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Standardised terminology for the description and analysis of equine locomotion

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Summary

Terminology for the analysis of equine locomotion is reviewed and the most appropriate terms selected for use by research workers in this field. Each cycle of limb movement comprises a stance phase, when the hoof is in contact with the ground, alternating with a swing phase. The stance phase is subdivided at the mid-stance position into an initial decelerative phase followed by a propulsive phase. When the stance phases of different limbs occur concurrently, the term overlap refers to the duration of simultaneous ground contact. Single support is the term used to describe the phase when the limb is in its stance phase unaided by any other limb. A gait consists of a limb coordination pattern repeated at each stride. The start and finish of the stride must be designated as a prerequisite to the determination of stride length, stride duration and stride frequency. In asymmetrical gaits, such as the gallop, the stride as a whole will have a stride stance phase, when one or more limbs are in contact with the ground, and a suspension phase. In symmetrical gaits, such as the trot and pace, the stride consists of left and right stance phases and suspension phases. Advanced placement and advanced lift off measure the time between ground placement and lift off respectively of consecutive limbs. The line of motion indicates the progressive movement of the centre of gravity in the X-Y plane. Measurements in the Y-Z plane, such as line gait and overcrossing, describe the ground placement of the hooves relative to the line of motion. Diagonal width is the distance between diagonal limb pairs in this plane.

Introduction

STANDARDISATION of nomenclature for the phases of equine locomotion has been recommended by Leach and Crawford (1983). This suggestion resulted from a survey of published reports of equine locomotion and biomechanics (Leach and Dagg 1983) which showed confusion and lack of consistency in the use of current terminology. Certain workers have recognised this problem and have defined terms required for their specific research programmes. For example, the important studies of Fredricson *et al* (1972), Dalin *et al* (1973) and Drevemo, Dalin, Fredricson and Hjertén (1980a) provided innovative and accurate methods of describing and measuring the gait of Trotters. However, some of their terms cannot be applied or adapted to other gaits. It is important that the terminology used to describe equine locomotion be applicable to different gaits so as to prevent the use of redundant terms and to facilitate comparison of different gait types.

The purpose of this paper is to propose a basic terminology for use in the description and analysis of equine locomotion with particular reference to the racing gaits of Standardbreds and Thoroughbreds.

General terminology

It is recommended that individual limbs be called the right or left frontlimbs and the right or left hindlimbs. The terms limb or leg, hind or rear, and front or fore can be used interchangeably. The terms near and off for the left and right legs respectively (Jordan 1910; Adams 1974) should not be used.

Limb pairs are defined as follows: diagonal limb pair — a frontlimb of one side and the hindlimb of the opposite side; ipsilateral limb pair — a frontlimb and hindlimb of the same side; contralateral limb pair — a front or hindlimb of one side and the front or hindlimb of the opposite side, respectively. The diagonal and ipsilateral limb pairs are named left or right in accordance with the hindleg of the pair. In the past, diagonally opposite limbs have been inappropriately called correlated feet (Jordan 1910).

The terms lead leg and non-lead leg are acceptable in descriptions of asymmetrical gaits. Asymmetrical gaits are those gaits in which the limb coordination pattern of one side does not exactly repeat that of the other side (eg, canter, gallop). Symmetrical gaits are those in which the limb coordination pattern of one side repeats that of the other side, half a stride later (eg, trot, pace). A lead leg is the last leg of a contralateral limb pair to leave the ground and must be specified for both the frontlimb pair and the hindlimb pair. A non-lead leg is the first leg of a contralateral limb pair to leave the ground. The correct use of these terms is illustrated in a description of rotary and transverse gallops in the caption to Fig 1. These terms have not always been defined and used accurately. For example, Adams (1974) erroneously referred to the right hindlimb as being the lead leg of a horse using a left lead transverse gallop. The non-lead leg has been called the trailing leg (Hildebrand 1959, 1977) or lagging foot (Howell 1965).

Phases of the limb cycle

Each complete limb cycle includes a phase when the limb is in contact with the ground and a phase when the limb is not in contact with the ground.

