methods

In order to describe the morphological traits 15 body measurements and body weight were carried out on 158 sport horses. These measurements (all in cm) were: height at withers (a), height at back (b), height at croup (c), thorax depth (d), hearth girth height (e), body length (f), head length (g), ancoliure (h) and neck (i) length, croup length (j), hearth girth (k), cannon girth (l), chest width (m), croup width at hips (n) and croup width at ischium (o). Body mass (p) was calculated using specific formulas (kg). For a better description of these equines there were made another 3 measurements on bone angles (all express in degrees): the inclination of scapula (q), the hock joint angle (r) and the pelvis inclination (s).
For the jumping parameters description, we obtained for one of the most used obstacles, the

vertical fence. All studied jumps were been executed during show jumping competitions and recorded with a video camera and a photo one. In this sense, the following height dimensions were the standard values for the jumps (values established by FEI, for every competition level). In order for the F, E, D, C and B levels, the vertical was situated respectively at 80, 100, 110, 120 and 130 centimeters height. The arena was covered classically with grass or with sand.

It was measured four parameters for every jump: the taking-off distance, the landing distance, and the distance between bar and limbs for the front legs and for the hind legs. The taking-off distance, was measured between the last contact of the hind limbs with the earth and the base of the obstacle. The distances between bar and limbs, were calculated by measuring for the front legs the nearest point of a limb in the moment immediately after started the ascendant phase, and for the hind limbs the nearest point between one of these and the bar in the last moment before the front limbs take the contact with earth. The landing distance, it was represented by the measurement from the base of the obstacle and the first contact of the front limbs with the earth after the jump.

For the mathematical modeling which follows were taken into count the entire length of the jump and the average limbs-bar distance over the vertical fence.

The connections between the dependent variable (the length of the horse jump and the bar-limbs distance) and the body measurements of the horse have been established and analysed by the use of mathematic research in order to explain and foresee the variation of the dependent variable. The multiple regression analysis has been used and the statistical significance of the parameters has been analysed during the research.

The multilinear regression model introduces the horse control variables and it estimates the contribution of each variable to the explanation of the dependent variable variations while all the other variables have constant values. There is a need to mention that the regression does not prove the causal chain between the variables, but it helps the study of their nature and their interference.

The 15 body measurements, the body weight and 3 bone angles as independent variables have been taken into account. The dependent variables have been represented by the total length of the jump over the vertical fence, and the bar-limbs distance in the same obstacle, at the same jumps.

The following multilinear regression model has been used in order to introduce the importance of the above mentioned features (point 1 in table 1). After processing the data on the 5 competition licence, ***K*** had different values according not only to the height and the type of the obstacle, but also to the different values of ***Y***, which varied according to the total length of the jump and to bar-limbs distance. The 19 morphological traits taken into work, were represented with letters from *a* to *s*. The regression equation parameters (the partial constant rate and partial coefficients) have been estimated according to the smallest squares using the Data Fit 8.2.79 Oakdale Engineering programme. A procedure of determining these parameters has been made so that it should minimize the total error and maximize the correlation between the observed values of the dependent variable and those calculated by using the regression model in the same time.

The statistic significance of the regression model has been tested by checking the 0 hypothesis, according to which there is no connection between the dependent variable and any other independent variable. On the one hand, this testing had into account the global significance evaluation of the regression model, on the other hand it focused on the evaluation of the partial regression coefficients (namely, evaluating the importance of each independent variable). In both cases, the F test has been adapted accordingly.

The initial equation and the definition model are number 2 and 3 in table 1.

Table 1. Mathematical equations used in the computing data's process

Nr.	Equations
1	$y = a_0 + b_1 x_1 + c_2 x_2 + d_3 x_3 + \ldots. + s_{19} x_{19}$
2	a*x1+b*x2+c*x3+d*x4+e*x5+f*x6+g*x7+h*x8+i*x9+j*x10+k*x11+l*x12+m*x13+n*x14+o*x15+p*x16+q*x17+r*x18+s*x19
3	Y=a*x1+b*x2+c*x3+d*x4+e*x5+f*x6+g*x7+h*x8+i*x9+j*x10+k*x11+l*x12+m*x13+n*x14+o*x15+p*x16+q*x17+r*x18+s*x19

