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Kinematic study of the locomotion of two crossbreds of lambs

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Summary — In the present study we suggest the use of kinematics for measuring locomotive abilities of two lamb crossbreds, bred for meat production (Berrichons and BMC), facing three environmental conditions: walking on a regular mud floor, walking on a stony ground and jumping from an uphill slope. In order to observe their locomotive strategy, animals were free to move around. Classical kinematic analysis was modified in relationship to the experimental context. Spatial and temporal data (stride length and duration, time interval between footfalls of limbs, amplitude of angular variations of articular segments) were collected to quantify motor coordination and limb posture. The BMC spontaneously adopted a more extensive scale of gaits with lateral sequences, they also used a wider range of speeds (0.8–2.5 m/s) with larger stride length (0.82 m) on the regular floor. On the stony ground, both breeds adapted their gaits in the same way, walking slowly (0.5–1.2 m/s). A large behavioural difference appeared between both breeds during the approach phase of the jump. For example, Berrichons slowed down and adjusted the feet position before jumping. Conversely, BMC showed the greatest manoeuverability as regards the obstacle. This study shows a difference in locomotive stategies between breeds according to the exercice. It underlines a better ability of BMC to walk in the varying conditions that characterise extensive grassland. Thus, the data of kinematic analysis should be used as an indicator for the selection of production animals.

kinematics / locomotive capacity / lambs / meat production

Résumé — Étude cinématique de la locomotion chez deux races d'agneaux croisés. Nous proposons d'utiliser une analyse cinématique pour quantifier et comparer les aptitudes locomotrices de deux races croisées d'agneaux selectionnées pour la production de viande (Berrichon, BMC). Pour de telles approches fonctionnelles, la vitesse et les allures des animaux sont classiquement contrôlées par l'utilisation d'un tapis roulant ou par une conduite à la longe. En effet, chez les animaux domestiques, les études cinématiques sont destinées à déceler les anomalies de la marche qui nécessitent des conditions standardisées. Afin d'observer les stratégies locomotrices des animaux, nous les avons laissés libres de leurs déplacements face à trois dispositifs expérimentaux susceptibles de reproduire des conditions naturelles : sol de terre battue plat et régulier, sol recouvert de pierres et franchissement d'un dénivelé. L'analyse image par image de films vidéo réalisés à 25 images par seconde a permis

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de mesurer les paramètres spatiaux et temporels (longueur et durée des enjambées, écarts entre les posés des quatre membres) qui traduisent la coordination motrice des quatre membres dans une allure donnée. Au cours du cycle locomoteur, le fonctionnement des chaînes articulaires constituées par les segments des membres a pu être estimé par l'amplitude de variation des angles compris entre ces segments. L'amplitude de variation des angles, comparable pour les deux races, varie en fonction du type de contraintes environnementales auxquelles sont soumis les animaux. Sur le sol empierré et au cours du saut, celle des angles les plus distaux des membres pelviens s'accroît. Des différences d'allure n'apparaissent aussi entre les races qu'en fonction du système de contrainte. Les BMC adoptent sur le sol de terre battue plat et régulier une gamme de vitesse plus étendue, associée à des séquences locomotrices latérales. Sur le sol empierré, pour éviter les obstacles, les animaux adaptent leur allure en modifiant la longueur de l'enjambée et la durée du cycle. La différence de comportement locomoteur la plus significative se manifeste au moment du saut. Les Berrichons réduisent considérablement leur vitesse lors de la phase d'approche et effectuent des mouvements d'ajustement. Au contraire, les BMC montrent une plus grande manœuvrabilité vis-à-vis de l'obstacle. La préparation au saut ne requiert de leur part ni ajustement de l'allure, ni modification de l'amplitude de l'enjambée, ni augmentation de la durée du cycle. Ces résultats mettent l'accent sur la variation des stratégies locomotrices des agneaux confrontés aux mêmes systèmes de contraintes. Ils soulignent que les BMC ont une meilleure faculté d'adaptation aux milieux variés qui caractérisent un élevage extensif. À ce titre, les données de l'analyse cinématique seraient de bons indicateurs pour la sélection des animaux de production.

cinématique / capacité locomotrice / agneaux / production de viande

INTRODUCTION

Standing, getting up to their feet when lying down, walking to a feeding area, or inside the farming location may be important for welfare and quality in animal production. Furthermore, production systems (confinement, stabling, intensive or extensive grassland) in regions evolve according to modifications in socio-economic conditions. Therefore, the ability of farm animals to adapt to different locomotive constraints needs to be measured and preserved.

