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Principles of Donkey Movement

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Abstract

Observed through historical epochs and evolutionary periods, the movement of mammals basically developed into two groups. One group consists of ungulates (Perissodactyla), and the other group consists of ungulates (Artiodactyla). Among ungulates, wild and tame horses, wild and tame donkeys, and semi-donkeys were distinguished by the specific movement of their legs forward. We call this whole group Equiden.

Keywords: Donkey, Movement, Biostatics, Biodynamics

Introduction

As is well known, the limbs of the ancestors of equids ended with five toes. The toes fused, and only the distal part of the middle toe remained as the base on which the limb rests on the ground. Immediately after birth, a donkey foal has a fully formed hoof and can follow its mother shortly after parturition. The legs, like the entire body of hoofed animals, are structured like those of predators, meaning they allow for rapid movement when needed.

The domestic donkey (Equus asinus) has a very specific body structure. Its design ensures that the interrelationship of different body regions enables great endurance. The fact that this species originates from wild ancestors, developed and evolved in Africa, clearly indicates that the species adapted to harsh climatic and ecological conditions. Such an environment resulted in harsh conditions that imposed a corresponding biological response. The donkey is a working animal, and there is no differentiation of breeds for milk or meat production.

The specific body structure emerged as a biological response to the living conditions. Today, there are practically no geographical areas where the domestic donkey is not used for various, often transport-related, tasks. In highly developed countries, the role of the domestic donkey is significantly changing. The donkey increasingly finds a place in tourism or certain forms of sport. In addition, it is not uncommon for donkeys to be used as therapy animals, particularly for children with special needs.

Despite the changes in its role and tasks in developed countries, in much of the world, the domestic donkey still performs heavy transport work. To do this, it must have a corresponding biostatic body model. One of the essential and key traits is the body's conformation. The height of the croup is greater than the height of the withers (Babić 1938 [1], Essert 1959 [4], Lucia Casini *et al*. 2007 [9], Urošević *et al*. 2019, Ivanković *et al*. 2000 [7], Yilmaz and Ertugrul 2011 [16], 2012 [17], Folch and Jordana 1997 [5], Yilmaz and Wilson 2013 [18]).

Every body, including biological ones, is composed of a vast number of small particles or cells. Earth's gravity pulls each individual cell downward. Thus, every body cell is subject to the force of gravity. The direction of these forces is vertical, downward, toward the ground. All these parallel lines, originating from each cell, combine to form a resultant that represents the body's mass, and the point of attack of the body's mass is the center of gravity.

The body mass of the donkey, like any other body, can be represented using vectors. Each body mass is defined by: a) intensity — this is the measured mass in kilograms, b) the direction of the force of gravity (Earth's gravity), which is vertical, c) the direction of the force — downward, and d) the point of attack of the forces — the center of gravity. It can be defined as the point of the imagined resultant of all the masses of the individual parts of the donkey's body, or the sum of all forces (resultant) acting on the body.

In the available literature, there is no data on the topographical location of the donkey's center of gravity. Based on the basic principles of biomechanics, the center of gravity is located on a horizontal plane parallel to the ground, resting on the tip of the sternum (Urošević, Drobnjak, 2018). To determine the center of gravity, i.e., the central point of the complex system of forces, it is necessary to know the individual masses of each part of the system and the points of attack of those forces.

The biostatic model determines the biodynamic effect, or the production of biokinetic energy. Movement, or the forward displacement of the body, is the result of the creation of biokinetic energy and its transfer from the rear part of the body, where it is generated, to the front part. The most efficient transfer of biokinetic energy is made possible by the appropriate biostatic model, or body structure, which leads to the biodynamic effect that we define as movement.

The Specific Body Structure of the Donkey

When discussing the anatomical characteristics of the donkey's body, it is important to note that the number of thoracic vertebrae, and therefore the number of ribs, is not constant. Most donkeys have 18 thoracic vertebrae, but there are individuals with 19. The donkey has 6 lumbar vertebrae (Marisa Hafner 2013) [6], unlike the horse, which has 7 lumbar vertebrae (Brem 1998) [2].

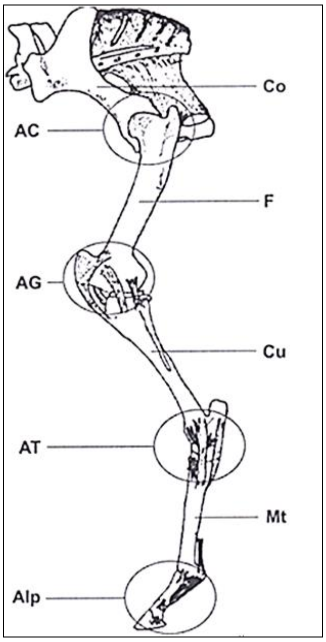
The center of biokinetic energy production is the hip joint (articulatio coxae). It should be noted that the donkey has a specifically positioned pelvis, with the ilium (os illium) being more sloped compared to other animals. This anatomical peculiarity results in a lower-positioned hip joint. The hip joint is ball-shaped, which is why it is called Articulatio spheroidae. A healthy, well-formed hip joint has the ability to move in three planes: a) Sagittal – in which complex processes of bending (flexion) and extending (extension) occur. b) Transverse – in this plane, the processes of abduction and adduction occur in the hip joint. c) Vertical – this plane allows the processes of pronation (inward rotation) and supination (outward rotation).

