Form and Function:

An Empirical Study of Speed

A single galloping stride

and the

Conformation Characteristics

of Borzoi

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Introduction

Even the word "borzoi" means swift in Russian. The borzoi was developed over centuries by wealthy noblemen to be a dog with great speed and power. These were large dogs - expensive to hunt with and maintain. Their purpose was to put on an impressive show by running down prey on open terrain. Undoubtedly the different noble families bred dogs most suited to the local prey, climate, and territory as well as their own tastes as to color and style. However, speed was the essential characteristic that made a borzoi a borzoi.

This study was designed to help understand what physical characteristics are most essential to borzoi speed.

The American and Federation Cynologique International (FCI 2000) borzoi standards were used to determine what anatomical features were measured. Such descriptions as "forelegs somewhat flattened like blades with the narrower edge forward" were measured as width and depth of foreleg at 2 cm above the carpus. Most cosmetic details such as teeth, color, tails, and head shape were excluded.

Borzoi included in the study were 2 to 6 years old, in excellent health and condition, with bitches not within 30 days post a heat cycle. Borzoi were volunteered by their owners from a wide variety of kennels in England, Germany, and across the United States. Each borzoi in the study was measured standing in show position with hocks perpendicular for the following:

sex_____   age_____

Height at withers (cm)_____

Height at elbow (cm) _____- taken from floor to point of elbow

Width of chest (in) _____- taken at widest point

Depth of chest (in) _____ -taken at level of T 11

Width of loin (in) _____-taken at level of iliac crest

Depth of tuck up (in)_____ - taken at narrowest point

Width of rear (in) _____- taken at widest point

Length of back (cm) _____ - taken from sp. pr. of T1 to sp. pr. of T11

Length of loin (cm) _____ - taken from s.p. of T11 to iliac crest

Length of croup (cm)_____ - iliac crest to ishiatic tuberocity

Ear set (mm) _____ - from top of skull to the base of the auricular cartilage

Width of foreleg (mm) _____ - taken at 3cm above the carpus

Depth of foreleg (mm) _____- taken at 3cm above the carpus

Length of foot (mm) _____ -on ground, from pad to base of toenail.