For a few species of domestic mammals, especially horses, kinematic studies of locomotive movements are carried out to provide quantitative parameters commonly used as indicators for genetic improvement (Barrey et al, 1993). Kinematics is principally applied to detect lameness and to improve athletic performances. For production animals, studies on locomotion are very scarce and only concern highly selected breeds which have widespread pathologies in all cases (Elliot and Doige, 1973; Abourachid, 1993; Abourachid and Renous, 1993). In order to detect individual locomotive disorders, the analysis conditions are standardized. The floor is flat and regular without obstacles, and the displacement velocity is steady. The animals are commonly set on a treadmeal or lead at hand or with a rider for horses (Fredricson et al, 1983; Herling and Drevemo, 1996).

In this study, we suggest the use of kinematic analysis as an indicator for measuring locomotive abilities of lambs, bred for meat production, when they are faced with different environmental conditions. These conditions represent those found in different farming lands. Animals were not guided in order to observe the strategy freely adopted facing the different experimental conditions.

MATERIALS AND METHODS

Animals

Kinematics of the locomotion of two crossbred lambs in view of meat production was studied. Size and morphological traits of the two breeds were similar. The two crossbred lambs originated from crosses of Romanov ewes (used for their fertility and prolificacy) with Blanc du Massif Central and Berrichon du Cher rams. Animals were produced at the experimental farm of Langlade (Inra- SAGA). Crossbreds were preferred to pure breeds because they are destined for production and therefore up against farming constraints, whereas pure breeds which may present marked features, have specific farming conditions because they are used for reproduction. Hybrid lambs, called in this study Berrichon lambs and Blanc du Massif Central lambs (BMC) were all males, and grouped together in a single research farm stable. They received the same diet until they were about 4 months old and reached the weight of about 40 kg. Because the two crossbreds have almost the same adult size, kinematic analysis was carried out at the same development stage in both breeds. This development stage corresponds to the traditional slaughtering age in meat production.

Six lambs, three Berrichons and three BMC, were shaved and their hips marked with red ink on the skin of BMC and with blue ink on Berrichons. Overground locomotion was filmed with a videocamera Hi8 (Sony CCD-V800E) at 25 frames per second, which is sufficient for the relatively slow speed of the gaits we studied (< 2.5 m/s). Lambs moved in a 3 meter wide and 15 meter long passage. The camera was placed on a tripod at the same height as the moving animals. The tripod was placed half-way down the passage 3 meters from the center thus ensuring a 3-meter stretch of the passage could be filmed. Markings were drawn every 20 cm along the passage. Animals moved freely in one direction or the other. Animals were submitted to three experimental conditions. Firstly, they moved on a regular mud floor. Secondly, stones of about 30 cm^3 were placed on the ground at 20 to 40 cm from each other. Thirdly, we used an inclined plane in the passage. It obliged lambs to climb on an uphill slope and be faced with a steep variation in level. The end of a 1.5 meter wide and 2 meter long wooden board was raised by 35 cm at one end. Lambs walked up the board and jumped off at the end.

Single frame analysis of the videotape

Quantification of spatial and temporal variables of limb footfalls.

Leg movements coordinate exactly in a cyclic and repetitive manner. During one cycle, each foot is successively on the ground (stance phase) and off the ground (swing phase), and covers a distance corresponding to one stride's length. Temporal and spatial measurements of the different events of the cycle include essential information of motor coordination of limbs.

In order to study locomotion on the regular mud floor and on the stony ground, videotaped sequences showing a succession of cycles where the lambs are moving at a steady speed, parallel to the camera field, were selected. At steady speed, in symmetrical gaits, each foot contact lasts the same fraction of the cycle and has the same stride length (Hildebrand, 1965). Therefore, no separate statement is needed for each leg and stance and swing phases of one foot, chosen as reference, define a cycle. Thus, cycles showing large differences in limb contact duration were eliminated. On each cycle, we measured the total duration, the contact duration of each limb with the ground (stance phase), the time lag between footfalls of homolateral limbs (right forelimb-right hindlimb and left forelimb-left hindlimb) which indicate locomotive coordination. We also measured stride length of each limb. We calculated the four limb mean contact durations. Frames were used as time units (time interval between two frames = 0.04 s). The speed was obtained by dividing stride length by cycle duration.