3. Results and discussion

After having processed the data of the observed sample tests, the values of the regression equation coefficients have been registered for the studied horse jumps over the vertical fence in the entire length of the jump and the bar-limbs distance. Thus, *x1, x2, x3, ..., x19,* being the coefficients corresponding to the *a, b, c, ..., s* variables interpreted as points of the regression line $y = f(x_j)$ while all the values of x_j (for *j<>i*) are constant. It has been proved that the *a* variable is unnecessary, taking into account that the *a, ..., s* variables are included in the model (as an alternative hypothesis, *a* is necessary in the model to predict the *y* values). In this case, a (Student) partial t test has been used, calculated according to the variation explained by x_i, excluding the explanation based on the other variables .The obtained *prob (t)* probabilities included in the table, show that for the *p<5% coefficients*, the hypothesis rejects the analysis leading us to the conclusion that the variables corresponding to those coefficients cannot be removed from the model. On the other hand, the variables corresponding to the *p>5% coefficients* can be removed from the model. R^2, the multiple determination coefficient, which explains the influence of the *y* dependent variable upon the studied parameters *(a, b, ... s),* has also been calculated for each particular licence and obstacle (the length of the jump and the corresponding to the bar-limbs distance).
After calculating R^2, the multiple determination coefficient which explains the influence of the *y* dependent variable upon the studied parameters *(a, b, ... s),* (the term parameter is statistically used, it actually refers to the morphological trails; *mathematical model based on regression equation*, namely the total length of the jump and the bar-limbs distance were considered parameters in this context), the following situations has been obtained:

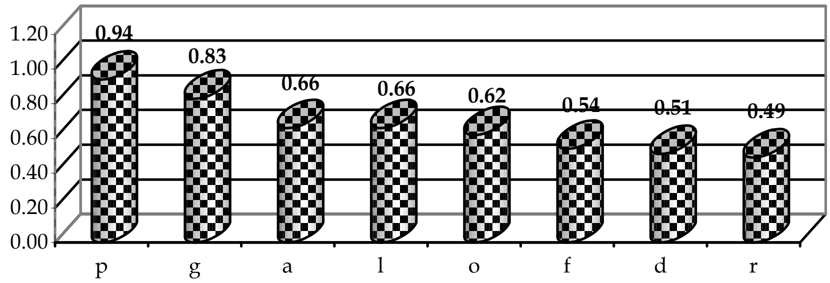

Figure 1. Main influence characters for the B level in the length of the jump at the vertical obstacle

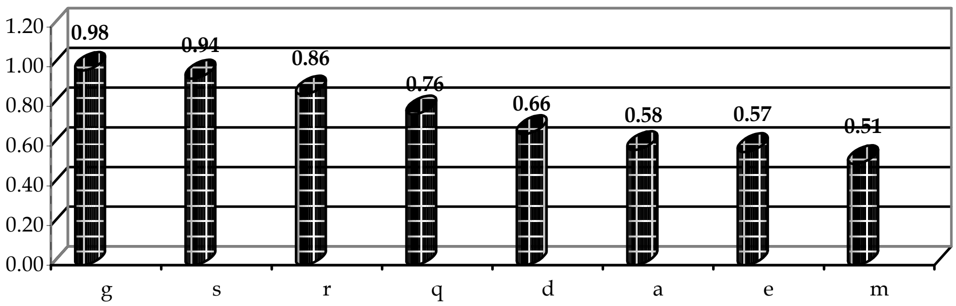

Figure 2. Main influence traits for the B level in the bar-limbs distance at the jump over the vertical fence

B level – 130 cm height vertical fence

Length of the jump

$R^2 = 0.98665$, meaning that the explained variant is of 98.66%, and 1.34% stand for other factors that have not been included in the equation. Thus, for the length of the jump over the vertical, the mathematical model based on regression equation emphasized 8 major characters. The morphological characters are represented by figure 1. The lowest probability of about 5% was represented by the hock joint, one of the most important elements in the propulsion of the horse over the obstacle. Six other characters had intermediate values, as it follows: the length of the head (extremely important in the changing equilibrium point), 8.3%; height at withers and cannon girth 6.6%; croup width at ischium, 6.2%; body length 5.4%; thorax depth 5.1%.

Bar-limbs distance

R^2 = 0.99342, meaning that the explained variant proportion is of 99.34%, and only 0.66% depend on other characters. Eight other characters have been obtained again (figure 2) corresponding to *p>5%*. Comparing this result to the previous one, 4 of 8 characters have been repeated with different values as it follows; head length, 9.8%; hock joint 8.6%; thorax depth 6.6% and height at withers 5.8%. The new entry characters considered: pelvis inclination or the angle of the pelvis with the horizontal line, 9.4%; scapula inclination or the scapula reported to horizontal, 7.6%; hearth girth height, 5.7% and the chest width, 5.1%.