The phase of limb ground contact of the horse has been called the weightbearing phase (Ottaway 1954), limb contact

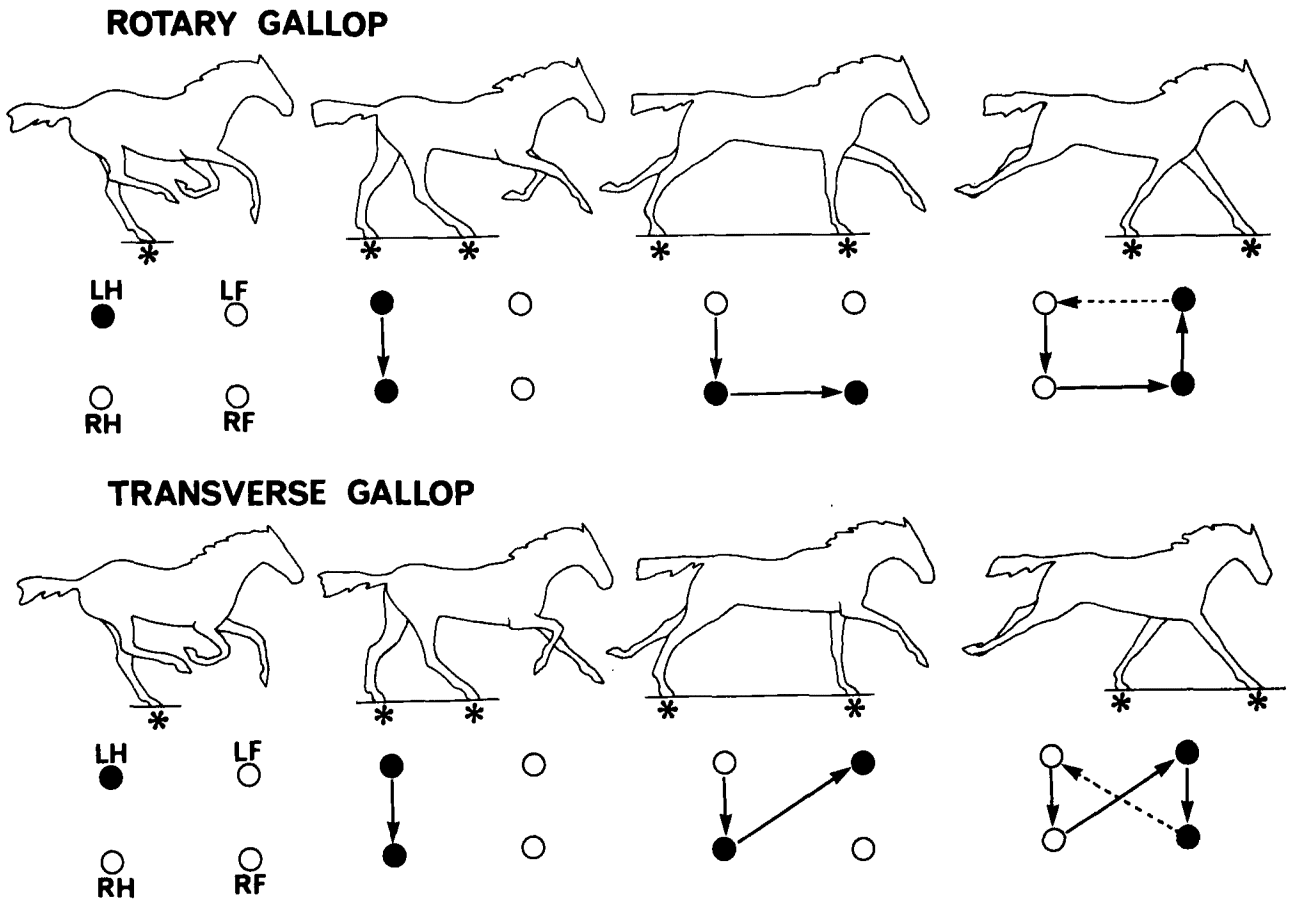

Fig 1. Diagramatic representation of the counterclockwise rotary gallop and right lead transverse gallop. In the rotary gallop the limbs are placed down in one of the following orders: left hind (LH), right hind (RH), right fore (RF), left fore (LF) (counterclockwise rotary gallop); RH, LH, LF, RF (clockwise rotary gallop). The term rotary is derived from the circular order in which the limbs are placed on the ground. In the counterclockwise rotary gallop illustrated the right hindlimb and left forelimb are the lead legs. In the transverse gallop the placement of limbs, and therefore the support pattern of the limbs, is transferred from the lead hindlimb diagonally to the forelimb of the opposite side, thereby transversing the body axis. As in the rotary gallops two forms of this gallop also exist, depending on the order of limb placement: LH, RH, LF, RF (right lead transverse gallop); or RH, LH, RF, LF (left lead transverse gallop). In the right lead transverse gallop illustrated the right forelimb and right hindlimb are the lead legs. The less precise terms right lead and left lead gallops are also acceptable for the right and left transverse gallops, repectively

interval (Hildebrand 1962), contact period (Prost 1970), support phase (Björk 1958; Fredricson *et al* 1972; Barnes and Pinder 1974; Sukhanov 1974; Geary 1975; Bartel, Schryver, Lowe and Parker 1978; Rooney, Quddus and Kingsbury 1978; Ray 1979) and stance phase (Dalin *et al* 1973; Drevemo *et al* 1980a; Jeffcott *et al* 1982). There is no reason to disqualify any of these terms, but the term stance phase is recommended as it suggests both limb position relative to the ground and limb function. It is also used routinely by human gait researchers such as Statham and Murray (1971), Burnett and Johnson (1971) and Sutherland, Olshen, Cooper and Woo (1980). In comparison, terms such as support and weightbearing imply only biomechanical responsibilities of the limb whereas the terms limb contact interval and contact phase are timing-related terms.