To analyse the locomotive behaviour of lambs on the inclined plane, we modified classical methods used for the study of horses jumping a fence (Leach et al, 1984; Clayton and Barlow, 1989; Barrey et al, 1993). The approach cycles and the jump cycle were independently analysed. Because the gait is modified during these cycles, each limb is considered independently. In order to study equivalent video sequences, the footfall of the trailing hindlimb was considered as the reference sequence. The trailing hindlimb (TH) is the first hindlimb that takes off during the jump stride, the other hindlimb is called leading hindlimb (LH). The same definition of trailing and leading forelimbs, TF and LF respectively, was used. The cycles (approach and jump) started and ended at the footfall of the trailing hindlimb. The following temporal measurements were recorded: 1) duration of the last approach cycle; 2) duration of the jump cycle; and 3) duration of the last stance phase of each foot before jump take off. We also measured four sets of spatial data: 1) distance of forelimbs before take off; 2) distance of hindlimbs before take off; 3) stride length of the reference hindlimb for the last approach cycle; and 4) distance of each foot from the edge of the inclined plane before take off.

Measurements of joint angles

The geometric effect of the movement is quantified by measurement of angular variations of articular segments involved in locomotion. Single frame analysis of the videotape enabled us to measure certain joint angles. They were not always physiological angles, which meant they were not strictly the vertex of bone mechanical axes. It was, for example, not possible to exactly locate the scapula covered by a thick muscular layer. We therefore chose to measure a segment representing the movement of the shoulder but not exactly that of the scapula. It gave an angular movement representative of the joint. On each frame, 12 points on the side of the animals facing the camera were digitized using the image analysis software Optimas. From those points, angular variations of height joints were calculated (fig 1). For the articular chains, an opening of the angle corresponds to an extension of the joint. Sums of each limb joint angles were also calculated and were expressed in radians. Maximal amplitude of angular variation during a cycle was calculated. This corresponds to the difference between maximal and minimal angular values of each joint. Angular variations were measured during the three experimental conditions, ie, walking on the regular mud floor, on the stony ground, during approach cycle and jump cycle.

Statistical analysis

Means and standard deviations of the parameters of cycles and the maximal amplitudes of angular variation were calculated. The general

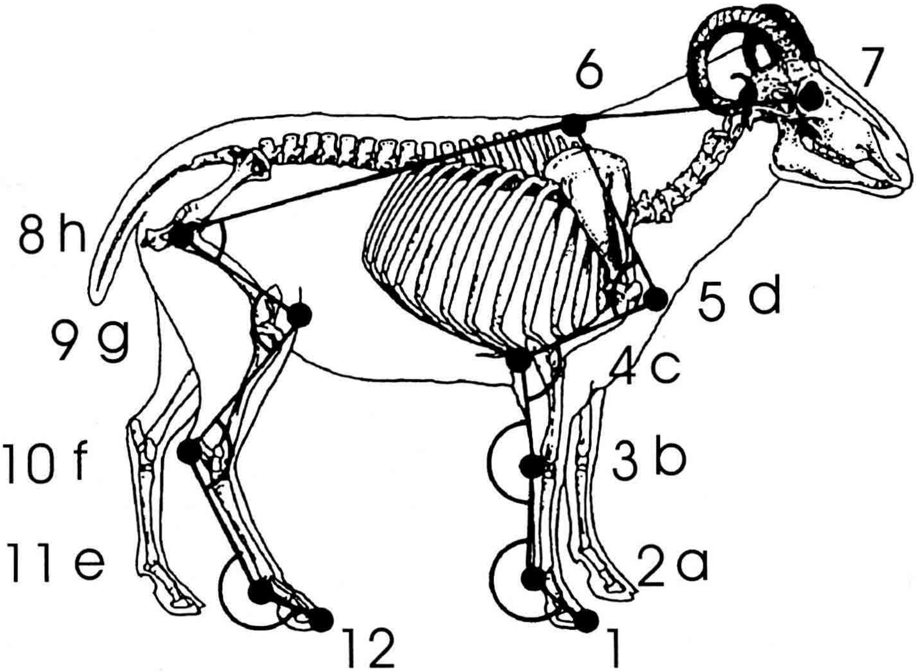


Fig 1. The studied limb markings and joint angles on a sheep skeleton (from Barone, 1976). Markings: 1, anterior extremity of the fore hoof; 2, fore declawed; 3, carpal posterior part; 4, ulna posterior part; 5, shoulder anterior part; 6, wither; 7, eye; 8, hip; 9, knee; 10, tarsal posterior part; 11, hind declawed. Angles: a, metacarpo-phalangeal joint; b, carpal joint; c, elbow joint; d, shoulder joint; e, metatarso-phalangeal joint; f, tarsal joint; g, knee; h, hip.

