Biltmore Challenge 2011 Final Report Draft 1

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The report is organized as follows:

- a general description of the situation including ambient conditions,
- presentation and interpretation of the results
- an appendix that provide tables of normal values for various measured biochemical and hematological parameters, with 'clinical' interpretation of deviation from normal.

There was no provision of existing data for the state of any of the horses in this study when at rest in a euhydrated condition. The strength of the interpretation that is provided below would be improved is such data were available.

General Description

This report presents the statistical results and scientific interpretation of 9 horses that completed the 100 mile ride, 10 horses that completed the 75 mile ride, 5 horses that started the 75 mile ride but did not complete, and 12 horses that completed the 50 mile ride. Of these 12 horses that completed the 50 mile ride 8 horses were placed in a 'slow' (speed less than 8 mph) and 4 were placed in a 'fast' (speed > 8 mph) categories. In addition, there were 2 horses that started but did not complete in the 50 mile ride, and another horse that started but did not complete in the 75 mile ride. This latter horse could not be included in the other 'pulls' from the 75 mile ride because it was unique in its responses.

Horses arrived at the Biltmore Estate up to 4 days prior to ride day (Saturday). We arrived Thursday late afternoon and started to collect pre-ride BIA and hydration data Friday morning. Data collection continued through to Sunday morning.

The weather conditions were favorable for the ride and at no time did ambient conditions indicate a need to restrict activity (Fig. 1). As expected, humidity was greatest in the morning and lowest in the afternoon, while radiant heat load was greatest in the afternoon. Of importance to the ride is that the WBGT remained in the safe zone for strenuous exercise at all times.

The terrain was a mixture of solid, firm and soft (wet sand) footing through a mixture of shaded and open areas, with some moderate vertical challenges. The course for the 100 milers consisted of 6 loops, with 5 loops for the 75 milers and 4 loops for the 50 milers; horses returned to the start area at the end of each loop.

