Effect of early training on the jumping technique of horses

Susana Santamaría, DVM, PhD; Maarten F. Bobbert, PhD; Willem Back, DVM, PhD; Ab Barneveld, DVM, PhD; P. Rene van Weeren, DVM, PhD

Objective—To investigate the effects of early training for jumping by comparing the jumping technique of horses that had received early training with that of horses raised conventionally.

Animals—40 Dutch Warmblood horses.

Procedure—The horses were analyzed kinematically during free jumping at 6 months of age. Subsequently, they were allocated into a control group that was raised conventionally and an experimental group that received 30 months of early training starting at 6 months of age. At 4 years of age, they were an analyzed kinematically during free jumping. Subsequently, both groups started a 1-year intensive training for jumping, and at 5 years of age, they were again analyzed kinematically during free jumping. In addition, the horses competed in a puissance competition to test maximal performance.

Results—Whereas there were no differences in jumping technique between experimental and control horses at 6 months of age, at 4 years, the experimental horses jumped in a more effective manner than the control horses. However, at 5 years of age, these differences were not detected. Furthermore, the experimental horses did not perform better than the control horses in the puissance competition.

Conclusions and Clinical Relevance—Specific training for jumping of horses at an early age is unnecessary because the effects on jumping technique and jumping capacity are not permanent. (Am J Vet Res 2005;66:418-424)

Show jumping is one of the most popular equine sports. Successful performance in competition depends on the combination of the skill of the horse and rider to clear all the fences in a short period.

Characteristics of the horse such as talent and physical conformation for jumping and the personality to perform under challenging conditions have been reported as key factors that will make a horse a good jumper. Initial maximal jumping capacity of the horse partly depends on the anatomic and physiologic properties of the musculoskeletal system that allow the horse to project its body sufficiently high into the air to clear the obstacle. However, the horse also needs to rotate and fold its body around the obstacle without touching it. Theoretically, the latter jumping technique could be a matter of talent, could be acquired by training, or a combination of both.

Many studies on racing Thoroughbreds and Standardbreds have focused on the effects of training on physiologic and metabolic parameters and on biochemical parameters of the skeletal tissues. Training of horses competing in these events starts at an early age and is mainly aimed at improving the physiologic adaptation to exercise at high speed. Training of Warmbloods, however, typically does not start before the horses are trained for riding at the age of 3 years. Before that age, most of the would-be dressage horses and show jumpers are kept at pasture or in stables, depending on climatic conditions. Nevertheless, some experts in the field speculate that training at foal age helps to develop a better ability to control the movements of the limbs, trunk, head, and neck, which would be of use in successfully clearing fences. If this assumption was true, substantial progress could be made in jumping technique by altering the traditional way of training.

The purpose of the study reported here was to determine whether early jumping training has an effect on jumping technique at adult age by comparing kinematic and kinetic data from horses that had been raised conventionally (without early jumping training) with data from horses that received jumping training as foals.

Materials and Methods

Horses—A group of 40 Dutch Warmblood foals (born in the spring of 1998) with reasonably good expectations of their future jumping ability, according to the breeding values of their sire and mare, participated in this study. Foals were kept in pasture with their dams until weaning at the age of 4 months, when they were taken to a free-stall barn.

Training—At the age of 6 months, the kinematics of the foals were measured while they free-jumped a 0.60-m fence. After this, the foals were allocated randomly into a control group and an experimental group. Groups were blocked for sex and expected breeding-stock value for show jumping (on the basis of performances of dam and sire), expressed in a so-called jumping index. The control group was kept in a free-
stall barn in the winter and turned out to pasture in the summer, whereas the experimental group started a training program involving free jumping 2 times/wk and walking in a horse walker 3 times/wk. This training lasted for 30 months. Two foals were removed for reasons unrelated to the experiment (ataxia and colic). At the end of training, all horses were trained for riding during 4 weeks. During the first 2 weeks, the horses were habituated to saddle and bridle, and during the following 2 weeks, the horses were ridden during lunging exercise. Subsequently, the horses, which at that time were approximately 3 years old, were taken to the Dutch Equine Training Centre in Deurne and trained to jump within a 5-week period. For economic reasons, restriction of group size was necessary; therefore, at that time, the 8 worst horses (with respect to behavior and mobility [ie, no lameness]) were removed from the study because they had less characteristic jumping ability of 3-year-old horses in events to select future breeding stock.