linear model of variance analysis (GLM procedure, SAS, 1988) was used to investigate the effects of exercise type, breed and exercise type × breed interactions. The *t*-test was used to compare group means and null hypothesis was rejected at the 0.05 level of significance. When comparing more than two means, the repeated *t*-test (LSD option) was used to determine which means differed from each other (SAS, 1988).

RESULTS

Spatial and temporal analysis of cycles

Means, standard deviation and coefficient of variation of the gait parameters of the locomotion on regular mud floor and stony ground are presented in table I.

Because velocity is a function of space and time (V = stride length / cycle duration), two methods may be used by animals to accelerate: increase stride length or decrease of cycle duration. We plotted speed as a function of cycle duration to show speeds used by lambs during experimentation and to determine the strategy used to accelerate (fig 2). On the regular mud floor, from 0.5 to 1 m/s, the cycle duration decreased as speed increased. From 1 to 2.5 m/s, the cycle duration did not decrease much. Because the speed is a function of stride length and cycle duration, it means that the acceleration was mainly due to an increase of the stride length. The correlation between speed and cycle duration was high ($r = 0.81$). The BMC breed used a wider range of speed, from 0.8 to 2.5 m/s with larger stride lengths for the fastest speeds, whereas the Berrichon breed walked slower, from 0.5 to 1.35 m/s. Concerning walking on the stony ground, both breeds adapted their locomotive behaviour in the same way: they walked slowly (from 0.5 to 1.2 m/s), and the correlation between cycle duration and speed was at its lowest ($r = 0.61$). Cycle durations were very variable but not speed, that means the stride length also fluctuated probably because of the presence of obstacles on the floor.

All symmetrical gaits can be represented by two parameters expressed as a percentage of cycle duration and plotted on a graph according to Hildebrand (1965) (fig 3). The duration of stance phase is shown on the abscissa, this variable is associated with speed. The time lag of the fore footfall after the homolateral hind footfall is shown on the ordinate; it describes a gradual succession of gaits. If the homolateral fore and hind limbs swing together (0% and 100%) the gait is named pace. At 50%, the diagonal opposite limbs swing together and the gait is a trot. In gaits represented between pace and trot on the upper part of the graph, the hind footfall is followed by the fore footfall on the same side and is named lateral sequence. On the lower part of the graph, the hind footfall is followed by the opposite side fore footfall and the sequence is diagonal. On the regular mud floor, the stance durations corresponded to gaits ranging from very slow to fast (walking and trotting). The stance duration was slightly higher for Berrichon breed. The BMC lambs spontaneously adopted a more extensive scale of gaits and used more lateral sequences, as seen for the lower values of time interval between the homolateral limbs and the important value of the coefficient of variation of this variable. On the stony ground, lambs used very slow to moderate walk and trot, the stance duration was slightly lower in the BMC breed but globally higher than on the regular mud floor. The lateral and diagonal sequences were equivalent for the two breeds.

A large behavioural difference appeared during the jump (table II). Berrichon lambs approached the jump slowly, the duration of the approach and the jump cycles was longest, the approach stride length was shortest and the duration of the stance phase of leading hind and forelimbs was longest. Berrichon lambs seemed to hesitate before jumping off, they put their feet near the edge

Table I. Spatial and temporal variables of limb footfalls on regular mud floor and on stony ground.

