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EDITORIAL

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Science in brief: The Dorothy Havemeyer International Workshop on poor performance in horses: Recent advances in technology to improve monitoring and quantification

The Dorothy Havemeyer International New Technologies in Equine Poor Performance Workshop was held between 23 and 26 May 2022 in Gallatin Gateway, Montana, USA with the generous support of Boehringer-Ingelheim, Platinum Performance, and the Havemeyer Foundation. Goals were to share technological advances to assess poor performance and catalyse progress in equine performance and safety. Attendees from eight countries and five continents delivered 29 oral presentations on factors related to athletic performance including injury prevention, cardiac disease, motion analysis, thermoregulation, the use of wearables or mobile health and novel methods for assessment of muscle function. Focused breakout discussion sessions promoted the exchange of ideas and allowed delegates to question, comment and identify gaps in current knowledge and plans for action. Two keynote speakers provided key expertise and information to support and contextualise research presentations and discussions. This summary provides an overview of the topics discussed and conclusions reached. Several other innovations not summarised here are likely to be excellent additions to the body of knowledge on equine poor performance.

1 | INJURY PREVENTION

The rate of injury in Thoroughbred racehorses in the United States is approximately 1.2 injuries/1000 horse starts.[1] Motivated by the evidence that racehorse fatal injuries are a manifestation of chronic repetitive loading, Dr Susan Stover used machine learning techniques to examine the relationship between the exercise histories of Thoroughbred racehorses and injury. Good average precision was achieved for a test data set different from the data set used to train the machine learning algorithm and results developed in the test model suggested that the algorithm was robust when used adjusted to the overall population. Allan Page presented work designed to determine whether horses with catastrophic racing injuries demonstrate differential expression of select mRNA when compared with non-injured control horses. Three genes (IGF1, IL1RN and MMP2) were significantly different in injured horses compared with non-injured controls. An increase in inflammatory markers measured by mRNA analysis was also demonstrated in a group with more frequent intense exercise compared with a group with less frequent intense exercise and allowed turn out. It is plausible that mRNA expression may also give insights into (mal)adaptations to training.

Dr David Lambert's keynote presentation elaborated on decades of experience studying the factors associated with success in Thoroughbred racehorses. This inspirational presentation included elegant and practical explanations of the physiology and biomechanical mechanisms that define a racehorse and dictate elite performance. The lessons derived from Dr Lambert's experience analysing physiological metrics over the years and the constant pursuit of health and performance improvement were a highlight of the meeting. Additionally, Dr Lambert provided data of stride analysis using onboard monitors in a large population of successful horses and horses that suffered catastrophic musculoskeletal injuries during racing. These onboard monitors are used at racetracks to reduce fatalities through early identification of stride changes by assigning 'red, orange or green flags' according to stride characteristics. During the study period, 20 horses died or were euthanised due to musculoskeletal injuries and the majority of these horses had received a 'Red Flag' during the previous race and one three races prior.

A tiered approach to injury prevention could include screening based on onboard stride monitors, exercise histories and mRNA expression analysis. The logistics of such a programme are complex and would need to consider the diagnostic accuracy, epidemiological factors, and idiosyncrasies of the racing industry in different areas of the world. Testing for a disease in low-prevalence populations will likely result in many false-positive results, as demonstrated by the studies described above, and would be non-specific for the reason of increased risk. A yet-to-be-defined second tier of tests, in which imaging and cardiovascular testing may be heavily represented, may be needed following screening tests. The ability of different sports and regulatory organisations to handle the workload, follow-up and consequences of testing are important parts of a potential preparticipation screening programme.

The comprehensive approach of the Hong Kong Jockey Club to injury prevention was explained by Dr Cate Steel. This approach is possible due to specific circumstances in Hong Kong and based on race day identification of horses that perform below expectations. The approach uses rapid postrace examination by means of physical examinations, trotting examinations, ECGs, and endoscopy. More detailed examinations the day following the race and mandatory reporting of detected abnormalities are also part of this approach. Lameness, exercise-induced pulmonary haemorrhage, tracheal mucous and arrhythmias are the most commonly identified problems, and it is suspected that some abnormalities remain undetected. Findings of postrace examinations are made

public when considered clinically relevant and a protocol also exists to determine when horses can return to racing.

2 | WEARABLE TECHNOLOGY

The feasibility, user perceptions, summary of data from different populations and accuracy of wearables in monitoring race and sport horses were presented in a series of abstracts. Internal and external training loads such as distance, speed, heart rate, heart rate variability, stride characteristics, acceleration, jump characteristics or respiratory sounds and associations among these were proposed as possible measurements that could describe volume, intensity and frequency of training or that would identify medical problems causing poor performance. In a keynote presentation, Dr Tim Gabbett highlighted the concept of the training injury paradox.[2] This concept proposes that the training load performed by an athlete proportionally dictates adaptations. More consistent training loads (i.e., higher chronic loads) provide larger adaptations and are associated with reduced injury risk. Conversely, high acute loads which dramatically exceed chronic loads (fatigue exceeding fitness) are associated with greater injury risk in both horses and humans.[3,4] The group recognised the potential of this approach and the need to define the most relevant loads for different equestrian disciplines, the accuracy of workloads to predict injury and the relevance of different training loads to define sports demands and therefore guide training design.