Drevemo *et al* (1980a) described the mid-stance position as the point when the metacarpus is in a vertical position in the forelimb or when the hoof is vertically beneath the hip joint in the hindlimb. This term is useful in gait analysis as long as it is clear that it is descriptive of limb position rather than limb timing (ie the mid-stance position is not necessarily the temporal mid-point of the stance phase). The mid-stance position, as defined by Drevemo *et al* (1980a), has been called the close packed position by Ratzlaff (1974) and Rooney (1977). This latter term suggests that a unique anatomical congruency of the carpal bones exists only when the metacarpus is in a vertical position, but this theory has not been investigated biomechanically. This term is not encouraged for this reason and because it is not applicable to analysis of the hindlimbs.

The division of the stance phase into deceleration and propulsion phases has been used in gait analysis (Björck 1958; Drevemo *et al* 1980a). Drevemo *et al* (1980a) defined the deceleration phase as the heel contact to mid-stance position and the propulsion phase as the mid-stance position to toe off. This division is justified since it has been shown experimentally that the horizontal forces between the hoof and ground change at mid-stance from a decelerative force in the first part of the stance phase to a propulsive force in the last part of the stance phase (Pratt and O'Connor 1976). It must be emphasised, however, that much still has to be learned about the horizontal forces and the exact manner in which they can be used in such analysis of limb action.

The term swing phase has been used by many authors to describe the phase when the limb is not in contact with the ground (Björck 1958; Fredricson *et al* 1972; Barnes and Pinder 1974; Pratt and O'Connor 1978; Drevemo *et al* 1980a; Jeffcott *et al* 1982). It is the preferred term for equine locomotion research because it implies both functional and timing elements. Other terms used previously for this phase are the non-weight-bearing phase (Ottaway 1954), restoration phase (Sukhanov 1974) and non-contact period (Prost 1970).

