International workshop on linear profiling delivers new knowledge about traits important for sport horse performance

Emma Thorén Hellsten, Kathrin F. Stock

How can we better predict sport performance of horses at an early age? How can we create more precise and objective selection tools for sport horse breeders? How can the latest advances in technology benefit the assessment of horses? Those were key issues and the theme for the much-anticipated International Workshop on Linear Profiling in the Warmblood Horse (IWSLP). After an involuntary break of three years, finally, a group of 63 studbook representatives, judges and scientists from 16 countries met in the very North of Germany, referred to as 'Holsteinische Schweiz'. To strengthen the exchange and collaboration of science and practice across countries and studbooks, a series of meetings on linear profiling in the Warmblood horses and related topics has been arranged since 2013. The meeting organized on March 29-30, 2023, was the 7th IWSLP, superbly arranged by the international working group on LP, which is linked to the Horse Commission of the European Federation of Animal Science and its permanent working group Interstallion.

Linear scoring (or: linear profiling)

Instead of expressing how bad or good some phenotype is relative to a theoretical optimum (valuating score), the linear value reflects the proximity of the phenotype to the most extreme expressions. For example, the length of the neck of a horse can be described between extremely short and extremely long - without any consideration of which neck length would probably fit the breeding goal best. Linear descriptions of traits relative to biological extremes have the clear advantage of independence from breeding goals. There are many examples of successful use of linear traits in animal breeding. More recently the importance of linear systems for horses have increased, too. They are referred to as linear scoring or - in order to avoid confusion and misinterpretation with the valuating scoring - **linear profiling**. Another beneficial attribute of linear systems is the refinement of trait definitions. The more objective and more detailed information of linear profiles provides transparency of the assessments of horses that cannot be achieved in the traditional system of valuating scoring, where many traits are usually clustered into trait groups like “legs” “type” etc.

Further information linear profiling and the linear systems used by different studbooks can be found at https://www.equinephenotypes.org/Texte/recording_ENG.html (section phenotype recording)

All participants were highly motivated to exchange experiences, learn from each other and get some impulses for own future activities in the field of linear profiling (LP) and beyond. It was delightful to experience the pleasant atmosphere and openness with which the exchange on technical and practical topics took place, and to see how uncomplicated knowledge transfer between science and practice can happen. Thanks to the gorgeous team of Gut

Schönweide, the participants had ideal conditions for the practical part on horse assessment and were delighted to see as a bonus how horse keeping in perfection may look like.

Several studbooks have adopted LP as part of their breeding programs, and many more are in the process of implementing it. Kathrin Stock from vit (IT Solutions for Animal Production), Germany, in charge of organizing the workshops on LP from the very beginning, started this year's event by giving a resumé of lessons learned from the studbooks that have implemented LP and the experiences of using the data it has generated. Her first advice when creating a studbook-specific linear scheme was to check available systems in other studbooks, but in the end define a linear scheme which fits your own studbook and your breeders' needs. A system that doesn't correspond to the breeder's needs won't be accepted, used, and understood. Still, Kathrin Stock emphasized, it's very important to avoid the pitfall of 'valuating linear profiling' but make the difference between the LP and the traditional valuating scoring very clear from the start. She further explained that although it may look like there are many different schemes used among studbooks, the main traits and trait groups are still very much the same. Pilot studies have shown consistency of linear data recorded with different linear schemes in different studbooks and high genetic correlations between similarly defined traits. A strong advice from Kathrin Stock was to form a science-practice partnership to monitor the assessment of horses via LP already from the start. By such regular data analyses, any problems with the use of the scale or calibration of evaluators may be detected early and necessary measures can be taken. Also, making useful statistics from the assembled linear information as early as possible will show the breeding community how they can benefit from the new system and hence increase the acceptance for it.

While many studbooks are now in the phase of implementing LP, some of the studbooks that have used it for a while could present interesting findings from the data that have been produced so far. António Vicente from the Lusitano Horse Breeders' Association (APSL) and assistant professor at the Polytechnic Institute of Santarém, Portugal, reported that LP has been used since 2017 in the assessment of conformation and gaits of the Lusitano horse. Their protocol includes 63 traits and 23 'defects', using a 9-point scale from 0 to 40. A tablet is used to collect the linear profiles, and annual judges' meetings are arranged to homogenize the assessment among the 23 judges who are responsible for LP of Lusitano horses worldwide. The first analyses of the data show low to moderate heritabilities, where gaits were in the upper range and limbs in the lower range. The patterns of genetic parameters are looking rather similar to those found for Warmblood sport horses. Next step for the APSL is to start using the information from the LP for breeders' guidance with selective mating. There are also plans on estimating genetic correlations between the linear traits and the results from gradings of morphology and gaits at registrations and of functionality and performance at competitions which, for the Lusitano horses, include dressage and working equitation.