Elasticity of skin (mm) _____- taken at withers

Angle of croup (degrees) _____ lumbar spine & pelvis

Angle of hock (degrees) _____ - metatarsals perpendicular

Angle of shoulder (degrees) _____ -spinous process & humorous

Angle of pastern (degrees) _____ -dorsal surface

anticline

croup angle
iliac crest
ischiatic
tuberocity

shoulder
angle

hock
angle

pastern
angle

spine of scapula

anticline

iliac
crest

isciatic
tuberocity

point
of shoulder

lateral
epicondyle

hock
joint

carpal
joint
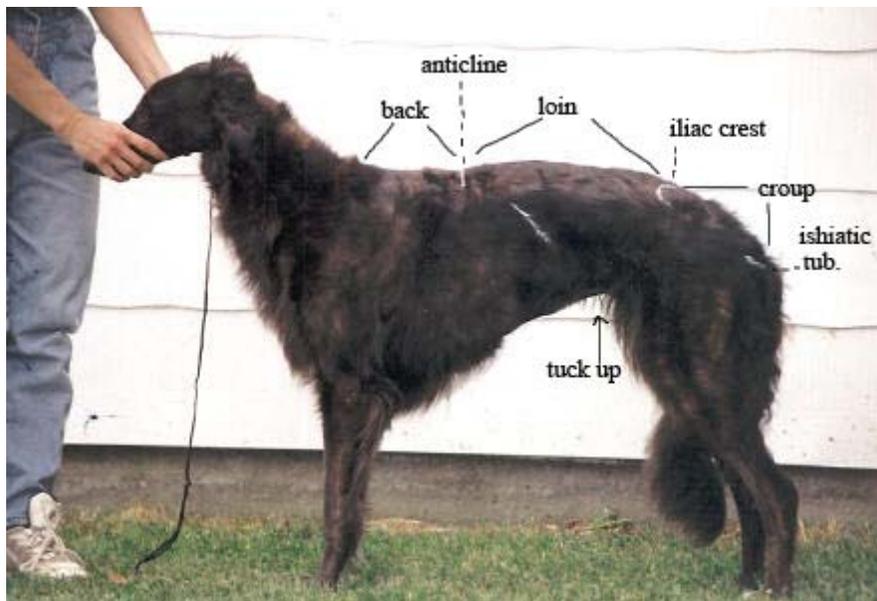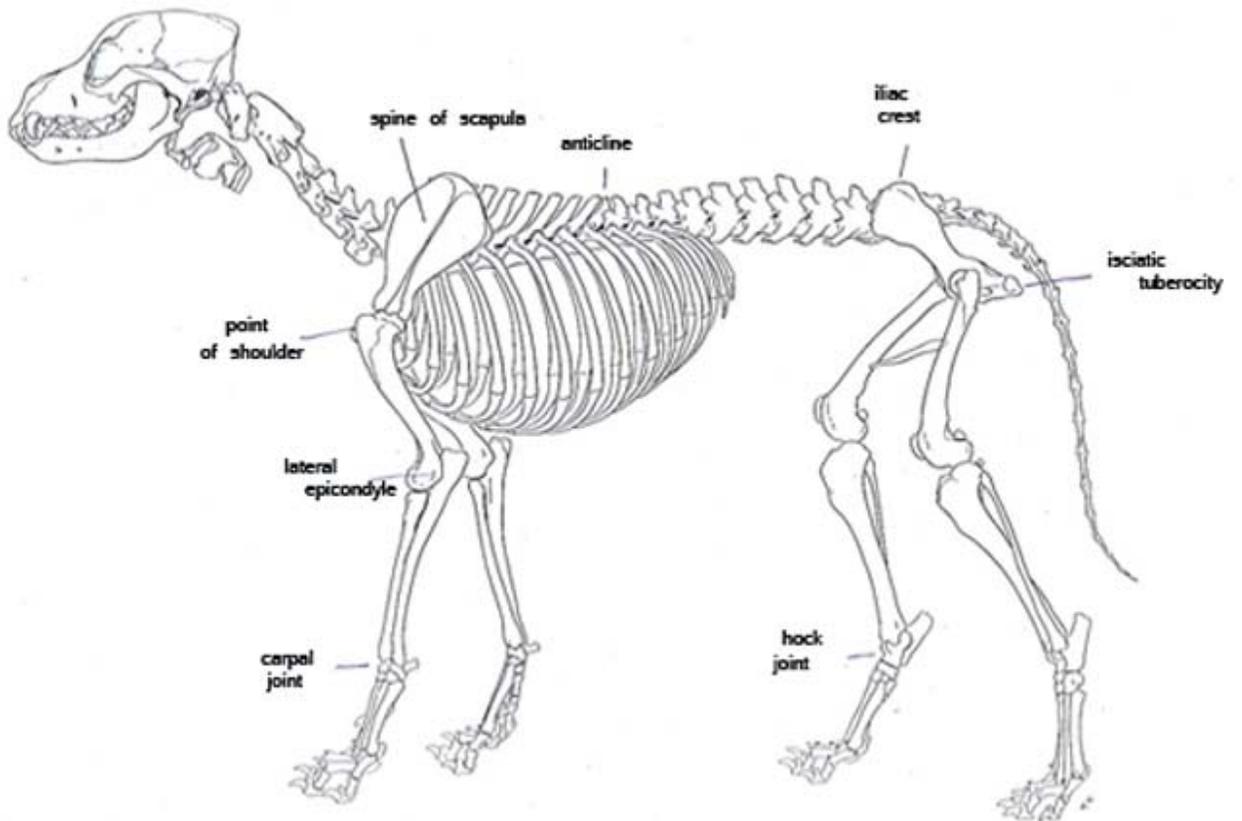
Each borzoi was encouraged to run as fast as possible by chasing after a drag lure made of a rabbit fur squawker through two pairs of electronic eyes set exactly 150 feet apart. They were allowed a 150 foot running start and an approximate 100 foot run off. Dogs who did not appear to be running with maximum effort were excused from the study. Time was measured with a Polaris FarmTek Rodeo Sprint Timer to one-thousandth of a second. 191 borzoi qualified to be included in the study. All the data collected is available at: www.nktelco.net/teine/ssdata191.htm. Statistical analysis was assisted by Dr. John D McGinnis, Associate Professor of Finance, Penn State University. Variables compared to SPEED (feet/second) in the study include:

1- HEIGHT = height at withers

2- LEG = height at elbow / height at withers

3- CHEST = width of chest / depth of chest

4- CHEST/REAR = width of chest/width of rear

5- LOIN WIDTH = width of loin

6- TUCK UP = depth of tuck up / depth of chest

7- LOIN LENGTH = length of loin / [length of back + length of loin]

8- CROUP LENGTH = length of croup / height at withers

9- FOOT = length of foot / height at withers

10- BONE = width of foreleg / depth of foreleg

11-EAR SET

12- SKIN ELASTICITY

13- REAR WIDTH = Width of rear / height at withers

14- REAR ANGLE = angle of hock

15- CROUP ANGLE

16- PASTERN ANGLE

17 - SHOULDER ANGLE

18 - REAR SYMMETRY = dogs with rear angle greater than croup angle vs. dogs with rear angle less than croup angle

Table 1
Descriptive Statistics of Variables of Interest

Panel A: Basic Variables

Variable	mean	standard deviation	minimum	maximum	variation coefficient
speed (feet/second)	47.48	2.41	40.62	52.34	5.07%
withers height (cm)	77.36	3.94	68	90	5.10%
rear width (in)	9.59	.56	8	10.75	5.90%
loin width (in)	5.61	0.51	4.25	7	9.07%
ear set (mm)	32.43	5.85	20	49	18.04%
skin elasticity (mm)	62.79	17.89	29	114	28.49%
age (years)	3.47	1.34	2	6.75	38.58%
sex (1 = male)	0.46	0.50	0	1	109.67%

Panel B: Angle Variables

Variable	mean	standard deviation	minimum	maximum	variation coefficient
croup angle	151.68	6.08	130	166	4.01%
rear angle	148.13	7.02	128	164	4.74%
shoulder ang	125.08	8.31	106	152	6.64%
pastern	167.02	6.50	141	180	3.89%

Panel C: Relative Variables (Monotonic)

	mean	standard deviation	minimum	maximum	variation coefficient
leg = elbow/withers	0.54	0.02	0.47	0.58	2.95%
chest = width/depth	0.52	0.05	0.39	0.65	10.05%
chest/rear (width)	0.68	0.06	0.50	0.88	9.49%
tuck-up = tuck depth/ chest depth	0.53	0.05	0.41	0.70	9.91%
% loin = loin/(loin+back+croup)	0.45	0.03	0.37	0.51	6.44%
bone = width/depth of foreleg	0.66	0.07	0.51	0.88	9.96%
foot = foot(mm)/withers(cm)	0.97	0.09	0.58	1.24	8.99%
rear sym = 1 if hock angle > croup angle	0.32	0.47	0.00	1.00	144.82%
croup = croup/withers	0.26	0.02	0.21	0.31	6.37%

The fastest borzoi ran 150 feet in 2.866 seconds = 52.4 ft/sec = 35.7 mph = 57.4 km/hr

Average borzoi speed was 150 feet in 3.16 seconds = 47.48 ft/sec = 32.4 mph = 52.1 km/hr

The slowest borzoi ran 150 feet in 3.693 seconds = 40.6 ft/sec = 27.7 mph = 44.6 km/hr

Table 2
Statistical comparison of Fastest 80 Borzoi Versus Slowest 80 Borzoi.

	Fastest Borzoi		Slowest Borzoi		Statistical Results	
Variable	mean	variance	mean	variance	t-stat	p-value
htwither	76.93	13.21	77.66	18.78	-1.1564	0.2493
Leg	0.54	0.00	0.54	0.00	1.0208	0.3089
Chest	0.53	0.00	0.52	0.00	0.9986	0.3195
Chst/rear	0.68	0.00	0.69	0.00	-0.7724	0.4410
loin wdth	5.65	0.18	5.58	0.32	0.9502	0.3435
tuck-up	0.52	0.00	0.54	0.00	-2.1018	0.0372
% loin	0.47	0.00	0.43	0.00	10.532	0.0000
Ear set	29.45	20.33	35.74	32.22	-7.7579	0.0000
Bone	0.65	0.00	0.69	0.01	-3.9701	0.0001
Foot	0.97	0.01	0.97	0.01	-0.0207	0.9835
skin elast	51.13	150.21	75.55	330.88	-9.9601	0.0000
Croup angle	152.34	35.01	151.10	40.07	1.2774	0.2033
Rear angle	146.73	49.32	149.74	49.66	-2.7083	0.0075
Shldr angle	124.88	62.03	125.95	83.59	-0.7968	0.4268
Pastern	167.36	25.73	166.83	48.35	0.5586	0.5772
Rear sym	0.23	0.18	0.46	0.25	-3.2458	0.0014
Croup	0.27	0.00	0.26	0.00	1.7844	0.0763
Rear width	9.67	0.23	9.53	0.38	1.6719	.0426
Sex	0.44	0.25	0.46	0.25	-0.3159	0.7525

Analysis

TABLE 2 compares the fastest 80 borzoi to the slowest 80 borzoi.