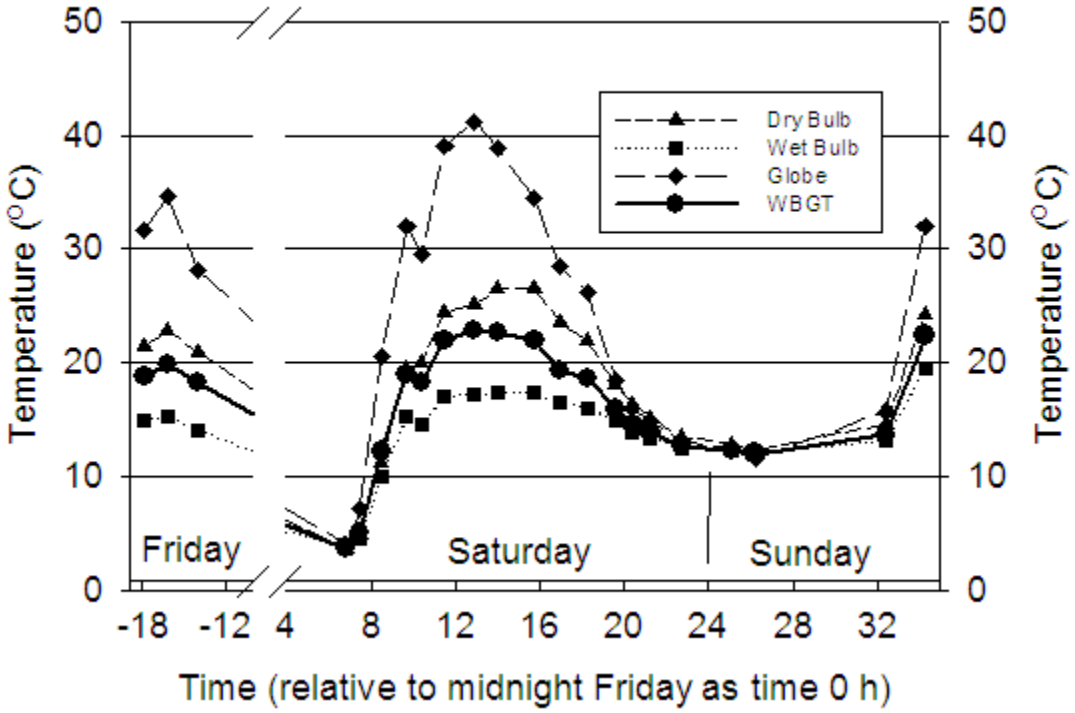

Figure 1. Time course of change in temperatures from 1pm Friday afternoon (-17.8 hours) until 10:15 am Sunday. The numbers on Saturday correspond to time using the 24 hour clock. Dry bulb temperature is the 'normal' temperature that one measures using a typical thermometer. Wet bulb temperature corrects the dry bulb temperature for the effects of humidity and wind. Globe temperature is a measure of the radiant heat load – this is high when the sun is shining. The wet bulb globe temperature (WBGT) is a weighted average of the temperatures measured by the different probes, and gives a measure of the 'effective' temperature, i.e. takes into account humidity, wind and sun; It is the temperature that it feels like.

Presentation and Interpretation of the Results

Speed

The fastest riding times were 10:19:12 for 100 miles (speed = 9.7 mph), 7:14:54 for 75 miles (speed = 10.2 mph) and 4:46:10 for 50 miles (speed = 10.5 mph). Thus the shorter the distance, the faster the speed for these front runners.

Amongst all research horses that completed the ride, the 100-milers had the fastest speed, sustained at a group average of about 9 mph for the first 3 stages (Fig. 2). Thereafter, there was a progressive slowing of average speed with each successive state. Average ride speed for 100 miles was 8.0 mph, giving an average ride duration of 12.5 hours. The top 7 horses at 100 miles had an average ride duration of 10 h 31 min, nearly 2 hours less.

The 'fast' 50 milers were nearly identical in speed to that of the first 3 stages of the 100 milers, and completed with an average speed of 8.86 mph. In contrast, the 'slow' 50 milers completed with an average speed of 6.35 mph. The 75 mile horses that were pulled averaged a faster (~1 mph) speed than horses that completed. These 75 mile finishers did not show a significant change in speed over the 5 stages and, on average, exhibited average speeds between that of the 'fast' and 'slow' 50 milers; average ride speed was 7.31 mph.

100 Mile Research Horses

As a group these horses showed a lower magnitude of change from pre-ride values and a lower frequency of occurrence of abnormal values than the other groups. On this basis it could be argued that, as a group, these horses were both fitter (physical conditioning and genetically) than the other groups. Therefore the results from this group are presented first.

100-1: Indices of Hydration

Plasma total protein concentration (TP) is used as an indicator of hydration (Rose 1986-II; Harrison 1985; Carlson 1978; Gillespie – Steerman; Lindinger and Ecker 1995). Pre-ride values for TP for 8 of 9 published endurance studies is 7.0 or less (Rose 1986-II, Lindinger and Ecker 1995), with one study reporting a pre-ride TP of 7.9 g/dl (Lucke and Hall 1978). Taken together, the average pre-ride TP is 6.7 g/dl.

A euhydrated horse, i.e. one that is not under- or over-hydrated will have a TP of very close to 6.5 g/dl, i.e the initial TP or TP_i. An estimated of dehydration can be obtained from the formula:

$$\text{Estimated \% dehydration} = (TP_f - TP_i) / TP_i \times 100\%, \text{ where } TP_f \text{ is any final TP.}$$

A horse presenting with a TP of 7.0 therefore has an estimated dehydration of:

$$\text{Estimated \% dehydration} = (TP_f - TP_i) / TP_i \times 100\%$$

$$= (7.0 - 6.5) / 6.5 \times 100\% = 7.7\%$$

The other useful indicator of hydration in a euhydrated horse at rest, that is not excited prior to or during the time of blood sampling, is the hematocrit (HCT) or packed cell volume (PCV). In euhydrated endurance horses at rest this value is typically very close to 34%. Thus,

$$\text{Estimated \% dehydration} = (HCT_f - HCT_i) / HCT_i \times 100\%$$

A horse presenting with a HCT of 37% therefore has an estimated dehydration of:

$$\text{Estimated \% dehydration} = (37 - 34) / 34 \times 100\% = 8.8\%$$

When both TP and HCT are increased at the same time, this indicates dehydration because the simultaneous increases can only occur as a result of loss of fluid from the blood compartment, which

reflects losses of fluid from the whole body when horses are at rest and not within 2 hours of finishing hard exercise.