In the two Oldenburg studbooks, OL and OS, LP was implemented in 2012. It is used at foal shows, studbook registrations, mare performance tests and evaluations of stallions. Inge Workel from the Oldenburg breeding society demonstrated that OL / OS are using 186 traits in total, but only the obvious deviations of trait expressions are actively documented for each horse, using a tablet. The average numbers of documented deviations for average trait expressions differ between tests but would typically be around 10 at foal shows, 11 at

studbook registrations and 30 at mare performance tests. The scale used is from -3 to + 3 where 0 is the middle score. Non-documented traits are automatically set to 0. The system was originally developed in Oldenburg but is now used by several other German studbooks. So far the Oldenburg studbooks have collected 34.600 linear profiles whereof approximately one third is from adult horses and two thirds are from foals. All linear data are included in the estimation of 46 descriptive breeding values that are publicly available for the breeders to support them in their mating choices. Since 2021, the Oldenburg studbooks offer an online tool for pairing support, which is based on the descriptive breeding values for mares and stallions and available through the breeders' individual online accounts. By that breeders can get help to find suitable stallions for their mares. With short video clips, Inge Workel provided some insight into the conditions under which LP is routinely performed in OL / OS. In the practical part of the workshop, the participants all got a hands-on experience with the German LP system under the knowledgeable supervision of Inge Workel and Peer Eitenmüller from the Oldenburg breeding society and from Maren Schlender and Bo Eitenmüller from the Hanoverian breeding society. Their colleagues from the Westfalian and Holstein studbooks added to the exercises with comments based on their own experiences from routine LP as did participating evaluators from other countries. By that, the group got a very good impression of how LP can contribute to more objective and concrete discussions about horse assessments.

Several studies have been performed based on LP data collected by the Oldenburg studbooks. Kathrin Stock shared some of the latest findings on genetic and genomic correlation analyses of linear traits and their implications for targeted support of sport horse breeding. Estimated breeding values (EBVs) for linear conformation and performance traits for active mares and broodmares were used, together with EBVs for sport traits from the national genetic evaluation for riding horses in Germany (FN). Linearly described conformation aspects were found to play an overall minor role for sport performance in dressage and show jumping. There were some associations between linear conformation traits and dressage performance, but they were mostly weak. This was not unexpected, and expectations were also met or surpassed with regard to performance-relate linear traits: Linearly described gait aspects were found to play a relevant role of for dressage sport performance, and there were indications of stronger association relating to of hind limb than to front limb movements. For jumping, closer associations to sport performance were found for linearly described traits relating to strength and quickness than to specific jumping technique aspects. In the genomic part of the study, the genetic similarity of apparently 'similar' characteristics of different gaits were investigated, but no indications for reasonable amounts of shared genetic basis were found. On the other hand, the obvious genetic similarity of analogous linear traits in foals and adults horses were nicely illustrated. In her take home messages Kathrin Stock emphasized the high value of detailed linear phenotypes for current and future breeding applications for sport horses. Descriptive breeding values are already an appreciated tool for breeders because it provides early and specific information on the inheritance of stallions and targeted support of mating decisions on a wide range of traits. Rightfully so, this study establishes, because of the positive correlations to future sport performance. Kathrin Stock concluded that even the (conformation) traits that did not show high correlations to sport performance per se are

valuable tools for monitoring the development in a sport horse population. This is much appreciated especially regarding functionality, balanced and responsible breeding, and possibly health issues, which is already on the agenda for further studies.

