HORSE MONITORING PROJECT AT READY STEADY TOKYO TEST EVENT August 2019

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Index

EXECUTIVE SUMMARY

Conditions during the Ready Steady Tokyo test event in August 2019 were thermally challenging, with Wet Bulb Globe Thermometer (WBGT) Index readings frequently in the region of 32-33°C. Despite this, horses coped extremely well with the conditions. The air-conditioned stables provided a temperature around 21-24°C without draughts through a fabric distribution ducting system.

The high-roofed and naturally ventilated indoor training arena provided a thermal environment that was between the stable conditions and the outside conditions. The WBGT Index in the indoor arena never exceeded 29°C, even when exterior conditions reached ~35°C WBGT. All horses remained in good health for the duration of the event.

On cross country day (13 August), the high WBGT Index, steep initial climb and sharp turns on the course produced a significant challenge for competing horses. Heart rates during cross country and blood lactate, heart rate and rectal temperature after cross country indicated that horses were working at close to maximal capacity.

All possibilities must be explored to mitigate the effects of the likely climatic conditions, including reduction in distance appropriate for the conditions and bringing the cross country start time forward to avoid the highest WBGT conditions that would normally peak between late morning and mid-afternoon.

As the WBGT Index readings recorded by the Tokyo Organising Committee of the Olympic and Paralympic Games (TOCOG) and the FEI showed some discrepancies due to differences of location and technology, consideration is required as to what WBGT measurements will be used for Games management decisions.

Horses exercising at maximal intensity at WBGT Index values over ~30°C are at increased risk of early fatigue, errors, falls, injuries and heat-related illness. Historic record analysis and onsite data collection show that very high values of WBGT Index are frequently reached between 11:00 and 12:00 in Tokyo during the Games period. Competition and training schedules have been set to reflect this. However, the cross country at Sea Forest (SFC) is currently scheduled to end at approximately 12:00 and clearly it would be extremely advantageous for horse and athlete welfare if it could be completed by 11:00.

Two innovative monitoring devices were tested during the event. The first of these was a new device from Polar which allows vets to obtain a horse's heart rate rapidly and very accurately but also displays the ECG. This technology was found to be very easy to use, reliable and could be considered for use by teams during the Tokyo 2020 Olympic Games.

The second technology that was used was infra-red thermal imaging (thermal cameras/thermography) as an aid to vets and stewards through monitoring skin surface temperature. In thermally challenging conditions it can be easy for horses to become over-heated and a horse may rapidly go from being alright to at risk of heat exhaustion or heat stroke.

Thermal imaging is a non-invasive, non-contact technology that allows the surface temperature of exercising horses to be measured at a distance of up to 15 metres. As a result of making comparisons between surface temperatures of horses and their rectal temperature, we found that with the correct protocol, thermal cameras can be used to provide a rapid and accurate estimate of a horse's rectal temperature. Consideration of how this technology may be deployed during Tokyo 2020 is currently underway.

Key elements to ensuring both health and performance in a thermally challenging environment such as could be experienced during Tokyo 2020 are:

- Ensuring horses are in good health before travel
- Ensuring horses are fully fit to compete
- Allowing sufficient time to recover from travel
- Implementing measures to minimise risk of over-exerting horses in the most thermally challenging conditions
- Modifying training and warm-up to ensure horses do not become too hot
- Using aggressive cooling techniques

While the purpose of this report is not to make recommendations but to deliver scientific data based on which recommendations can be made by the relevant bodies, there are still some recommendations contained within it which are already being actioned.

This report covers four areas relating to the Ready Steady Tokyo 2019 test event:

- General monitoring of horses before & during the test event
- Detailed cross country analysis
- Polar equine Healthcheck app & sensor evaluation
- Feasibility of infra-red thermal imaging to estimate rectal temperature

(1) GENERAL MONITORING OF HORSES BEFORE & DURING THE TEST EVENT

SUMMARY
The environmental conditions experienced during the test event were consistent with historical data and onsite measurements made by the Tokyo Organising Committee of the Olympic Games (TOCOG) during the past three summers. The air-conditioned stables and the naturally ventilated indoor arena functioned as anticipated and specified. The monitoring was, to a certain extent, incomplete but this was to be expected as the primary focus for participating National Federations (NFs) was to test the facilities, collect their own data and test their own processes. However, sufficient information was obtained to show that horses coped well with the conditions and climate mitigation protocols.

BACKGROUND
A draft outline proposal to monitor horses taking part in the test event was approved by the FEI and a detailed proposal prepared and submitted in May 2019. Direct interaction with participating NFs, TOCOG and the Japan Racing Association Equine Research Institute began in late June 2019.

PARTICIPATION
Germany – 3 horses from Europe (international)
Great Britain – 2 horses from Europe (international)
Australia – 1 horse from Europe (international)
Japan – 6 horses from Europe (international)
Japan – 5 horses from Japan (national)

PARTNERS PROVIDING EQUIPMENT
The following companies provided equipment free of charge:

- Handheld ECG and heart rate monitors – Polar (FIN)
- Thermal comfort and activity sensors (stable) – Orscana, Arioneo (FRA)
- Activity sensors (gait, duration of exercise etc) – Equestic (NED)
- Heart rate, speed and stride sensors (exercise) – Equimetre, Arioneo (FRA)
- Transport temperature monitoring – Epona Biotec (AUS)

RESULTS

Environmental Data

Kestrel 5400 Heat Stress Trackers set to record an average of the shade temperature, relative humidity, black globe temperature and WBGT Index every 10 minutes (i.e. an average of all readings over the previous 10-minute period) were positioned in the main venue stables, in the indoor training arena and in the main competition arena. On cross country day, the unit in the stables was moved to the temporary stables at Sea Forest (SFC) and the unit from the main arena was moved to the cross country course.

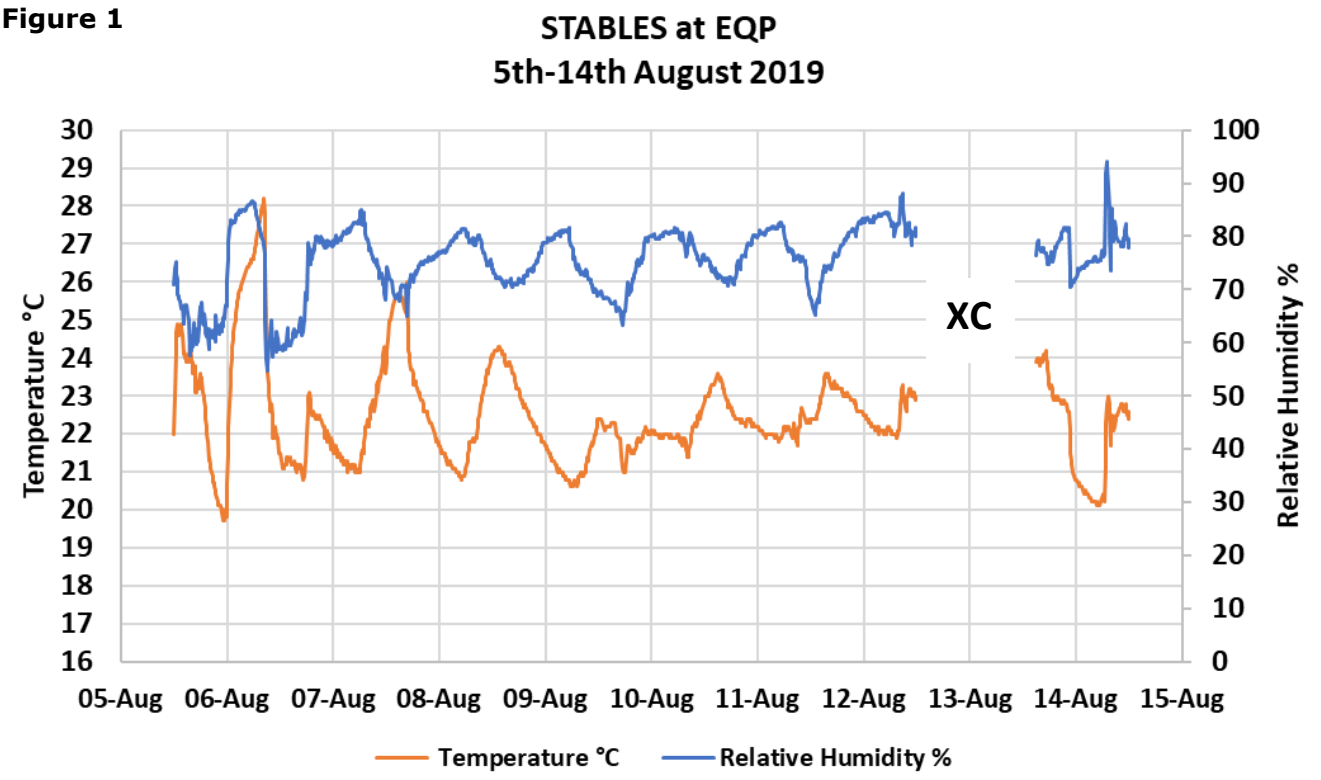
Stables at Bajikoen Equestrian Park (EQP)

Conditions in the stables were constantly monitored for the duration of the test event and for around 48 hours prior to the arrival of the international horses (Figure 1).

Even with limited entry and exit of the stables, the internal conditions were influenced by external environmental conditions. That is, as the external temperature increased from sunrise, so the internal temperature rose and humidity fell, with the pattern reversing in the evening and overnight. The coolest stable temperatures were recorded just before sunrise. The change in temperature was around 5-6°C.