Experimental protocol—In the 3 experimental sessions, kinematic data were collected while the horses jumped a vertical target fence in a jumping track. The horses were familiarized with the jumping conditions and practicing free jumps in the experimental setting a few days before the day of the actual measurements. For the measurements, kinematic markers were attached to specific anatomic locations on the left side of the body (Figure 1) and the horses were subsequently monitored during jumping by infrared cameras operating at 240 frames/s. For the measurements at the age of 6 months, 3 infrared cameras were used, whereas for the measurements at the ages of 4 and 5 years, 6 cameras were used. The cameras were placed in a semicircle facing the target fence, such that the field of view included the last canter stride before the target fence, the jump, and the first canter stride after the fence. In the 3 experimental sessions, the height and depth of the calibrated field of view were 3.5 and 4 m, respectively, whereas the length was 6.5 m in the measurements at 6 months and 10 m in the measurements at 4 and 5 years. This arrangement allowed measurement of marker positions in the calibrated field of view with an accuracy of 0.3 mm in all 3 dimensions. The target fence was a vertical fence with a height of 0.60 m when horses were 6 months old, 1.05 m when horses were 4 years old, and 1.15 m when horses were 5 years old. An expert who was familiar with the horses chose the heights by use of the criterion that all the horses, even the poorest jumpers, could jump the fence without too much difficulty. To prevent the horses from approaching the target fence too fast, the approach to the jump was standardized. At foal age, a cross-pole fence was placed 5 to 6 m from the target fence to restrict the foals to 1 canter stride between fences. The target fence used at the age of 4 and 5 years was preceded by 2 lower vertical fences placed at distances that restricted the horses to 1 canter stride between fences; the second fence was 1.7 m from the first fence, and the third fence was 0.7 m from the second fence. The latter arrangement is similar to that used by the Royal Dutch Warmblood Studbook of the Netherlands (KWPN) to evaluate the jumping ability of 3-year-old horses in events to select future breeding stock.

Data collection and processing—The time histories of the marker coordinates were smoothed by use of a 4th-order, zero-lag Butterworth filter with a cutoff frequency of 6 Hz and used to calculate the time history of the x- and y-coordinates of the center of gravity (CG) of the horse in accordance with a segmental model defined elsewhere. Because the literature provides no information on the percentages of total mass of the segments of the body of a foal, the adult model was used to calculate the position of the CG in foals. Because we could confirm that the trunk of the horse, the mass of which contributes 65% to the total mass of the horse, grows more or less allometrically,1 it seemed unlikely that substantial errors were introduced by use of this model. Because markers were only on the left side of the body, it was assumed that the right and left extremities of the horse moved symmetrically. This introduced errors, but these were small because most of the mass of the horse is located in the trunk. The time histories of the CG were differentiated with respect to time to yield CG velocities and accelerations.

In the experiments that took place at the age of 4 and 5 years, the horses first performed a few warm-up jumps and subsequently performed 10 to 15 jumps, during which data were collected. During these measurements, the number of faults (fence knocked over) and refusals of the first 10 jumps were recorded. For further analysis, we selected 4 successful
jumps in which the fence was approached with a left lead during canter. In the experiments that took place at the age of 6 months, the number of trials per horse was limited to 5 to avoid fatigue. From these trials, only 2 to 4 jumps/horse with data usable for the analysis were obtained. Because not all of the foals jumped consistently during the different trials, only 1 jump/foal was analyzed, and that was the jump in which the CG reached the greatest height. For the selection of this jump, the lead of canter of the approach stride was not taken into account.

A jump may be subdivided into a push-off phase and an airborne phase. The push-off phase can be further subdivided into a phase in which the forelimbs generate force and a phase in which the hind limbs generate force. For statistical analyses peak values found in the time history of vertical acceleration of the CG \(y_{CG}\) and in the time history of rate of change of effective energy \(\dot{E}_{eff}\).

**Table 1**—Mean ± SD values for kinetic and kinematic variables calculated for control (C) and experimental (E) groups of horses during free jumping over a fence when horses were 6 months, 4 years, and 5 years of age in a study of effects of early training on jumping technique. Height of the fence was 0.60 m at 6 months, 1.05 m at 4 years, and 1.15 m at 5 years.