	Regular mud floor		*Stony ground*		*Breed effect*	*Ground effect*
	BMC (n =*11*)	*Berri* (n =*11*)	*BMC* (n =*8*)	*Berri* (n =*11*)	(*F-ratio value*)	(*F-ratio value*)
Speed (m/s)	1.53 ± 0.60 cv = 39.2	0.97 ± 0.26 cv = 23.7	0.79 ± 0.18 cv = 22.8	0.73 ± 0.17 cv = 23.3	7.31[a,b]	22.62[a,b]
Cycle duration (s)	0.59 ± 0.18 cv = 32.2	0.74 ± 0.17 cv = 23.0	0.88 ± 0.20 cv = 22.7	0.89 ± 0.17 cv = 19.0	0.93	15.66[a]
Stance phase duration (% cycle)	57 ± 6 cv = 10.5	63 ± 5 cv = 8.0	64 ± 7 cv = 10.9	67 ± 5 cv = 7.5	4.90[a]	9.84[a]
Time lag between homolateral footfall (% cycle)	32 ± 13 cv = 30.9	50 ± 6 cv = 12.0	49 ± 7 cv = 14.3	48 ± 7 cv = 14.6	1.16	1.23
Stride length (m)	0.82 ± 0.09 cv = 11.0	0.68 ± 0.06 cv = 8.8	0.67 ± 0.10 cv = 14.9	0.63 ± 0.07 cv = 11.1	11.13[a]	15.38[a]

Values are means ± SD. F-ratio values refer to significant main effects identified by 2-way (breed × ground) analysis of variance. [a] Effects are significant, $P < 0.05$. [b] Significant interaction between two effects. Degrees of freedom, 37. cv, coefficient of variation.

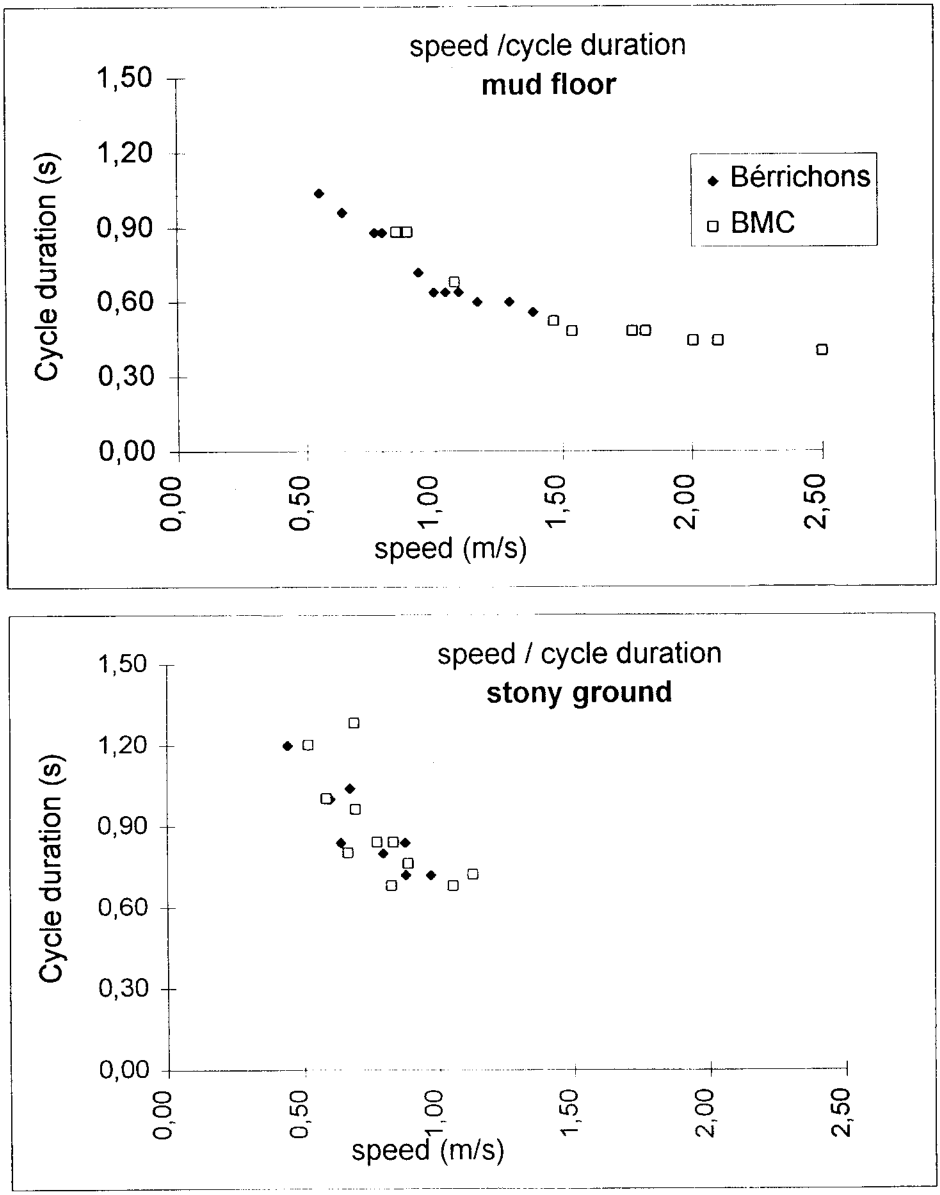
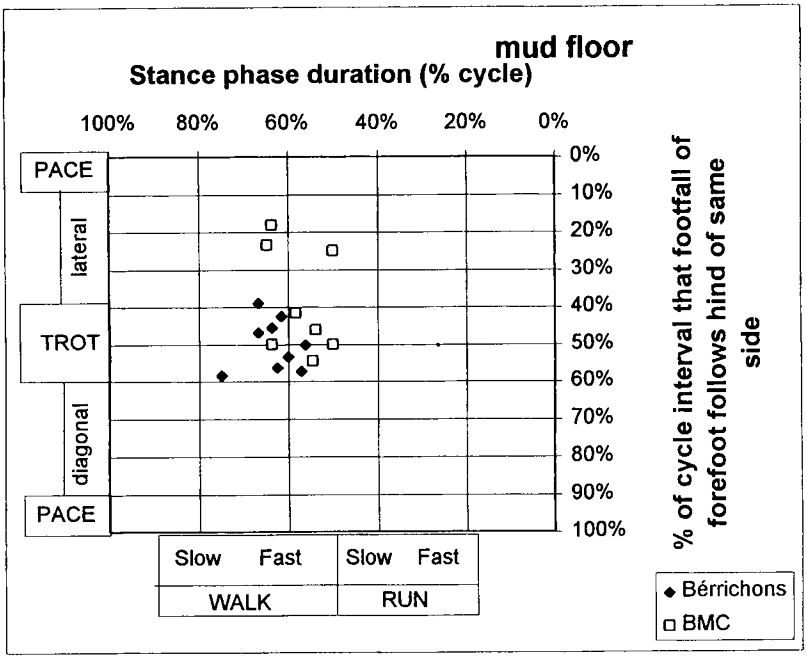