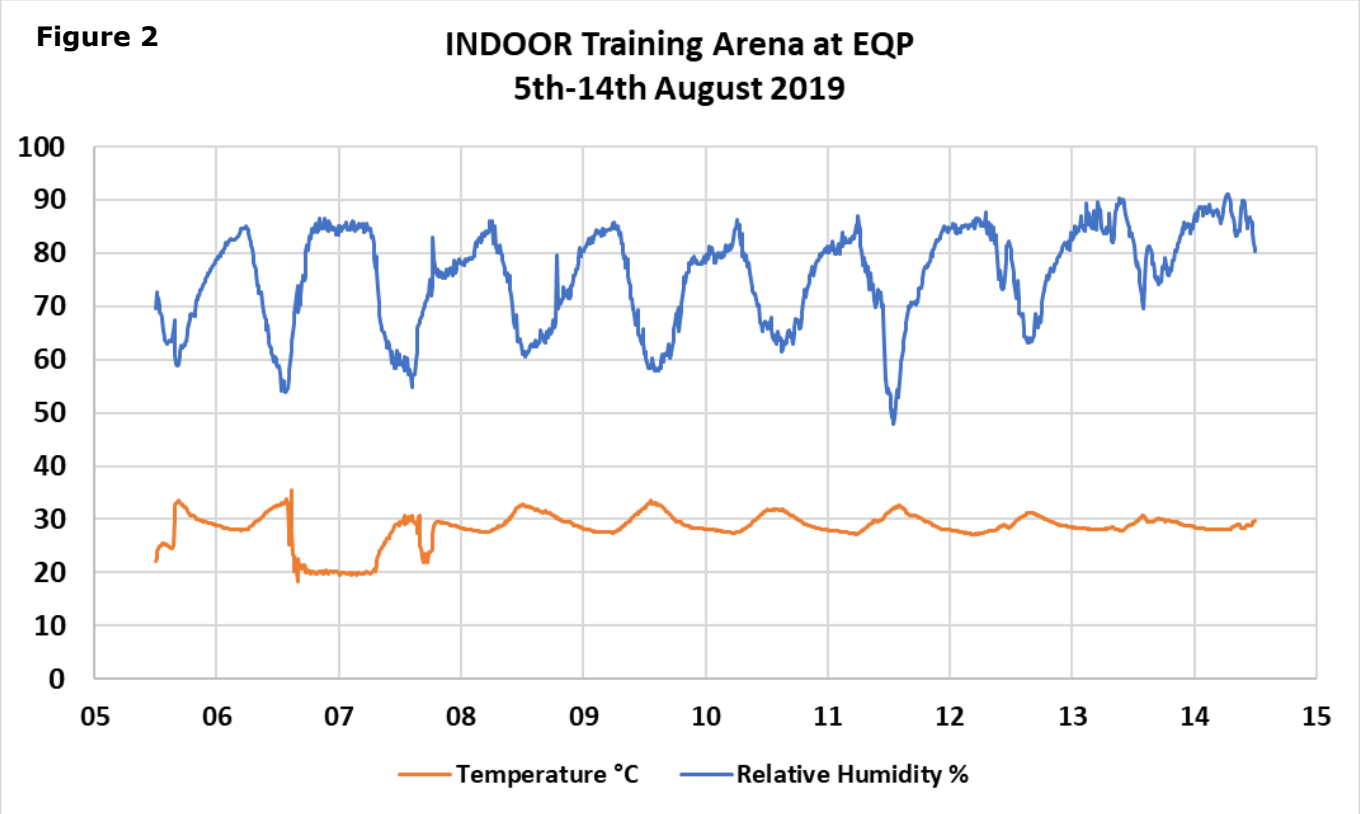
With the arrival of horses on 7 August, the air-conditioning system was set to maximum in an attempt to provide a constant temperature around 23°C. In order to achieve this, additional ventilation was provided by removing a number of the outlet "cones" on the overhead air distribution ducting. This stabilised the temperature between 21°C and 24°C. With more horses in each block and with more movement in and out during the Games, further adjustments to the air-conditioning are likely to be required.

Figure 1



Indoor Training Arena

The naturally ventilated, non-air-conditioned indoor training arena provided a significantly less thermally stressful environment in which to train horses during the day, with WBGT ranging between 26 and 29°C compared with 27-37°C WBGT in the outdoor main arena. The temperature and humidity in the indoor training arena over the course of the test event are shown in Figure 2 (below). Peak WBGT in both the indoor arena and main arena was typically observed during the middle of the day.



Main Arena

The monitoring unit for the main arena was placed in a corner which received full sunlight all day from sunrise and which was also shielded from wind and in an area which received heavy irrigation. As such, these conditions were some of the worst that might be expected, with WBGT values peaking temporarily as high as 37°C, but typically around 34-36°C during the hottest part of the day (Figure 3).

Comparable values on the training arenas and training tracks may have been 2-3°C lower. However, this still represents a very high level of thermal stress, at the top end of what has been experienced at previous major championships. The locally measured micro-climate data is higher than but consistent with the TOCOG supplied WBGT data (Figure 4).

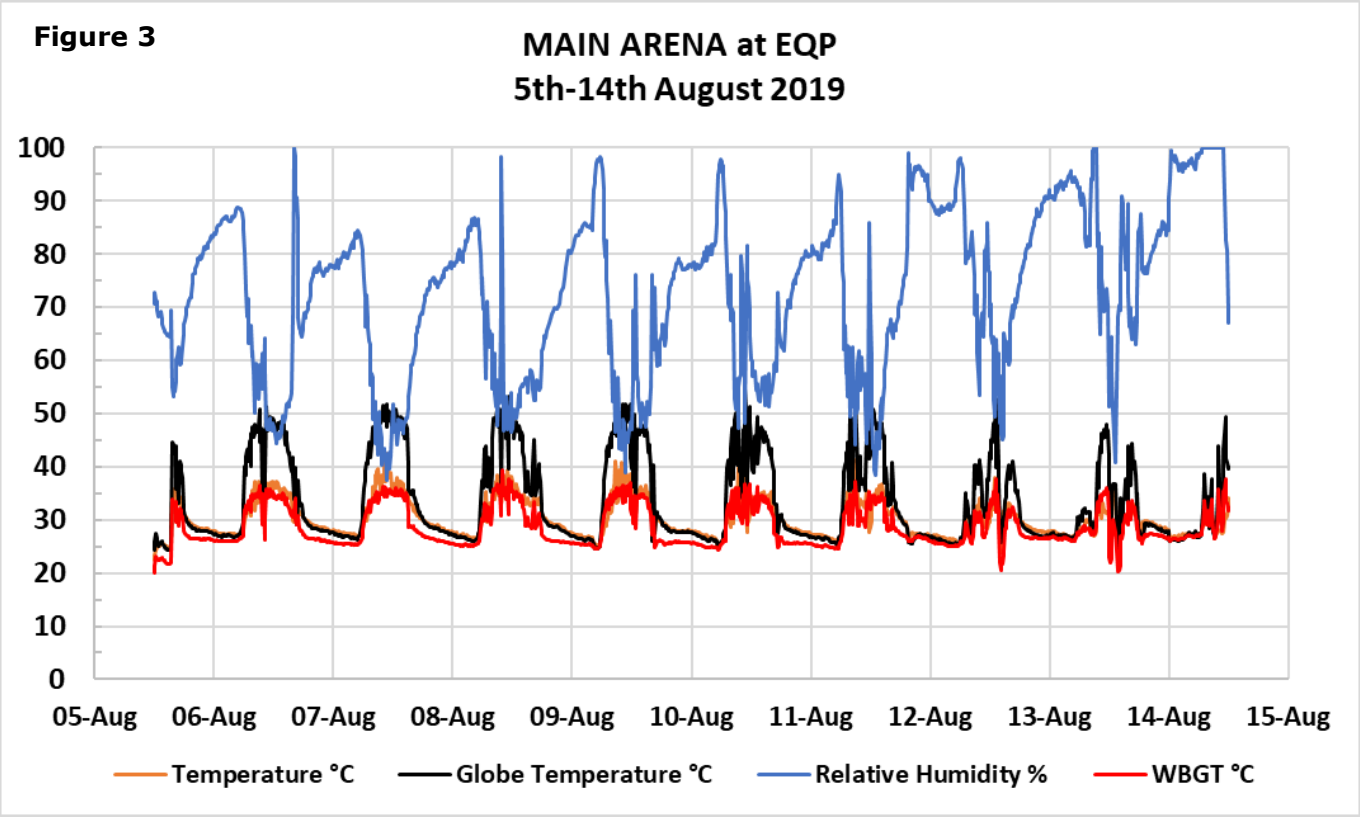
The Kestrel unit in the main arena was positioned in a corner receiving full sunlight from sunrise and was sheltered on two sides, limiting air movement. In addition, humidity was artificially increased in the arena due to footing irrigation.

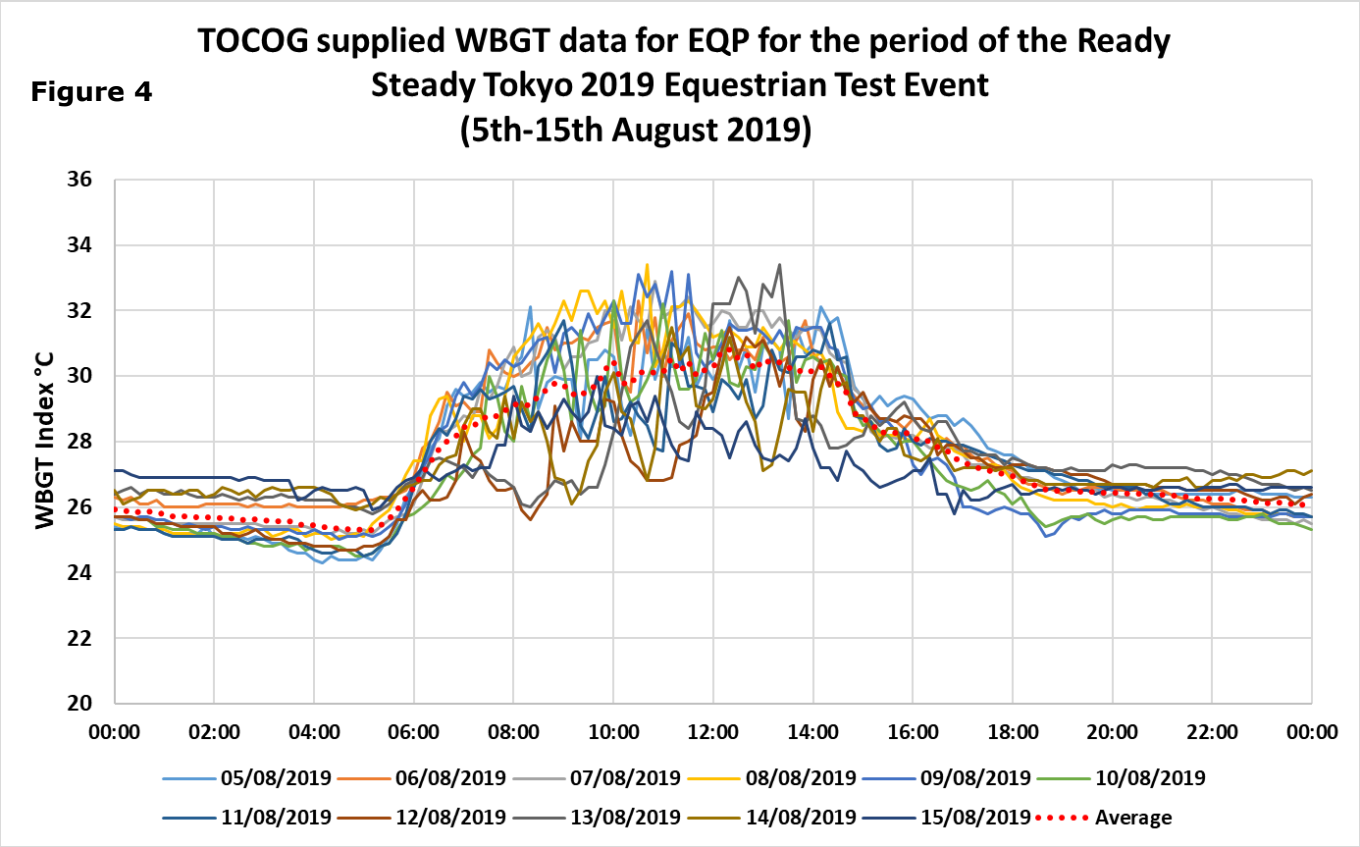
The TOCOG unit was positioned away from the main arena on the opposite side of the road in a compound just outside the venue.

