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Colombian Criollo Equine Gallop Variations

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Abstract

Kinematics is a noninvasive technique for observing locomotion characteristics in equines and other species through video analysis. The present study aimed to identify the gallop characteristics of the Colombian Criollo horse and verify whether they exhibit a suspension phase through kinematic analysis. Horses were ridden and filmed from a lateral perspective while galloping along a five-meter linear trajectory during an official breeding event. Movement was analyzed via Windows Movie Maker® software, which enables the examination of 30 frames per second to observe the support and lift sequences of the thoracic and pelvic limbs throughout the trajectory. The data revealed 10 cycles of asymmetric gaits classified as marching, with an average speed of 2.29 m per second (SD = 0.64 m/s). The horses executed cycles consisting of anterior and posterior tripedal support (100%), anterior and posterior monopedal support (97.5%), diagonal bipedal support (95%), posterior bipedal support (87.5%), lateral bipedal support (30%), and quadrupedal support (17.5%). None of the sequences resembled the three-beat canter variations. They did not conform to the characteristic cross- or rotational four-beat gallop patterns, as the horses did not exhibit a suspension moment. Therefore, the Colombian Criollo horse's gallop is distinct from that of other breeds because of its marching nature and absence of a suspension phase.

Keywords

Biomechanics; horses; Colombian Criollo; kinematics; gallop; locomotion

1. Introduction

Canter and gallop are natural gaits performed by equines of different breeds. They are classified as asymmetric and leaping because of a suspension phase within their movement sequences. These gaits can consist of either three or four beats and are recognized as patterns of high-speed locomotion [1–3]. Like other natural gaits, gallop and canter exhibit subtle variations influenced by factors such as breed, aptitude, training, sport activity, and work or leisure purposes.

Canter is a three-beat, asymmetrical gait that includes five support phases and a notable suspension phase. The length of a canter stride can vary from 4.3 to 8 meters, with speeds ranging from 5 to 9 m/s, reaching 18 to 38 km/h in some instances. The canter can be classified as right- or left-leaded, depending on which thoracic limb is the last to lose ground contact prior to the suspension phase [2–5].

Gallop is a four-beat, asymmetrical gait that includes a suspension phase and five or seven support phases. It can be categorized as either transverse or rotational. The transverse gallop is the predominant type, characterized by an initial support phase that features a posterior monopedal stance on one side, followed by an anterior monopedal stance on the contralateral limb before suspension occurs. The rotational gallop starts with a posterior monopedal stance, where, before the suspension phase, the ipsilateral thoracic limb touches the ground. This gait includes a suspension phase that concludes the movement cycle and is categorized according to the last thoracic limb that makes contact before

the suspension occurs. The speed of these gaits ranges from 12 to 14 m/s, reaching up to 54 km/h, with stride lengths of up to 8 meters **[2–9]**, making them the fastest equine gaits.

According to the Colombian Federation of Equine Associations (FEDEQUINAS), the gallop of the Colombian Criollo horse is characterized as a diagonal-paced gait with three distinct beats. This sequence begins with a pelvic limb support phase, followed by a diagonal bipedal support phase, and concludes with an anterior monopedal support phase, all of which are repeated cyclically **[5,7]**. Therefore, the objective of this study was to identify and describe the kinematic characteristics of the Colombian Criollo horse's gallop.

2. Materials and Methods

This study was reviewed and approved by the Ethics Committee on Animal Use (CEUA) of São Paulo State University "Júlio de Mesquita Filho" (UNESP), under protocol No. 0203/2021. All procedures complied with institutional guidelines and were conducted in accordance with current regulations on the ethical use of animals in research.

In this study, 40 healthy Colombian Criollo horses, aged between 36 and 48 months and undergoing training, were recorded while performing the gallop. The group consisted of 22 females and 18 males (*stallions*), and identification through the recordings was not possible. All horses had registration certificates and microchips issued by FEDEQUINAS.

Filming was performed during the Grade A national equine event in Chiquinquirá, Colombia, in August 2021, in an indoor environment with controlled lighting. The track on which the gait was evaluated was constructed of solid, compact wood, which enhances the resonance of the footfalls and facilitates the identification of timing by judges and spectators; for this reason, it is referred to as the "sonorous track." This structure is installed at ground level in a straight line, ensuring uniformity and remaining free of obstacles **[9]**. It measures 15 meters in length and 2 meters in width; in its middle third, a linear trajectory of 5 meters (*filming trajectory*) was marked. This track is officially implemented in all equestrian events endorsed by FEDEQUINAS. The camera used (*Sony Handycam HDR-CX405*®) was positioned perpendicularly and mounted on a tripod in a static position throughout the filming process **(Supplementary Figure 1)**.

