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Conformation measurements and limb analysis for jumping performance in Indian sporting horses

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ABSTRACT

The present investigation was undertaken to establish baseline limb conformation characteristics and evaluate their association with jumping performance in Indian sporting horses. Fifty clinically sound Indian sporting horses trained for show jumping under uniform management and training conditions were included in the study. Linear measurements of major limb segments and joint angles of the forelimbs and hindlimbs were recorded using standard morphometric techniques based on anatomical landmarks. Descriptive statistics and logistic regression analysis were employed to assess the relationship between conformational traits and jumping performance. The results demonstrated considerable uniformity in body conformation among the horses studied. Several forelimb and hindlimb measurements, particularly limb proportions and selected joint angles, showed positive associations with jumping performance, indicating their functional importance in locomotion, propulsion, and landing stability. Limb conformation appeared to contribute more substantially to athletic performance than overall body size, highlighting the importance of proportional skeletal development in jumping horses. The findings provided baseline morphometric information for Indian sporting horses and emphasize the value of objective conformation assessment in the early identification of animals with superior athletic potential. These reference data might be useful for breeding programmes, performance evaluation, and selection strategies aimed at improving the efficiency and soundness of Indian sporting horses used in equestrian sports.

Keywords: Conformation, Indian sporting horse, Joint angles, Jumping performance, Limb morphometry, Sport horse

The Indian sporting horse has been developed through systematic crossbreeding of indigenous mares with imported Thoroughbred and European warm blood bloodlines to produce horses suitable for equestrian sports. These horses are primarily maintained by the Indian Army and are widely used in show jumping, eventing, dressage and polo. Their athletic performance depends on the coordinated interaction of musculoskeletal structure, physiological capacity and training, among which body conformation is considered one of the most important determinants of functional ability and long-term soundness.

Conformation refers to size, shape and proportional relationship of different body parts that collectively influence movement efficiency, balance and biomechanical performance (Holmström 2001). In jumping horses, appropriate limb proportions and joint angulations contribute to stride quality, propulsion, shock absorption and landing stability, thereby reducing the risk of musculoskeletal injuries while improving competitive performance (Koenen *et al.* 1995; Clayton and Schamhardt 2001). Previous investigations have demonstrated significant associations between morphometric traits and athletic performance in warm bloods, Thoroughbreds and other sport horse breeds (Holmström and Philipsson 1993; Anderson *et al.* 2004; Borowska and Lewczuk 2023). Consequently, objective conformation assessment has become an important component of breeding and selection programmes in many countries.

Despite the increasing use of Indian sporting horses in national and international equestrian competitions, published information describing their limb morphometry and joint conformation remains extremely limited. Selection of young horses in India is still largely based on pedigree and training performance rather than objective structural evaluation. Establishing baseline morphometric characteristics may therefore improve the early identification of horses with superior athletic potential

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and facilitate evidence-based breeding and management decisions. Recent advances in equine conformation research have emphasized the use of objective morphometric and linear scoring systems for evaluating athletic potential and improving the selection of sport horses (Borowska & Lewczuk 2023).

Accordingly, the present study was undertaken to establish reference values for limb conformation measurements and joint angles in Indian sporting horses trained for show jumping and to evaluate their association with jumping performance.

MATERIALS AND METHODS

The study was conducted on 50 clinically sound Indian sporting horses specialized in show jumping and maintained by the Remount Veterinary Corps of the Indian Army. All horses had successfully qualified for national-level jumping competitions by clearing obstacles of 1.30 m. The study population consisted of geldings aged 5–15 years, maintained under uniform feeding, housing, health care, and training practices to minimize environmental variation.

Conformation assessment: Both subjective and objective conformation assessments were performed. Subjective evaluation was carried out according to the guidelines of Stashak (1987). Before recording measurements, each horse was walked for a few strides on a level surface and then positioned squarely with equal weight distribution on all four limbs and a normal head and neck posture. This standardized stance minimized measurement error associated with body position.

Forelimb and hindlimb alignment were evaluated using the plumb-line method. In the forelimb, an imaginary vertical line extending from the point of the shoulder was expected to pass centrally through the limb and terminate near the heel bulbs. Hindlimb alignment was assessed by dropping a vertical line from the point of the buttock through the hock to the ground, following standard conformation assessment procedures.