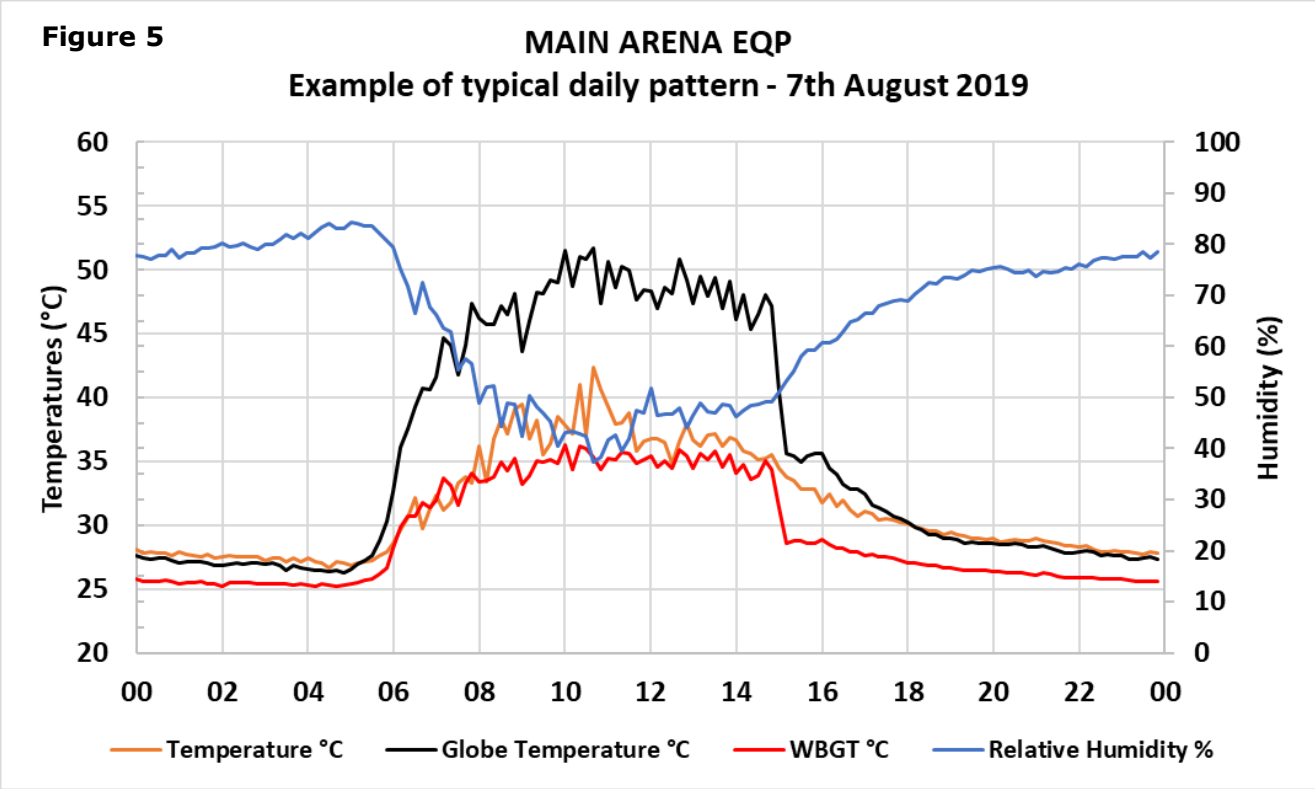
The combination of different physical locations and technical specifications of the two systems explains the small differences in absolute WBGT readings.

Consideration is required as to what WBGT measurements will be used for Games management decisions (e.g. TOCOG equipment or FEI supplied equipment).

An example of the detail over the course of a typical day from readings taken in the main arena is shown in Figure 5.

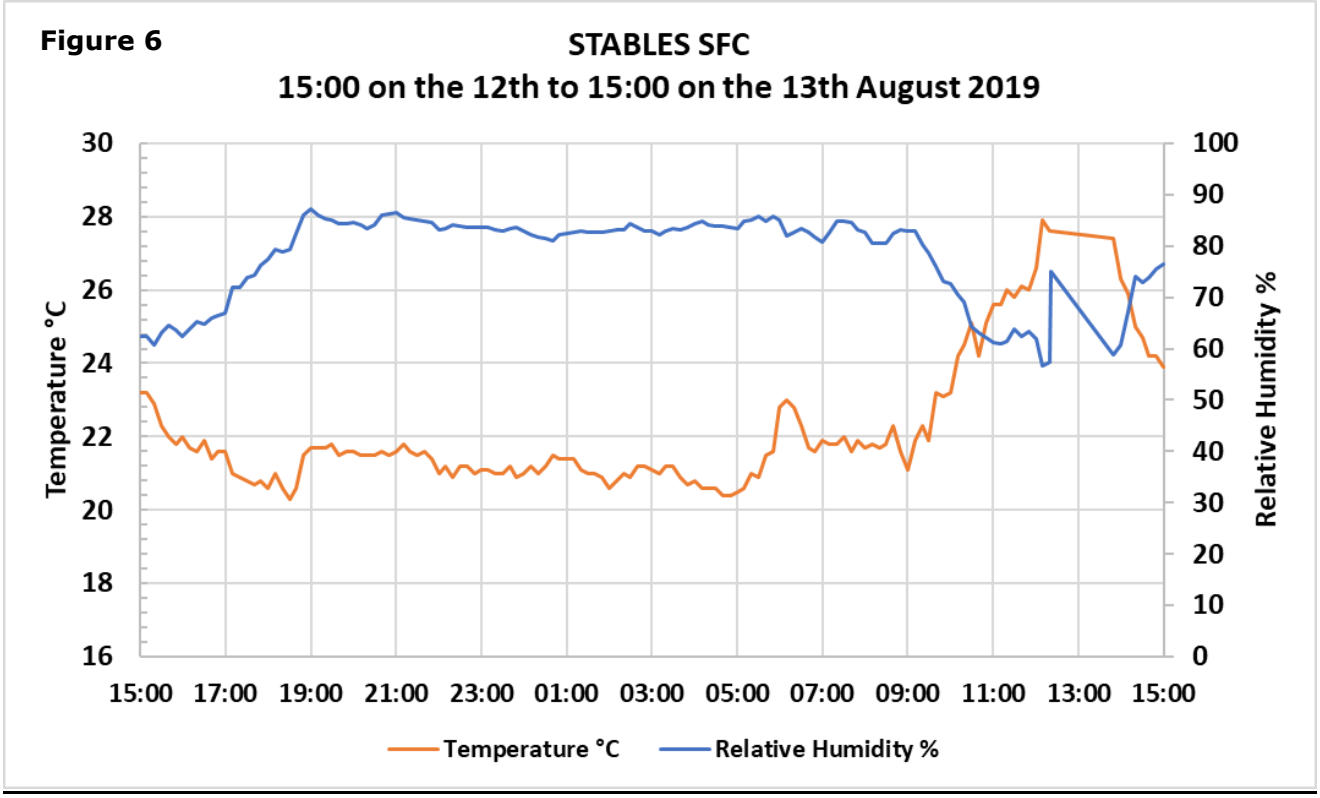






Stables at Sea Forest (SFC)

The temporary stables at SFC ran at a similar humidity but a slightly lower temperature (~21°C) than the stables at Bajikoen (~23°C), see Figure 6. The air-conditioning at SFC could not maintain a constant temperature on the morning of cross country. This was most likely due to the high number of horses and personnel movements in and out. The FEI and TOCOG are working on a solution to this issue. In addition, the venting of the air-conditioner outlets was directly onto some stables/horses and this is not desirable. Some teams chose to switch off units where the airflow was direct on to horses. Deflector plates should be installed to direct airflow up so that horses are not exposed to direct airflow. TOCOG are proposing solutions to this problem.



Cross country course at Sea Forest (SFC)

The monitoring unit was positioned on the grass in an open and well-ventilated area close to fence 15. WBGT index was stable around 35°C during the period of the cross country (Figure 7). This compares with ~32-33°C as measured by the TOCOG station on the highest point of the course (Figure 8).