Fig 2. Gait graphs, speed as a function of cycle duration on regular mud floor and on stony ground.



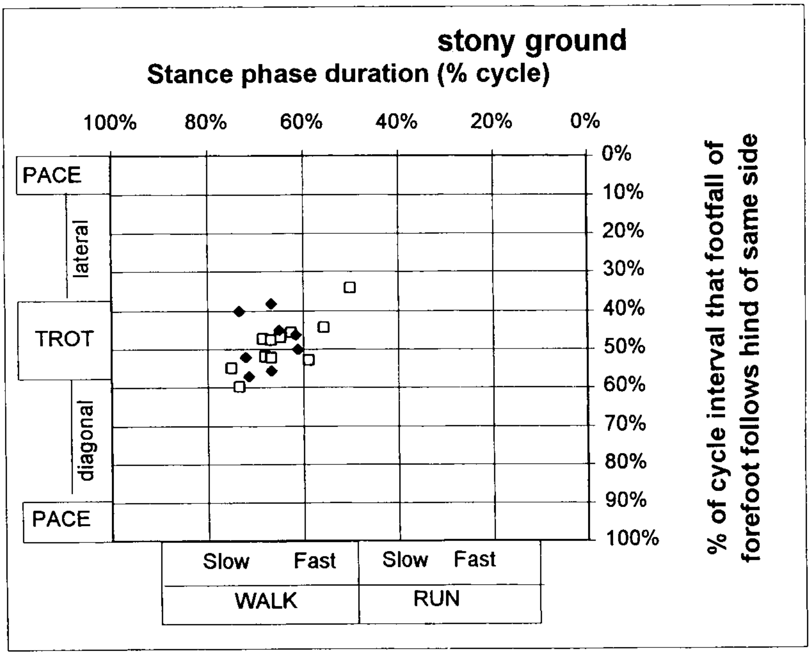


Fig 3. Gait graphs, duration of the stance phase as a function of the time lag of the fore footfall after the homolateral hind footfall, on regular mud floor and on stony ground.

Table II. Spatial and temporal variables of limb footfalls during jumping.