Partly on the same subject, Åsa Gelinder Viklund from the Swedish University of Agricultural Sciences presented a study on linear traits associated with sport performance in the Swedish warmblood horse. The Swedish Warmblood Association (SWB) use LP since 2013, which means the oldest horses with LPs are now 13 years old and some of them have had time to reach the highest classes in sport. In this study, phenotypic differences between show jumping and dressage horses were investigated as well as phenotypic associations between traits from LP and referring to sport performance in dressage and jumping. Significant but not always big differences were found between horses bred for jumping and dressage for all linearly scored conformation traits, except for some traits referring to leg stance. Linear gait and jumping traits were likewise significantly different between horses bred for dressage and jumping, where the largest differences were found for all trot traits, and for the jumping traits scope, power of take-off, direction of take-off and technique of back. Several linearly scored traits turned out to show a significant association with competition performance. For show jumping, those included all linear jumping traits and the few linear gait and conformation traits. Åsa Gelinder Viklund showed that as expected, several traits describing trot and canter and also several conformation traits showed significant associations with dressage performance, while perhaps somewhat surprising, such association was not found for any of the linear walk traits. The shapes of the phenotypic relationships were also studied, and most of the significant linear jumping traits showed a linear or almost linear association to competition performance in show jumping, which Åsa Gelinder Viklund explained as indicating 'the more the better'. However, she also underlined and illustrated with examples that optima for linear traits may in many cases be found somewhere between the average and the extreme, or (like for linear traits relating to correctness) close to the average. Despite obvious differences between the disciplines for several traits, results were consistent with regard to this general rule that extremes are not always what to aim at. Accordingly, the presented results from research based on linear data from Germany and Sweden were very consistent and nicely complemented each other with their phenotypic and genetic / genomic focusses. Åsa Gelinder Viklund ended her talk with the prospect that the research team now wants to continue studying the correlations between LP and sport performance also on the genetic levels and to investigate the associations of linear traits with health and durability.

Steven Janssens and his team at the Katholic University of Leuven, Belgium, had looked into early life jumping traits and their genetic correlations with later success in show jumping competitions in Belgian Warmblood horses (BWP). The BWP use LP for free jumping since 2003 and for jumping under saddle since 2014. The same traits are described during free jumping and jumping under saddle using a 9-point scale from -20 to 20. There were seven early life jumping traits from LP included in the investigation – scope, take-off (power/quickness), technique of forelegs, technique of back, technique of haunches, attitude (willingness) and care – and also four linear traits describing canter, namely stride length, impulsion, elasticity, and balance. Steven Janssens showed that the linearly described jumping traits assessed early in the horse's life were found to be heritable and moderately to highly

correlated with competition performance in show jumping. Again, consistency of the results across countries, sport horse populations and linear systems was very good to see, and the gain in insights into how to breed for sport performance became clear. This was particularly so for the BWP presentation because the favorable correlations with LP had motivated further investigations on how efficient it would be in terms of breeding progress to select horses for breeding based on their performance as young horses, compared to selection based on sport performance later in life. It turned out that selection based on early life jumping traits assessed by LP of free jumping, was much more efficient when it comes to scope, take-off, technique of back and forelegs.

Data collection using sensor technology may not be seen as a form of linear description, but could for sure be very useful as an additional source of information, for example when it comes to the education and training of judges. Michela Ablondi and Vittoria Asti from the University of Parma, Italy, and Annik Gmel from the University of Zurich, Switzerland, showed the sometimes puzzled crowd, with their talks and later also in the practical part, how to apply sensors on strategic parts of the horses body in order to measure symmetry of movements, regularity, impulsion, etc. The three scientists explained based on their research experience how sensor technology may be helpful to objectively describe performance traits such as gait quality, and possibly also jumping technique. In summary, use of sensor data may be a necessary step on the way to teach computers how to objectively assess the conformation, movement and jumping of horses in the future, i. e. approach supplementary use of artificial intelligence (AI) and AI-facilitated description of horses.

Concerning the use of AI and image recognition, the French research team of the project SoGen and French sport horse breeders are already well on their way. Bernard Dumont St. Priest, director of development, innovation and research at the Institut Français du Cheval et de l'équitation (IFCE), France, presented on 'Your foal in 3D'. By placing 28 markers on strategic points of the horse's body, measuring body's heights, lengths, and widths, and filming each horse in movement by four synchronized cameras, the French team has collected data and performed morphological analyses on 2000 horses. Their efforts have resulted in a tool for 3D 'morphotype' prediction for foals produced by a stallion. This tools is based on estimated patterns of body measures referred to as 'morphotypes' which are supposed to be genetically transmitted and basically show how the average offspring of a stallion is expected look like in 3D, compared to the breed average – also shown in 3D. By generalizing the method and under the precondition of available data on progeny, such results could be generated for any stallion. What the SoGen project has produced is an objective tool that not only describes bits and parts of the horse but considers the horse's body as a whole. Bernard Dumont St. Priest explained that the limitation of the method is currently the time to locate the landmarks on an image, so the next phase will be to use AI and image recognition to speed up the process. The SoGen team also aims to estimate genetic parameters for the different measures. It is important for the breeders to know the levels of heritability and how many offspring need to be measured to ensure a reliable prediction of a stallion's 'morphotype'. SNP genotyping of the measured horses will allow investigating if there are any major genes involved in the formation of 3D conformation measures and the physical development of the individual horse.