The lower the p-value the more significant the difference between the two groups. A p-value of 0.0001 indicates that there is 1 chance in 10,000 that the difference between the two groups is due to chance. Any variable with a p-value lower than 0.05 is considered statistically significant. The t-stat gives both the direction and magnitude of the significance.

% LOIN shows the greatest association with speed (p-value of 0.0000 and a t-stat of 10.5319). This means that the faster dogs have considerably longer loins than backs. Short backs with long loins are HIGHLY significant.

SKIN ELASTICITY has the next largest association with speed (p-value of 0.0000 and a t-stat of -9.8923). The negative t-stat means that LESS skin can be easily pulled up in the faster dogs. Tight skin is also HIGHLY significant.

EAR SET shows a large association with speed (p-value of 0.0000 and a t-stat of -7.7579). The faster dogs' ears are set significantly closer to the top of the skull.

BONE also shows a large association with speed (p-value of 0.0001 and t-stat of -3.9701). The faster group have much narrower forelegs as compared with the width.

Borzoi with REAR SYMMETRY such that croup angle is larger (more open) than the hock angle are significantly faster (p-value of 0.0014 and t-stat of -3.2458).

The fast group had significantly smaller REAR ANGLES than the slower group (p-value of 0.0075 and t-stat of -2.7083).

The fast group also had higher TUCK UPs than the slower group (p-value of 0.0372 and t-stat of -2.1018).

The faster group had wider REARS than the slower group (p-value of 0.0426 and t-stat of 1.6719).

Table 3

Regression Output of Conformation Variables on Speed. Variables are arranged by relative impact (beta coefficients) from the largest on top to the smallest on the bottom.

variables	coefficients	std. error	t-statistic (df=181)	p-value	95% confidence interval lower	upper	relative impact[*]
Intercept	33.9654	3.8579	8.804	0.0000	26.3532	41.5776	
% loin	35.8468	4.2457	8.443	0.0000	27.4694	44.2242	0.432
ear set	-0.1174	0.0205	-5.722	0.0000	-0.1578	-0.0769	0.283
skin elast	-0.0356	0.0065	-5.448	0.0000	-0.0486	-0.0227	0.276
croup	17.7101	6.7044	2.642	0.0045	4.4814	30.9389	0.122
tuck-up	-4.4811	2.0107	-2.229	0.0135	-8.4485	-0.5137	0.097
rear sym	-0.3694	0.2245	-1.645	0.0508	-0.8123	0.0736	0.072
chest	1.8019	2.0747	0.869	0.1931	-2.2918	5.8957	0.039
foot	0.5133	0.9833	0.522	0.3012	-1.4269	2.4535	0.022
bone	-0.4228	1.3891	-0.304	0.3806	-3.1637	2.3182	0.013

Number of Observations = 191

Adjusted R^2 = 69.4%

*Relative impact measures the change in speed measured in standard deviations for a one standard deviation change in the independent variable.

Regression analysis looks for LINEAR relationships. Table 3 reports measurements (coefficients) that increase or decrease DIRECTLY with speed as estimated through Ordinary Least Squares Regression Analysis. The lower the p-value the higher the statistical significance of the coefficients; that is, the less likely they differ from zero just by chance. A p-value of 0.0001 means that there is 1 chance in 10,000 that the true coefficient is zero. A coefficient with a p-value lower than 0.05 is considered statistically significant. The t-stats give both the direction and magnitude of the significance.

% LOIN is once again the most important contributor to speed (p-value of 0.0000 and a t-stat of 8.443). The longer the portion of the topline is from the anticline to the iliac crest, the faster the dog.

EAR SET has a very strong linear relationship with speed (p-value of 0.0000 and a t-stat of -5.722). The higher the ear is set to the occipital crest, the faster the dog.