Figure 7

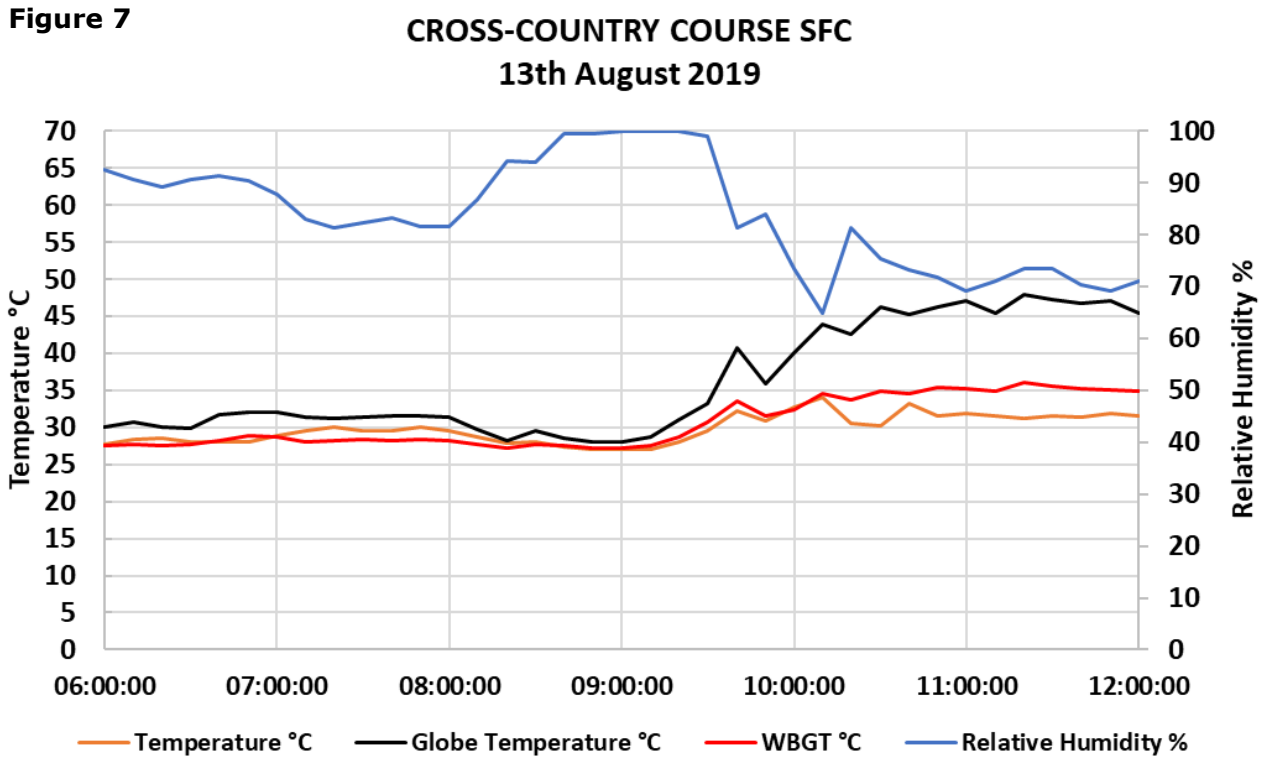
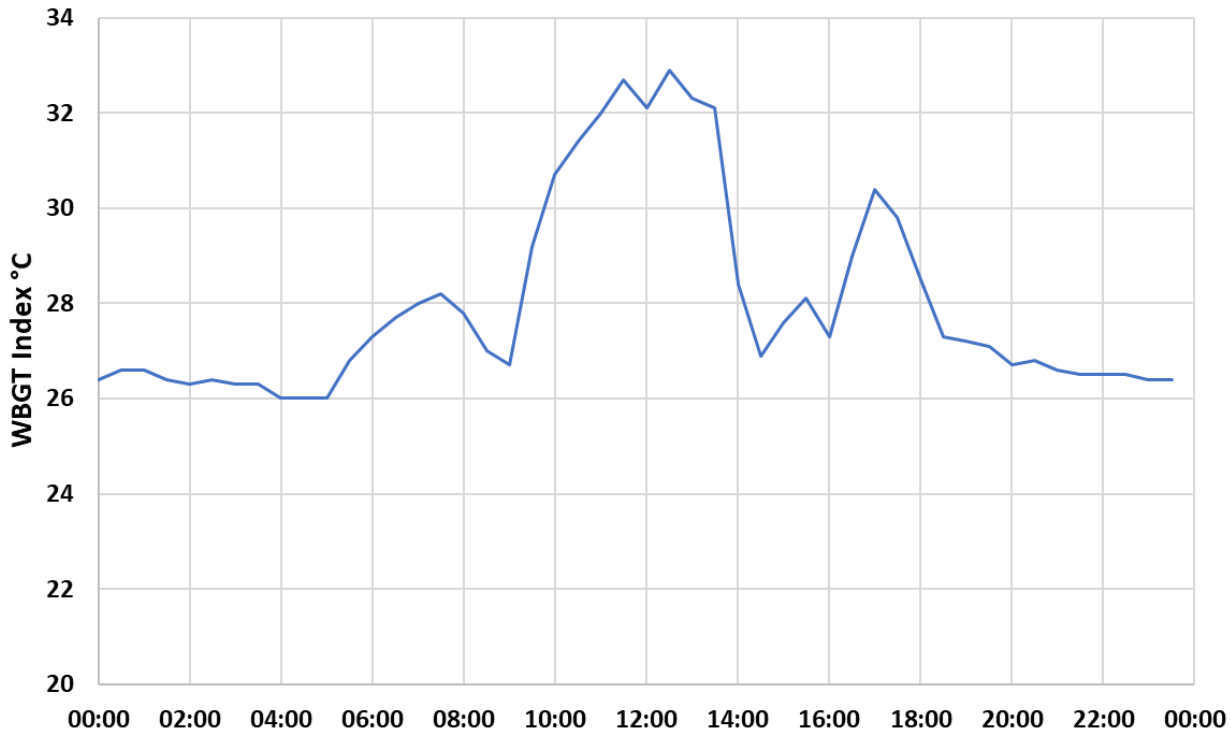


Figure 8 WBGT TOCOG supplied data 13th August 2019 (cross-country) for SFC



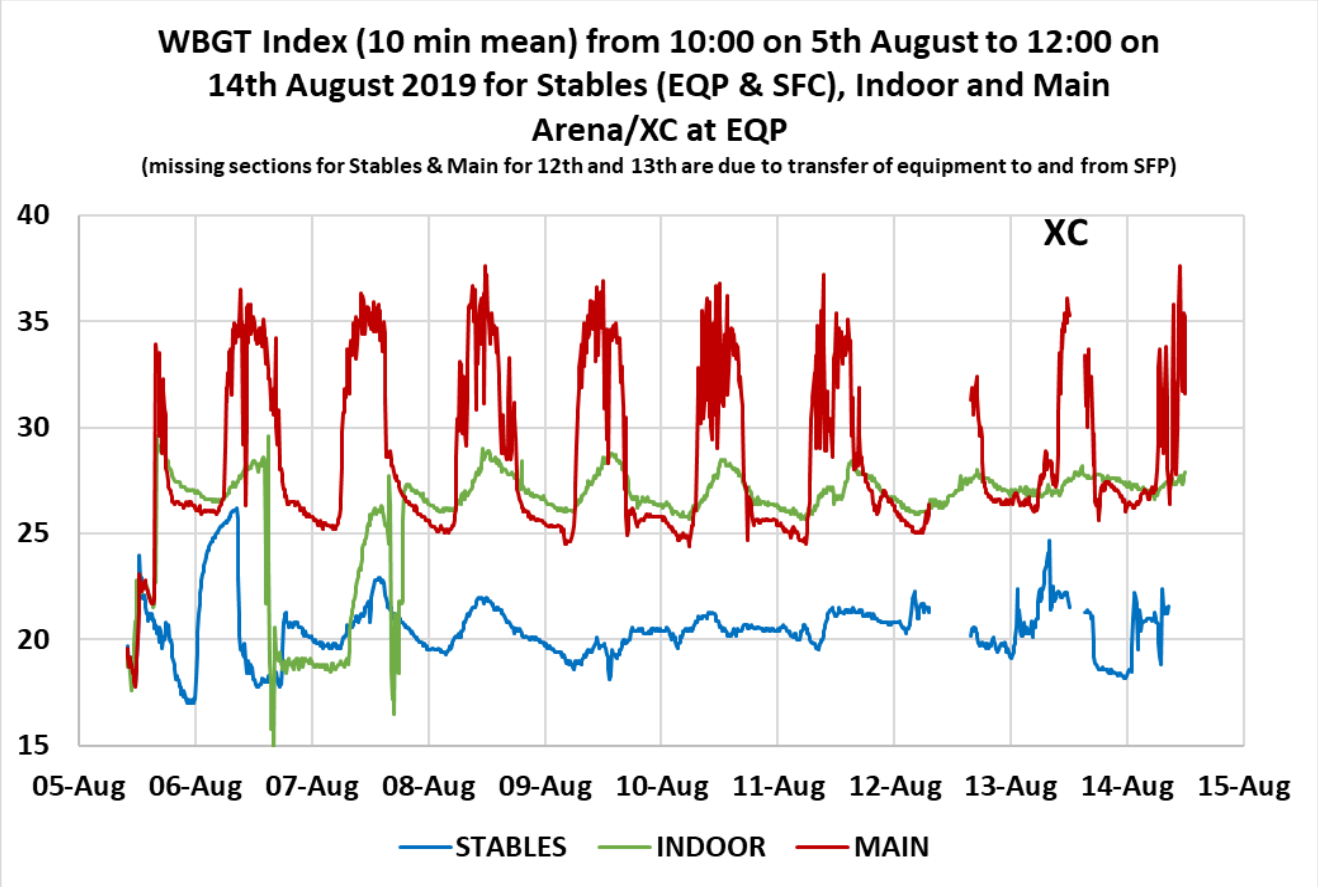
Environmental data summary

The measurements made on site during the test event were consistent with measurements and analysis of historical records for both Bajikoen and Sea Forest. The stables provide a comfortable environment for horses to recover from travel, training and competition with a target temperature of ~23°C, just below the upper limit of the horses' thermoneutral zone (~25°C).

During the day, especially between 07:00 and 16:00, the indoor arena provided a significantly less thermally stressful environment in which to train/warm-up.

A comparison of the WBGT Index in the stables at Bajikoen and Sea Forest, the indoor arena, main arena and cross country course at Sea Forest is shown in Figure 9.

Figure 9



Daily diaries

The following variables were requested to be recorded in the morning and evening over a 21-day period starting around seven days before travel: rectal temperature, respiratory rate, heart rate, behaviour, appetite, thirst, urination, droppings, cough, nasal discharge, any other comments. Rectal temperature was slightly elevated on arrival but thereafter was in the expected range. Respiratory rate averaged between 13 and 22 breaths per minute throughout the period of the test event. Average heart rates were between 32 and 43 bpm.

The following observations were made on the international horses only. Behaviour score was primarily reported as normal, with 60% of horses being reported to be "slightly depressed" around the time of travel. Thirst score was reported to be "normal" for the majority of the monitoring period, with 65% of horses having a "slightly reduced" thirst on 12 August (Dressage). No data was reported for cross country. 50% of horses were reported to have a "slightly increased" thirst on 14 August (Jumping). Urine appearance and dropping appearance were both generally considered "normal". Only a few isolated instances of "occasional" cough were reported.