Length Angles

Fig.1. Reference points of Angles and length measured laterally in Indian sporting horses.

Morphometric measurements: Objective morphometric evaluation was performed following the procedures described by Mawdsley *et al.* (1996), Anderson *et al.* (2004), and Holmström (2001). Linear measurements were recorded using a flexible measuring tape, whereas joint angles were measured using a standard goniometer.

Measurements included shoulder length, arm length, forearm length, fore cannon length, thigh length, gaskin length, and hind cannon length. Joint angles recorded were shoulder, elbow, carpal, fore fetlock, hip, stifle, tarsal, and hind fetlock angles from the lateral aspect, together with anterior measurements of the shoulder, elbow, carpus, and fore fetlock joints. Anatomical landmarks were identified before measurement to ensure consistency and repeatability (Fig. 1).

Statistical analysis: Data were analysed using IBM SPSS Statistics Version 20.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics including mean, standard deviation, minimum, maximum, and 95% confidence intervals were calculated for all morphometric variables.

Table 1. Descriptive statistics of the forelimb length and angles in jumping category of Indian sporting horses.

Parameter	Mean ± SD	Std. Error	95% CI (LB–UB)	Min	Max
Shoulder length	58.91 ± 3.09	.433	58.04 - 59.78	51.00	68.00
Arm length (lateral)	37.30 ± 2.05	.287	36.72 -37.87	32.50	41.00
Arm length (front)	21.04 ± 4.87	.683	19.67 - 22.42	16.00	47.00
Forearm (lateral)	45.79 ± 1.59	.223	45.34 - 46.24	42.50	49.50
Forearm (front)	46.81 ± 1.74	.244	46.32 - 47.30	43.40	51.00
Fore cannon (lateral)	27.04 ± 1.86	.260	26.52 - 27.57	21.00	29.50
Fore cannon (front)	27.15 ± 1.57	.220	26.71 - 27.60	24.00	30.00
Shoulder angle (lateral)	101.03 ± 5.82	.816	99.40 - 102.67	90.20	116.30
Shoulder angle (front)	106.83 ± 9.59	1.34	104.13 - 109.53	93.50	143.90
Elbow angle (lateral)	118.98 ± 9.66	1.35	116.26 - 121.70	97.80	132.60
Elbow angle (front)	133.49 ± 11.49	1.61	130.26 -136.72	100.00	148.90
Carpus angle (lateral)	174.04 ± 9.54	1.33	171.36 - 176.73	119.10	182.00
Carpus angle (front)	176.79 ± 8.51	1.19	174.39 - 179.18	137.20	183.50
Fetlock angle (lateral)	142.61 ± 3.57	.500	141.60 - 143.61	137.00	151.50
Fetlock angle (front)	174.77 ± 2.67	.37	174.02 - 175.52	169.30	179.40

Table 2. Descriptive statistics of hindlimb lengths and angles in jumping category of Indian sporting horses.

Parameter	Mean ± SD	Std. Error	95% CI (LB–UB)	Min	Max
Thigh length	44.84 ± 3.31	.463	43.91 - 45.77	37.00	53.50
Gaskin length	55.30 ± 4.55	.637	54.02 -56.58	46.00	61.50
Hind cannon length	35.00 ± 4.07	.570	33.86 -36.15	29.00	57.00
Croup angle	137.95 ± 7.88	1.10	135.73-140.17	119.40	148.30
Croup hip joint angle	107.02 ± 5.61	.786	105.44-108.60	89.00	116.30
Hip joint angle	87.67 ± 5.97	.836	85.99- 89.35	80.00	99.90
Stifle joint angle	113.65 ± 5.60	.785	112.08- 115.23	104.70	130.40
Tarsal joint angle	150.57 ± 6.01	.841	148.88 - 152.26	139.90	161.40
Hind fetlock angle	152.03 ± 4.82	.676	150.67 - 153.38	142.80	163.10

Logistic regression analysis was performed to evaluate the association between conformation variables and jumping performance. The strength of association was interpreted using odds ratios (OR) with corresponding 95% confidence intervals. Statistical significance was considered at $P < 0.05$.