The hip joint allows for bending (flexion), extending (extension), rotation, abduction, and adduction.

In addition to the internal movement of the hip joint in these three planes, there is also some degree of lateral translation. This occurs as a result of the force applied in a lateral-to-medial direction.

The dynamic load on the hip joint during movement, that is, the transfer of biokinetic energy forward and the displacement of the body, is directly related to the magnitude and direction of the force acting on it.

The total load on the hip is the result of the vector summation of forces from the vertical, transverse, and horizontal components. The hip joint can withstand loads that exceed the body's own mass by 3-4 times. The distance between the center of the femoral head and the medial axis of the body represents the lever arm of the existing torque. The force acting on the femoral head, within the acetabulum, represents the sum of the forces of the individual levers.

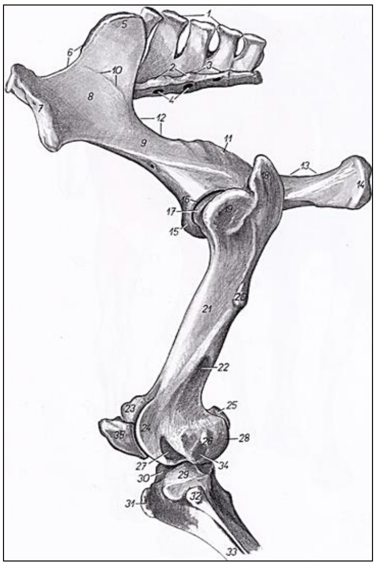


Picture 1: The hind limb of the horse (Žikić at al. 2016) [19]

Description: Co - *ossa coxae*, F - *os femoris*, Cu - *ossa cruris*, Mt - *ossa metatarsi*, AC - *articulatio coxae*, AG - *articulatio genus*, AT - *articulatio tarsi*, Alp - *articulationes interphalanges pedis*

Anatomically, a donkey has the same body parts and limbs as a horse, only with certain specificities.The donkey is characterized by a long and wide pelvis, therefore the hip joints are set wide. (Clara Sargentini *et al*. 2018 [3], Ivanković *et al*. 2000 [7], Essert 1959 [4], Urošević *et al*. 2015 [12], 2019). This means that the medial lever is longer than the lateral one, so the muscle strength must be proportionally greater.

The articulation of the femur must be very good, the hip joint must be very well closed. The associated musculature, which attaches to the femur and intestinal bone, must be strong, both flexors and extensors.



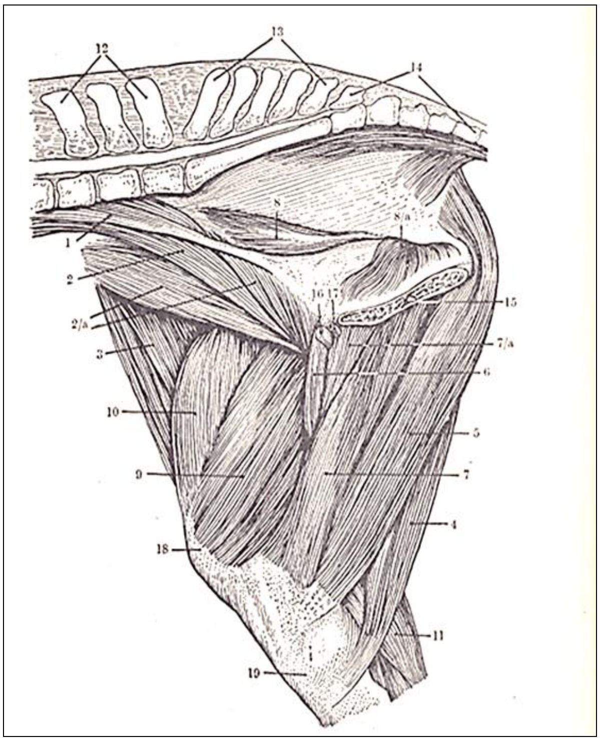
Picture 2: The skeleton of the pelvis and the proximal part of the hind limb, lateral side (Popesko, 2004) [11]

Description: 1. *crista sacralis mediana*, 2. *crista sacralis lateralis*, 3. *foramina sacralia dorsalia*, 4. *foramina sacralia pelvina*, 5. *tuber sacrale*, 6. *crista iliaca*, 7. *tuber coxae*, 8. *ala ossis ilii*, 10. *linea glutea*, 11. *spina ischiadica*, 12. *incisura ischiadica major*, 13. *incisura ischiadica minor*, 14. *tuber ischiadicum*, 15. *eminentia ilio pubica*, 16. *acetabulum*,17. *caput ossis femoris*, 18. *pars caudalis trochanteris majoris*, 19. *pars cranialis trochanteris majoris*, 20. *trochanter tertius*, 21. *corpus ossis femoris*, 22. *fossa supracondylaris*, 23,24.*trochlea ossis femoris*, 25. *condylus medialis ossis femoris*, 26. *epicondylus lateralis*, 27. *fossa extensoria*, 28. *condylus lateralis ossis femoris*, 29. *condylus lateralis tibiae*, 30. *eminentia intercondylaris*, 31.*tuberositas tibiae*, 32. *caput fibule*, 33. *corpus tibiae*, 34. *fossa mi.poplitei*, 35. *patella*

For movement to occur, well-developed muscles are essential. Two groups of muscles are distinguished: a) pelvic girdle muscles, and b) external muscles of the hip joint and croup (Žikić *et al*. 2016) [19].

