Relationships between Stride Length, Stride Frequency, Step Length and Velocity at the Start Dash in a Racehorse

Atsushi HIRAGA*, Akira YAMANOBE, and Katsuyoshi KUBO
Equine Research Institute, Japan Racing Association, 27-7 Tsurumaki 5-chome, Setagaya-ku, Tokyo 154, Japan

The present study was undertaken in effort to describe the relationships among each step length, stride length, stride frequency, and velocity during the start dash. Stride frequency reached its peak immediately after the start, while stride length required about 25-30 strides to reach its maximal level. Although substantial increase in velocity was attained by an increase in stride length, it appears that acceleration during the start dash is achieved by maximal increase in stride frequency. Mid step length reached a maximum level following several strides, however airborne step length required more time to reach its maximum. Therefore acceleration during the start dash is achieved by a maximal increase in mid step length since it is not possible to quickly increase airborne step length.

Key words: horse, step length, stride length, stride frequency

It has been demonstrated that horses run with the increase of stride length and stride frequency in proportion to the running velocity [1]. Yamane et al. [5] made horses run at 6 different velocities and found that both stride length and stride frequency increased linearly as the running velocity increased within the lower range; however at higher velocities the rate of increase in stride length tended to become lower, and the rate of increase in stride frequency became higher. In the same study, Yamanobe et al. [5] also showed that among the four step lengths (fore, mid, hind and airborne; Fig. 3)—which are components of stride length—airborne step length and mid step length increased at a higher rate than fore step length and hind step length as the running velocity increased. On the other hand, Kai et al. [2] observed that stride frequency almost reached its peak immediately after the start, while stride length required more time to reach its maximum level during quick acceleration at the start dash from the gate. It is important to know not only the relationship between stride length and velocity but also the relationship between each step length and velocity. Therefore, the present study was carried out to describe the relationships among step length, stride length, stride frequency and velocity during the start dash.

Three female Thoroughbreds (No.1; 5 year-old, No.2 and 3; 6 year-old) were used in this experiment. The horses were ridden by the same skilled rider. After starting from a gate, the horses were approximately run 300 m on a straight flat dirt track at full speed. Piezoelectric accelerometers (Model 501 ST, TEAC Corporation, Japan) were attached to the cannons of all 4 limbs to determine the acceleration curve (Fig. 1). Stride duration was obtained from measuring the time from one hoof impact to the next hoof impact to the next hoof impact for the same limb from tracings of the acceleration curve using a slide caliper. Stride frequency was determined by taking the reciprocal of stride duration. The stride length and step length values were obtained by measuring intervals between the hoof prints [5], and the velocity was calculated from stride length and stride frequency for each stride. Since acceleration curves were obtained completely only for one horse (No. 1), stride frequency was calculated for this horse alone.

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* corresponding author.
During an actual race, racing Thoroughbreds will cover first 200 m in 12-13 s on average. In the present experiment, the time required for running through the first 200 m was 13.8 s (No. 1). As such, we consider the protocol described for the present study reproduced the characteristic pattern of quick acceleration running which is observed at the start of a race.

Peak running velocity was reached at 25–30 strides after the start (Fig. 2). Similarly, stride length reached 7.2 m after 25–30 strides and remained constant thereafter (Fig. 2). The stride frequency, which was about 2.5/s immediately after the start, varied slightly during the first several strides, and became constant after the 8th stride, in which the horse began to run by transverse gallop. Mid step length was about 2 m immediately after the start and remained at this level, although there were slight variations (Fig. 3). Airborne step length increased linearly after the first several strides to the 20th stride, and thereafter increased to about 2.4 m in a gradual manner (Fig. 3). Fore step length increased slightly before leveling off at the 20th stride after reaching 1.2 m (Fig. 3). Hind step length, which was very short during the first several strides, increased slightly thereafter to reach about 1.0 m at the 20–30th stride (Fig. 3).

Although there were differences in stride length among individual horses, the pattern of changes was similar in all 3 horses (Fig. 4). In addition, the 3 horses showed a similar pattern of change in step length, although these values varied among individual horses. Although the stride frequency values were obtained completely only from one horse, the pattern of change in stride length and step length led to the assumption that all 3 horses had a similar starting dash. The results from horse No.1 are described below as a typical example.

The stride frequency reached its peak immediately after the start, while stride length required about 25–30 strides to reach its maximal level. These findings were consistent with those reported by Kai et al. [2]. Stride frequency at maximum running velocity is reportedly about 2.5/s [4]. In the present experiment, stride frequency reached this level immediately after the start. The variation in stride frequency seen
during the initial several strides during the start from the gate may be a characteristic of the increase in velocity running by rotary gallop which is an unaccustomed gait for horse. From the fact that stride length required time to reach its peak and stride frequency became constant at a high level from the beginning, it is reasonable to conclude that the substantial increase in velocity was attributable to an increase in stride length rather than stride frequency. However, it appears that acceleration during several steps after start dash is achieved by a maximal increase in stride frequency, because it is not possible to quickly increase stride length at this stage.

Changes in step length showed the following characteristic features: mid step length reached a near maximum level in the initial stage; airborne step length required more time to reach its maximum than did mid step length; and hind step length was very short initially. It has been shown that the rate of increase in mid step length increases when the running velocity is high, and it has been speculated that this increase results from a magnified propelling force of the hind limbs [5]. In the present study, hind step length was kept short to presumably magnify the propelling force. The changes in hind step length are thought to occur because of the near maximum level of mid step length which remained constant from the beginning. In contrast, airborne step length increased at a high rate and was most contributory to the increase in overall step length. However, its response to quick acceleration in the early stage was slow. This is probably because airborne step length increased as the result of an increase in inertia of the horse body in accordance with the increase in running velocity.

Leach et al.[3] have reported that almost all horses run by rotary gallop during acceleration from a standing position. In this experiment, during the first several strides after the start, the horses ran by half bounds in which the hind limbs landed almost simultaneously. Then, 2 of 3 horses (Nos. 1, 2) showed rotary gallop until they changed it to transverse gallop. This means that,
when making a starting dash, horses also use rotary gallop, which is characteristic of animals with a flexible spine. However the remaining horse showed a change from half bounds to transverse gallop while keeping the same order of limb landing (Fig. 4). It is unknown whether the No.3 horse ran with maximum effort. It is surmised that the type of gait used during start dash at horse racing depends on various factors such as position of each limb just before the start, the running velocity during the start dash and effect of jockey's action. In horse racing, it seems that not all horses necessarily run by rotary gallop when they actually start from the gate.

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