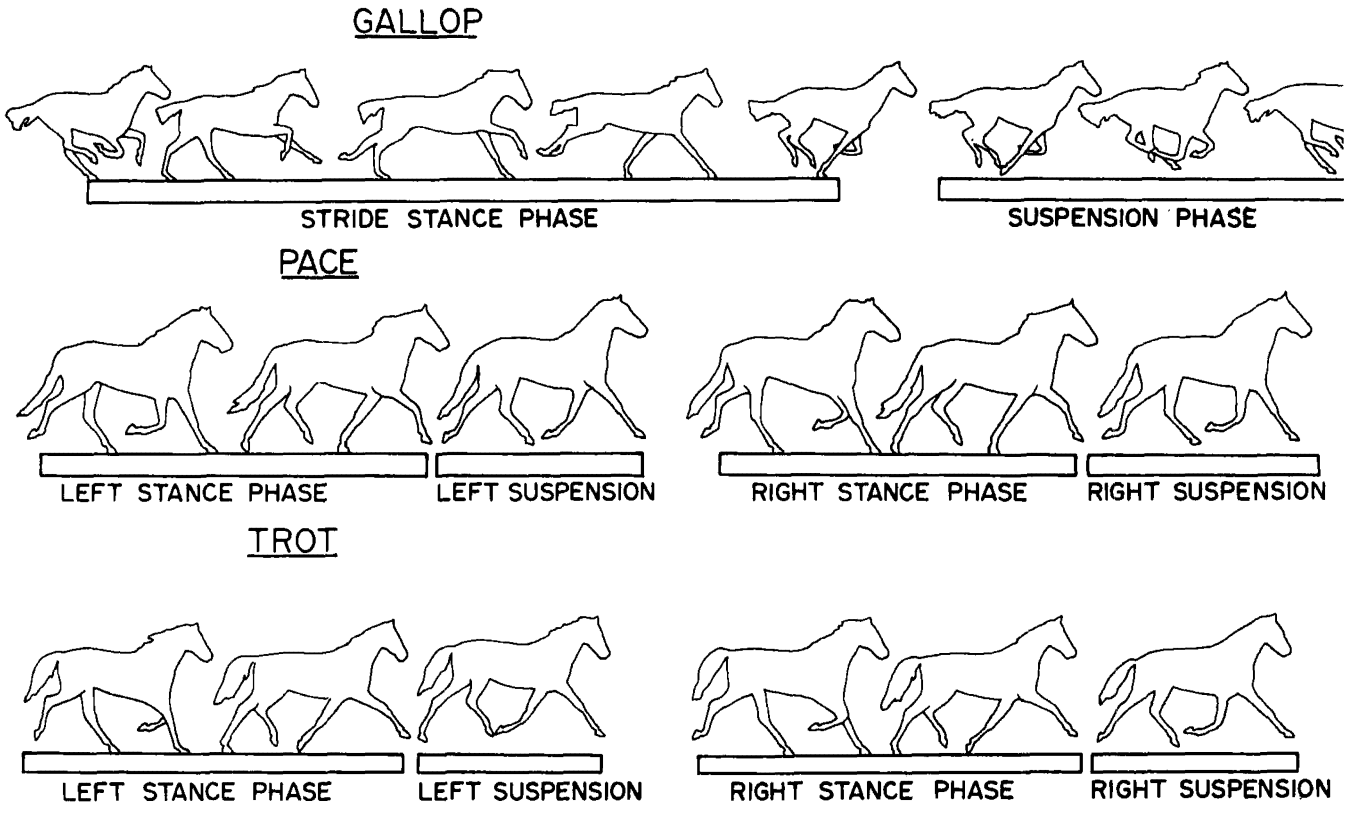

Fig 2. Diagrammatic representation of phases of the stride of the gallop, pace and trot

Phases of the stride

The stride is defined as a full cycle of motion (Hildebrand 1962) or as the repeated limb coordination and placement pattern exhibited by the horse in locomotion (Leach 1983). Since the pattern is repeated, the beginning of the stride can be at any point of that pattern and the end of that stride at exactly the same instant of the next pattern. For example, the gallop stride is considered to begin when the non-lead hindlimb is placed on the ground. In the trot and pace the stride begins at ground placement of the first limb of the left diagonal or left ipsilateral limb pair.

The stride of the gallop is divided into two distinct phases, the stride stance phase and the suspension phase (Fig 2). The stride stance phase begins with placement of the non-lead hindleg on the ground and ends at lift-off of the lead foreleg. The suspension phase is the phase from lift off of the lead foreleg to ground contact of the non-lead hindleg, a time when no limbs are in contact with the ground. Howell (1965), inappropriately, also used the term suspension phase to describe the phase of a high speed gallop between lift off of the lead hindleg and placement of the non-lead foreleg when no limb is in contact with the ground.

The limb coordination pattern used in symmetrical gaits such as the trot and pace requires additional descriptive terms, since it is not possible to divide the individual stride into a single stride stance phase and a single suspension phase, as was possible in the gallop.

In the pace (Fig 2) there is alternative movement of ipsilateral limb pairs. Therefore there are two phases of each stride in which no limb is in contact with the ground. The term left suspension phase is suggested to identify the phase following lift off of the left limbs, and the term right suspension phase to signify the phase following lift off of the right limbs. Both the left and right suspension phases would begin immediately following the stance phase of the last limb of the ipsilateral limb pair to leave the ground. There is no stride stance phase similar to that defined for the gallop. The terms left stance phase and right stance phase are therefore suggested to signify the phase beginning with initial ground contact of a limb on the left or right side respectively, and ending with lift off of the final leg of the ipsilateral pair to leave the ground.

In the trot there is alternative movement of diagonal limb pairs (Fig 2). For ease of establishing the required terms the diagonal limb pair is named according to the hindlimb of the pair. For example, the left forelimb-right hindlimb diagonal pair should be called the right diagonal pair. The right suspension phase is defined as that phase following lift off of limbs of the right diagonal pair, and left suspension phase as that phase following lift off of limbs of the left diagonal pair. These definitions are the same as those given by Drevemo, Fredricson, Dalin and Björne (1980b). The term left stance phase signifies the phase during which one or both of the limbs of the left diagonal pair are on the ground and the right stance phase occurs when one or both of the limbs of the right diagonal pair are on the ground.

Gait

A gait can be simply defined as a limb coordination pattern used in locomotion. A more explicit definition was given by Uspenskii (1953): Gait is a complex, strictly coordinated rhythmic movement of the entire body of the animal treated as an integrated complex of reflex acts that occur in accordance with the conditions of the environment and which are capable of producing progressive movements of different types inherent in each animal species.