SKIN ELASTICITY has a very strong linear relationship with speed (p-value of 0.0000 and a t-stat of -5.448). The less skin that can be easily pulled up, the faster the dog.

CROUP LENGTH has a strong linear relationship to speed (p-value of 0.0045 and a t-stat of 2.642). The longer the croup, the faster the dog.

TUCK UP has a linear relationship to speed (p-value of 0.0135 and a t-stat of -2.229). The higher the belly is from the bottom of the chest, the faster the dog.

REAR SYMMETRY is linearly related to speed (p-value of 0.0500 and a t-stat of -1.645). The flatter the croup angle is relative to the more angulated hock, the faster the dog.

Chest, foot, and bone do not appear to be linearly related to speed.

Table 3 lists the independent variables from top to bottom in order of their relative impact on speed as measured by the change in the standard deviation of speed associated with a one standard deviation change in the variable of interest. Table 4 is a stepwise regression further documenting the relative impact of the variables and their relationship to speed.

Table 4

Stepwise Regression Analysis displaying the best model for each number of variables chosen.

p-values for the coefficients

number of variables	% loin	ear set	skin elast	rear sym	chest	croup	tuck-up	bone	foot	Adjusted R²
1	.0000									.447
2	.0000		.0000							.617
3	.0000	.0000	.0000							.669
4	.0000	.0000	.0000			.0003				.688
5	.0000	.0000	.0000			.0003	.0215			.693
6	.0000	.0000	.0000	.0304		.0009	.0206			.697
7	.0000	.0000	.0000	.0377	.1882	.0028	.0133			.697
8	.0000	.0000	.0000	.0474	.1980	.0034	.0133		.2933	.696
9	.0000	.0000	.0000	.0508	.1932	.0045	.0135	.3806	.3012	.694

Table 5

Results of regressions of speed on CHEST and angle variables and the square of the angle variables for determine optima.

Variable	Beta (p-value)	Square Beta (p-value)	Minimum	Maximum	Optimum
Chest	78.59 (.0161)	-69.44 (.0332)	.3929	.6522	.5659
Rear Angle	.6905 (.1664)	-.0027 (.1345)	128	164	129.35
Shoulder Angle	.6414 (.0835)	-.0027 (.0723)	106	152	120.42
Pastern Angle	1.4479 (.0255)	-.0044 (.0254)	141	191	165.47
Croup Angle	-.1059 (.4575)	.0005 (.4396)	130	166	105.09**

**Croup optima is a minima implying smaller croup angles create slower dogs.

The optimal proportion of the CHEST for speed is 56:100 (.5659) or slightly wider than half the depth.

PASTERN ANGLE is statistically significantly related to speed. There is an optimal level of 165.47 degrees.

Shoulder angle is not as statistically significant (p-value 0.0723), but there is a tendency toward an optimal shoulder angle of 120 degrees.

Croup angle and hock angle are not significant by themselves, but the calculated optima reinforce the rear symmetry finding of flatter croup angles to smaller hock angles.

Discussion

This analysis suggests that certain characteristics contribute to the speed differences observed among borzoi with varying degrees of importance.

I. MOST IMPORTANT:

A. The three most influential conformational attributes to speed are comparatively short back & long loin, tight elastic skin and high set ears. These variables have no calculated optimal levels but continue **linearly** in a manner so that more is better.