The primary lever for the transfer of biokinetic energy is the femur. The generated energy is transferred from the hip joint to the thigh muscles, whose contraction moves the hind limb forward, allowing it to make contact with the ground and push the entire body forward. The generated biokinetic energy results in the biomechanical effect we describe as movement.

Among the muscles, the primary producer of biokinetic energy is the psoas major muscle (m. psoas major), which originates from the last thoracic and all lumbar vertebrae and attaches to the trochanter minor. Its main role is to flex the hip joint. The result of this mechanical action is the forward movement of the hind limb in a cranial direction (forward). In this crucial kinetic phase, the iliacus muscle (m. iliacus) also plays a role in moving the hind limb forward. It originates from the iliac fascia and the iliac wing and also attaches to the trochanter minor. This muscle is also a hip flexor, and by its flexion, it moves the hind limb forward.



Picture 3: Musculi pelvis et femoris equi (facies medialis) (Ellenberger-Baum, cit.Kovacs 1967) [8]

Description 1: *m.psoas minor*, 2. *m psoas major*, 2/a *m iliacus*, 3. *m. tensor fasciae latae*, 4. *m.semitendinosus*, 5. *m.semimembranosus*, 6. *m.pectineus*, 7., 7/a. *m.adductor*, 8.,8/a. *m.obturator internus*, 9. *m.vastus medialis (tibialis)*, 10. *m.rectus femoris*, 11. *m.gastrocnemius*, 12. *vertebrae lumbales*. 13. *os sacrum*, 14. *vertebrae coccygeae*, 15. *symphysis pelvina*, 16. *lig.accessorium*, 17. *vena pudenda externa*, 18. *patella*, 19. *tibia*

The donkey is characterized by its ability to sustain prolonged, slow movement. The femur is relatively short, which results in a shorter stride of the hind leg, consequently leading to a shorter stride of the foreleg. A short limb can bear a significant amount of mass but cannot move it over a long distance. This also influences the transfer of biokinetic energy generated in the hip joint. In other words, donkeys take short steps but can walk for long periods without significant fatigue. This characteristic endurance is facilitated by a specific biostatic body model.

There is very little data on the length of the femur and its relation to withers height and the height of the hindquarters. Urošević *et al*. (2015) [12] reported that the average femur length in males was 29.86±3.43 cm, and in females, it was 30.29±2.14 cm. The differences in absolute values were not statistically significant. The authors also reported that the average tibia length in males was 37.86±3.15 cm, and in females, it was 39.00±3.16 cm. Again, the differences in absolute values were not statistically significant.

When observing the ratio of femur length to the overall height of the hindquarters, it was found to be 28.41% for both males and females, indicating that the femur length as a percentage of croup height is the same in both sexes. The relative ratio of tibia length to the height of the hindquarters is 36.02% in males and 36.58% in females, showing that the tibia length is also consistent relative to croup height in both sexes. This research was conducted on donkey populations in Romania, North Macedonia, and Turkey. In the studied populations, the average withers height was 101.33 cm (Urošević *et al*. 2015) [12].

In their study of the morphology of the Baroque donkey, Urošević *et al*. (2019) found that the average withers height in males was 115.5±4.5 cm, and the croup height was 118.3±5.7 cm. The average withers height in females was 112.2±5.7 cm, and the croup height was 117.0±5.4 cm. The average femur length was 31.4±2.7 cm in males and 32.5±2.1 cm in females, while the average tibia length was 42.4±3.0 cm in males and 41.4±3.3 cm in females. When these values are compared relative to croup height, the femur length was 26.54% in males and 27.78% in females. The tibia length was 35.84% of croup height in males and 35.38% in females.

The difference in withers height between the two groups of donkeys was 11% in favor of the Baroque donkeys, but the relative proportions of the body measurements remained consistent. Clara Sargentini *et al*. (2018) [3] studied the exterior of the Italian Amiata donkey breed and found that the average withers height, across four locations, was 126.82 cm. The average femur length was 40.95 cm, and the tibia length was 32.12 cm, with an average croup height of 129.95 cm. This data shows that this breed of donkey is also overbuilt, with the hindquarters higher than the withers. When the relative proportions of the femur and tibia lengths to croup height are examined, the femur length was 31.51%, and the tibia length was 24.72%.

Thus, differences in body size do not cause significant changes in the relative proportions of individual morphometric parameters. This is completely justified and logical. A similar biostatic model allows for the same principles of biokinetic energy production and biomechanical movement.

Brem (1998) [2] noted that, in horses, the optimal angles for the shoulder joint are 90-100 degrees, the elbow joint 130-140 degrees, the stifle joint 90-100 degrees, and the hock joint 130-140 degrees.

In their study of the biostatic model of donkeys in Romania, North Macedonia, and Turkey, Urošević *et al*. (2017) [13] found that the average shoulder joint angle in male donkeys in Romania was 72.8±3.1 degrees, and in females, it was 93.8±9.5 degrees. The variation in shoulder joint angle in males ranged from 70.6 to 75.0 degrees, while in females, it ranged from 70.8 to 104.0 degrees, with a statistically significant difference between the sexes (p<0.05).