For inclusion in the experiment, prior to the test, each horse was evaluated and examined by veterinarians, who certified their health, in addition to the anti-doping test conducted by FEDEQUINAS. Horses with physical or locomotor abnormalities were excluded from the competition, which constituted the exclusion criterion. The horses, grouped by sex, were ridden by professional riders certified by FEDEQUINAS and performed a collective warm-up to demonstrate their gaits. This warm-up lasted 10 minutes, consisting of 2 minutes at the walk, 4 minutes in "trocha" (a characteristic gait of the Colombian Criollo horse), and 4 minutes at the gallop. Subsequently, each horse was individually filmed while performing the gallop on the sonorous track, resulting in a total of 40 video recordings.

Chronophotographic analysis was performed individually for each video using computer software (Windows Movie Maker®), which enabled frame-by-frame evaluation and facilitated the identification of at least two sequences (strides) with the same number and order of the support moments for each horse. Regardless of the number of supports identified, the criterion was established that, during the execution of the cycle, all four limbs must make ground contact and that the sequence be repeated at least twice for this identification. **Supplementary Figure 2** served as a reference. Subsequently, the sequences were recorded and graphically represented in Excel®, together with the total number of frames corresponding to the trajectory **(Supplementary Figure 3)**.

To estimate the speed, the displacement of the body and its center of gravity relative to a reference point as a function of time were determined. In other words, it was based on the division of distance covered over time (speed = distance covered ÷ time) **[8,9]**. Speed was also calculated by counting frames per second divided by the standardized distance of 5 meters. Each frame corresponded to 0.033 s, and the footage was 30 frames per second.

Following the identification of the support moments in the trajectory, two identical and cyclic sequences of support moments were established for each horse. This approach aligns with the framework presented by Beck **[8]**, wherein these support sequences constitute the cycle of movement characterized by the regular and repetitive execution of support moments. The systematic distribution of these support moments facilitates the auditory and observational recognition of traits such as beats, strides, and speed.

Gait cycles were categorized into symmetrical and asymmetrical types. A symmetrical gait is defined by a consistent repetition of support moments, which are generated by either the right or left limbs and progress with an equivalent contralateral repetition. For instance, in the trot, a right diagonal bipedal support is followed by a left diagonal bipedal support as the corresponding contralateral element, interspersed with moments of suspension. Conversely, the asymmetrical gait lacks the repetitive nature of equivalent contralateral support moments.

The gaits were also classified as marching or jumping. In marching gaits, the horses always have at least one hoof in contact with the ground during the execution of the cycle. In jumping gaits, they exhibit a moment of suspension **[3,4,10]**, where the horse loses contact with the ground. After the gait cycles were identified and the variations presented by the horses in the gallop were classified, the sequences were organized into groups containing the respective number of animals according to the gait cycle performed.

3. Results

Cinematographic analysis revealed that 95% of the horses displayed a single type of gait throughout the trajectory, whereas 5% exhibited two different gait types **(Table 1)**, indicating a transitional cycle. Frame-by-frame analysis identified ten variations of the gallop (A–J) **(Figure 1)**, corresponding to ten distinct gait sequences.

The ten identified sequences in the locomotion of Colombian Criollo horses (A–J) were generally classified as marching and asymmetrical gaits, with an average speed of 2.29 m/s **(Supplementary Table 1)**. In terms of gallop variation, groups A, B, and C presented three beats, whereas cycles D,

E, F, G, H, I, and J presented four beats. These data correlate with the canter and the racing gallop, showing similarities in timing—three beats for the former and four for the latter—although variations were noted in the support moments and beat patterns throughout the execution of the cycles.

For the analysis and description of these sequences, the subsequent monopedal support moment was used as the initial reference point for the corresponding cycles. Importantly, monopedal support in these sequences does not always coincide with the beats, indicating that the analysis can be conducted at any support moment due to the repetitive nature of the pattern. This approach further clarifies the description of the strides exhibited by the horses in each group.