	BMC (n = *7)*	*Berri* (n = *5)*	*Breed effect (F-ratio value)*
Temporal variable(s)			
Duration of approach cycle	0.46 ± 0.15	0.82 ± 0.06	23.33[a]
Duration of jump cycle	0.70 ± 0.10	0.86 ± 0.15	5.35[a]
Duration of the last stance phase of each foot before jump			
Trailing forelimb	0.26 ± 0.14	0.63 ± 0.15	19.71[a]
Leading forelimb	0.25 ± 0.12	0.36 ± 0.15	1.32
Trailing hindlimb	0.28 ± 0.12	0.55 ± 0.16	11.15[a]
Leading hindlimb	0.25 ± 0.10	0.33 ± 0.14	1.32
Spatial variables (m)			
Distance of forelimbs before takeoff	0.47 ± 0.19	0.05 ± 0.06	20.27[a]
Distance of hindlimbs before takeoff	0.24 ± 0.12	0.09 ± 0.09	5.68[a]
Stride length of reference hindlimb for the approach cycle	0.88 ± 0.20	0.56 ± 0.09	10.31[a]
Distance of each foots from the edge			
Trailing forelimb	0.74 ± 0.33	0.04 ± 0.07	20.33[a]
Leading forelimb	0.28 ± 0.25	0.02 ± 0.03	5.16[a]
Trailing hindlimb	0.65 ± 0.22	0.11 ± 0.13	22.73[a]
Leading hindlimb	0.45 ± 0.42	0.08 ± 0.07	3.73

Values are means ± SD. F-ratio values refer to significant main effect identified by analysis of variance. [a] Breed effect is significant, $P < 0.05$. Degrees of freedom, 9.

of the board as is seen on the measurements of the distances of feet from the edge of the board. They prepared for the jump with small adjusted strides in order to put both forefeet and both hindfeet on the same front lines, respectively. The distance between forelimbs and hindlimbs was very short and the stance duration of the leading limbs was shorter than that of the trailing limbs which confirms the adjustment of position in preparation for the jump.

Amplitude of angular variations

At steady speed, on a regular mud floor and on stony ground, amplitudes of angular variation were measured for each cycle of each analysed sequence. For the jump sequences we measured the angular variations of the trailing forelimb and hindlimb of the right side, during the approach cycle and the jump cycle.

Means, standard deviations and coefficients of variation are presented in table III. Measurements of the amplitude of angular variation did not show difference between both breeds and the breed × exercice interactions were found to be not significant in all cases, and thus were not shown in the table III. Differences were only observed between the different kinds of exercises. Amplitudes of angular variation were progressively higher toward the distal extremity of limbs. Conversely, coefficients of variation were the highest on proximal joints and on irregular grounds. The ground effect was more important on the hindlimb and especially on distal joints of this limb. Amplitudes of angular variation of hindlimb were significantly the highest on stony ground and during jumping. On irregular floors, both breeds adapted their movements in the same way. They increased the amplitude of flexion-extension of joints, especially distal joints of hind limbs.

DISCUSSION

For production animals, the majority of kinematic studies are carried out to detect locomotive disorders, eg, lameness. These disorders are strongly related to rearing conditions such as nutrition, quality of litter and floor or lack of exercise (Herling and Drevemo, 1996), or to modifications of body conformation principally resulting from selective breeding for meat production (Abourachid, 1993; Abourachid and Renous, 1993). Kinematic analysis is also used as a criterion to assess and improve athletic performances of horses by selection (Barrey et al, 1993). These studies thus enable breeders to modify and adjust the rearing techniques and the orientations of selection. In the present study, we suggest the use of kinematics on healthy production animals, as an indicator for testing and selecting genotypes for their locomotive abilities as regards environmental conditions of farming lands. In this study, the number of animals and the number of analysed sequences was low. Consequently we cannot draw up a final conclusion, but a method has been tested and presented.

Kinematics is used to quantify behavioural observations in relation to locomotion. This analysis provides spatial and temporal data that enables comparisons of animals faced with different kind of locomotive exercises. The selected experimental design implies that the lambs move freely. This is strongly required in order to observe the locomotive strategy and consequently the reaction toward some physical features of the ground, despite the problem of obtaining sequences with regular gait (eg, lambs may have stopped and turned around).

Limb postures measured by the angular variations were similar for the two breeds. According to exercise type, differences were observed for displacements of distal segments of hind limbs on the stony ground and during jumping. These data are of great

Table III. Amplitudes of angular variations of articular segments.