**Figure 2**—Illustration of the angular variables calculated in a study of effects of early training on jumping technique. At 4 and 5 years of age, the back was represented by the line (segment) from the top of the shoulders to the spinous process of S2. At 6 months of age, it was represented by the line (segment) from the top of the shoulders to the metatarsophalangeal joint of the left hind limb.

\[
\begin{align*}
\text{Hind limb} = & \text{Angle of hind limb retroflexion, determined from } \phi_{\text{Back}} \text{ and } \phi_{\text{Hind limb}}. \\
\text{Hind limb-retrofl.} = & \text{Angle of hind limb retroflexion, determined from } \phi_{\text{Hind limb}}. \\
\phi_{\text{Joint}} = & \text{Angle of the joint of interest (shoulder, elbow, carpal, hip, stifle, or tarsal), measured at the flexion side (the angle becomes smaller if the joint is flexed more).} \\
\phi_{\text{Back}} = & \text{Angle of the back with the left horizontal.} \\
\phi_{\text{Hind limb}} = & \text{Angle of the line (segment) from hip to the metatarsophalangeal joint. } \\
\end{align*}
\]
which occurred during both fore- and hind limb push-off phases were calculated. From the data collected at 6 months, however, calculations were not performed for such peaks during the forelimb push because for some foals, the data from the approach stride were incomplete. In addition, the following exact moments were selected from the jump to calculate values of kinematic and kinetic variables: takeoff, forelimb clearance, apex of the jump, hind limb clearance, and landing. To detect the exact moment of takeoff, the exact moment that $y_{CG}$ decreased to zero was found and then a straight line was fitted to the time history of vertical acceleration around this exact moment and extrapolated to the exact moment that $y_{CG}$ became maximal.

### Results

#### Short-term effects of early training

There were no differences between groups in morphometric variables at 6 months or 4 years of age. The $y_{CG}$ at the square standing position of the control and the experimental groups was $1.20 \pm 0.04$ m and $1.18 \pm 0.05$ m at 6 months of age, respectively, and $1.43 \pm 0.05$ m and $1.43 \pm 0.07$ m at 4 years of age.

There were no significant differences in kinematics between the control and experimental groups at the age of 6 months (Table 1). However, at the age of 4 years, several differences were found between the groups. The experimental horses produced a smaller peak $y_{CG}$ and peak $E_{ed}$ during hind limb push, took off with a lower vertical velocity of the CG ($v_{CG}$), and reached a lower $y_{CG}$ during the airborne phase. Furthermore, they flexed their forelimbs more and landed closer to the fence than the control horses (Figure 3). The ISD was less in the experimental group. The level of significance was set at $P < 0.05$ for all comparisons.

#### Statistical analyses

To compare jumping kinetics and kinematics between the control and experimental groups at a given age by use of commercially available software, an ANOVA was performed for each variable by use of data from the highest jump at the age of 6 months and the mean of 4 jumps at the ages of 4 and 5 years. For each variable, it was confirmed that results were almost identical by use of the mean value for the 4 jumps or the value of only the highest jump. Finally, to study the effect of training on the intra-individual variability at the ages of 4 and 5 years, the intra-individual SD (ISD) of the 4 jumps for each variable was calculated for each horse. An ANOVA was subsequently performed to compare the mean ISD of the experimental group with the mean ISD of the control group. The level of significance was set at $P < 0.05$ for all comparisons.

### Puissance competition

One month after the measurements at 5 years of age, all 29 horses participated with their riders in a puissance competition. The horses were required to jump a combination of 3 fences in which the last fence was raised progressively during 6 rounds. The first fence of the combination was always 0.60 m high, whereas the second fence was 1.00 m high in the first round and 1.10 m in the rest of the rounds. The height of the third fence in the first round was 1.00 m and was raised 0.10 m/round until it was 1.50 m. The distances between fences were adapted in accordance with the increasing height of the last fence. A horse was allowed to repeat a jump if it knocked the fence over or refused jumps. The number of times a horse knocked a fence over or refused to jump was recorded. Some horses were not able to complete the entire competition and were withdrawn. This decision was at the discretion of the trainer. The horses were classified into 3 groups: the best jumpers were the horses that did not knock over any fences or refuse any of the jumps including the last round at 1.50 m, the worst jumpers were the horses that had to be withdrawn at some stage of the competition, and horses that eventually completed the competition, but with a certain number of faults or refusals, were classified in an intermediate category.

#### Statistical analyses

To compare jumping kinetics and kinematics between the control and experimental groups at a given age by use of commercially available software, an ANOVA was performed for each variable by use of data from the highest jump at the age of 6 months and the mean of 4 jumps at the ages of 4 and 5 years. For each variable, it was confirmed that results were almost identical by use of the mean value for the 4 jumps or the value of only the highest jump. Finally, to study the effect of training on the intra-individual variability at the ages of 4 and 5 years, the intra-individual SD (ISD) of the 4 jumps for each variable was calculated for each horse. An ANOVA was subsequently performed to compare the mean ISD of the experimental group with the mean ISD of the control group. The level of significance was set at $P < 0.05$ for all comparisons.
mental group, these percentages were 2.1% and 1.4%, respectively. These jumps were discarded from the analyses and therefore did not influence the kinetic and kinematic outcome.