3 | MOTION SENSORS, IMAGING AND REHABILITATION

A block of abstracts presented at the meeting was dedicated to the description and comparison of motion under different circumstances like water treadmill, postural stability during sedation or the comparison of sound versus ataxic horses. Scintigraphy, elastography and acoustomyography were modalities for which changes with training or injury were described. Imaging and motion sensors are likely to have a prominent and growing role in performance assessment. The investigation of kinematics has grown exponentially and defining outcomes relevant to performance and specific to discipline, the most relevant variables, and data processing methods would allow sharing and integration of data. It was discussed that imaging and advanced motion characteristics have a place as second-tier tools in the puzzle of injury prevention and assessment of poor performance.

Dr Sherry Johnson presented information about the short-term beneficial effects of blood flow restriction on local superficial digital flexor tendon muscle oxidative capacity and hydrogen peroxide release. The local changes appreciated were consistent with acute metabolic adaptations of increased mitochondrial density and an improved ability to oxidise substrate. The most useful variable to monitor during the rehabilitation of equine athletes was an area of discussion during breakout sessions. Standardisation of protocols for assessing motion and lameness, criteria to decide progressions in training, and the concept of building chronic trainings load towards the maximal acute load were discussed in this context. Additionally, the paradigm of designing rehabilitation programmes to improve both local-tissue capacity and sport-specific capacity was discussed.[5]

4 | THERMOREGULATION

Two studies described hyperthermia, effects on energy utilisation in skeletal muscle and interactions with pH. A study of continuous monitoring of thermoregulatory responses using a gastrointestinal pill in endurance horses and trotters during field exercise showed a similar magnitude of change in core temperature but different timing and large interindividual variation. Another study used respirometry to evaluate the effect of temperature, pH and a combination of both, on muscle metabolism. These studies highlighted the relevance of thermoregulation on exercise performance and particularly on energy metabolism during aerobic exercise. Due to its key role in performance, thermoregulation could receive attention beyond considerations about safety, exhaustion and welfare.

5 | CARDIAC RHYTHM

Welfare and performance implications regarding equine cardiac arrhythmias were also critically evaluated. The prediction and detection of atrial fibrillation (AF) were discussed in a series of abstracts. Dr Laura Nath presented information showing that cumulative starts, cumulative distance, cumulative prize money and prize money per start were reduced in the 90 days prior to AF identification in Thoroughbred racehorses. Horses with AF finished a greater margin behind the winner and AF was associated with higher grades of exercise-induced pulmonary haemorrhage. Age was not associated with AF, nor was there evidence for cumulative volume of exercise training. Dr Sam Franklin presented information on electrocardiographic measurements of P wave duration and dispersion (Pd). There were no significant associations found between age, sex, bodyweight, resting heart rate or years spent racing and the minimal duration of the P wave (Pmin), maximal duration of the P wave (Pmax) or Pd. However, a significant effect of exercise intensity was identified for both Pmax and Pd, with higher Pmax and Pd in exercising horses. Horses with a history of AF had significantly higher Pmax and Pd compared with apparently healthy controls. Dr Charlotte Hopster Iversen presented information showing that implantable loop recorders can be used for detection of paroxysmal AF and can be a useful tool for surveillance of horses with poor performance. A mobile application using the built-in cell phone accelerometer to detect the apex cardiac beat was described by Dr Glenn Van Steenkiste. This application was able to detect AF without any additional hardware. The method had promising accuracy, sensitivity and specificity for AF detection. This may be a useful tool for AF detection by owners.

Methods to obtain ECG at rest and during exercise were also explored and discussed. Dr Fe ter Woort[6] presented data showing that ECGs obtained using a fitness tracker had less artefact during exercise than another widely used ECG device. ECGs obtained with

the fitness tracker had the limitation of displaying only one lead and they were not obtained at racing speed. Dr Perse McCrae presented data showing that resting ECGs recorded utilising textile electrodes were of the same quality as ECGs recorded with Ag/AgCl electrodes, thus demonstrating that textile electrodes are a practical and reliable alternative to the standard electrodes typically used for equine ECG monitoring. Monitoring tools that are more user-friendly may allow clinicians and owners to obtain large numbers of ECGs that can be used for frequent clinical monitoring and research purposes. It was suggested that cardiac monitoring should complement tests for musculoskeletal disease in injury prevention programmes as these likely represent the second most common cause of death during exercise and represent a large percentage of exercise-associated deaths.[7,8] In this context and expanding to many other aspects of the exercising horse the creation of shared or opensource databases was discussed. Open-source databases have been available for decades to investigators in many fields including arrhythmia evaluation in humans and have promoted progress in science.[9,10] The logistics, privacy issues, methods of communication, standardisation, definitions, competing interests of potential users and expenses are difficulties that would need to be overcome. No consensus was achieved regarding the feasibility of this approach in equine medicine and performance, but it was considered worthwhile to invest efforts in this concept.

6 | CONCLUSION

The consensus was that technology is making performance and safety evaluations more accessible and detailed and has the potential to transform the equine industry if added to a solid understanding of the physiologic, medical and horsemanship context. Injury prevention programmes, quantification of training loads, standardisation of motion analysis, creation of databases and rehabilitation protocols emerged as areas that can take advantage of technological advances and need investigation. The format of small groups with highly motivated individuals in a retreat style proved to be ideal to achieve the goals of the workshop. The two keynote speakers actively contextualised many of the discussions and became key in discussions. Participants highlighted the quality of intellectual stimulation provided by the presentations and the interactions during 4 days the group were together in beautiful and remote mountains of Montana. The group is confident that this event will trigger future projects and collaborations that will greatly benefit the welfare and performance of equine athletes and advance the scientific understanding of the physiology and specific disorders relevant to performance horses.

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