In summary, daily diary information gave no cause for concern over health or welfare. Only minor disturbances were observed and these were primarily related to the post-transport period, as expected.

Weight diaries
Pre-travel weights were provided for only five international horses. The average bodyweight loss as a result of the flight was 2.4% for these horses.

Using the permanent weighbridge sited at Bajikoen, the mean daily weight loss as a result of exercise was -4.8kg ±4.4kg (range +5.5 to -12.5kg). Weighing was not possible before and after cross country at Sea Forest as no weighbridge was available there.

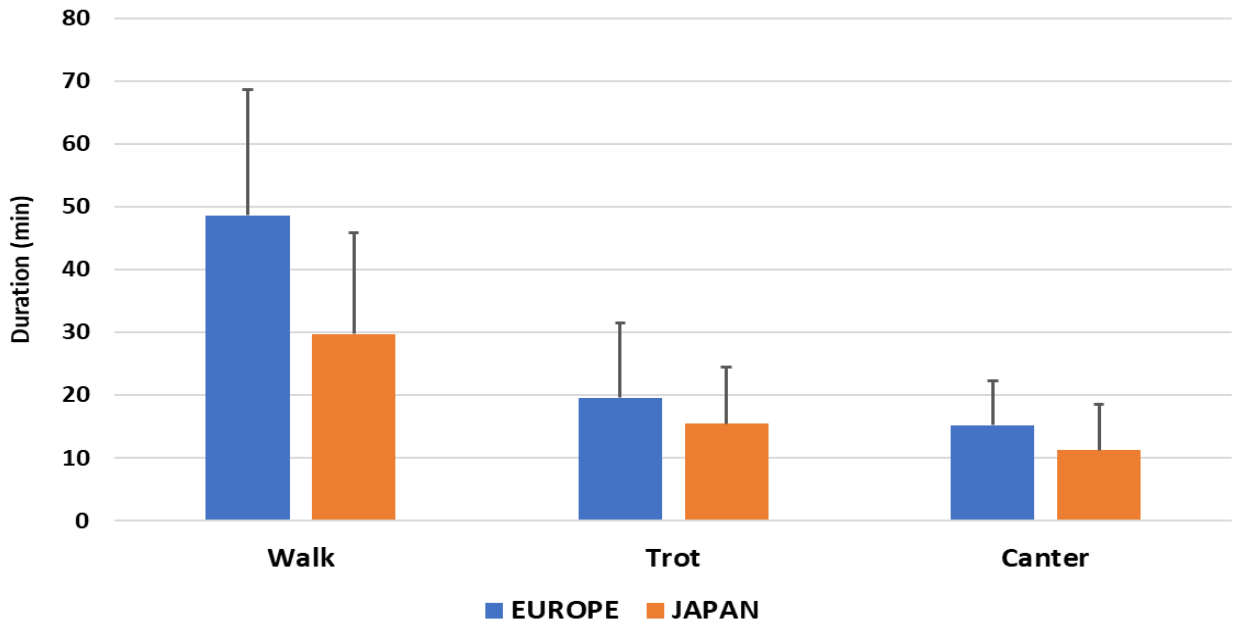
Horses maintained their bodyweight, either expressed as their pre-travel weight or post-arrival weight, with no evidence that horses were losing weight during their time in Tokyo.

In summary, weight loss as a result of exercise was not excessive (maximum recorded loss = 12.5kg) and horses maintained their bodyweight.

Blood analysis
Blood samples were taken from all international horses (n=12) within an hour of arrival at the stables (7 August), early morning before exercise on the day of the first horse inspection (11 August) and early morning before exercise on the day after the completion of the competition (15 August). The results from the blood testing were entirely consistent with travel and exercise in fit Eventing horses.

Monitoring of daily training (Equestic Saddle Clip)
Eight athletes used the Equestic Saddle Clips and 70 rides were recorded, with a total average ride time of 52.8±0.9 minutes. A similar number of rides were recorded in Europe (n=36) and in Japan (n=34). The average ride time in Europe (53.2±21.5 min) tended to be longer than in Japan (46.1±23.2 min), see Figure 10.

Figure 10 Average duration of time spent in Walk, Trot or Canter for International horses at home in Europe or in Japan (mean±SD)



Monitoring of stabled thermal comfort & activity (Orscana, Arioneo)
Teams did not use rugs or flysheets on horses when stabled at Bajikoen with the exception of one or two horses on some occasions. A small amount of data was obtained from several horses before travelling. The data obtained was unfortunately insufficient to analyse or draw any conclusions.

Monitoring during competition (Equimetre, Arioneo & Polar)
Teams elected to use either the Equimetre system or the Polar heart rate and GPS system.

(2) DETAILED CROSS COUNTRY ANALYSIS

Summary
This section of the report considers the environmental conditions (WBGT Index) during the test event, the overall effort of the test event cross country course and the track for 2020 and the physical responses of the horses to the cross country.

The thermal conditions were challenging. WBGT Index exceeded 32°C throughout.

The course on its own, excluding any comment on the technical nature of the fences, was only 10% harder than a totally flat course. However, the climb at the start and the five relatively sharp turns contributed to an increased effort compared with a course with less tight turns. It is estimated that the test event course would have placed as much demand on competing horses as a flat course around 40% longer with fewer sharp turns in cool conditions.

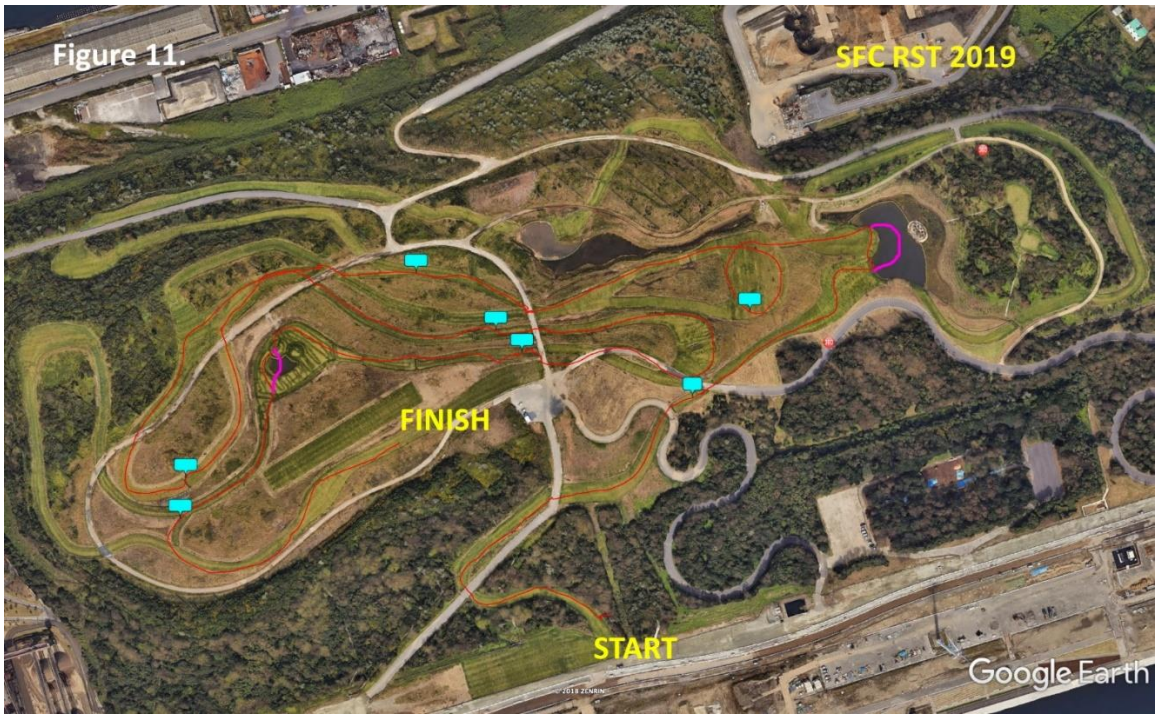
The heart rates during cross country, and the heart rate, rectal temperature and blood lactate levels following cross country are all consistent with intense, near maximal exertion. The heart rate during cross country is considerably higher than previously seen during Eventing competitions up to 5* (formerly 4*) level, but consistent with heart rates during and post-cross country at the Athens Olympic test event in 2003.

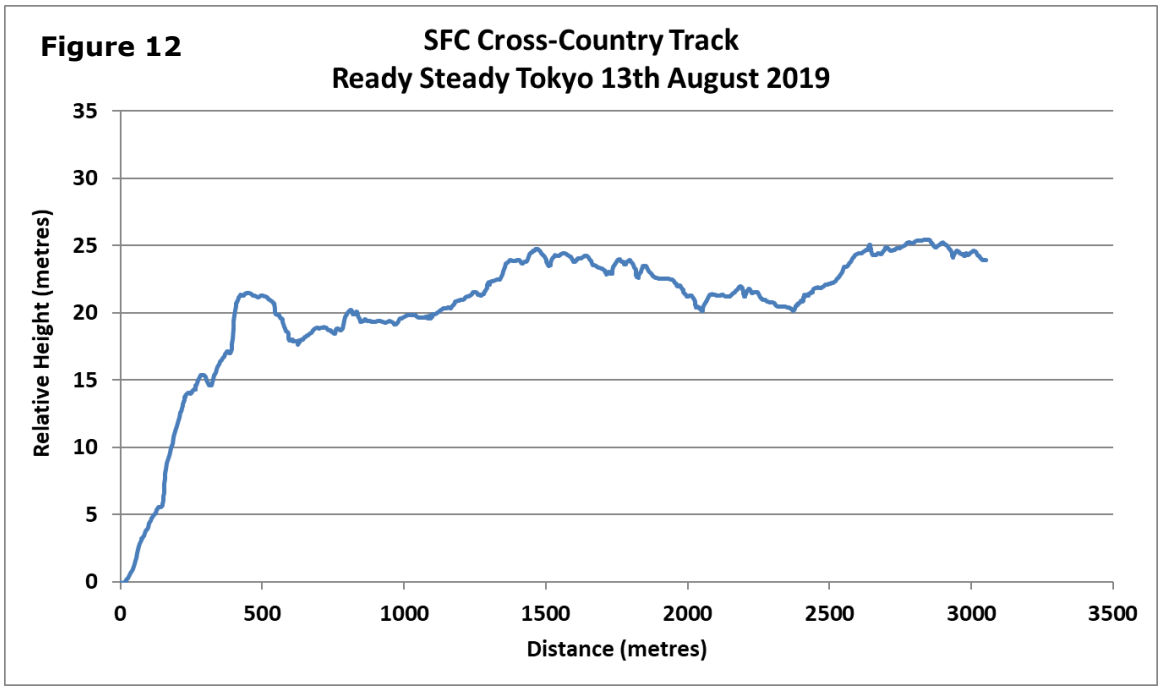
In conclusion, this course in these conditions represented a very intense physical challenge to the group of horses that competed. A significantly longer challenge in similar environmental conditions, albeit with fitter and higher ability horses, is likely to result in much increased potential for major heat-related issues.