RESULTS AND DISCUSSION

General body measurements and performance association: The descriptive statistics of general body measurements are presented in Table 1, while the association of these traits with jumping performance is summarized in Table 3,4 and 5. The relatively narrow variation observed among the morphometric traits indicated that the horses included in the study represented a uniform population maintained under similar breeding, nutritional and training conditions. Such uniformity minimized environmental variation and allowed a more reliable assessment of the relationship between conformation and athletic performance.

Among the general body measurements, pelvis length showed the strongest positive association with jumping performance. The pelvis forms the structural foundation for the attachment of major hindquarter muscles, including the gluteal and hamstring muscle groups, which are primarily responsible for propulsion during take-off. A well-developed pelvis provides greater leverage and facilitates efficient transmission of muscular force from the hindquarters to the forehand, thereby enhancing jumping ability. Similar observations have been reported in Warmblood sport horses, where pelvic dimensions were positively associated with athletic performance and biomechanical efficiency (Holmström and Philipsson 1993; Koenen *et al.* 2004).

Body weight also demonstrated a positive association

Table 3. Positive association of the length parameters of fore quarter in horses of different group

Parameter	T1 (n=50)	%
Shoulder length (SL)	31	62
Arm length (lateral) AL(l)	16	32
Arm length (front) AL(f)	34	68
Fore arm length (lateral) FAL(l)	23	46
Fore arm length front FAL(f)	33	66
Fore cannon length (lateral) FCL(l)	44	88
Fore cannon length (front) FCL(f)	22	44

Representation of OR as 1< positive relation, 1= no relation and 1> negative relation, with 95% CI

Table 4. Positive association of the angle parameters of fore quarter in horses of different group

Parameter	T1 (n=50)	%
Synsarcosis lateral view	29	58
Shoulder joint angle lateral view	31	62
Shoulder joint angle front view	20	40
Elbow joint angle lateral view	3	6
Elbow joint angle front view	2	4
Carpus joint angle lateral view	6	12
Carpus joint angle front view	40	80
Fore fetlock joint angle lateral view	22	44
Fore fetlock joint angle front view	32	64

Representation of OR as 1< positive relation, 1= no relation and 1> negative relation, with 95% CI

Table 5. Positive association of the length and angle parameters of hind quarter in horses of different group

Parameter Type	Parameter	T1 (n=50)	%
Length	Thigh length (TL)	49	98
	Gaskin length (GL)	34	68
	Hind cannon length (HCL)	9	18
Angle	Croup angle	29	58
	Croup hip joint angle	0	0
	Hip joint angle	3	6
	Stifle joint angle	2	4
	Tarsal joint angle	26	52
	Hind fetlock joint angle lateral	33	66

Representation of OR as 1 < positive relation, 1 = no relation and 1 > negative relation, with 95% CI.

with jumping performance. However, athletic efficiency appears to depend more on an appropriate balance between body mass and musculoskeletal development than on body weight alone. Horses with adequate muscular development and balanced body proportions are capable of generating greater impulsion without compromising agility or coordination during jumping.

Neck length showed a moderate association with jumping performance. The neck plays an important role in maintaining balance by acting as a counterweight during take-off and landing. Appropriate neck length contributes to postural control, facilitates adjustment of the centre of gravity, and improves coordination throughout the jumping sequence. Similar functional roles of neck conformation have been described in elite sport horses (Lawrence 2001).

In contrast, height at withers and breast width showed comparatively weaker associations with jumping performance. These observations suggested that overall body size is less important than proportional body conformation in determining athletic ability. This finding agrees with previous reports indicating that harmonious body proportions and biomechanical efficiency are more reliable indicators of performance than absolute stature (Back 2001, Holmström 2001).

Digital image analysis has recently emerged as a reliable alternative for objective morphometric assessment in horses (Unal *et al. 2025*). Overall, the findings indicated that morphometric characteristics associated with the hindquarters contribute more substantially to jumping performance than general body dimensions. Objective evaluation of these traits may, therefore, provide a valuable tool for the early selection of young horses intended for competitive jumping disciplines.