In North Macedonia, the average shoulder joint angle in male donkeys was 77.8±2.6 degrees, with a range from 75.0 to 80.0 degrees. In females, the average shoulder joint angle was 81.3±2.5 degrees, with a range from 80.0 to 85.0 degrees. A statistically significant difference between the sexes was also found here.

For donkeys in Turkey, the authors found that the average shoulder joint angle in males was 80.0 degrees, with a range from 75.0 to 85.0 degrees. In females, the average angle was 81.7±5.8 degrees, with a range from 75.0 to 85.0 degrees, with no statistically significant difference between the sexes.

When compared with Brem's (1998) [2] data on optimal shoulder joint angles in horses, it can be concluded that the donkeys studied in Romania, North Macedonia, and Turkey have a more closed shoulder joint angle.

Regarding the hind limb joints, Urošević *et al*. (2017) [13] found that the average stifle joint angle in males was 99.21±6.80 degrees, with a range from 85.0 to 110.0 degrees. In females, the average angle was 108.80±10.08 degrees, with a range from 85.0 to 130.0 degrees. The overall average stifle joint angle was 104.50±9.89 degrees, with a range from 85.0 to 130.0 degrees, and the differences between sexes were statistically significant (p<0.01).

The average hock joint angle in males was 128.90±12.58 degrees, with a range from 104.0 to 145.0 degrees. In females, the average angle was 129.90±11.95 degrees, with a range from 95.0 to 145.0 degrees. Overall, the average hock joint angle was 129.40±12.04 degrees, with a range from 95.0 to 145.0 degrees, and there were no statistically significant differences between sexes.

When compared to the optimal values for horses (Brem 1998) [2], the minimum hock joint angle in donkeys is smaller, indicating a more closed hock joint, while the maximum values are similar to those of horses.

Unlike the hind legs, which generate biokinetic energy, the forelegs do not have such a role. During movement, or while "pushing" the body forward, the forelegs support the body mass and allow the hind legs to cyclically generate biokinetic energy.

In the entire process of movement, as well as standing, the center of gravity plays a crucial role. If the center of gravity shifts more caudally (backward), the hindquarters bear about 60% of the body mass, while the forequarters bear 40%. In this case, the hindquarters must first use the biokinetic energy to support the body mass, and the remaining energy is used to push the body forward, enabling movement.

If the center of gravity shifts more cranially (forward), the distribution of body mass changes significantly. The forequarters bear 60% of the body mass, and the hindquarters bear 40%. In this scenario, the lighter hindquarters require significantly less biokinetic energy to support the body, and more of this energy can be used to transfer the body forward more easily and quickly.

The position of the center of gravity is defined by the intersection of the horizontal and vertical planes. The horizontal position of the center of gravity is located at the level of the sternum, and its position is determined by intrauterine development. The center of gravity can only shift horizontally, either forward or backward. The specific morphological segment where the horizontal and vertical planes intersect is not mentioned in the available literature.

Two primary morphometric factors define the position of the center of gravity: The position of the croup (its height) and the position of the neck (the angle at which it is attached to the body).

Two postulates can be defined here:

1. A neck positioned relatively low, attached at an angle of up to 30 degrees, and a croup positioned higher than the withers.
2. A neck positioned high, attached at an angle greater than 30 degrees, and a croup positioned at the same height as or lower than the withers.

There is only one piece of data in the available literature regarding the angles of the croup and neck. Urošević *et al*. (2015) [12] reported that the average croup angle in males was 15.0±3.92 degrees, with a range from 10.0 to 20.0 degrees. In females, the average croup angle was 18.35±4.59 degrees, with a minimum of 10.0 degrees and a maximum of 25.0 degrees. These differences were statistically significant (p<0).

The angle at which the neck is attached to the body in male Baroque donkeys, as reported by Urošević *et al*. (2019), averages 24.0° ± 5.4°, with a significant range of variation from 15.0° to 30.0°. In females, the average neck attachment angle is 22.1° ± 5.2°, with a similar range of 15.0° to 30.0°.

These two basic biomechanical postulates define the position of the center of gravity. In the first case, which represents the desirable biomechanical body model of a donkey, the center of gravity is shifted forward. This increases the biodynamic capacity, meaning the rear part of the body is less burdened than the front. The production of biokinetic energy is at an appropriate level, facilitating the typical biomechanical movement of the donkey.

In the second case, which is entirely undesirable and not observed in normally developed donkeys, the center of gravity is shifted backward. This places greater stress on the hindquarters, impeding the production of biokinetic energy. Insufficient energy levels prevent easy movement.

This provides an explanation as to why donkeys are built with the rear of their body higher than the front. When studying the morphometric parameters of donkeys, Urošević *et al*. (2019) found the average height at the withers in males to be 106.6 cm ± 3.2 cm, and in females, 105.7 cm ± 3.5 cm. These differences were not statistically significant. However, the average height of the sternum in males was 70.9 cm ± 2.4 cm, and in females, 66.3 cm ± 3.3 cm. These differences were statistically significant (p<0.001).

These morphological characteristics in the biomechanical model, and their statistically significant differences, support the theoretical axiom: **"The higher the center of gravity, the faster the animal, but the less stable it is, and vice**

versa. A lower center of gravity results in slower movement but greater stability."
From a biological standpoint, it is entirely justified that females have a lower center of gravity. Pregnant females need to be stable while moving, and it is not desirable for them to move quickly.