The 100 milers had a pre-ride TP 7.0 g/dl and HCT of 37.2% (Table 100-1) which indicates dehydration in some horses. One may argue that because these values fall within the normal range for horses (appendix) that this should not indicate dehydration and should not be of concern. This view is flawed because it does not recognize that the TP and HCT of a euhydrated horse is typically very close to 6.5 g/dl and 34%, respectively. Trying to achieve the euhydrated condition prior to the start of the ride should be an important goal. The main sources of dehydration pre-ride likely include sweating during transport (with inadequate replacement of fluid and nutrients), anxiety at the ride site (resulting in inadequate ingestion of fluid and nutrients). For these reasons it is important to use effective strategies for maintaining hydration during transport and after arrival, and if dehydration has occurred to use effective rehydration strategies.

One can use changes in TP over the course of the ride and recovery to estimate changes in hydration over time, as was done with this study. A euhydrated TP of 6.5 g/dl was also used to get an estimate of the pre-ride dehydration.

The percent change in plasma volume (%dPV – see below) is calculated as a slight variation:

$$\%dPV = (TP_f - TP_i) / TP_i \times 100\%$$

$$= (TP_f - 6.5) / 6.5 \times 100\%$$

The pre-ride %dPV was -4.3 (Table 100-1) indicating an average pre-ride dehydration of about 4%. Given that clinical dehydration is a 5% decrease in body weight, this value needs to be taken seriously.

The time of blood sampling in all horses was such that immediate effects of exercise and post-exercise recovery (i.e. intercompartmental fluid shifts) are negligible. As the ride progressed, there were ongoing increases in TP and HCT, with progressive loss of PV until Stage G. This is also seen in the decreases in measured body weight that occurred, as well as the calculated losses of body water (BW), extracellular fluid volume (ECFV), intracellular fluid volume (ICFV), increases in the number of red blood cells per ml of blood (RBC) and hemoglobin concentration (HGB). Most of these values (i.e. body weight) and calculations do not take a pre-ride dehydration into consideration. The BW loss at stage G was 19.4 Litres (about 5 gallons) and it is safe to say that some horses had this magnitude of dehydration at the start of the ride. The dehydration is large and very important. It would be very useful to have body weight from these horses under euhydrated conditions, at rest, at home prior to transport to ride sites.

After stage G there was some recovery of hydration, indicated improved effectiveness of rehydration strategies, slowed ride speed and likely improved willingness of horses to take in fluid and nutrients during the last part of the ride. On average, overnight recovery was modest, with only a few horses achieving a pre-ride state of hydration.

The total carbon dioxide concentration (TCO2) was decreased by stage G, consistent with a mild alkalosis (raised blood pH) that typically occurs with dehydration in endurance horses (Rose 1986-II).

100-2: Indices of muscle or other tissue injury

Strenuous exercise and dehydration both contribute to injury that can occur to muscles, heart, liver and kidneys. Many blood indicators of tissue injury will increase slightly during exercise then return to normal values – this is a normal response and to be expected (Table 100-2; Rose 1982-II).

The indicators creatine kinase (CK), creatinine (CRE), aspartate aminotransferase (AST) originate from skeletal and heart muscles (CK, CRE, AST) and liver (AST). These increased normally during exercise and started returning to normal after the ride.

γ-glutamyl transpeptidase (GGT) originate from liver cells and is an indicator of liver injury, as is AST. There was a very minor increase in GGT at the end of the ride, and this was normalized over night.

The indicator blood urea nitrogen (BUN) is a measure of the nitrogen arising from protein breakdown in the body – as muscle cells are disrupted and die during prolonged or intense exercise, BUN will rise. The increases in BUN seen in these horses is a normal response to intense endurance exercise.

Total bilirubin (TBIL) is the product of hemoglobin (the main protein inside red blood cells) breakdown by the liver. It is an indicator of red blood cell damage resulting from intense exercise, dehydration and oxidative damage to red blood cells. The increases in TBIL that occurred are normal and to be expected for this type of exercise.

100-3. Indices of immune function and inflammation.

