# Morphological Attributes Associated with Speed of Running in Horses

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**Summary**

*Thoroughbreds, a breed noted for high speed running, were compared with other members of their species to identify adaptations which would favour their superior athletic capabilities. Measurements were taken from preserved skeletons of 'elite' Thoroughbreds and horses dissected by the author.*

*Forelimb and hindlimb bone lengths were compared with back length and liveweight. There was little difference between different Thoroughbreds or between Thoroughbreds and other types of horse with respect to the limb length to back length ratio, and Thoroughbreds did not have longer legs relative to their liveweights than non-athletic horses. However, Thoroughbreds had a greater mass of their hindlimb nearer the hip joint than other breeds. This feature favours a high natural frequency of hindlimb movement and facilitates a higher stride frequency and consequently a faster speed of running in Thoroughbreds as compared to other breeds of horses.*

While the theme of this conference is based on the physiological responses of horses when stimulated by exercise, consideration must be given to the possibility of diverse responses to the same exercise stimulus by individuals with differing innate morphological, physiological and biochemical properties.

One of the most important aspects of training a horse is to improve its ability to run quickly over a given distance. For this reason it is desirable to identify characteristics associated with speed of running in known elite athletes, so that the possibilities of enhancing or simulating these attributes by training or exercise may be considered.

The Thoroughbred breed of horse has been selected for swiftness over a period of approximately 300 years, and it epitomises fast running among the equine species. It is possible therefore to define athletic characteristics in horses by comparing structural and biochemical properties of Thoroughbreds with those of other members of their species. While the microscopic and biochemical properties of skeletal muscles are undoubtedly important in dictating athletic capacity, gross anatomical attributes must also be considered.

Gross body proportions of Thoroughbreds and other members of their species were investigated by dissection, and mathematical analysis was carried out on the data thus collected. Total body weight was recorded before death. Weights of the major tissues and organs were recorded when dissected. Details of this study are given elsewhere (Gunn 1976). Measurements were taken from the preserved bones of 7 equine skeletons and 22 Thoroughbreds and 17 other horses which were partially or totally dissected by the author.

There are a number of features which differentiate Thoroughbreds from other breeds of horse, both as adults and during growth (Gunn 1976). In this presentation, consideration is given to two of these factors in adults: limb length and natural frequency of limb movement.

For the purposes of this study, bones are considered as passive levers transmitting forces applied by muscles to relatively fixed surfaces, thereby propelling the animal. The length of the limb obviously dictates the distance through which the hoof travels during a swing, which in turn is a determinant of the length of the stride. An animal with very long legs will have a longer stride length than one with short legs, so long as the spine remains as a rigid platform from which the limbs may swing and there is no airborne phase of the gait. As the gait for galloping in different types of horses is similar, such possibilities need not be considered.

Visual observations suggesting that animals noted for their high speed of running are characterized by having long legs in relation to other parts of their body, while animals noted for their strength rather than fleetness have proportionately shorter legs were reported by Hayes (1904). Comparisons of bulldogs with greyhounds, leopards with cheetahs and draft horses with Thoroughbreds are quoted as examples of this phenomenon by the same author. Such comparisons should consider measurements of limb length compared with back length or liveweight. Although there are variations in the number of vertebrae within some breeds of horse (Jones and Bogart, 1971) it is unlikely that this small and infrequent variation would constitute a significant factor in limb length to trunk length ratio. In this study limb length is considered to be the combined length of the individual limb bones, thereby overcoming the problem of allowing for angles of articulations in live or dead specimens.

Measurements of the preserved bones from a group of elite Thoroughbreds which were exceptionally good runners over different distances during the last three centuries, as well as from a Shire horse, a Shetland pony and Przewalskii's horse were taken at the Natural History Museum, London, and at the Irish National Stud. The forelimb to back length ratios of Persimmon, St Frusquin and Przewalskii's horse were identical at 1.3 while those of Arkle, Eclipse, Brown Jack and a Shetland pony were also identical at 1.2. The hindlimb to back length ratios of Eclipse and the Shetland pony were similar with a value of 1.0, while those of Persimmon, St Frusquin, Arkle, Brown Jack and Przewalskii's horse were also similar with a value of 1.1. Thus, irrespective of the size or type of horse, the values for the forelimb to back length ratio of 1.2 to 1.3 and the hindlimb to back length ratio of 1.0 to 1.1 indicate the similarity of the gross shape (as indicated by limb length to back length ratios) of all the equines investigated. The values for the corresponding ratios in the fastest running terrestrial animal, a cheetah, were 1.2 for the forelimb and 1.0 for the hindlimb, not unlike the values recorded for horses.