Table 1: Mean height values of certain morphometric parameters of female baroque donkeys (cm) (Urošević *et al*.. 2019)

Ridge height	*Back height*	*Croup height*	*The height of the top of the sternum*	*Height of the shoulder joint*	*The height of the elbow joint*	*Height of the knee joint*
112,2+/-5,7	109,3+/-5,2	117,0+/-5,4	75,6+/-2,5	80,3+/-2,9	68,5+/-3,1	71,2+/-4,6

The data in the table show that the baroque donkey belongs to the group of tall (big) donkeys. The average height of the withers of females was 112.2 cm with a variation of plus and minus 5.7 cm. Particular attention must be paid to the next parameter, which is the height of the back. The central part of the back is lower than the withers by 2.7%, and the immediately following parameter, the height of the withers, is higher than the height of the withers by 4.3%. This relationship of these three parameters represents the desired, desirable, upper line of the donkey. The habitat of the white baroque donkey is not a hilly area, but a plain, so these percentage differences are relatively small.
The data in the table show that the top of the sternum is at a height between the shoulder and elbow joints. In relation to the height of the withers, the top of the sternum is at 67.38% of the height of the withers. It should also be noted that the knee joint is practically at the same height as the elbow joint.

Picture 4: White baroque donkey. A clearly visible slightly down back and a slight sublime croup (Foto. M.Urošević)

Table 2: Mean height values of certain morphometric parameters of male baroque donkeys (cm) (Urošević *et al*. 2019)

Ridge height	*Back height*	*Croup height*	*The height of the top of the sternum*	*Height of the shoulder joint*	*The height of the elbow joint*	*Height of the knee joint*
115,2+/-4,5	112,8+/-6,5	118,3+/-5,2	77,0+/-5,7	81,2+/-2,7	71,0+/-2,5	73,6+/-3,7

The average height of males is not significantly greater than the average height at the withers in females. Males also display the desirable topline, where the back is slightly lower than the withers, specifically by 2.08%. Additionally, males are higher at the rear, by 2.69%.
In males, the sternum is positioned slightly higher than in females in absolute terms, but when viewed as a percentage, the sternum in males is located at 66.84% of the withers' height. In males, the sternum is positioned between the shoulder and elbow joints. As with females, the knee joint is at a similar height to the elbow joint.
In both sexes, the knee joint is placed higher than the elbow joint but lower than the shoulder joint. Therefore, the knee joint lies on a horizontal plane between the shoulder and elbow joints. The shoulder joint is positioned higher than the sternum in both sexes, and the knee joint is lower than the sternum, i.e., the center of gravity.
It is interesting to examine the relationship of the hock height (tarsal joint - articulatio tarsi). This anatomical part is a complex joint, practically consisting of four joints, formed by the articulation of the lower leg bones (the tibia and fibula) with the tarsal and metatarsal bones. Brem (1998) [2] states that the optimal hock joint angle in horses is between 135 and 140 degrees. In the available literature, there is very little data on the hock joint angle in donkeys. Urošević *et al*. (2019), studying the Baroque donkey in Austria, determined that the average hock joint angle in males was 128.0° ± 9.1°, and in females, 130.7° ± 6.2°. Analyzing the morphometric parameters of donkeys in Turkey, Romania, and North Macedonia, Urošević *et al*. (2015) [12] found that in the overall population, the average hock joint angle in males was 104.00°, and in females, 95.00°. These differences in absolute values were not statistically significant.
The average hock height in male Baroque donkeys was 45.6 cm ± 1.6 cm, while in females, it was 43.7 cm ± 3.0 cm. When these values are related to the height at the withers, it is found that for males, the hock height represents 39.48% of the withers' height, and for females, 38.95%. In the overall population from Turkey, Romania, and North Macedonia, the relative ratio of hock height to withers height in males is 32.57%, and in females, also 32.57%.

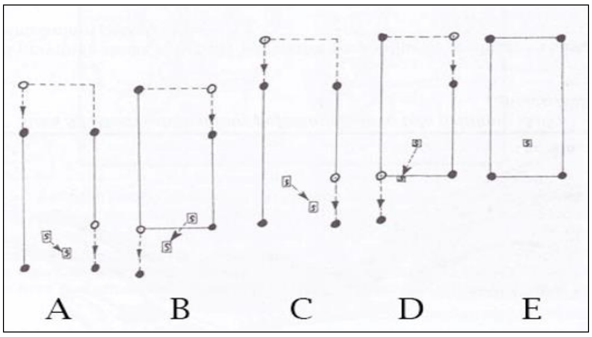
When it comes to types of movement, a donkey can move in the following ways: a) walking b) trotting c) galloping The slowest mode of movement is walking, while the fastest is galloping.

Walking

Walking represents a complete cycle of movement. It is the smallest, repetitive, coordinated part of locomotion. In the available literature, there is no data on the correlation between stride length and the height of a donkey's withers. In dogs, stride duration significantly depends on withers height (Raith, 2010, cited by Urošević, Drobnjak, 2018). Based on observations of donkeys of various withers heights, it could be assumed that this statement holds true for them as well.