A number of hematology values provide information on immune function and systemic inflammation that can be a consequence of intense exercise, clinical dehydration or other illness.
There are many types of white blood cells (WBC) of which 5 were measured in this study: monocytes (MON, MON%), neutrophils (NEU, NEO%), eosinophils (EOS, EOS %), lymphocytes (LYM, LYM%), basophils (BAS, BAS%). The % expresses the subtype as a percent of all of the WBCs. The increases in WBC, and the WBC sub-types MON, NEU and decreases inEOS, BAS and LYM were minor and normal for this type of exercise (Table 100-3).

100s: Summary

Horse in this group showed evidence of underlying dehydration before the start of the ride. The ride itself resulted in a peak dehydration of 19.4$\pm$3.4 litres, equal to 4.6 % of total body water. There was evidence of minor muscle damage and selective activation / suppression of WBC activities.

Areas for improvement revolve around hydration: improve strategies for maintaining hydration before the ride, during the ride and after the ride. This can best be accomplished using the proper balance of electrolytes with water, as well as adequate intake of macronutrients (as feed and forage).

75 Mile Research Horse Finishers

As a group, similar to the 100 milers, these horses appeared to be in very good physical condition for the ride. The changes in horses in this group were qualitatively similar to those of the 100 milers. The notable differences will be highlighted.

75-1: Indices of Hydration

The average pre-ride TP was 6.77 g/dl and HCT 35%, very close to the ideals of 6.5 and 34, respectively, indicating mild dehydration in some horses and other horses that were truly euhydrated. Also similar to the 100 milers, the peak dehydration occurred mid-way through the ride, with no difference in hydration parameters at stages E and G (Table 75-1). The total BW loss of 16.6 L at stage G was similar (not statistically different) from that lost by 100 milers at stage G. As a group though, the 75 milers were better hydrated at the start of the ride, and hydration was better maintained during the ride, than the 100 milers.

A notable difference from the 100 milers is that the plasma TP values during the ride were greater than that seen in the 100 milers; at the same time HCT was slightly lower than the 100 milers. This suggests a greater extracellular dehydration in the 75 milers (note the larger %dPV and decrease in ECFV in 75 milers – Table 75-1). An explanation for this difference is not obvious and may be due to differences in sweating rate or fluid / electrolyte supplementation between these two groups.

One other notable difference from the 100 milers is that plasma [glucose] (GLU) was depressed at stage E, indicating that muscle carbohydrate use exceeded the rate of liver and g.i. glucose supply – this is usually associated with high metabolic demands and inadequate macronutrient intake in the preceding stage or two.

Other hydration parameters and TCO2 changed similar to that seen in 100 milers – please refer to that section for an interpretation.

75-2: Indices of muscle or other tissue injury

The changes that occurred in these parameters were exercise-normal and similar to those that occurred in the 100 milers (Table 75-2). Please refer to the 100 miler description for the interpretation.

75-3. Indices of immune function and inflammation.

Another difference from the 100 milers is that blood platelets (PLT) and platletcrit (PCT; the number of platelets as a percent of total blood cells) progressively increased such that by stage G these were significantly elevated from pre-ride values (Table 75-3). Even when elevated compared to pre-ride, these values were within clinically normal ranges. Platelets are involved in the blood clotting process and, in addition, the production of many growth factors that are released into the blood. The increase is pronounced and cannot be explained on the basis of fluid loss (dehydration) from the blood. It is likely that the stress of exercise caused an increase in platelet formation.

All other hematological parameters changed similar to that seen in 100 milers; please refer to that section for interpretation.

75 Mile Research Horse Pulls

The 5 horses included in this analysis all completed through to the end of stage E. As a group, these horses started fast, at a pace similar to that seen by the 100 milers during the first part of the ride, and significantly faster than the 75 milers that finished. This raises the possibility that the high speeds and increased metabolic demands may have contributed to the reasons for pulling these horses.

75-4: Indices of Hydration

Plasma TP was 7.01 $\pm$ 0.19 g/dl, similar to that seen in the 75 mile finishers, and pre-ride HCT averaged 32.5% (Table 75-4) somewhat lower than in the 75 mile finishers. Therefore some of these horses exhibited mild dehydration and others were euhydrated. It can be concluded that pre-ride hydration status did not contribute to reasons for these horses being pulled.