C level – 120 cm height vertical fence

Length of the jump

R^2 = 0.67920, that means a proportion of 67.92% explicated variance, lower than in the B case, and an implicit value of 32.08 percentage points for the not included trials. A large number of characters registered again values upper than 5 (figure 3): neck length, 9.1%; height at back, 9.0%, head length, 8.8%; chest width, 8.2%; croup length, 8.1%; scapula inclination, 7.2%; body weight, 5.9%; croup width at ischium, 5.8% and ancoliure length 5.7%.

Bar-limbs distance

Lower with almost 10 percentage points was R^2 = 0.58350 (58.35%). Indeed, the unexplained part was 41.65%. Low value, low number of traits (figure 4): the hock joint, 9.9% was the higher value and at the other side was the croup length, 4.9%. Between these were the chest width, 8.5%; the head length, 8.4%; croup width at ischium, 7.9% and body length, 6.1%

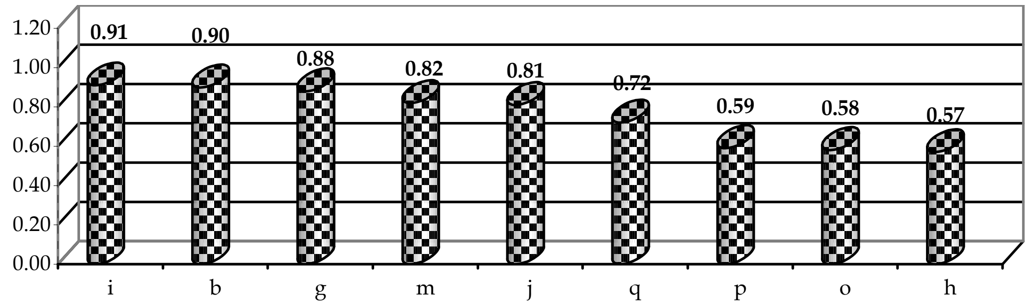

Figure 3. Main influence characters for the C level in the length of the jump at the vertical obstacle

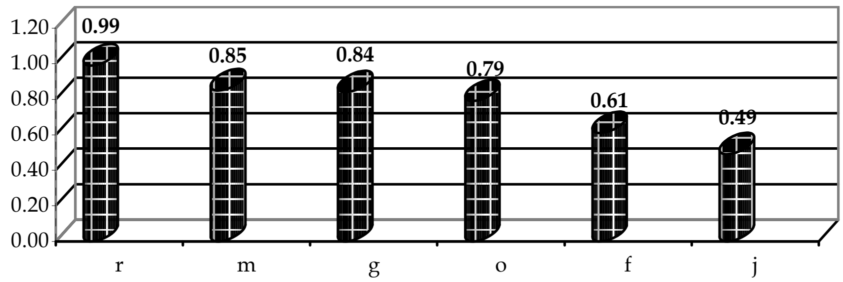

Figure 4. Main influence traits for the C level in the bar-limbs distance at the jump over the vertical fence

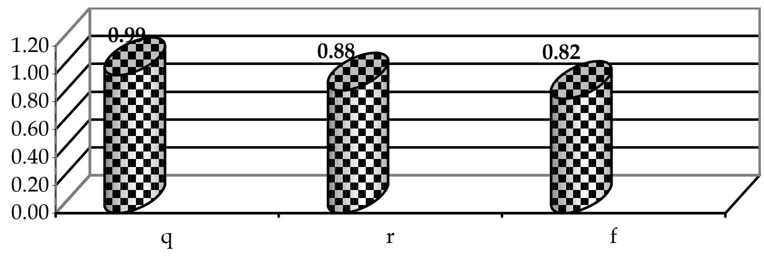

Figure 5. Main influence characters for the D level in the length of the jump at the vertical obstacle

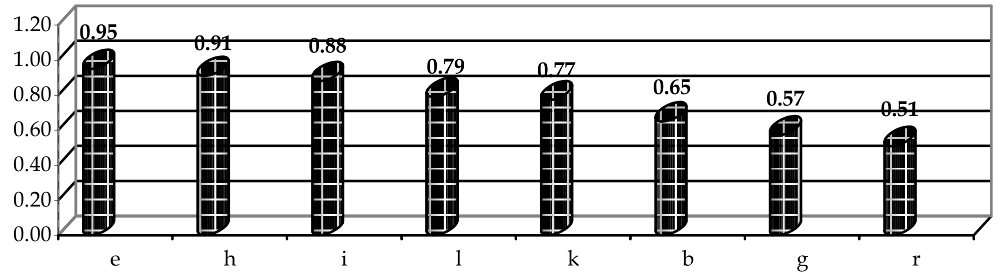

Figure 6. Main influence traits for the D level in the bar-limbs distance at the jump over the vertical fence

D level – 110 cm height vertical fence

Length of the jump

A score under 50 percentage points was obtained here with R^2 = 0.48656 (48.65%), that it means more than a half (51.35%) for this case, was remain to be explained by other non-computed data's. Height probability results came out for three morphological characters (figure 5): scapula angle with the horizontal, 9.9%; hock joint, 8.8%; body length, 8.2%.