Forelimb morphometry and joint angles: The descriptive statistics of forelimb measurements and joint angles are presented in Table 1, whereas their association with jumping performance is summarized in Tables 3. The results indicated that several forelimb conformational traits contribute substantially to jumping performance, emphasizing the importance of balanced limb proportions for efficient locomotion and athletic function.

Among the linear measurements, fore cannon length exhibited the strongest positive association with jumping performance. The fore cannon acts as the principal lever during the swing phase of locomotion and plays an important role in controlling limb inertia. A relatively shorter and well-proportioned cannon reduces the moment of inertia of the distal limb, allowing faster limb protraction and more efficient forelimb folding while negotiating obstacles. In addition, balanced cannon proportions help distribute landing forces more evenly across the distal limb, thereby reducing mechanical stress on tendons and ligaments. Similar observations have been reported in sport horses, where distal limb proportions were associated with improved jumping efficiency and reduced risk of musculoskeletal injury (Rooney 1998, Walker *et al.* 2014).

Shoulder length and forearm length also demonstrated positive associations with jumping performance. A long and well-sloped shoulder provides greater freedom of movement at the scapulohumeral joint, increasing stride length and facilitating smooth elevation of the forehand during take-off. Likewise, adequate forearm length contributes to increased muscular leverage and enhances shock absorption during landing. These structural characteristics enable horses to clear obstacles with greater efficiency while minimizing excessive loading of the distal forelimb. Comparable findings have been reported in Swedish Warmbloods and other sport horse populations, where longer forearms and well-balanced shoulder conformation were considered desirable traits for jumping performance (Holmström and Philipsson 1993, Langlois *et al.* 1978).

Joint angulation is equally important in determining the biomechanical efficiency of the forelimb. Equine biomechanical research has expanded considerably in recent years, providing objective tools for evaluating locomotion, conformation and athletic performance in sport horses (Egenvall *et al.* 2022). The present study showed that shoulder, carpal and fore fetlock joint angles were more closely associated with jumping performance than elbow joint angles. Appropriate shoulder angulation improves stride elasticity and facilitates elevation of the forelimbs during obstacle clearance. Similarly, proper carpal alignment contributes to effective dissipation of impact forces during landing, while optimal fetlock angulation enhances elastic energy storage within the suspensory apparatus, thereby improving locomotor efficiency.

In contrast, elbow joint angles exhibited relatively weaker associations with performance. The elbow primarily functions as a stabilizing joint during weight bearing, and its range of variation is generally limited in well-trained sport horses maintained under standardized selection programmes. Consequently, elbow conformation may contribute less to variation in jumping ability than more distal joints that directly influence limb mechanics during take-off and landing.

The combined influence of limb proportions and joint angulation indicated that forelimb efficiency depends on the harmonious interaction of skeletal alignment and muscular function rather than any single conformational trait. Horses possessing balanced forelimb conformation are likely to demonstrate improved stride coordination, enhanced shock absorption and greater mechanical efficiency during repeated jumping efforts. These observations supported the previous reports that objective assessment of forelimb conformation can assist in the early identification of horses with superior athletic potential and reduced susceptibility to orthopedic disorders (Anderson *et al.* 2004; Weller *et al.* 2006; Borowska and Lewczuk 2023).

Hindlimb morphometry and joint angles: Recent studies have demonstrated that body conformation traits are closely associated with athletic performance and can be incorporated into breeding and selection programmes for

sport horse (Wang *et al.* 2025). The descriptive statistics of hindlimb measurements and joint angles are presented in Table 2, whereas their association with jumping performance is summarized in Tables 4. The hindlimbs constitute the primary source of propulsive force during jumping, and their structural conformation plays a decisive role in determining the magnitude and efficiency of take-off. The present findings indicate that several hindlimb morphometric traits are functionally associated with jumping performance, emphasizing the importance of balanced hindquarter development in Indian Sporting Horses.