The most important conformational attribute to speed is having a comparatively short back and long loin. The back is from T-1 to the anticline (T-11) and the loin is from the anticline to the iliac crest. The fastest borzoi measured have a loin length approximately twice the length of the back.
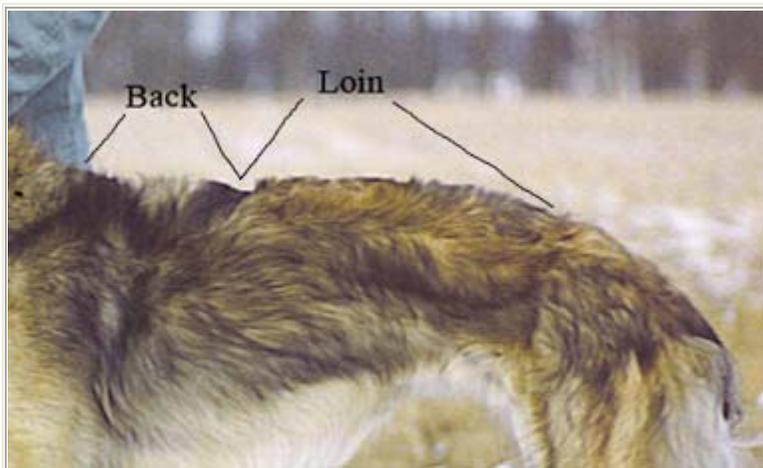
| the loin is twice the length of the back (faster) | the loin is nearly the same length as the back (slower) |
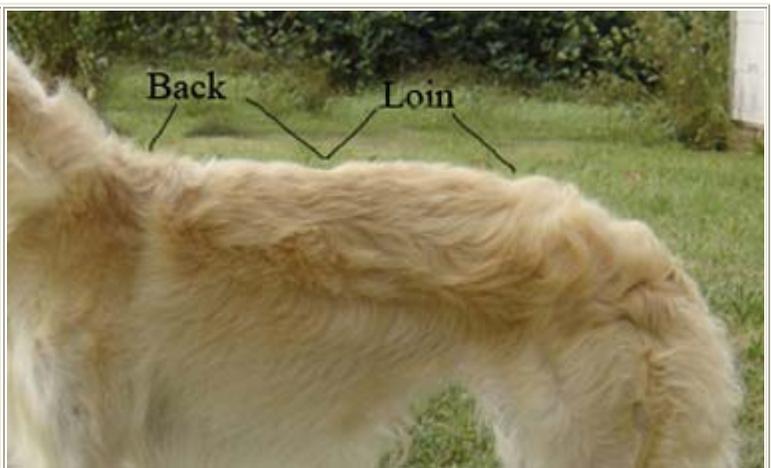
Russian standard: BACK is broad, muscled, elastic, forming with the loin and croup a curve which is more pronounced in the males. The highest point of this curve is situated in the region of the first or second lumbar vertebra. LOIN Long prominent, muscled, moderately broad.

AKC standard: BACK -- Rising a little at the loins in a graceful curve. LOINS: Extremely muscular, but rather tucked up, owing to the great depth of chest and comparative shortness of back and ribs.

FCI standard ('06): BACK -- Broad, muscled, elastic, forming with the loin and croup a curve which is more pronounced in the males. The highest point of this curve is situated

ahead of the middle of the loin or in the region of the 1st or 2nd lumbar vertebra.. <u>Loin:</u> Long, prominent, muscled, moderately broad.

The next important factor for speed is tight elastic skin. Tighter skin is correlated with increased speed.

Russian standard: SKIN -- Supple, elastic Faults: insufficiently supple and elastic Serious faults: loose skin

AKC standard: NECK -- Clean free from throatiness

FCI standard ('06): SKIN -- Supple, elastic

Another most important factor to increased speed is high set ears. The closeness of the ears set to the top of the skull correlates positively with speed.

| Higher set ears (faster) | Lower set ears (slower) |

Russian standard: EARS -- Small, supple, mobile, set on or above eye level and backwards...

AKC standard: EARS -- Small and fine in quality, lying back on the neck when in repose with the tips when thrown back almost touching behind the occiput; raised when at attention

FCI standard ('06): -- EARS Small, thin, mobile, set on above the eye level and backwards....

B. A very important contributor to speed is having **rear symmetry** with a proportionally larger croup angle (flatter) to a smaller hock angle (more bend). Another way of describing this is that the faster dog's rears are set further <u>behind</u> the pelvis and less <u>under</u> the pelvis. This also makes the hind legs appear longer in the faster dogs. This variable is already a proportion, so optimal levels are not calculated.


| croup angle bigger than hock angle (faster) | croup angle smaller than hock angle (slower) |

Russian standard: CROUP -- Long, broad, slightly sloping. The width of the croup measured between the two hip bones must not be less than 8 cm. <u>Faults:</u> Narrow, short, steep. <u>Serious Faults:</u> Very narrow, very short excessively steep (goose rump) HINDQUARTERS ... When the dog is standing true, the vertical line dropping from the ischiatic tuberocity must pass in front of the center of the hock joint and of the metatarsals. Upper thigh well muscled, long, placed obliquely. Lower thigh long, muscled, placed obliquely....

AKC Standard: HINDQUARTERS -- Long...; strong first and second thigh....