Bar-limbs distance

In the case of the mathematical modelling regression equation for the bar-limbs distance, the result was higher, respectively R^2 = 0.53163 (53.16%), that turns the balance in the favour of the well-known elements and only 46.84 on the other side. Like figure 6 shows, the obtained values were: hearth girth height, 9.5%; ancoliure length, 9.1%; neck length, 8.8%; cannon girth, 7.9%; thorax girth, 7.7%; back height, 7.5%; head length, 5.7% and the hock joint, 5,1%.

E level – 100 cm height vertical fence

Length of the jump

R^2 = 0.66430, respectively 66.43% was the proportion of the explicated variance at this level; correspondently, 33.57% was in the favour of other elements that were not take part in this analyze. Out of the 19 tested morphological traits, 8 obtained to stay in the first half of the results (figure 7): body length, 9.1%; height at croup, 8.3%; chest width, 6.1%; croup width at ischium, 5.2%; height at withers, 5.1% and pelvis inclination, 4.9%.

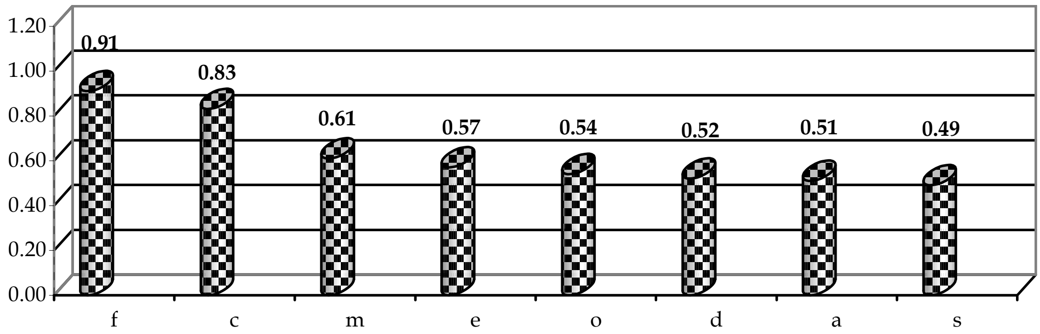

Figure 7. Main influence characters for the E level in the length of the jump at the vertical obstacle

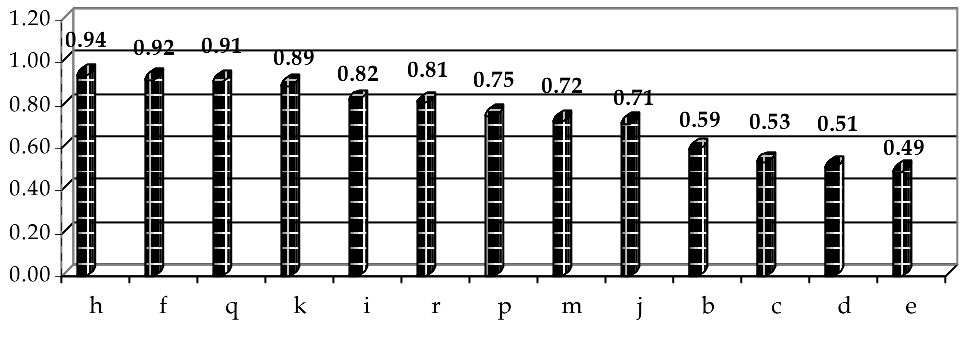

Figure 8. Main influence traits for the E level in the bar-limbs distance at the jump over the vertical fence

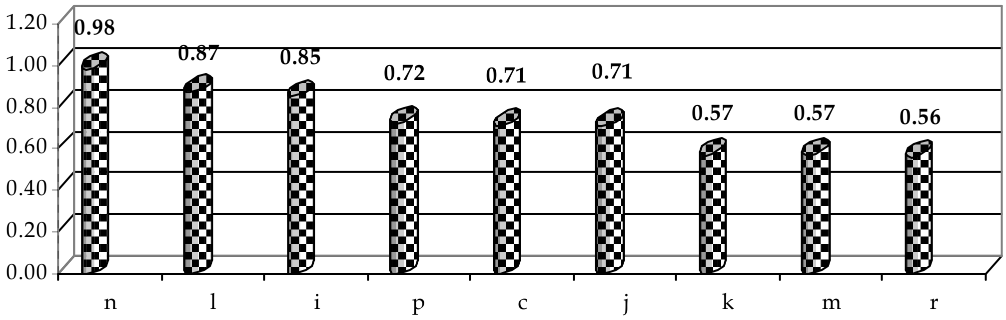

Figure 9. Main influence characters for the F level in the length of the jump at the vertical obstacle