**Long-term effects of early training**—There were no differences between control and experimental groups in morphometric data at the age of 5 years. The $y_{CG}$ at the square standing position of the control and the experimental groups was $1.46 \pm 0.04$ m and $1.45 \pm 0.05$ m, respectively.

From all of the differences in free jumping technique between groups found at the age of 4 years, no differences remained between groups at the age of 5 years, although ISD was less in the experimental group in a few variables related to forelimb and hind limb push (Table 1).

In addition, observation of the performance of the first 10 jumps of each horse during the measurements at the age of 5 years revealed that 2.1% of the jumps performed by the control horses were refused and 1.4% of the jumps resulted in faults. These percentages were 1.4% and 4.3%, respectively, in the experimental group.

**Puissance competition**—Of the 29 horses competing, 7 succeeded in completing the puissance competition without faults or refusals. Four of these 7 horses were from the experimental group, and 3 were from the control group. At the other end of the spectrum, 9 horses (5 from the experimental group and 4 from the control group) were not able to complete the whole series of jumps and had to be withdrawn. The remaining horses had either committed faults or refused 1 or more jumps. This intermediate group consisted of 13 horses (6 experimental and 7 control).

**Discussion**

The raising and training of would-be performance horses is a lengthy, labor-intensive, and expensive process in which the outcome is uncertain. This statement is especially true for those branches of equestrian sports in which horses perform at peak level at a relatively advanced age, such as dressage and jumping. It would be of great benefit to the equine industry if the juvenile period of horses could be used either for selection based on traits that are indicative of future performance or for the application of early training programs that would enhance athletic performance later in life. The questions as to whether such traits can reliably be identified and whether early training indeed affects later performance can be only answered by conducting longitudinal studies in a few variables related to foal and adult data was possible. The second set of kinematic measurements took place when the horses were 4 years old. Regarding the jumping kinetics and kinematics of the control group at the age of 4 years, it was found that despite the minimal jumping experience of the horses, the intra-individual variation in the variables studied was significantly less than the interindividual variation, meaning that each horse had its own individual jumping technique. Subsequently, correlations were found in the order of 0.7 to 0.8 between various crucial variables describing the relationship between jumping kinetics and kinematics at foal age and at 4 years of age in the control group. This indicated that technique was consistent across ages and that, therefore, observations of free jumping foals might have a predictive value for future performance unless training would be dominant relative to talent.

The question that needed to be answered next was the question addressed in the first part of the present study: what is the effect of early training on the jumping technique of horses at the moment that they would normally start receiving specific training for jumping? The answer to this question, on the basis of findings in the present study, was that there is an effect of early training. Whereas at 6 months of age there were no differences between the control and experimental groups, which was to be expected at this age because no intervention had taken place yet, several differences were found at the age of 4 years. During the hind limb push, the experimental horses produced lower peak $y_{CG}$ and peak $E_{k}$ and therefore took off with a lower $y_{CG}$ jumped less high, and (because they had the same horizontal velocity of the CG) jumped less far. Despite the fact that their CG trajectory was closer to the fence top, they managed to clear the fence by similar distances from fetlock to the fence top (that is, both groups had similar values of vertical distance between the fetlock joint of the left forelimb and the top of the fence and of vertical distance between the fetlock joint of the left hind limb and the top of the fence during forelimb and hind limb clearance). They achieved this by flexing the forelimbs more at forelimb clearance and by being more rotated with the trunk at hind limb clearance (at hindlimb clearance, $y_{CG}$ was 10 cm lower and the angle of the back was more inclined). Interestingly, the experimental horses positioned their CG less beyond the fence at the apex of the jump than the control horses. Experts in the field consider this a characteristic of good jumpers. Moreover, in the experimental group, reduced ISD was found in the horizontal distance from the CG to the top of the fence and $y_{CG}$ at the apex of the jump and in the vertical distance between the fetlock joint of the left hind limb and the top of the fence at hind limb clearance, suggesting that the experimental horses were better at estimating distances, controlling their motion, or both. This was further supported by the fact that experimental horses made fewer faults. It is important to mention that none of the differences found between the 2 groups could have been a consequence of differences in fitness because before the measurements at the age of 4 years, both groups remained in pasture for a period of 6 months.