FCI Standard: HINDQUARTERS ... When the dog is standing true, the vertical line dropping from the ischiatic tuberocity must pass in front of the center of the hock joint and of the metatarsals. Upper thigh: well muscled, long, placed obliquely. Lower thigh: long, muscled, placed obliquely.

A significant contributor to speed is the chest. For optimal speed the chest should be slightly wider than half its depth.
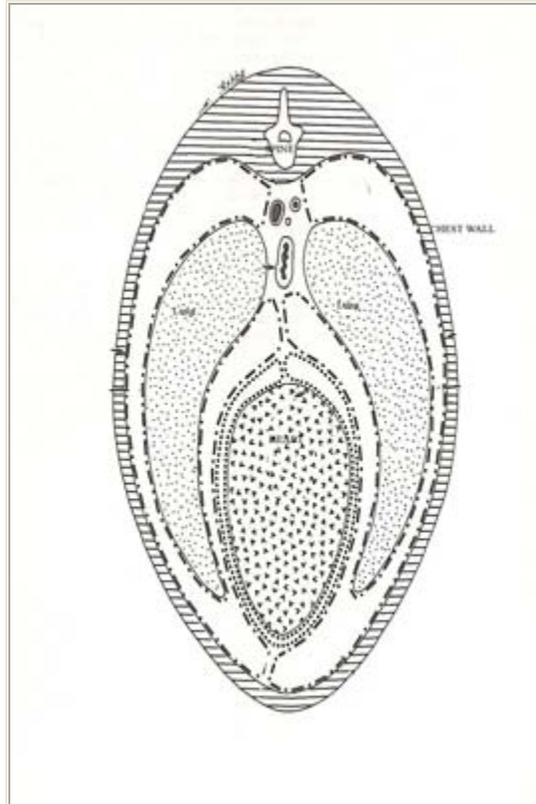
This chest is a drawing showing the thorax at T8 approximating a chest proportion of 6.25 to 12.

Russian standard: CHEST -- Of oval cross-section, not narrow, yet not wider than the croup, spacious, reaching down almost to elbow level. The region of the shoulder blades being flatter, the chest gets gradually wider toward the false ribs, which are short; seen in profile it forms a change in slope..... Faults: Chest narrow, flat, not deep, sternal line much higher than the level of the elbows. Serious faults: Chest hollow in its front part, barrel -ribbed.

AKC Standard: CHEST -- Rather narrow, with great depth of brisket.

FCI ('06) standard: CHEST -- Of oval cross-section, not narrow, yet not wider than the croup, spacious, reaching down almost to elbow level. The region of the shoulder blades being flatter, the chest gets gradually wider toward the false ribs, which are short; seen in profile it forms a change in slope.

Another significant contributor to speed is bladed bone. When measured at 2 cm above the carpus the fastest borzoi are 1.5 to 1.6 times deeper than wide (when viewed from the front).

| bladed bone (faster) | bladed bone | rounder bone (slower) | rounder bone |

Russian Standard: FOREQUARTERS .... Forearm is clean, long, of oval cross section; seen from the front, narrow; seen in profile, broad..... Serious faults: ...forearm of round cross section.

AKC standard: FORELEGS -- Bones straight and somewhat flattened like blades, with the narrower edge forward....

FCI standard ('06): FOREARM -- Clean, long, of oval cross section: seen from the front narrow, seen in profile, broad.

II. MODERATELY IMPORTANT:

The next variables are more moderate contributors to speed.

Length of croup is in this category. Longer croups are faster.

| Longer croup (mod. faster) | Shorter croup (mod. slower) |

Russian standard: CROUP -- Long, broad, slightly sloping... Faults: Narrow, short, steep.