Among the linear measurements, thigh length demonstrated the strongest positive association with jumping performance, followed by gaskin length, whereas hind cannon length exhibited a comparatively weaker association. The thigh accommodates the major propulsive muscles, including the gluteal, quadriceps and hamstring muscle groups, which generate the force required for explosive extension of the hip and stifle joints during take-off. A longer and well-developed thigh increases the area available for muscular attachment, thereby improving force production and mechanical efficiency. These observations are consistent with previous studies in Warmblood and Thoroughbred horses, where hindquarter development was identified as a major determinant of jumping ability and athletic performance (Holmström *et al.* 1990, Mostafa and Elemmawy 2020).

The moderate association observed for gaskin length further supports the importance of proportional hindlimb development. The gaskin acts as an intermediate lever that transmits muscular force from the thigh to the distal limb. Appropriate gaskin proportion facilitates coordinated extension of the stifle and hock joints while maintaining stability throughout the take-off phase. In contrast, the relatively weaker association of hind cannon length suggested that distal hindlimb dimensions perhaps, contribute less to propulsion than the proximal muscular segments, although they remain important for maintaining balance and absorbing landing forces.

Joint angulation of the hindlimb showed clear functional significance. Hind fetlock angle, croup angle, and tarsal (hock) angle exhibited comparatively stronger associations with jumping performance than the hip and stifle joint angles. Proper hock angulation permits efficient flexion during limb loading and rapid extension during take-off, thereby maximizing propulsion while minimizing unnecessary energy expenditure. Similarly, optimal fetlock angulation enhances elastic energy storage within the suspensory apparatus, allowing part of the mechanical energy generated during landing to be recovered during the subsequent stride. This elastic mechanism contributes to both performance and locomotor economy.

The relatively limited association observed for the hip and stifle joint angles may reflect the comparatively small variation present within the study population, which consisted of horses selected and trained under similar management conditions. Previous investigations have likewise reported that differences in overall hindquarter proportions often explain more variation in jumping performance than isolated joint angles (Magnusson and Thafvelin 1990, Senna *et al.* 2015).

Collectively, the present findings demonstrate that efficient jumping performance depends on the harmonious interaction of hindquarter musculature, skeletal proportions and joint alignment. Horses possessing balanced hindlimb conformation are better able to generate propulsive force, maintain stability during obstacle clearance and absorb landing impacts efficiently. These results highlight the value of objective hindlimb morphometric evaluation as a practical tool for the early selection of Indian Sporting Horses with superior athletic potential and long-term functional soundness.

Functional significance and practical implications: The present study established the first comprehensive baseline dataset on limb conformation measurements and joint angulation in Indian sporting horses trained for show jumping. The findings demonstrated that balanced limb proportions and appropriate joint angulation are more closely associated with jumping performance than overall body size, emphasizing the importance of functional conformation in equine athletic performance.

Objective morphometric evaluation provided a practical and reproducible approach for identifying horses with desirable structural characteristics at an early age. Incorporating conformation assessment into breeding and selection programmes might improve the efficiency of selecting young horses with superior athletic potential while reducing the cost and time associated with training animals that are structurally less suited for competitive jumping. Furthermore, objective conformation records may assist veterinarians, breeders and trainers in detecting structural deviations that could predispose horses to orthopedic injuries or reduced performance during intensive athletic activity.

The relatively uniform conformation observed among the study population also reflected the effectiveness of systematic breeding, management and training practices adopted by the Indian Army. Nevertheless, the observed variation in selected morphometric traits indicated that objective conformation assessment remains valuable even within a genetically and environmentally uniform population. Integrating morphometric measurements with pedigree information, performance records and modern genetic selection tools may further enhance the development of high-performance Indian sporting horses.

Although the present investigation provides important baseline information for limb morphometry and joint angulation in Indian sporting horses trained for show jumping. The study was conducted on a limited number of horses maintained under a single management system. Future studies involving larger populations, multiple training centres and longitudinal performance records are required to validate these findings and develop reliable

conformation-based selection indices for Indian sport horses.

These findings highlight the potential value of objective conformation assessment as a complementary tool for the early selection of horses with superior athletic potential. The reference data generated in this study may support breeding programmes, performance evaluation and management strategies aimed at improving the quality and competitiveness of Indian Sporting Horses used in equestrian sports. Further investigations involving larger and more diverse horse populations are recommended to strengthen conformation-based selection criteria and enhance their application in equine breeding programmes.

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