Results of the first part of this study revealed that early training had a major effect on jumping technique at 4 years of age. The differences between the groups...
were logical and biomechanically consistent, so there seems little reason to attribute them to type I errors attributable to performing more than 1 comparison without adjusting the P value. A direct implication of this finding is that early training can have a confounding effect at selection events for young horses. Good technique at these events can be a result of inherent good technique only or of lesser technique but effective training at a young age. In countries such as the Netherlands, Germany, or France where horses of 3 or 4 years of age participate in events that include assessment of free jumping technique to select future breeding stock, judges should be especially aware of this.

Horses are evaluated while jumping relatively low fences during these selection events, so it may not always be easy to judge whether a horse is performing well because of superior genetic potential or because of mediocre genetic potential and a lot of training.

The question of whether the effect on jumping technique persists after the horses are enrolled in the conventional training program was addressed in the second part of the study, when both groups of horses were measured again at 5 years after having received 1 year of intensive training for jumping with a rider. From 4 to 5 years, the horizontal velocity of the CG at takeoff decreased and the $y_{CG}$ at takeoff increased in all horses. The latter was obviously necessary to clear the extra 10-cm fence height at the age of 5 years. At this age, no significant differences remained in any of the variables determining jumping technique between the experimental and control groups when performing submaximal free jumps. It appears that the control horses had quickly learned to clear fences at a submaximal height just like the experimental horses.

There was an overall increase in both groups at 4 and 5 years of age for $y_{CG}$ at various exact moments of the jump. This was obviously related to the increase of 10 cm in fence height. However, the increase was substantially less in the control group than in the experimental group. If one examines the $y_{CG}$ at the apex of the jump in both groups of horses and concentrates on the differences between measurements at 4 and 5 years, it is clear that to cope with the extra 10 cm, the control horses raised their CG less at the apex of the jump than the experimental horses. Because the experimental horses already raised their CG less at the age of 4 years, they had to increase this vertical position by the full 10 cm to clear the fence. The control horses cleared the fence with a greater elevation of CG at the age of 4 years but had improved their technique to the same level as the experimental horses at the age of 5 years. This explained how in the control group the mean increase in the maximum $y_{CG}$ could be less than the increase in height of the fence.

The improvement of efficiency (ie, having less elevation of CG while clearing the fence) in the control group was possible by virtue of an improvement in the technique of clearing the fence with the limbs. With regards to the forelimbs, the horses increased the flexion of all joints, especially the elbow. Perhaps not surprisingly, the configuration of the forelimbs of the control horses at 5 years of age was very similar to that of the experimental horses at the age of 4 years. The experimental horses at 5 years of age had their forelimb joints slightly more flexed than the control horses, but these differences were not significant. With respect to the strategy to clear the fence with the hind limbs, the control horses rotated their trunk much more at the age of 5 years than they did at the age of 4 years, whereas the experimental horses had very similar configurations at both ages. In addition, the changes in stifles and tarsal flexion from the measurements at 4 to 5 years of age were greater in the control group. The increase in experience in jumping by the control horses was further evidenced by the fact that the differences in numbers of faults and refusals during the measurements between both groups substantially decreased and reached a similar value.

The last part of this longitudinal study, the puissance competition, was planned to investigate whether the outcome of the comparison made on the basis of submaximal jumps could be representative of performance during maximum height jumps. Although, admittedly, there are many more factors that determine ultimate show jumping performance in competition, it was felt that the outcome of the puissance competition as carried out in this study was a good indication of the jumping capacity of the horses (ie, the ability to clear high fences). There were no differences in the distribution of best and worst jumpers between groups, indicating that early training did not affect maximal jumping performance.

Interestingly, horses from the experimental group in our study had significantly lower ISD than horses in the control group in variables related to forelimb and hind limb push. We previously speculated that low variation from jump to jump could be an indication of better jumping ability.5 However, the outcome of the puissance competition made it clear that such low ISD when performing submaximal jumps is neither advantageous nor disadvantageous when performing maximal jumps.

It can be concluded that early training for jumping has a short-term, but not a permanent, effect on jumping technique. In terms of jumping capacity, there also seems to be no major lasting effect. Thus, an early start of specific training for show jumping, as is common in some other branches of equestrian activities, does not offer advantages, compared with the classical approach in which the horses do not receive specific training until they are trained for riding at 3 years of age. It should be emphasized that this conclusion only refers to the effects on performance of specific training for jumping. Other recent studies15-18 have revealed beneficial effects of a limited amount of early exercise for conditioning the tissues of the equine musculoskeletal system. Our final conclusion is that carefully controlled exercise at foal age may help in improving strength and resistance of the musculoskeletal tissues, training for specific athletic performance at that age is futile.

References

AJVR, Vol 66, No. 3, March 2005