The horses in group A showed a sequence with three beats in five support moments, with the left posterior monopedal support as the first moment of support, which marks the first beat (b); at moment two, the second beat (b), was performed during the left diagonal bipedal support and followed by the left anterior tripedal support; at moment three, the horses exhibited a left diagonal bipedal support resulting from the elevation of the left pelvic limb; and at moment four, they generated the third beat (b), which was supported by the right forelimb. The right anterior support, together with the anterior diagonal, generated the right posterior tripedal support and ended with the right anterior monopedal support, resulting from the elevation of the diagonal (moment five), thus repeating the cycle.

The horses in groups B and C exhibited a sequence similar to that shown by group A during the execution of three periods: the first with the left pelvic limb, the second with the left diagonal bipedal support, and the third marked by the remaining anterior support. However, when the sequence was displayed, seven moments of support were formed. The essence of marking the three beats was preserved, but the breakover provided by the support that constituted the cycle increased by two moments of support in each sequence. For example, anterior monopedal support at moment six was maintained when the left pelvic beat was marked at moment seven (in groups B and C), resulting in diagonal bipedal support. Thus, it is important to recognize that the presentation of the breakover in the sequence has multiple causes, as the horse adapts during locomotion by distributing weight in a balanced manner across the thoracic and pelvic limbs.

In the analysis of group D, the sequence comprised five moments of support and four distinct beats. The first beat (b) was initiated during left posterior monopedal support, followed by the second beat (b), which occurred during posterior bipedal support when the right pelvic limb contacted the ground. The sequences then transitioned to the left anterior tripedal support, where the third beat (b) was generated through contact with the left thoracic limb. Subsequently, the right thoracic limb marked the fourth beat (b), while simultaneously the right pelvic limb was lifted, thus generating the moment of right posterior tripedal support. In the final moment of support, right anterior monopedal support was observed, resulting from the elevation of the diagonal support.

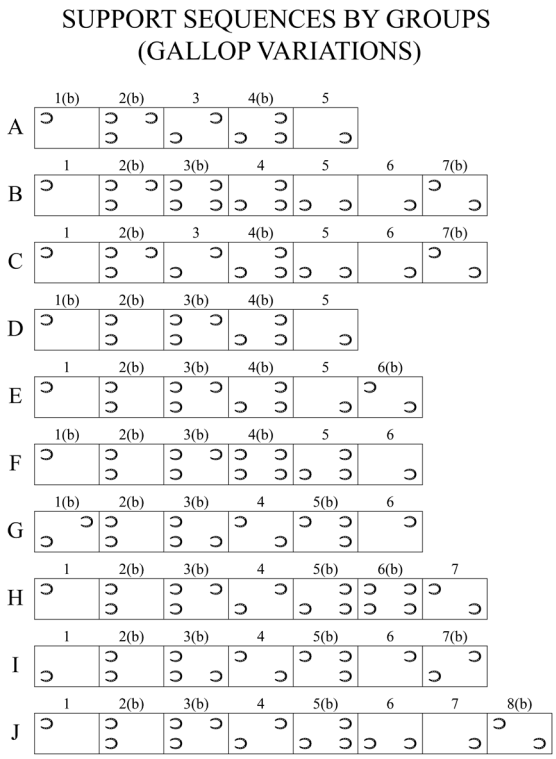

Figure 1: Steps by groups (A–J), showing the beats (b) and the number and type of supports displayed by the horses during the gallop.

Comparative analysis of group E revealed a similarity in the articulation of beats; however, a key variation was observed in the breakover presentation. Specifically, during moment six of Group E's sequence, there was sustained contact of the hoof from the right thoracic limb, whereas the left pelvic limb marked the following beat. This resulted in right diagonal bipedal support, a moment not observed in the Group D sequence. Consequently, this distinction resulted in the formation of a beat characterized by six moments of support and four beats.

The horses in group F exhibited a variation characterized by six moments of support and four beats. In contrast to the variation observed in group D, an additional moment of support was observed between the tripedal supports, specifically a quadrupedal support (moment four). However, the timing of the four locomotor limbs was similar to that of the horses in group D.

Group G was the only group that did not exhibit a moment of posterior monopedal support. Initially, a left diagonal bipedal support was observed, followed by the lifting of the thoracic limb and simultaneous support from the left pelvic limb, which constituted the second beat (b) and led to the generation of a posterior monopedal support. The third beat (b) occurred when the right thoracic limb was engaged at moment three. This was followed by continued right diagonal bipedal support. At moment five, the fourth beat (b) was indicated by the hoof of the left thoracic limb, which created a left posterior tripedal support. The sequence concluded with a left anterior monopedal support. The breakover of

this last support, noted at moment six, was first evidenced at moment one, where the hoof marking of the right pelvic limb was identified, indicating that it was not marked simultaneously by the diagonal support that formed the sequence.