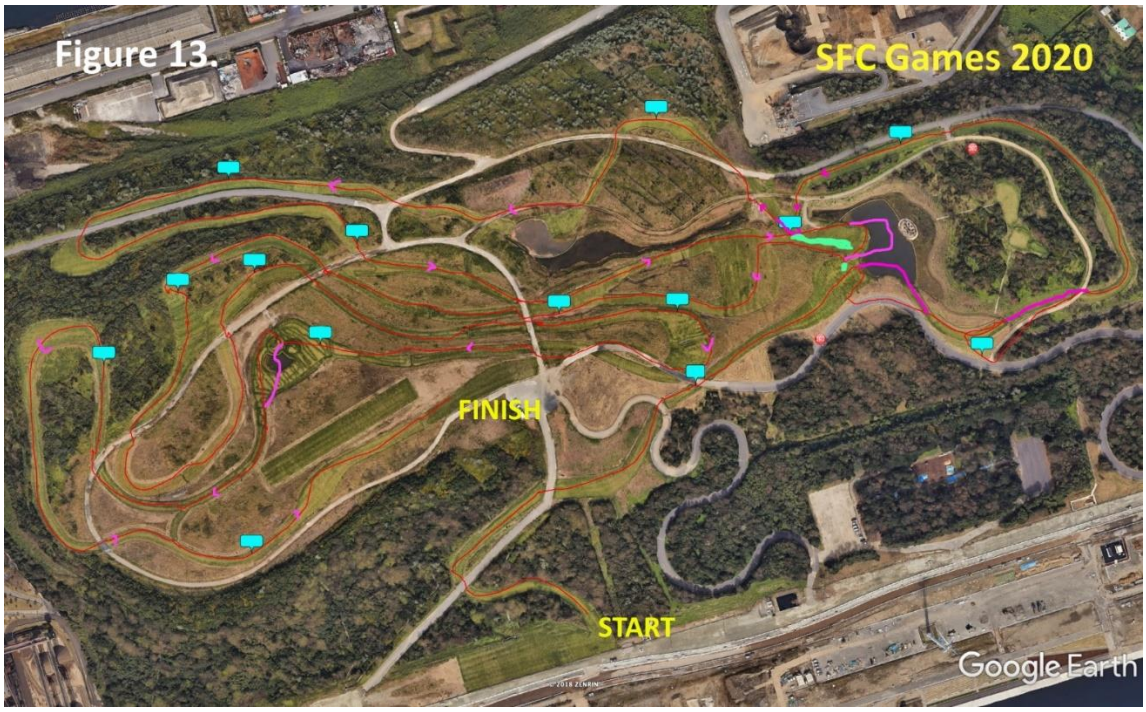
All possibilities must be explored to mitigate the effects of the likely climatic conditions, including reduction in distance appropriate for the conditions and bringing the cross country start time forward to avoid the highest WBGT conditions that would normally peak between late morning and mid-afternoon. As a result, the track for 2020 is currently being re-evaluated.

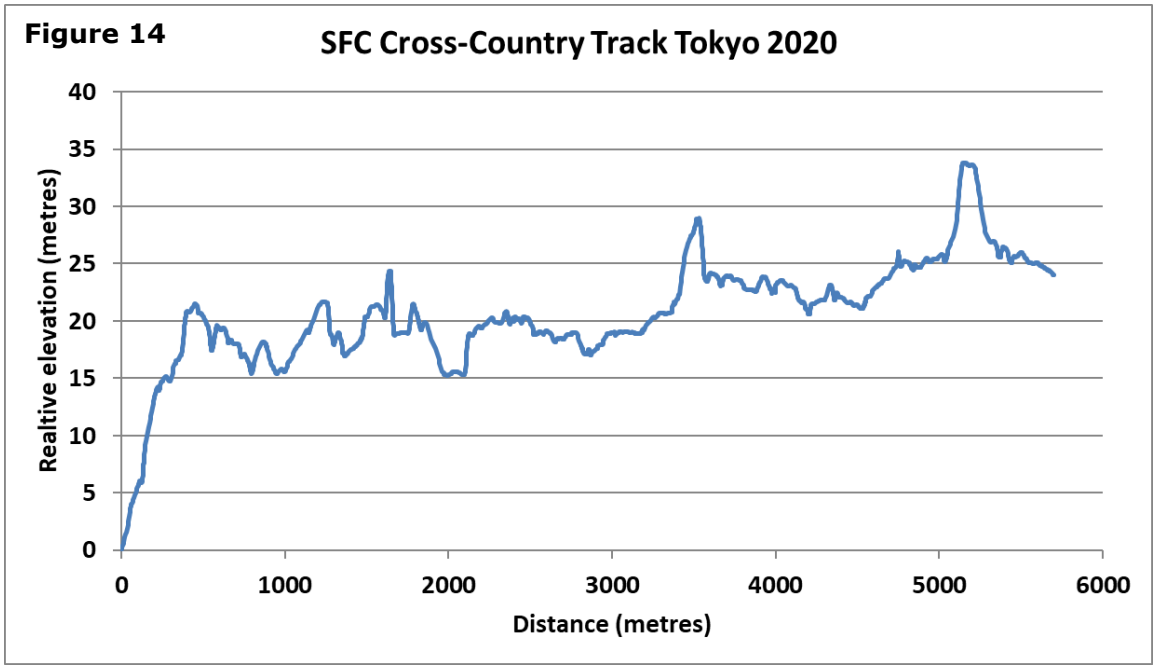
CROSS COUNTRY COURSE ANALYSIS

Professor Lars Roepstorff (SWE) provided detailed information from a GPS survey of the 2019 test event course (Figures 11 & 12) and the 2020 Games tracks (Figures 13 & 14) immediately following the cross country on 13 August 2019. The figures below show distance and elevation.









The overall effort of each course was calculated using the approach as published by Schroter and Marlin (Equine Vet J Suppl 34 2002 397-401) and first used to make decisions on cross country course length at the Atlanta 1996 Olympic Games.

The length of the Tokyo 2019 test event cross-country was 3,050 metres with a speed of 550m/min. The rules for the Olympic Games normally define a course of 5700m at 570m/min. The calculated increase in effort due to the terrain (uphill and downhill gradients) for the whole course is +13% for 2019 and +6% for the Tokyo 2020 track. This has already resulted in an initial re-evaluation of the track for 2020.

To put the expected effort in context of previous course measurements, this has been compared with the analysis undertaken for Atlanta 1995 and 1996 and for long format cross country courses done at the same time (Figure 15). It is possible to analyse any course to make a comparison if we have the distance and elevation data. This analysis shows that a 5,700 metre track as originally proposed would be similar in effort to 1995 long format 3* events at Bramham (GBR) or Blenheim (GBR).

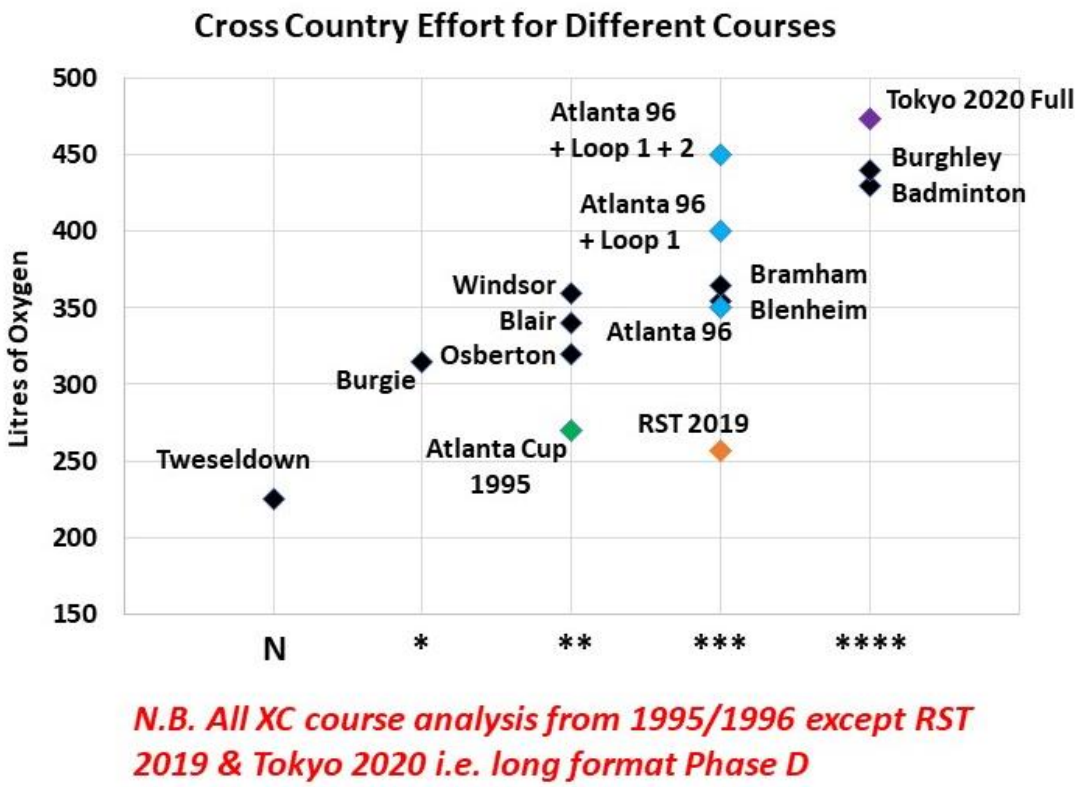
We can also estimate that the previously planned Tokyo 2020 full track at a WBGT of 28-32°C would be around 22-35% more effort than the same track in cool conditions (maximum WBGT of 20-23°C). Tight turns will also increase energy expenditure. We currently do not have good data to calculate this but a conservative estimate could be +5%.