Another moderate contributor to speed is tuck up. Higher tuck ups are faster.

| higher tuck up (moderately faster) | lower tuck up (moderately slower) |
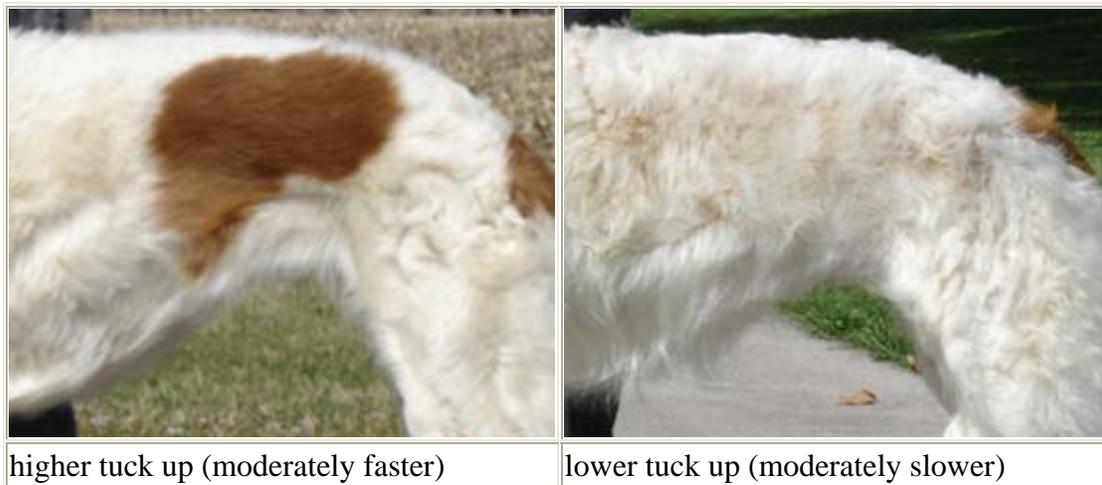
Russian standard: ....the chest gets gradually wider toward the false ribs, which are short; seen in profile it forms a change in slope.

AKC standard: LOINS -- Extremely muscular, but rather tucked up,

FCI standard: BELLY -- Well tucked up, the underline rises abruptly towards the abdomen.

Pastern angles have an optimum level of 165 degrees.

pastern angle 165 degrees (moderately faster)

Russian standard: PASTERN slightly oblique in relation to the ground.

AKC standard: PASTERNs strong

FCI standard: METATARSUS (pastern) -- Slightly oblique in relation to the ground.

Rear width has an association with speed in this population. Rear widths ranged from 8.25in (21cm) to 10.75in (27cm). Faster dogs had wider rears.

Russian standard: HINDQUARTERS Seen from behind: straight parallel, set slightly wider than the forequarters.

AKC standard: HINDQUARTERS ....somewhat wider than the forequarters...

III. NOT SIGNIFICANTLY IMPORTANT:

Attributes that do not have a significant impact on speed in this population are shoulder angle, height, leg length, loin width, and length of foot. Either these characteristics have little impact on speed or they are within an acceptable range in the borzoi population studied.

Shoulder angle had an optimal level of 120 degrees, but it was not quite significant (p-value of .0723 in table 5).

Shoulder angle120 deg.

Russian standard: FOREQUARTERS Shoulder blades long and oblique, upper arm moderately oblique.... Angle of the scapulo-humeral articulation well pronounced.

AKC standard: SHOULDERS: Sloping, fine at the withers and free from coarseness or lumber.

Height: The height at the withers of the measured borzoi are 68 to 90 cm. Only 5 borzoi out of 191 measured are above 85 cm and none are below 68 cm.

Russian standard: Desirable height at the withers for males: 75-85 cm, for females: 68 - 78 cm.

AKC standard: SIZE: Mature males should be at least 28 inches (71 cm) at the withers and mature bitches at least 26 inches (66cm) at the withers.

Leg (height at elbow/ height at withers) has an average of 0.54 with a range of 0.47 to 0.58. The borzoi in this study have a leg length as described in the Russian standard.

Russian standard: The height of the forelegs from the elbow to the ground is equal or a little superior to half the height at the withers.

Loin width has no observable association with speed in this population.

Russian standard: LOIN Long, prominent, muscled, moderately broad.

AKC standard: LOIN: Extremely muscular, but rather tucked up...

Length of foot does not contribute to speed in this population.

Russian standard: Lean, narrow, of elongated oval shape (called "harefeet"); toes arched, tight.

AKC standard: FEET: Hare-shaped, with well-arched knuckles, toes close and well padded.

Conclusion:

The borzoi as described in the Russian standard is a fast borzoi according to this data. The FCI, AKC, English, and Canadian standards do not disagree with either the Russian standard or the study results but are generally not as explicit; therefore, more subject to personal interpretation. Any interpretation of any borzoi standard that promotes a slower, less functional sighthound would be an incorrect interpretation.