The investigations of Hildebrand (1965, 1976, 1977, 1980) and others (Grogan 1951; Sukhanov 1974) indicated

that horses have the ability to perform many gaits and that the whole system may be viewed as continuous transitions of limb coordination patterns: 'The various named gaits of horses are not distinct and independent but instead form a continuum within which boundaries are somewhat arbitrary and often based on factors of breed and style rather than on differences in the general manner of moving the legs (Hildebrand 1965). Man has classified the most identifiable of these limb movement patterns into gaits such as the walk, trot, canter and gallop. This oversimplification is clearly shown by the fact that there have been over 167 symmetrical gaits defined for the horse (Hildebrand 1965).

It is difficult for a researcher to describe all equine gaits precisely because a universally acceptable classification system is not available (Sukhanov 1974), the descriptive terms used are ambiguous (Dagg 1973) and the numerous graphic methods of representation do not completely document the gait (Sukhanov 1974; Leach and Dagg 1983). However, the gaits (gallop, trot, pace) of racing horses considered in the present paper are readily identifiable and understood. However, research papers should, whenever possible, include data of velocity, limb timing and distance measurements and stride measurements so that the reader can identify precisely the characteristics of the gait being studied.

Terminology for temporal measurements

The various phases of the limb cycle and stride require special terms to document temporal measurements. Stride duration is the time required to complete one stride. It has previously been referred to as the stride interval (Hildebrand 1962) and total time of support (Schryver, Bartel, Langrana and Lowe 1978). Stride frequency is the number of strides per unit time. In addition, there are a number of specific time-related phases of the limb and stride which require further description.

Overlap is defined here (Fig 3) as the time when part or all of the stance phase of a limb occurs concurrently with all or part of the stance phase of a second limb. This is in agreement with the definition of overlap given by Pratt and O'Connor (1978). The term bipedal support used by Dalin *et al* (1973) and later by Drevemo *et al* (1980b), although not incorrect, should be discouraged because it is not as universally applicable to locomotion research as the term overlap and it may be confused with the term bipedal gait commonly used to describe the locomotion of the human. Similarly, the term double-support (Alexander 1978) should not be used. The term single support is recommended to describe the phase when the limb is in its stance phase unaided by other limbs.

Advanced placement (Fig 3) is a measurement of the time between the placement of one limb on the ground and the subsequent placement of a second limb. A similar measurement, used by Drevemo *et al* (1980b) to describe the gait of trotters, was called the duration of diagonal dissociation. Earlier this research group had called it landing disassociation (Dalin *et al* 1973). The term advanced placement is recommended since it can be applied to any limb combination at any gait and is not restricted to the diagonal limb pairs.

Drevemo *et al* (1980b) also documented the duration of diagonal dissociation at take off which is a measurement of differences in the time of lift off of the diagonal limb pairs of the trot. Although this measurement has not been used previously, in order to maintain consistency it is suggested that the term advanced lift off be adopted so that it can be applied to other gaits and limb pair combinations.

Adams (1974) used the term impure trot to describe a trot

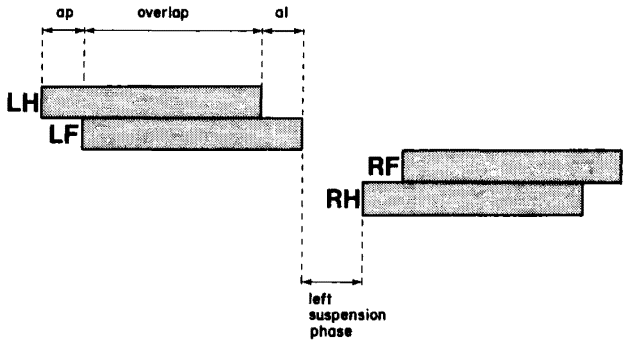

Fig 3. Diagrammatic representation of overlap, advanced placement (ap) and advanced liftoff (al) of the left limbs during the stride. Horizontal bars represent the stance phase duration of the left hindlimb (LH), left forelimb (LF), right hindlimb (RH) and right forelimb (RF)

where the horse exhibits advanced placement or advanced lift off. This term should be discarded because a Trotter is unlikely to have exactly similar action of the hind- and forelimbs and because the term implies the existence of an idealised pure gait, which does not, in reality, exist. Less precise terms such as hasty hindlimb or hurried foreleg (Podhajsky 1967; Ljungquist 1976), although descriptive, should be discouraged in scientific analysis of locomotion.