As an estimate, a 5,700m track as originally proposed with a WBGT index of ~30°C would be around 40% harder (climate ~30% + terrain ~6% + turning ~5%) than the same distance over flat terrain with gentle turns in cool conditions, i.e. it would ride more like a course of ~8,000m.

Similarly, the 2019 test event track, whilst only 3,050 metres in length, would have ridden around 45% harder (climate ~30% + terrain ~10% + turning ~5%) than the same distance over flat terrain with gentle turns in cool conditions i.e. it would ride more like a course of ~4,400m.

Horses exercising at maximal intensity at WBGT Index values over ~30°C are at increased risk of early fatigue, errors, falls, injuries and heat-related illness. Historic record analysis and onsite data collection show that very high values of WBGT Index are frequently reached between 11:00 and 12:00 in Tokyo during the Games period. Competition and training schedules have been set to reflect this. However, the cross country at Sea Forest (SFC) is currently scheduled to end at approximately 12:00 and clearly it would be extremely advantageous for horse and athlete welfare if it could be completed by 11:00.

Figure 15



NB: RST in the above chart refers to Ready Steady Tokyo 2019 test event.

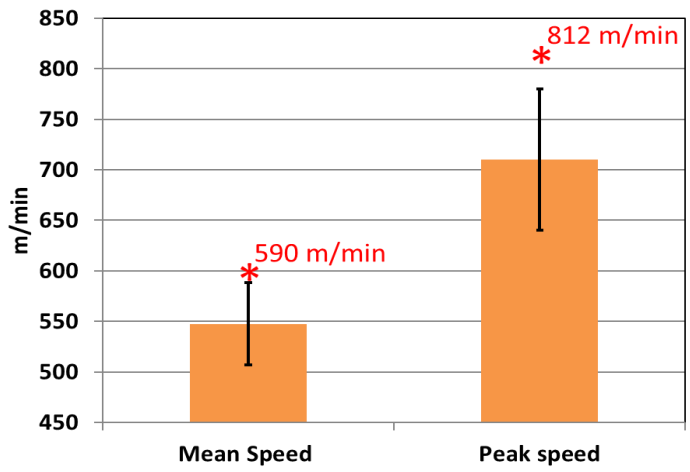
CROSS COUNTRY HORSE PHYSIOLOGICAL RESPONSES

The data on horse physiological responses to cross country has been reported elsewhere, but the data for heart rate during and following cross country, blood lactate levels following cross country and temperature and heart rate is included here for reference.

Speed on cross country

The speed for cross country was 550 m/min. Over the track of 3,025 metres this gave an optimum time of 5:30 minutes. Figure 16 summarises data from 11 horses fitted with GPS. Seven of the 16 horses that competed finished the course with no time penalties. The bar height represents the average (mean) values and the vertical black line represents plus and minus one standard deviation of the average (mean±SD). This means that 95% of the measurements are between the top and the bottom of the vertical black line. The red asterisks show the highest individual values recorded.

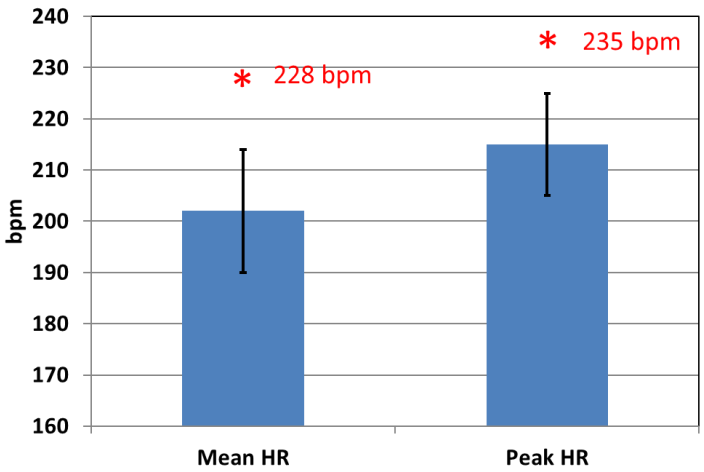
Figure 16



Heart rate on cross country

The mean (±SD) and mean peak (±SD) heart rates for 12 horses are shown below (Figure 17). This excludes two horses for which the data was lost and two horses that did not to wear heart rate monitors on cross country. The red asterisks show the highest individual values recorded.

Figure 17



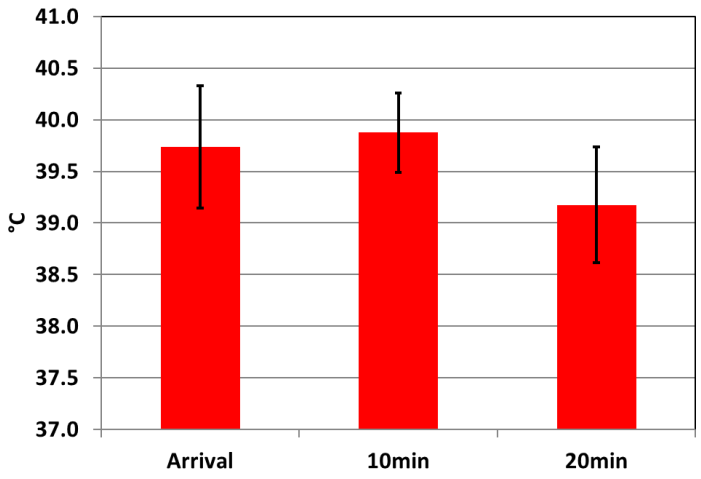
Blood lactate

Samples for blood lactate were collected at 10 minutes post-cross country from 16 horses. Median blood lactate was 10 mmol/l (range 1.5-18.6 mmol/l).

Rectal temperature after cross country

Rectal temperature (mean±SD) was recorded in all 16 horses on arrival at the cooling area and after 10 and 20 minutes (Figure 18). The highest recorded temperature on arrival was 40.9°C.

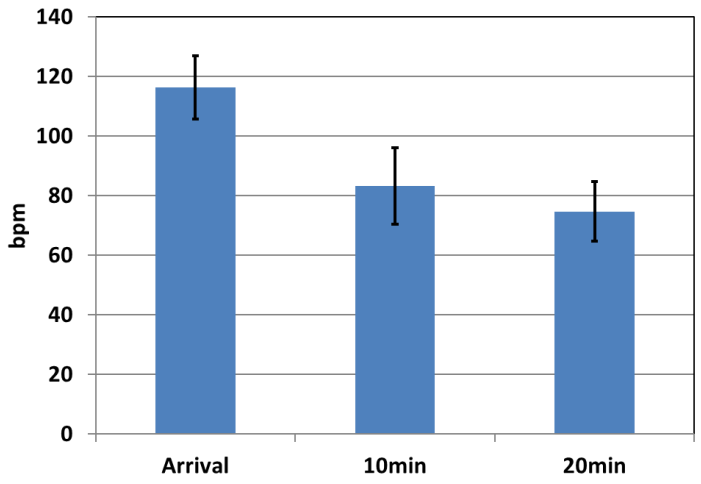
Figure 18



Heart rate

Heart rate (mean±SD) was recorded in all 16 horses on arrival at the cooling area and after 10 and 20 minutes (Figure 19).

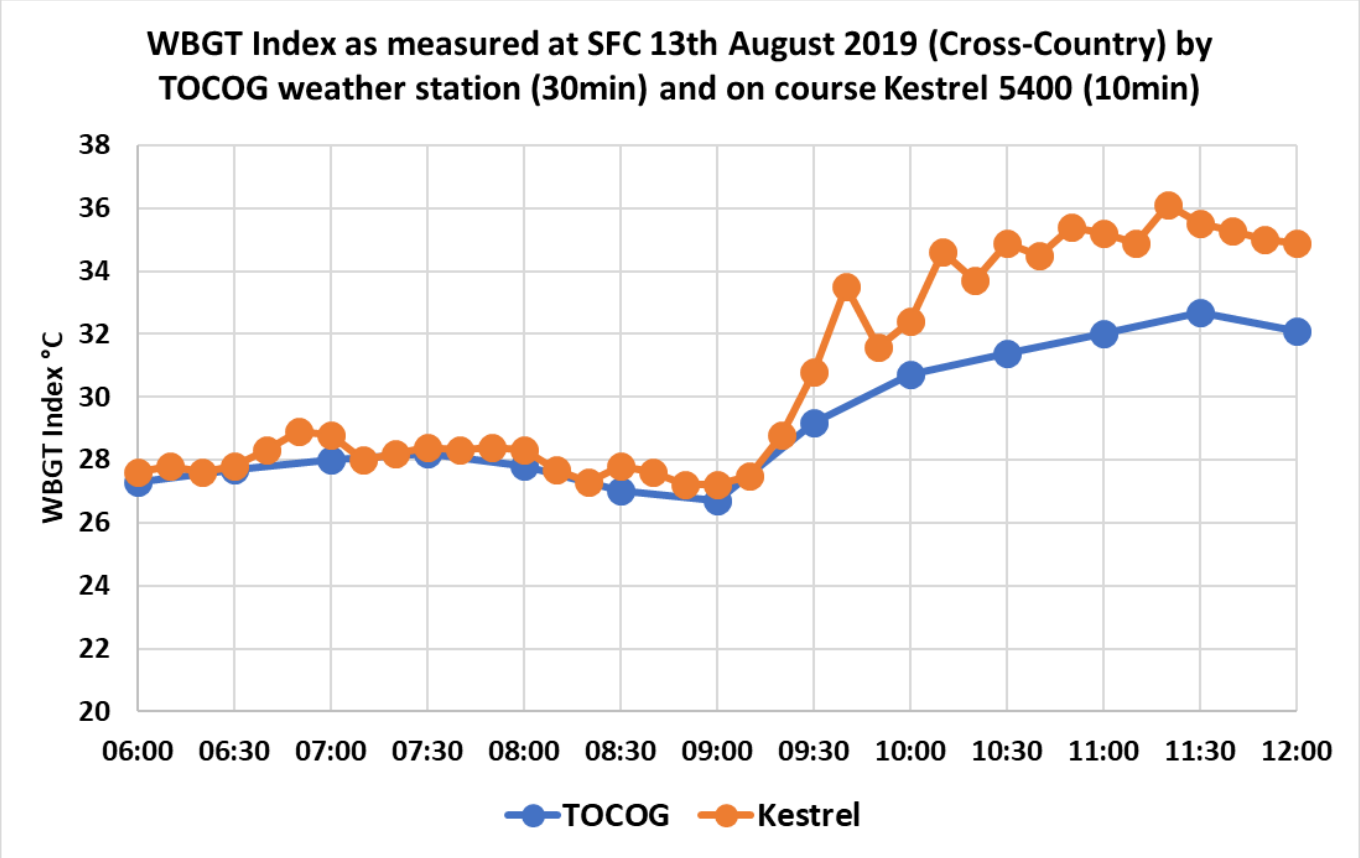
Figure 19



CROSS COUNTRY ENVIRONMENTAL CONDITIONS

The TOCOG station reported WBGT readings every 30 minutes, whilst the FEI's Kestrel 5400 station reported WBGT every 10 minutes (Figure 20). The two stations gave similar readings until 09:00 when the weather was overcast with light rain. When the weather cleared and the sun came out, the two stations gave a similar trend but different absolute readings. This may be due to the different averaging periods, the different locations of the stations, the height of the sensors above the ground and the different physical structure and configuration of the equipment. However, previous experience allows us to conclude that these conditions were severe i.e. WBGT in the range 32-34°C.