The length of a donkey's stride certainly depends on the height of the withers, i.e., the size of the donkey. Babić, in 1939, wrote about stride length and movement speed. Studying the Apulian donkeys imported into Croatia (Dalmatia), he found that the average stride length in males was 1.44 meters, while in females, it was 1.41 meters. Interestingly, both sexes completed a stride in 0.98 seconds. The author determined that the average height of the withers in the donkeys he studied was 128.8 cm.

During walking, the donkey always moves in a diagonal pattern — the left front and right hind legs move together, followed by the right front and left hind legs. As the legs move, the weight shifts, causing the center of gravity to move in the direction of the advancing front leg.



Picture 5: The rectangle under the body while standing on all 4 legs and in the phases of movement. Analogous to dogs (Urošević, Drobnjak, 2018)

A - while standing still, with all 4 feet on the ground, it is possible to draw a rectangle around the hoof in which the center of gravity is located.

B - movement begins, the front right leg and the rear left leg move. The center of gravity shifts to the front right leg as its movement shifts the total load. The center of gravity does not go out of the frame outlined by the front left and right hooves. The front right and rear left rested on land.

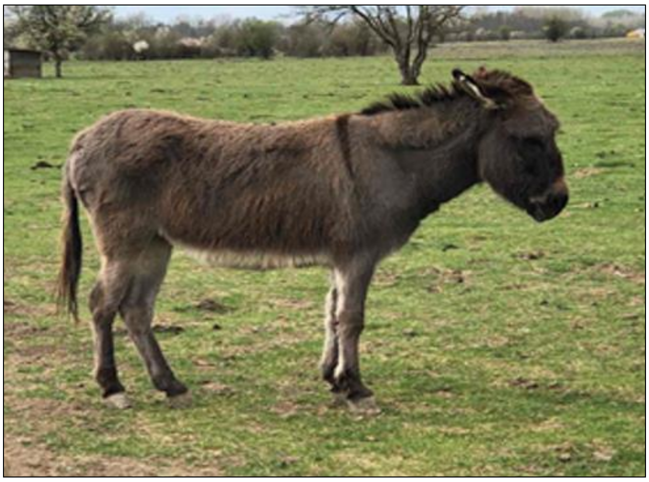
C - after the support of the front right and rear left, the action of the front left and rear right legs begins. Now the center of gravity shifts towards the direction of movement of the front left leg.

D - when the front left and rear right legs are supported, the cycle starts again with the movement of the front right and rear left, the center of gravity moves to the right, in the direction of movement of the right leg.

E - the cycle continues by moving the front left and the back right and so alternately, the donkey moves.

This is the most common way a donkey moves. It is often referred to as a "crossed" walk because the diagonal legs, front left–back right and front right–back left, are in motion. During walking, the legs in action do not make contact with the ground simultaneously. Walking typically begins with the movement of a front leg.

As the donkey moves, the hind legs push the body forward, while the front legs are responsible for covering ground and compensating for the forward shift of the center of gravity. It is clearly visible that the hind legs are more muscular compared to the front legs. Their primary role is to act as levers for support and propulsion.



Picture 6: A clearly visible difference in the muscularity of the rear and front legs. Donkey in the "Zasavica" nature park (Serbia) (Foto: M.Urošević)

The whole body must be in an equilibrium (balance) position. For that, it is necessary that the legs stand in a balanced position. When walking, two or three feet have contact with the ground. This is the basic difference compared to trotting where two legs must always be in contact with the ground.

Picture 7: Standing phase – all four feet resting on the ground (Foto: M.Nemecek)

When the body is in a resting phase, the vertical load force is in a linear relationship with the basic anatomical characteristics. These include the length of the humerus, the length of the femur, the size of the hooves, and, of course, the body mass.

Walking as a form of movement involves several phases through which each leg passes. If standing is taken as the starting position, then the support of the hoof on the ground is the first phase. Next is the lifting of the leg, where the hoof leaves the ground. The leg is raised to a certain height where it briefly remains in a hovering phase. After that, the next phase follows, which is the lowering of the leg. The final part of the leg-lowering phase is when the hoof first touches the ground, followed by support. This is the resting phase. The shorter this phase, the faster the walking movement.

The front leg is lifted shortly after the maximum extension of the shoulder joint. During the resting phase, the shoulder joint is bent while the elbow joint is extended.

Just before the leg is lifted and the hoof leaves the ground, the shoulder joint reaches its maximum flexion, and the elbow joint opens. The opening of the shoulder joint occurs during the swing phase, reaching its maximum just before the hoof makes contact with the ground.

During the swing phase, the elbow joint is bent, and then it extends (opens) again.

Picture 8: Front leg lifting phase, bent shoulders and elbow joint. Below the front knee, the leg is relaxed, soon followed by bending of that joint as well (Foto: M.Urošević)

Picture 9: Baroque donkey in Austria. Raising the front leg, with the bent shoulder joint is bent and the elbow joint of the front knee is bent (Foto: M.Nemecek)

When it comes to moving the hind leg, it also goes through several stages. Lowering of the hind leg and contact of the hoof with the ground occurs a short time after maximum flexion of the hip joint and a short period of time before maximum extension of the knee joint. The ankle joint is in the extension phase. When it comes to the hock joint, it should be noted that it is in a phase of greater extension at the moment of lifting the hind leg, when the hoof no longer has contact with the ground.