There is confusion regarding the precise definition of the word step. In human locomotion the duration and distance of a step are the time or distance, respectively, between successive foot placements on the ground (Scrutton 1969; Burnett and Johnson 1971; Chao, Laughman and Stauffer 1980). Drevemo *et al* (1980b), following the example of Jordan (1910) and Lamoreux (1971), defined the right step as the time interval between the left hoof contact and the subsequent contralateral hoof contact, and the left step as the time interval between the right hoof contact and the subsequent contralateral hoof contact. They termed the step occurring between the forelimbs the forestep and that between the hindlimbs the hindstep. The left and right foresteps and hindsteps would be documented in routine gait analysis as advanced placement measurements between contralateral limbs. It is therefore recommended that the terms step, forestep and hindstep should not be used in locomotion analysis.

Drevemo *et al* (1980b) described the measurement overreach duration of the trot as the time interval from the event when one forehoof leaves the ground to the event when the ipsilateral hind hoof touches it. If the hindlimbs land before or with the forelimbs then the overreach duration would be the same as one of the suspension phases of the trot. In the clinical context overreach implies abnormal hindlimb placement and for these reasons it is preferred not to use the term overreach as a specifically named variable in routine analysis.

Another word that is extremely difficult to define relative to gait analysis is cadence. The musical definition implies a rhythmic sequence or the measure of a phrase but this is not easily applied to gait analysis. In dressage terminology it describes a gait combining rhythm with impulsion or lively animation (Podhajsky 1967; Ljungquist 1976) but it is based on qualitative judgement rather than a quantitative measurement. In human locomotion research cadence refers to the number of foot strikes per minute (Chao *et al* 1980), a measurement which is often referred to as tempo in dressage (British Horse Society 1982). This is confusing because tempo can also be used to indicate the velocity of gait (Ljungquist 1976). Because of these ambiguities it is recommended that the term cadence should not be used in equine gait analysis

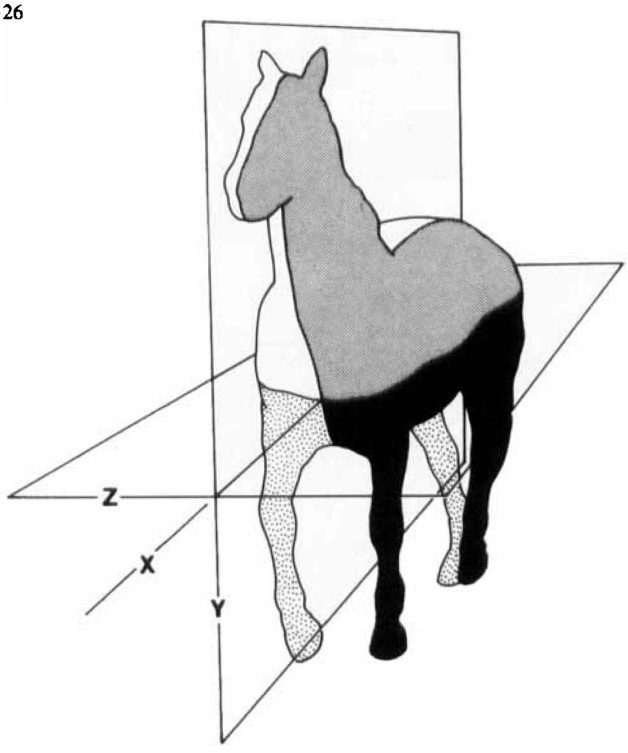

Fig 4. Illustration showing the X, Y, and Z axes used to identify the plane of limb movement

Terminology for distance measurements

Distance measurements relating to the stride are made in three planes (Fig 4). The line of motion is defined as the pathway of the centre of gravity in the X-Y plane. Other measurements in this plane are the stride length, which is horizontal distance in the plane of progression covered during one stride, and the distance between consecutive limb placements.

In the Y-Z plane the adduction and abduction of the limbs can be determined from their placement relative to the line of motion. For the trot Dalin *et al* (1973) used the terms line-gait and overcrossing (Fig 5), which can also be applied to other gaits. In line-gait the limbs are placed on or close to the line of motion, whereas in overcrossing they contact the ground on the contralateral side of the line of motion (ie, they cross the line of motion) and are thus assigned a negative value. A similar method of analysis was used by Jordan (1910) though he did not assign specific names to the variables measured. The line gait should not be confused with the line trot and line pace (Jordan 1910), which refer to gait specific methods of limb placement. In this case the ipsilateral limbs are placed equidistant from the median line, which is midway between the sulky wheels, but not necessarily on or close to the median line. The use of the latter terms is not recommended.

Another measurement, which may have some application in the analysis of trotting horses, is the diagonal width (Dalin *et al* 1973). It refers to the distance in the Y-Z plane between the two limbs of a diagonal pair (Fig 5).