To round off the intense and interesting workshop program, Inge Madsen, chair of the International Young Breeders (IYB), talked about LP in Education and Training. The IYB wish to include LP in the training and competitions for young breeders because many studbooks now use LP in assessing breeding stock at studbook inspections. Furthermore, including LP in the education of young breeders is expected to support the overall learning process, would help them to understand the specific terminology and to communicate with other breeders. Apart from the benefit for their own development as a breeder, the improved insight into horse evaluation could be the stepping stone into a judging pathway. The IYB believes that including LP in the “side by side” practice used in the education and competitions of young breeders could help the young breeders to see and understand the reasons for the numerical scores awarded the horse at the same occasion. The main challenges that have so far hindered wider implementation of LP in the IYB curriculum are related to collating and correcting of evaluation results at the competitions. The tasks ahead for the IYB board is to select and consolidate the set of LP traits to a common IYB LP scheme. Once a reasonable and manageable number of informative traits has been defined, agreement must be achieved with regard to clear trait descriptions and the language used for these descriptions. This may then be a good basis for further planning of how to possibly move from the current manual handling of results to a safe technical solution. In all, very challenging tasks for IYB, but once completed it could benefit all studbooks as a common platform for LP.

The concluding discussions touched upon subjects such as deciding on and be very clear about what is the reference population that all horses are compared to in a given studbook. If there are multiple breeding goals within the same population, it is very important to be clear about whether a horse is compared to the entire population, or only to the horses bred for the same discipline within that population. Lacking clearness and confusion in this crucial aspect may throw the whole usefulness of LP and collected linear data overboard risking the trust of breeders and high reputation of LP.

It was suggested to possibly carry the concepts of an 'absolute mean' vs. 'relative mean' into the technical discussion. For any linear trait, you may (at least theoretically) firmly define the average which remains unchanged and relative to which horses now and in the future are described. Although such fixed reference may facilitate tracking breeding progress by phenotypic trend analyses (in addition to the genetic trend analyses), the risk is high that you get stuck with LP: If there is breeding progress and the optimal trait expression is closer to one end of the linear scale, assigned linear values will soon cumulate there which implies shrinking your scale from the original 9 or 7 points to just 3 or so used for the majority of horses. The reduced phenotypic variance will interfere with further breeding progress, and breeders may become annoyed by seeing close to no differences between individual horses with regard to the respective linear trait(s). The alternative approach that may be referred to as working with a 'relative mean' implies that the zero is always reflecting the population mean at that point in time, i. e. the zero is following the possible breeding progress. This facilitates continued use of the full linear scale and by that optimal reflection of the phenotypic variance. However, high demands on experience, knowledge and harmonization of judges and their training must be considered. Stability of the overall phenotypic mean close to the zero further means that breeding progress can only be tracked by genetic trend analyses. It is important to clearly

communicate and explain it to the breeders that LP must be understood within the given contemporary group of horses. So if, for example, dressage horses have been selected for longer legs and breeding progress has been made, a horse described as average or relatively long-legged ten years ago, may today rank among the those horses described as relatively short-legged. In a studbook working with absolute definition of the mean, this horse may today be described as ten years ago, but correct interpretation of the phenotypic data for today's breeding would require knowledge of the current phenotypic distribution. Accordingly, any LP system has its challenges and pitfalls relating to the linear phenotypes, and it is important to increase the awareness of that among those working with LP. On the genetic level, breeding values for linear traits from a given evaluation run will produce a clear and consistent ranking, regardless of how the phenotypic mean is defined. The high value of genetic linear profiles and its reasonable appreciation by breeders and studbooks became obvious from this reasoning.

The open discussion about the news from science and also key principles of LP was much appreciated by the representatives of the different studbooks. After the official ending of the workshop, talks in smaller groups continued for a while, and the renewed contacts across the equine community will likely help further development of LP and working with linear data. The next IWSLP is supposed to be organized in 2024 as a one-day digital meeting, followed by the next two-days physical meeting in 2025.

The international group of 63 workshop participants enjoyed the beautiful surroundings and perfect conditions for the practical session on linear profiling and use of sensor technology for objective movement assessment at Gut Schönweide, Grebin, Germany. (Photo: Gut Schönweide)