The combined lengths of the propodial (humerus and femur) and epipodial (radius and ulna or tibia and fibula) segments in the forelimb and hindlimb had a constant relationship with total limb length in adult animals of the same type. Because the metapodial segment (carpus, metacarpus and phalanges) sometimes had sections removed for other studies, combined propodial and epipodial lengths were used to indicate limb length in the horses dissected by the author. Although in purely statistical terms it is not correct to draw inferences from a ratio of limb length and liveweight, such ratios have some merit for comparitive purposes.

The mean ratio of combined forelimb propodial and epipodial segment lengths to liveweight in the dissected Thoroughbreds was 0.19. A similar ratio in a Clydesdale was 0.17 while that of a Shetland pony was 0.38, indicating a much longer forelimb length relative to liveweight in the smaller horse. A similar situation exists in the hindlimb where the propodial plus epipodial length to liveweight ratios for both the Thoroughbreds (0.18) and Clydesdale (0.17) are less than the corresponding ratio in a Shetland pony (0.36).

While the combined lengths of the propodial and epipodial segments may bear a constant relationship to total limb length, the possibility that their ratio to one another may vary was also investigated. The mean ratio of the propodial to epipodial segment lengths in the forelimb of all the Thoroughbreds (0.72) was similar to that of the other horses (0.72). Likewise, there was little difference between the hindlimb ratios of the Thoroughbreds (1.12) and other horses (1.17).

These results demonstrate that there is little difference between different Thoroughbreds or between Thoroughbreds and other types of horse in limb length to back length, or limb length to liveweight ratios, or in relative bone lengths within the limb. Therefore, alterations in limb length or within limb bone lengths are not associated with athletic ability in adult horses.

If a limb is likened to a pendulum, the natural oscillatory frequency of the limb (i.e. the speed at which the limb will swing, unaided, once it has started swinging) will depend on the length of the limb and on the distance between the centre of gravity of the limb and the centre of rotation of the limb (i.e. a joint) Muscular forces are required to move the limb faster or slower than the natural oscillatory frequency. If two limbs are required to swing at a rate higher than their natural frequency of oscillation, the limb with the higher natural frequency will require the smaller additional force, i.e. it will need less energy to do so. The natural frequency of the limb is increased by moving the centre of gravity of the limb nearer to the pivot. This happens during protraction, i.e. when the limb is being moved forward during the stride, when flexion of the joints shortens the length of the pendulum and increases the natural frequency of the swing of the limb. A similar result is achieved by the adaptive development of the running limb, as can be seen in the interspecies adaptive changes which favour running, e.g. in the comparison of the limbs of an elephant and gazelle where most of the muscle mass is found to be located nearer the pivot in the better runner. The possibility that horses specialized for running quickly may have the centre of gravity of their hindlimbs nearer the hip joint in comparison to other members of their species is now considered.

An index of the position of the centre of gravity of the hindlimb (which is generally accepted to have a greater propulsive function than the forelimb) may be obtained by comparing the weight of the proximal hindlimb muscles plus the femur with the weight of the distal hindlimb muscles plus the other bones of the hindlimb. The greater the proximal to distal ratio, the nearer the centre of gravity of the limb will be to the pivot, i.e. hip joint. The value of this ratio in Thoroughbreds (5.11) was greater than that in the other horses (4.66). As the natural frequency of oscillation of the limbs is a determinant of stride frequency, there is therefore a gross anatomical basis favouring a higher stride frequency in Thoroughbreds as compared to other members of their species.

The factors controlling the speed of running in mammals are shown on Table 1. Two of these have been considered in this paper. Although Thoroughbreds do not have longer legs than other horses, the greater mass of their limbs near the hip joint favours a higher natural frequency of their hindlimb in comparison with other horses. The relative importance of the other factors listed in Table 1 and the development of all the factors with growth and their response to training cannot be considered in this brief communication.

TABLE 1. Factors dictating the speed of running in mammals.

**Running speed**

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**Co-ordinated gait**

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| **Stride length** | **X** | **Stride frequency** |
|---|---|---|
| Leg length | | Natural frequency of limbs |
| Range of movement of joints | | Mechanical advantage of muscles |
| Acceleration capacity (force produced by muscles relative to body weight) | | Intrinsic speed of sarcomere contraction |
| Internal muscle architecture | | Repetivity of limb movement (aerobic and anaerobic energy supply mechanisms) |

## References

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