Figure 20

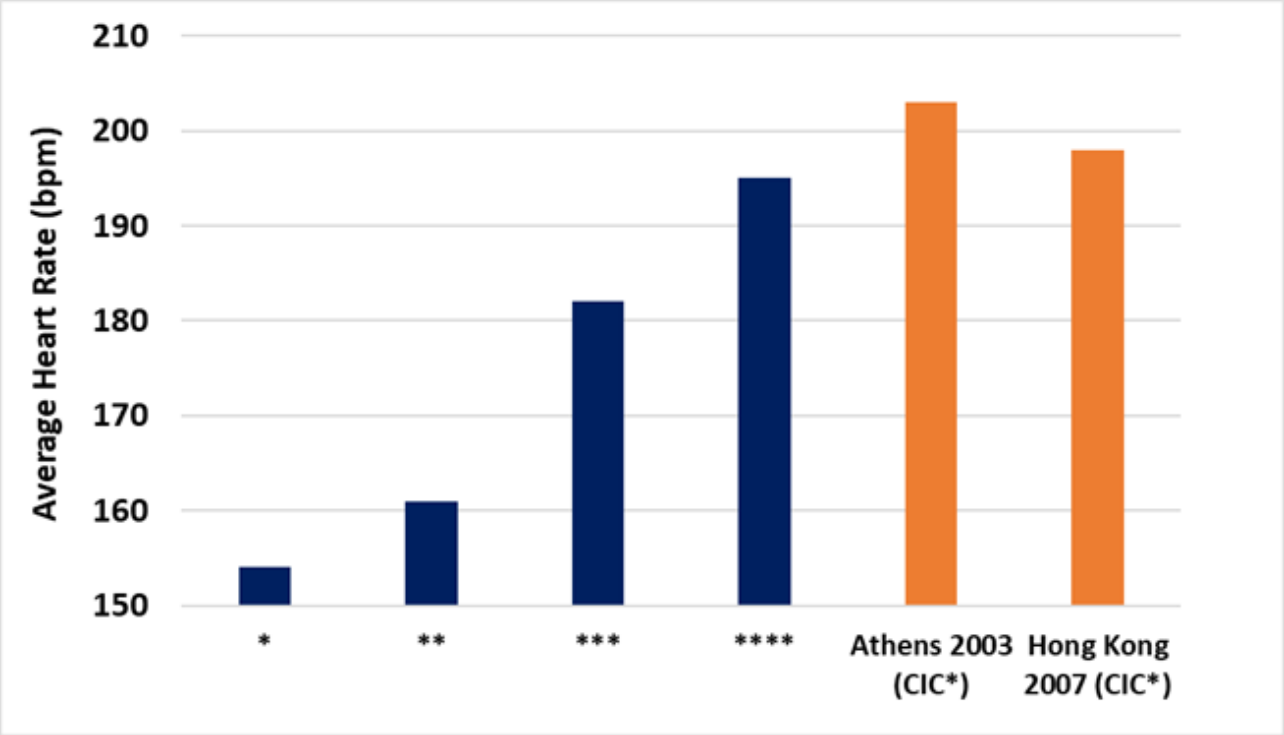


Conclusions

The horses competing in the test event cross country were working at near maximal exertion, as indicated by the high average heart rate, high blood lactate values, high heart rate on arrival at the cooling area and high rectal temperatures. While the horses competing at the Games in 2020 will be generally fitter and of a higher ability, the heart rates shown at the test event are higher than previously seen in horses competing in 1-4* level Eventing competitions (Figure 21 – former star levels), but similar to the heart rates measured at the Athens Olympic test event in 2003.

Figure 21

Mean heart rate for horses competing in long-format cross country at 1*, 2*, 3* and 4* level and at the Athens 2003 and Beijing 2007 test events



Data taken from: (Kohn and Hinchcliff 1995; Kohn *et al.* 1995; Marlin *et al.* 1995; White *et al.* 1995a; White *et al.* 1995b). Athens: Data collected during the Athens pre-Olympic test event (CIC*) in 2003; Marlin & Williams, unpublished data.

(3) POLAR EQUINE HEALTHCHECK APP & SENSOR EVALUATION

Polar have recently released a new app that allows horses' ECG and calculated heart rate to be viewed in real-time on an Android phone (Figures 22 & 23). This provides an extremely rapid and accurate heart rate as well as the opportunity to identify any dysrhythmias or abnormalities in the ECG. The system was tested out by the Japan Racing Association (JRA) veterinary team members and by several team vets, including in the cooling area following cross country.

Figure 22.

Figure 23.

(4) FEASIBILITY OF INFRA-RED THERMAL IMAGING TO ESTIMATE RECTAL TEMPERATURE

Rectal temperature is routinely used to assess horses competing in Eventing, particularly at the end of the cross country, and is especially valuable in thermally challenging environments. However, rectal temperature measurement requires the horse to be standing still and a small proportion of horses will not permit their temperature to be taken in this way.

At the 2019 test event we evaluated the potential for infra-red thermal imaging to be used as a non-invasive and rapid approach to assessing body temperature of horses during training, warm-up, competition and cooling. Previously it has been considered that thermal imaging would be subject to significant interference from solar radiation, the effect of orientation on the camera, sweat and other factors to be of any value.

Four thermal imaging devices, ranging in price from several hundred to 10,000 GBP, were evaluated. These included the Flir 1 iPhone attachment (~£300), the Flir C3 (~£500), the Flir E53 (cameras owned by the FEI ~£4,800) and the Flir B400 (£10,500). The Flir 1 and Flir C3 were found to be unsuitable for this purpose due to low resolution, low accuracy, slow frame rate, short useable range (distance) and short battery life.

Images were collected and analysed in a variety of ways.

Average temperature readings in a circle over the hindquarters provided very similar measurements to rectal temperatures (Figure 24). The mean difference between infra-red temperature and rectal for 25 paired measurements following training, dressage, cross country and jumping was 0.06±0.36°C.

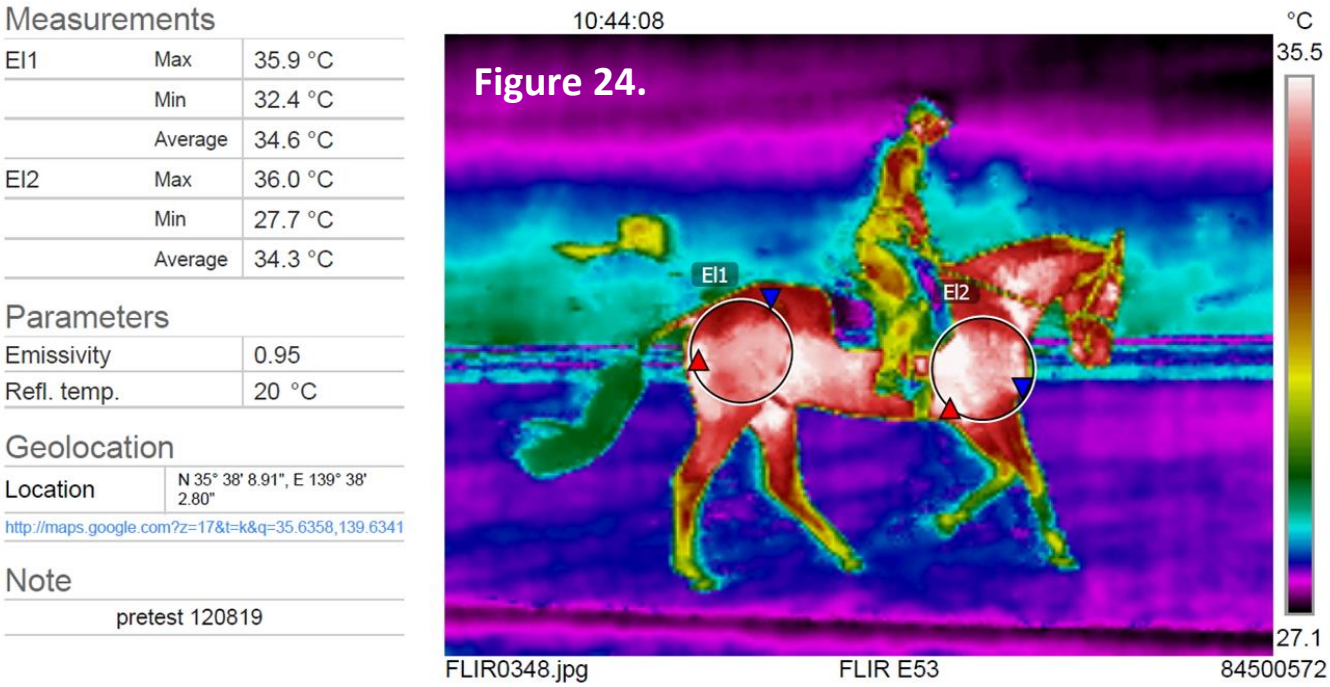


Figure 24.

In conclusion, it appears that infra-red thermal imaging, when used under a standardised imaging and analysis protocol, can give a good estimate of rectal temperature. Further analysis and validation is ongoing.

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