Useful information can also be conveyed for some equestrian events by describing the number of tracks on which the horse is moving. A track is defined as the linear placement of a limb in the X-Y plane. Each limb makes its own track but one or more of these may be superimposed giving rise to the terms one track, two track, three track and four track (Fig 6). Most equitation texts describe the horse as being straight when the hindfeet follow in the tracks of the ipsilateral forefeet, the body being curved in accordance with the line of motion. It is obvious that under these conditions the horse would be moving on two tracks (Fig 6), a fact that is recognised by Crossley (1978) but which most authors incorrectly refer to as being on a single track (Seunig 1956; Müseler 1965; Ljungquist 1976; British Horse Society 1982). Furthermore, lateral movements in which the horse progresses forward and laterally are often referred to under the blanket term of two track movements (Seunig 1956; Müseler 1965; British Horse Society 1982) when in fact they are performed on three or four

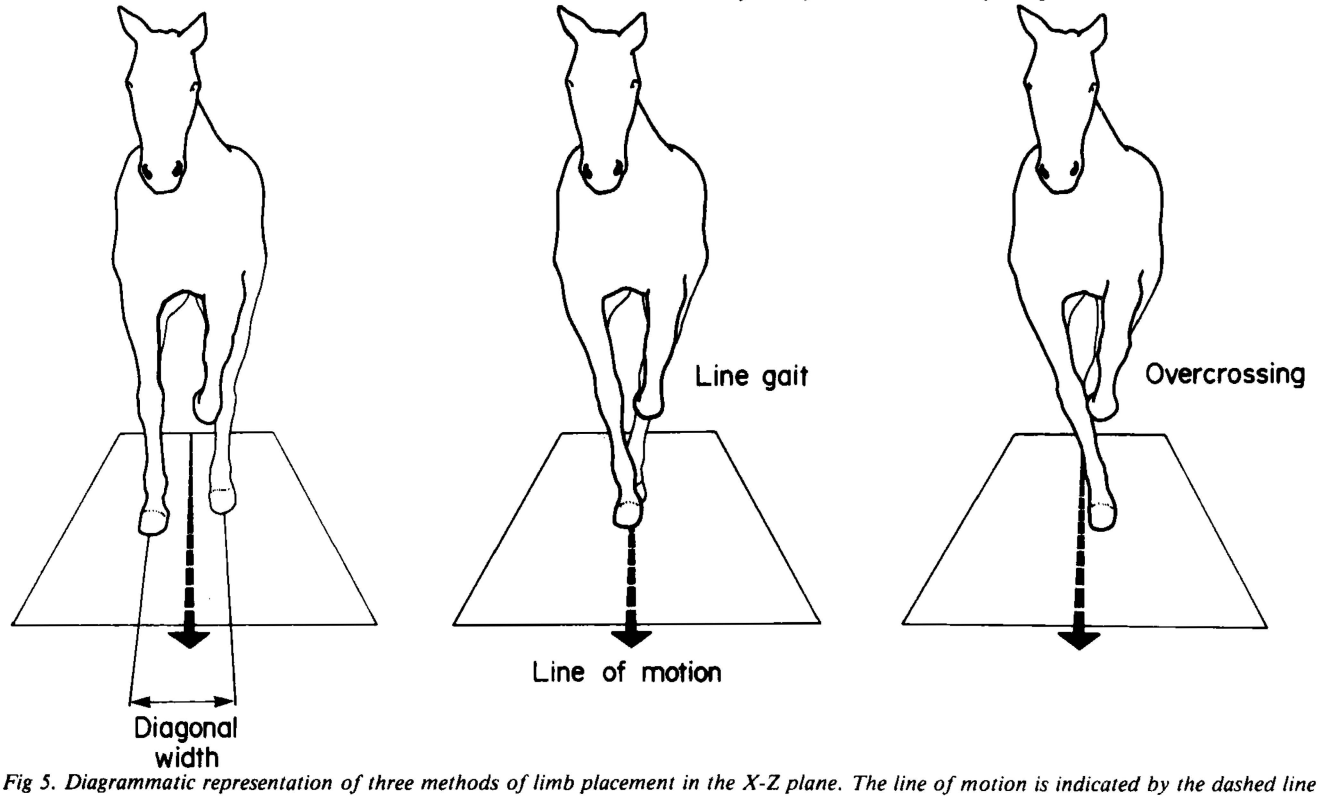

Fig 5. Diagrammatic representation of three methods of limb placement in the X-Z plane. The line of motion is indicated by the dashed line