Picture 10: Departure, front left extended forward, rear right back. (Foto:M.Urošević)

In the resting phase, the hip is extended, and the knee and ankle joint are bent. In donkeys, this phase of bending of these two joints is not particularly pronounced since, in general, donkeys have slightly more open corners of their hind legs.

The lifting of the leg occurs shortly after the maximum extension of the hip and ankle joint. The lifting phase is followed by the leg swing phase. During this phase, hip flexion occurs. The knee joint is sprung and maximum knee extension is reached shortly before the hoof hits the ground. In donkeys, in general, the hock is quite open. However, during the swing phase, it is maximally bent, and after that it is stretched. Just before the hoof touches the ground, the ankle joint reaches its maximum extension.

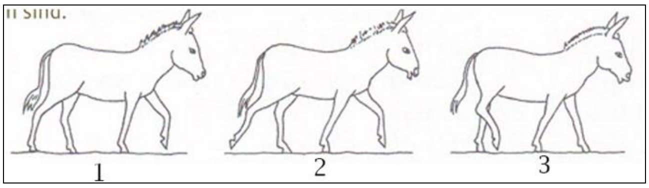
Pictures 11: The landing phase of the hind leg just before the hoof makes contact with the ground (Foto:M.Urošević)

In order for the body to move, to move forward, in proportion to the intensity of the biokinetic energy produced, it is necessary that the front legs have a regular angulation. Sufficiently long stride, and thus the total step, can only be with well-angled joints of the front leg. In addition to the correct angles, the length of the stride is significantly influenced by the length of the individual anatomical parts that make up the front leg. If the scapula is well positioned and the upper arm has sufficient length, the lunge length is determined by the medial line of the scapula extended to the floor.

Reducing the length of the upper arm causes a change in the position of the scapula. This results in a change in the place where the medial plane of the scapula meets the ground, which is at a smaller distance in front of the hoof. The consequence of this is a reduction in the stride length of the front leg.

In the case of anatomical disharmony, i.e. disturbance of the length of certain bones, primarily the upper arm and femur, inharmonious movement occurs.

When it comes to the length of the step, the donkey belongs to the group of animals that have a short step. When moving, the hooves of the hind legs do not catch up with the hooves of the front legs, but rest on the ground behind them.



Pictures 12: Representation of resting the feet on the ground when moving with a step (Hafner, 2013) [6]

1. Three legs are resting on the ground, the front left is in the air.
2. Two feet are resting on the ground, rear right and front left are in the air.
3. Three legs rest on the ground, the rear right is in the air.

No matter how easy and synchronized the leg movement seems, the newborn chick must learn and learn how to move the legs correctly. The correct rhythm of moving the legs allows easy and harmonious movement.

When walking, a donkey covers an average of 3.2 km/h. However, if their crest height is higher, that distance can be 4-5 km/h.

Picture 13: During tourist riding, the speed of the step by step is not particularly high (Foto:M.Urošević)

There is also a special type of movement, the "camel" step. In this case, the legs are simultaneously moved from one side of the body: Left front - left rear; right front - right rear.

Picture 14: Movement of the camel. Simultaneous leg action on one side of the body (Foto:M.Urošević)

Trot

While in other animals the trot enables the longest movement with the least consumption of biokinetic energy, this is not the case in the donkey. Of course, he can trot, his body structure allows him to do so, but certain specifics in the biostatic model dictate that the donkey prefers to walk at a pace and thus can cover long distances.

Movement at the trot is characterized by the synchronous movement of the rear and front legs, which move in rhythm: Rear right - front left; rear left - front right. With such a dynamic action of the legs, the center of gravity moves exclusively forward.

In contrast to the walking mode, where the center of gravity shifts in the diagonal plane in the direction of the moving front leg, in the trot movement, the center of gravity also shifts, but it moves straight forward in the medial body plane.

As can be seen in this case, there is an absence of a shift of the center of gravity towards one or the other front leg, which conditions the saving of energy consumption. Unlike other animals, among them is the horse, where the front part of the body is quite developed, this is not the case with the donkey. The front part of the body, the distance between the shoulder joints, of the donkey is significantly narrower than the back part of the body, especially the pelvis.

Picture 15: The distance between the shoulder joints is significantly smaller than the width of the pelvis (Foto: M.Urošević)

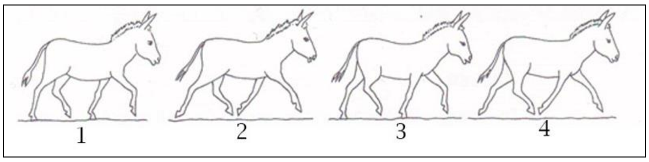
Therefore, it is significantly less (shorter) when moving with a step, moving the center of gravity in the direction of one or the other front leg, so that the loss of biokinetic energy is not great. This is the reason why the donkey is happy to move at a pace without much fatigue.

Picture 16: Donkey trotting race in Bački Vinogradi (Serbia) (Foto: M.Urošević)

When the donkey moves with a step, the movement of the body, the push, towards the front, occurs as a result of the power of the push realized in the hind legs. The biokinetic energy produced in the musculature of the back of the body is sufficient for the biokinematic effect of moving the body forward.