The horses in group H exhibited a gait characterized by four distinct beats across seven moments of support. The initial moment involved the monopedal support of the left hind limb, which resulted from the elevation of the right thoracic limb during the seventh moment. This observation indicates that during this phase of support, the horse did not demonstrate a distinct beat. Following this, the first beat was produced by the support of the right pelvic limb, constituting the second moment of posterior monopedal support. The second beat subsequently occurred through the support of the left thoracic limb, resulting in left anterior tripedal support during the third moment. The elevation of the left hind limb then facilitated the establishment of left diagonal bipedal support, noted as the fourth moment. Following this arrangement, the right anterior monopedal support produced the third beat, thereby illustrating a right posterior tripedal support during the fifth moment. The fourth beat was generated by the support of the left pelvic limb, which, in conjunction with the other limbs, established quadrupedal support at the sixth moment. The subsequent elevation of the left diagonal bipedal support ultimately resulted in right diagonal bipedal support during the seventh moment.

The sequence observed in group I exhibited similarities to the cycle observed in group H. However, a notable distinction was the absence of a moment of quadrupedal support. Consequently, the fourth beat was not present during the sixth moment, unlike in group H, where the horse displayed this beat during the seventh moment of support with its right pelvic limb. This, in conjunction with the pincer-like support provided by the contralateral thoracic limb, resulted in a left diagonal bipedal support configuration.

In contrast, group J demonstrated a tempo comprising four beats over eight moments of support, with a sequence akin to that of group C. The critical difference was that the horse exhibited a moment of posterior monopedal support during the second moment, as well as at least one additional beat. This support was observed during the dissociation of the diagonal (simultaneous) bipedal support, a characteristic feature of the three-beat gallop.

Five percent of the horses exhibited two variations of the gallop within their trajectories, belonging to two distinct gaits for each corresponding group (A + E and D + F). This finding indicates that individual horses may display more than one type of sequence as a characteristic of their locomotion. Specifically, the horse that demonstrated sequences A and E in its trajectory transitioned from a tempo characterized by five support moments with three beats to a tempo with six support moments and four beats, respectively. Conversely, another horse presented sequences from groups D and F, which similarly transitioned from a tempo with five support moments and three beats to one with six support moments and four beats.

Table 1: Number of Colombian Criollo horses per gallop variation and the respective percentage of the total analyzed horses.

Gallop Variations	Number of Horses	Percentage
A	1	2.5%
B	9	22.5%
C	9	22.5%
D	4	10.0%
E	2	5.0%
F	9	22.5%
G	1	2.5%
H	1	2.5%
I	1	2.5%
J	1	2.5%
A + E*	1	2.5%
D + F*	1	2.5%
Total	40	100%

*Two horses exhibited two different gait variations within the trajectory.

The types of supports observed across the different groups from A–J, which represent the total number of animals analyzed, indicated an incidence of 100% for anterior and posterior tripedal supports, which were common across all gallop variations. Additionally, there was a 97.5% occurrence of anterior and posterior monopedal support; a 95% occurrence of diagonal bipedal support; a 30% occurrence of bipedal lateral support; an 87.5% occurrence of posterior bipedal support; and a 17.5% occurrence of quadrupedal support. Notably, anterior bipedal support did not influence the variations in the gallop sequences represented in **Supplementary Table 2**.

4. Discussion

Kinematics has facilitated the identification of variations in locomotion exhibited by Colombian Criollo horses during the gallop, corroborating findings reported by various authors in kinematic studies **[10–16]**. The observed variations in galloping were particularly notable in the sequence of supports, the number of support phases, stride duration, and footfalls, with ten distinct locomotion cycles identified in the gait of the Criollo horses. A predominant characteristic of these variations was their adherence to three- and four-beat patterns, akin to those observed in cantering and racing gallops **[17]**.