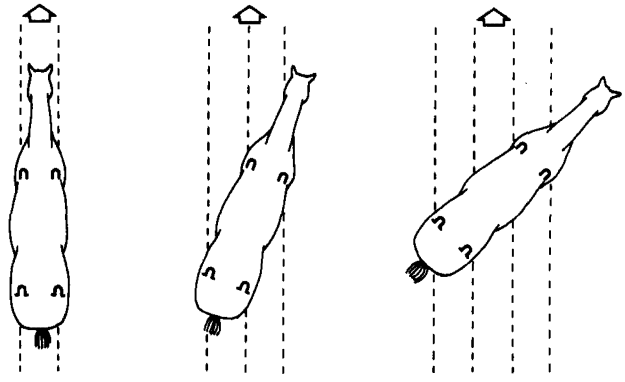

Fig 6. Diagrammatic representation of a horse moving on two tracks, three tracks and four tracks showing the linear placement of a limb on the ground in the X-Y plane (dashed line). Arrows indicate the direction of motion of the horse

tracks.

Step length has been defined as the distance between two consecutive hoof prints of one leg (Goubaux and Barrier 1904; Björck 1958). These authors are therefore equating stride with step. Sukhanov (1974) calls the same measurement a double step. Jordan (1910), Grogan (1951), Hayes (1969), Lamoreux (1971), Adams (1974), Butler (1974), Sukhanov (1974), Ray (1979) and Drevemo *et al* (1980b) define a step as the distance between successive imprints of the two forefeet or the two hindfeet, which is similar to the definition used for humans. Grogan (1951) states that step length is usually equal to one-half of the stride. Contrastingly, Alexander (1978) defines step length as the distance travelled by the centre of mass between the instant when a foot is set on the ground and the instant when the same foot is lifted. Goslow, Reinking and Stuart (1973) and Grillner (1975) call the stance and swing phases of an individual limb the step cycle. It is suggested that any term incorporating step be discarded because it is so poorly understood and other measurements fully document internal stride distance changes.

The term duration of overreach has been considered in the section on temporal measurements of the stride. Drevemo *et al* (1980b) have also defined the length of overreach as the distance by which the hindhoof precedes the imprint of the ipsilateral forehoof but, for the reasons stated previously, use of the word overreach is not encouraged. An alternative term to describe this distance might be overtracking (Ljungquist 1979; Marshall 1979; British Horse Society 1982), which is widely used in dressage training although this term does imply some excessive limb movement. However, in gait analysis this variable will be measured routinely without the necessity for a specific name since it is the distance between the hindlimb and forelimb involved. Jordan (1910) called the length of overreach the overstep of the trot and pace and described it as the distance by which the succeeding hindhoof preceded the forehoof. In the trot this would be the ipsilateral hindhoof, whereas in the pace it would be the contralateral hindhoof. The use of gait specific terms of this type is not recommended.

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ABSTRACT

Anaesthesia, pharmacology and therapeutics

Antagonistic effects of doxapram on xylazine in the horse

SHORT, C. E., HARVEY, R., GLEED, R. D. and MAYER, R. (1983) *Equine Pract.* **5**(5), 25-30.

THE paper describes a study designed to assess the value of using doxapram hydrochloride to antagonise the effects of xylazine. One stallion, two geldings and a mare were used. In the first phase, two horses received xylazine alone (1.1 mg/kg) and the remaining two horses received xylazine (1.1 mg/kg) followed by doxapram (0.55 mg/kg). Two weeks later the medication was reversed so that on completion of the study each animal had received both xylazine alone and the xylazine/doxapram combination. In this way each horse served as its own control. Both xylazine and doxapram were given intravenously and doxapram was not given until the full effect of xylazine had developed. The time from the administration of each drug until the development of its full effect was noted. Heart and respiratory rates were measured before and after medication. After medication arterial blood pressure was also measured (indirectly) and the electrocardiogram recorded. Recovery time from the full effect of xylazine to a fully alert state and a fully coordinated state was noted in all cases.

Heart rate fell after xylazine administration and one horse showed heart block. After doxapram administration blood pressure, heart rate and respiratory rate were higher than the corresponding values in the controls, although blood pressure remained adequate in the controls (95/62 systolic/diastolic mmHg). The heart block was not corrected by doxapram. The rate pressure product (mean heart rate × mean systolic pressure) was markedly higher after doxapram. The full effect of xylazine was achieved on average 3 mins after administration and that of doxapram on average 1 min. The increase in respiratory rate seen after doxapram lasted between 1 and 4 mins. Recovery from the full effect of xylazine to the fully alert state and the fully coordinated state was markedly shorter (by 65 and 45 per cent respectively) after doxapram compared with the control. No undesirable effects from doxapram administration were seen.

The authors conclude that doxapram could be considered a potential antagonist to the effects of xylazine in the horse, and could be used where overdose has occurred or to reduce the recovery time.

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