Picture 17: You should notice a wide pelvis and a wide rear part of the body (Foto:M.Urošević)

When it comes to trotting, the biokinetic energy produced only in the rear part of the body is not enough to push the body at the necessary speed. In this case, the muscles of the back and neck are activated. While the back musculature actively participates in pushing the body forward, the neck musculature does not have that ability, but the correct position of the neck and its downward movement causes the center of gravity to move forward. By moving the center of gravity forward, the load on the rear part of the body decreases, and by increasing the load on the front part of the body. The load on the front and back part of the body is based on the distribution of the total body mass of the donkey. If the center of gravity is more towards the back, the back part of the body is more loaded, and therefore the production of biokinematic energy and the bikinetic effect of movement are difficult. In the opposite case, when the center of gravity is more towards the front, then the situation changes. The greater load is on the front and less on the rear. This enables easier production of biokinematic energy, which is used less for moving the back part of the body, and more for transferring it to the front part and moving the body forward more easily.
When moving at a trot, we are talking about simultaneous touching of the ground with the diagonal hooves, front left - rear right; front right - rear left. While four beats are heard when walking, when trotting it's two beats since the crossed legs touch the ground almost at the same time. After touching the ground with the hooves, there follows a short jump phase when the hooves do not touch the ground, and in the air the position of the legs changes so that after the phase of lifting, hovering, and descending, the contact of the hooves with the ground follows.



Picture 18: Schematic representation of the trot movemen (Hafner, 2013) [6]

Description: 1 - Diagonal legs have support on the ground, 2 - Jump phase, 3 - The other two diagonal legs have support on the ground, 4 - The jump phase, only now the other front leg (left) is the leader

For a good trot, which implies long and sustained movement, which this type of movement is not typical for a donkey, the donkey must have a sufficiently long and low-set shoulder blade, strong loins, and long croup. Good angulation of the legs is very important. However, donkeys' legs, especially the hind legs, have slightly more open angles and are not the most suitable for trotting.

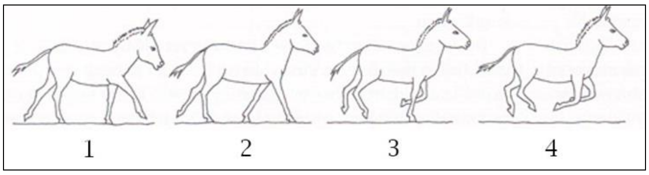
Gallop
This is the fastest way of movement and does not belong to the usual way of movement of donkeys. They quite rarely gallop, unlike horses. First, they do not have a body structure that is suitable for galloping. It has already been noted that the donkey has a rectangular body, and the typical canter body build is a square body. Of course, all animals can gallop, it's just a matter of how long and how many times a day they can repeat the gallop.

Picture 19: Galloping race of donkeys in theBački vinogradi (Serbia) (Foto:M.Urošević)

The change of movement to a gallop usually follows a fast trot. Since only the biokinetic energy of the muscles of the hind legs is not enough to move the body forward during the gallop, it is necessary to engage the longitudinal back muscles. In donkeys, the spring effect, which the back muscles have in other animals during the gallop, is not so pronounced. The full back is much more tightly connected and not as elastic. What will be the step forward of the front and rear legs, when moving at a gallop, depends on the elasticity of the back, i.e. the size of the possibility of their bending - springing like a spring. The action of stretching the back helps push the body forward more strongly.

Gallop is a type of movement in three beats. It is an asymmetrical movement. This means that the legs of one half of the body do not move symmetrically, but always a pair of legs, back or front, move one behind the other. The hooves of those legs do not touch the ground, nor do they separate from it, at the same time. This is the difference in relation to movement at a walk or a trot, where the front leg moves after the rear one and vice versa. Depending on which front leg is leading, left or right, it is called a left or right gallop.

At the time when the front hooves have contact with the base of the hind legs, they are in the air. At that moment, the lumbar part of the spinal column comes into a position of slight convexity. This position of the lower back makes it easier for the hind legs to move forward. The next stage in this movement is to straighten the currently formed spring and move the front part of the body forward. There are different forms of gallop such as racing, jumping, light. A light gallop is characteristic of a donkey.



Picture 20: Gallop phases (Hafner, 2013) [6]

Description: 1 - Diagonal support of two legs, 2 - Three hooves are on the ground, 3 - Only one, right, hoof on the ground, 4 - Jump phase, all legs are in the air

Back

The donkey belongs to the group of animals that are built, they move, basically, with a step, when pulling a load (cart) they move with a step or a trot, and exceptionally they can also gallop. For all animals that can move for a long time, with the same rhythm, a rectangular body is characteristic. The length of the body is greater than the height of the withers. There are donkeys where the difference is not big, but it exists.

Picture 21: Donkeys in Zasavica Nature Park. Visible slight depression of the back and overbuilt (Foto: M.Urpšević)

The connection between the rear part of the body, the hind legs, and the front part of the body, the front legs, is represented by the spinal column. It functions, in all animals, as a bridge over a river (channel, stream). The backbone is "above the water", and the foundations on the shores are the front and back legs.

Picture 22: Slightly more sunken back, clearly visible overbuilt (Foto: M.Urošević)

Conclusion

The structure of the donkey's body, a biostatic model, allows for long, constant movement. The front part of the body is narrower, lighter, than the back part. The typical movement is a walk, but it can move at a trot as well as a gallop.

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