According to the Fédération Équestre Internationale (FEI), the canter is a three-beat gait comprising six support phases. When cantering to the right, the sequence of footfalls is as follows: left hind limb, then simultaneously the right hind and left forelimbs, followed by the right forelimb. This is followed by a suspension phase, during which all four limbs are off the ground before the next stride begins **[18]**. This characteristic establishes it as a leaping gait. Similarly, the Portuguese Equestrian Federation defines the gallop as "a three-beat gait in which, in the right lead, footfalls occur in the following order: left hind, left diagonal, left fore, right

hind, and finally the right fore, followed by a suspension phase where all limbs are elevated before the initiation of the next stride" **[19]**, thus elucidating the sequence of footfalls observed.

Dressage horses represent four distinct categories of canter, arranged in ascending order of velocity as follows: collected, working, medium, and extended canter. These categories differ not only stylistically but also in their execution speeds. According to the regulations set forth by the Fédération Équestre Internationale (FEI), the collected canter is characterized by shorter strides, whereas the extended canter features lengthened strides, enabling the horse to traverse the maximum feasible distance. By definition, a canter is classified as a three-beat gait, indicating that the diagonal limb pair makes contact with the ground simultaneously. The dissociation of the footfalls of the diagonal limb pair marks the transition from the canter to the racing gallop.

In the present study, the simultaneous support of a diagonal biped in groups A, B, and C characterized the three-beat variations. Furthermore, the dissociation of diagonal bipedal support was identified, wherein the horses exhibited separate limb supports, subsequently resulting in four-beat gaits in groups D–J.

The gallop of the Colombian Criollo horse is defined as a gait exhibiting a diagonal rhythm and three beats **[5,15,20,21]**. In this gait, the horse executes the first beat with a pelvic limb, the second beat is denoted by diagonal bipedal support, and the third beat is represented by the support of the remaining thoracic limb **[15]**. This rhythmic pattern was consistently identified in groups A, B, and C, which demonstrated three-beat cycles with identical execution but differing support phases; five support phases were observed in group A, and six support phases were observed in groups B and C.

The gallop of Criollo horses is characterized by a three-beat gait that demonstrates a diagonal rhythm. Nonetheless, if this rhythm is not executed properly, the horses may inadvertently adopt a four-beat running motion similar to that observed in horses from groups D–J. This shift could stem from various influences, including rider intervention or training, which could further explain the variation noted in the horses from groups A + E. This particular horse exhibited a three-beat gait with five support phases before transitioning to a four-beat cycle that integrated six support phases.

In *Chalanería Colombiana*, Londono **[15]** described the gallop cycle alongside its support phases. The initial phase consists of right posterior monopedal support, which is succeeded by right anterior tripedal support, then left posterior tripedal support, and finally concludes with left anterior monopedal support. Consequently, these support phases recur cyclically as the horses execute the gallop. Comparative analysis with the sequences mentioned above reveals that horses in group A exhibit similarities with the three-beat pattern and its corresponding support phases. Notably, this group also demonstrates an additional diagonal bipedal support phase interspersed between the tripedal supports, culminating in a cycle comprising five support phases.

In a comparative analysis of three-beat variations (A, B, and C) during the gallop in relation to the canter cycle **[1–3]**, group A presented the most pronounced similarity. This group demonstrated a three-beat cycle comprising five support phases, paralleling the canter cycle **[1–4]**, albeit lacking a suspension phase. Conversely, groups B and C displayed one in which the three beats were generated by diagonal bipedal support, whereas the remaining two beats resulted from the respective forelimb and hindlimb movements.

The four-beat variations (D, E, G, H, I, and J) did not align with the characteristics observed in either the transverse or rotational racing gallops or with the four-beat gallop executed over six support phases **[1–4]**. The racing gallop in horses is primarily defined by monopedal support phases (hind and forelimbs) and bipedal support phases (hind, fore, diagonal, and lateral) **[1,3,4]**. Notably, the distinguishing feature of the four-beat cycles identified in this study was the inclusion of both anterior and posterior tripedal support phases, which are absent in the racing gallop **[2,4,8,11]**. The structure of these cycles was influenced by breakover-phase supports, thereby characterizing their unique composition.

Previous research has indicated that the transition from trot to gallop in equines occurs at speeds ranging from 3.7 to 4.7 m/s **[22]**, with other findings reporting velocities of 5.0 m/s **[23]** and variations between 3.2 and 5.8 m/s **[24]**. These metrics are critical, as the trot typically results in lower speeds than the gallop does **[13]**. In the present study, an average velocity of 2.9 m/s was recorded (with a standard error of 0.64), which is below the velocities reported in prior studies. However, the average speed documented for the collected canter was 3.27 m/s, with measurements of 3.91 m/s for the working canter, 4.90 m/s for the medium canter, and 5.97 m/s for the extended canter **[2]**. The speed most closely aligned with previously reported values was that of the collected canter, which correlated with the velocities observed in Criollo horses.