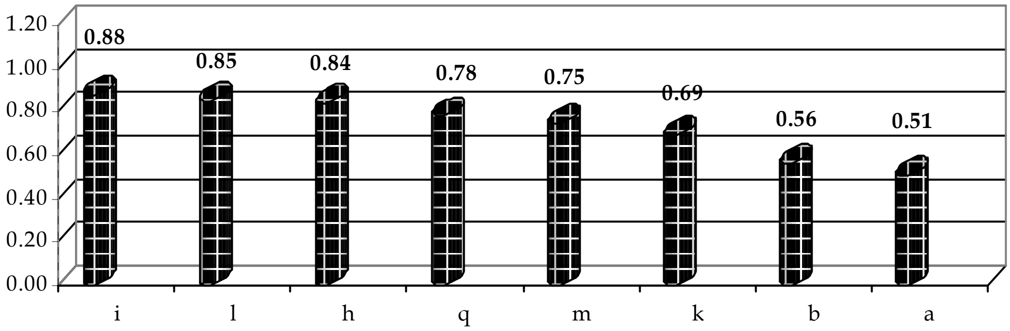

Figure 10. Main influence traits for the F level in the bar-limbs distance at the jump over the vertical fence

Bar-limbs distance

The second time, we registered here a score under 50 percent, with R^2 = 0.40792, respectively 40.79% versus 59.27% uncounted trials. Even the result in ensemble has a low participation; there were a lot of characters included (figure 8), as follows: ancoliure length, 9.4%; head length, 9.2%; scapula inclination, 9.1%; heart girth, 8.9%; neck length, 8.2%; hock joint, 8.1%; body mass, 7.5%; chest width, 7.2%; croup length, 7.1%; height at back, 5.9%; height at croup, 5.3%; thorax depth, 5.1% and heart girth height, 4.9%.

F level – 80 cm height vertical fence

Length of the jump

The last studied competition level, relieve a parameter R^2 = 0.61647 (61.64%) and implicit a not analyzed 38.36% trials proportion. Nine characters resulted here with percentage values from 9.8 to 5.6 (figure 9). There were: croup width at hips, 9.8%; cannon girth, 8.7%; neck length, 8.5%; body mass, 7.2%; height at croup, 7.1%; croup length, 7.1%; hearth girth and chest width, 5.7%; hock joint, 5.6%.

Bar-limbs distance

For the second measured parameter at this height, R^2 = 0.50998, that means an almost equal report for the explicated variance (50.99%) in one hand and for the non explicated variance (49.01%) in the other hand. Figure 10 show the main influence morphological characters at this point: neck length, 8.9%; cannon girth, 8.9%; ancoliure length, 8.4%; scapula angle with horizontal, 7.8%; chest width, 7.5%; heart girth, 6.9%; back height, 5.6% and height at withers, 5.1%

4. Conclusions

The power of explication, of the multiliniar regression model is indicated by R^2 which shows the percent of the dependent variable variance was explicated by the variance of the independent variables.

The taken into study parameters, respectively the entire length of the jump and the bar-limbs distance over a vertical fence, was explicated from 99.34% to 40.79% based on the taken into study biometrical characteristics of the sport horses. The length of the jump, count results from 98.66% (B level) to 48.65% for the D competition level; others in order were C with 67.92%, E with 66.43% and F with 61.645%. For the second distance, the highest result was 99.34% again for the B level; the lowest was for E, 40.79%. Like for the first parameter, the second place was for the C

level, 58.35% and than 53.16% for D level and 50.99% for the lowest level F.
The morphological characters, included in the above results, counted from 3 to 13 elements.
The horse selection, for sport generally and for obstacles particularly, is a theme for the owner, or the future owner, trainers and riders. To obtain a new generation with correct biometrical characters, is an important target which can start based on studies like this.
The obtained value, for the multiple determination coefficients, nearby 1.00, in most of the cases and especially for the high B and C levels, showed the efficiency of the model and a good selection for the included factors. The lower values for this determination coefficient, obtained sporadically, for the middle categories (D and E) and the lowest one F, showed in fact, that there are some sport horses which did not accede in the equestrian sports based on a correct conformation and good biometrical aspects, but probably on a greater capacity of détente and a lot of suitable work.

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