	Regular mud floor (n = *6)*	*Stony ground* (n = *9)*	*Approach* (n = *10)*	*Jump* (n = *8)*	*Ground effect (F-ratio value)*
Total forelimb	184.63 ± 19.57^{ac}	197.40 ± 31.26^{a}	109.24 ± 29.38^{b}	146.79 ± 51.02^{c}	11.05^{d}
	cv = 11	cv = 16	cv = 27	cv = 35	
Metacarpo-phalangeal	84.69 ± 10.34^{a}	103.42 ± 25.48^{a}	66.15 ± 25.12^{a}	80.58 ± 33.21^{a}	3.46^{d}
	cv = 12	cv = 25	cv = 38	cv = 41	
Carpal joint	75.54 ± 10.48^{a}	76.59 ± 6.93^{a}	78.77 ± 9.43^{a}	99.38 ± 19.40^{b}	6.86^{d}
	cv = 14	cv = 9	cv = 12	cv = 20	
Elbow	51.20 ± 6.24^{a}	54.83 ± 9.42^{a}	62.59 ± 13.64^{a}	63.49 ± 15.80^{a}	1.80
	cv = 12	cv = 17	cv = 22	cv = 25	
Shoulder	21.25 ± 4.44^{a}	27.97 ± 10.10^{a}	32.13 ± 8.50^{a}	35.79 ± 10.46^{a}	3.52^{d}
	cv = 21	cv = 36	cv = 26	cv = 29	
Total hind limb	129.23 ± 11.92^{a}	234.19 ± 31.26^{b}	87.20 ± 27.87^{a}	126.97 ± 49.21^{a}	19.28^{d}
	cv = 9	cv = 21	cv = 32	cv = 39	
Metatarso-phalangeal	59.24 ± 7.55^{a}	97.96 ± 20.99^{b}	65.54 ± 20.82^{a}	94.05 ± 24.57^{b}	7.21^{d}
	cv = 13	cv = 21	cv = 32	cv = 26	
Tarsal joint	47.40 ± 5.21^{a}	74.60 ± 23.56^{b}	57.70 ± 15.51^{ab}	93.73 ± 19.90^{c}	8.96^{d}
	cv = 11	cv = 32	cv = 27	cv = 21	
Knee	36.49 ± 6.52^{a}	55.75 ± 21.54^{a}	40.00 ± 11.09^{a}	83.64 ± 23.65^{b}	10.24^{d}
	cv = 18	cv = 39	cv = 28	cv = 28	
Hip	28.51 ± 6.45^{a}	35.31 ± 12.87^{a}	30.75 ± 10.02^{a}	38.62 ± 11.40^{a}	1.27
	cv = 23	cv = 36	cv = 35	cv = 30	

Values are means ± SD. F-ratio values refer to significant main effects identified by 2-way (breed × ground) analysis of variance and a *t*-test, means with the same letter (a,b,c) are not different at the 0.05 level. ^{d} Ground effect is significant, $P < 0.05$. Degrees of freedom, 25. cv, coefficients of variation.

importance because the hind limb is the main target for meat improvement. The relative development of body parts indeed is modified: the relationships between the back and limb lengths, the proximal and distal lengths of limb joints and the proportional development of hind and fore quarters are often altered in domestic mammals (Hammond, 1932; Marlowe, 1964; Gilbert et al, 1993). The proportions between muscle mass and supporting bone framework may also be modified (Truscott et al, 1976). These modifications in morphological equilibrium could bring about inabilities to perform some postural or locomotive movements.

The study of the gait (spatial and temporal data of footfalls) shows differences between both breeds according to the type of exercises. The BMC breed used the greatest scale of speeds and lateral sequences on the regular mud floor. In order to place their feet safely among obstacles on the stony ground, the lambs modified their gait by reducing the stride length and increasing the cycle duration. Jumping ability shows the main behavioural difference. Berrichons considerably decreased their speed during the approach phase, probably in order to adjust the position of their feet before jumping. Conversely, BMC showed the largest manoeuverability as regards obstacles. In the approach cycle, the preparation for the jump did not need particular modification of gait for stride amplitude and cycle duration, in comparison with displacement on the regular floor.

Based on these results, we cannot predict that Berrichons are not able to adopt such gaits. However, according to the experimental conditions, they adopted different strategies that translate a difference in the reactivity to environmental conditions. Thus, we suggest that Berrichons present a more restricted adaptability facing the conditions of extensive farming.

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