In general, the observed cycles have been classified as ambling gaits **[25–27]**, as no equine exhibited the characteristic moment of suspension **[28–30]**, which was initially reported by Muybridge in his seminal work, *The Animals in Motion* **[1]**. Through detailed photographic analysis, he reported that during high-speed locomotion, equines demonstrate a moment when all four limbs are simultaneously off the ground, with no contact with the surface. This hypothesis has been substantiated across various species **[1,2,7]** and confirmed in equines performing three-beat and four-beat gallops **[2,3,6,10]**. Conversely, it has been reported that during the execution of a collected canter, equines do not exhibit a moment of suspension **[2]**. This characteristic, which is correlated with the observed velocity, suggests that speed may influence the occurrence of the suspension phase.

The three-beat cycles A, B, and C were classified as transverse gallops **[1–4]** because the equines initiated these cycles with monopedal support from the left pelvic limb and concluded with support from the contralateral thoracic limb. Consequently, these cycles are characterized as right-led gallops, as illustrated in **Figure 1**. In groups B and C, the final support phase was executed with breakover support from the left pelvic limb before the repetition of the cycle (moment 7).

The four-beat groups D and F were similarly classified as right-lead transverse gallops. Conversely, variations in

groups E, H, I, and J interfered with the breakover support during the final support phase, resulting in diagonal bipedal support. This complication hindered classification, as these sequencing patterns have not been previously documented. Finally, group G did not present the monopedal posterior support phase during the cycle, rendering its classification infeasible. Nonetheless, it is essential to clarify that the strides were executed sequentially by all four limbs.

Several studies have demonstrated that surface characteristics exert a significant effect on equine locomotion, modifying kinematic parameters and the expression of gaits. Factors such as firmness, elasticity, and traction influence stride dynamics, movement symmetry, and limb loading, with direct implications for the execution of locomotor cycles **[31–35]**. In the present study, locomotion was analyzed exclusively on a wooden track. It should be noted that the Colombian Criollo horses begin their training on this same type of surface, since the 'sonorous track' is standardized by FEDEQUINAS for competition. Consequently, it is recommended that future research evaluate and compare the locomotion of the same group of horses on different surfaces in order to determine potential similarities or divergences.

Some limitations of the study include that the same rider did not ride all of the horses, and certain rider-related characteristics, such as weight, preparation time, and riding equipment, were not standardized, which is likely associated with the variations that were observed. In addition, the number of frames used in the recordings was limited; therefore, future studies should consider the use of high-speed cameras to achieve greater precision in the analysis of movements. Furthermore, the integration of kinetic and kinematic analyses is recommended to provide a more complete, detailed, and precise biomechanical description.

5. Conclusion

The present kinematic study demonstrated that Colombian Criollo horses exhibit a gallop characterized by an asymmetrical ambling gait, lacking a suspension phase in the sequence of limb support. Moreover, the average galloping speed observed in these horses was significantly lower than the cantering velocities reported in other equine breeds.

Supplementary Materials

The **Supplementary Materials** comprises three figures and two tables: Supplementary Figure 1 illustrates the recording track and the perpendicular positioning of the camera during filming; Supplementary Figure 2 depicts the support moments; Supplementary Figure 3 provides a schematic overview of the methodology used for video analysis; Supplementary Table 1 reports the recorded speeds (m/s); and Supplementary Table 2 summarizes the incidence of support-moment types across the gallop variations.

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Author Contributions

Conceptualization: Hector García Duarte, Ana Liz Garcia Alves, Carlos Alberto Hussni, Marcos Jun Watanabe, Ricardo Costa Aranha. Methodology: Hector García Duarte, Daniel Parra-Torres, Heitor Cestari, Celso Antonio Rodrigues, Carlos Alberto Hussni. Preparation: Hector García Duarte, Carlos Alberto Hussni. Feasibility Data: Hector García Duarte, Carlos Alberto Hussni.

Data Availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

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Conflicts of Interest

The authors declare no conflicts of interest.

Ethical Approval

This project received ethical approval from the Ethics Committee on Animal Use (CEUA) of São Paulo State University "Júlio de Mesquita Filho" (UNESP), under protocol No. 0203/2021.

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