The metabolic demands of the high speed, with resultant high rates of heat production, necessitated high rates of heat dissipation. In horses, this is mostly met by high sweating rates, resulting in dehydration. These horses showed a rapid loss of fluid from the body, such that at the end of stage E they had lost, on average, 20.2 L (Table 75-4) compared to the 14.5 L lost be the 75 mile finishers at stage E (Table 75-1). This would also be associated with high rates of heat storage in the body, particularly in contracting muscles. The combination of high rate of dehydration and progressive heat storage need to be considered as factors contributing to reasons for why these horses were pulled. Dehydration is associated with impaired physical and cognitive (mental) performance such that mis-steps and slips that can result in lameness are more likely to occur.

75-5: Indices of muscle or other tissue injury

The increases in these values are exercise-normal (Table 75-5) and similar to those seen in 75 and 100 mile finishers. There are no obvious signs of muscle or other tissue injury.

75-6. Indices of immune function and inflammation.

The red blood cell distribution width (RDWc; average diameter of red blood cells) significantly increased in this group of horses (Table 75-6). Because these cells are discoid in shape, the increase in width can be explained by the substantial decrease in PV associated with the rapid dehydration. The other hematological parameters changes in s similar way as that seen with the 75 and 100 mile finishers.

50 Mile Fast Research Horses

The average speed of these 4 horses was similar to those of the 75 and 100 mile finishers (Fig. 1). As a group these horses responded very similar to each other, which resulted in a large number of variables that changed significantly (statistically) during the ride.

50-1: Indices of Hydration

Pre-ride plasma TP averaged 6.9 g/dl, similar to that of the 75 milers and closer to the ideal of 6.5 g/dl than the 100 milers. Therefore these horses had mild dehydration at the start of the ride. These horses, overall, showed the greatest increases in TP and HCT (Table 50-1) of all the groups, indicating a rapid and pronounced plasma and extracellular dehydration associated with relatively high speeds that these horses maintained. The peak increase in TP to 8.35 g/dl at stage F translated to nearly 18% decreases in PV and ECFV, indicating a more rapidly occurring and pronounced extracellular dehydration than occurred in 75 and 100 milers. Possible explanations for this key difference are: 1) these horses were less fit, physically, and achieved higher sweating rates with similar metabolic requirements; 2) these horses received less water and electrolyte supplementation than 75 and 100 mile horses; and 3) that these horses, genetically, are quite different and experience much higher sweating rates for similar rates of metabolic energy expenditure.

Consistent with the rapid decreases in PV and ECFV (above), body mass decreased by 44 lbs during the first loop, equal to a decrease in TBW of 23.3 L, and the loss of TBW further increased to 27.6 L at stage F (Table 50-1). TBW recovered 4 L (about 1 gallon) at the 2 h post-race time point (stage H), with minimal further improvement over night.

The changes in the other hydration indices (Table 50-1) are in line with these relatively large fluid loss values and are all consistent with, and due to, dehydration.

50-2: Indices of muscle or other tissue injury

The increases in these values are exercise-normal (Table 50-2) and similar to those seen in 75 and 100 mile finishers. There are no obvious signs of muscle or other tissue injury.

50-3. Indices of immune function and inflammation.

The changes in these values are also exercise-normal (Table 50-3) and similar to those seen in 75 and 100 mile finishers.

50 Mile Slow Research Horses

The average speed of these 8 horses averaged more than 2 mph slower than that of the 50 mile fast horses (Fig. 1). This group of horses will be directly compared to the 50 mile fast horses.

50-4: Indices of Hydration

One of the interesting features of this group is that they showed more statistically significant changes in hydration parameters than any other group. I take this to mean that, as a group, these horses were either less physically conditioned to perform the activity or were genetically less endowed to perform well under these conditions.

Pre-ride plasma TP averaged 6.84 g/dl, similar to that of the 50 mile fast group, the 75 milers and closer to the ideal of 6.5 g/dl than the 100 milers. Therefore these horses had mild dehydration at the start of the ride. These horses showed the smallest increases in TP and HCT (Table 50-4) of all the groups, consistent with the slower speed and a reduced requirement for thermoregulatory cooling through sweating. Peak loss of body water and dehydration occurred by stage D, and thereafter there was recovery of hydration during the remainder of the ride to values not different from pre-ride at the 2 hour post-ride sample (Stage H).

The group showed a significant decrease in plasma glucose mid-ride (Stage E) indicative of an imbalance between energy intake and muscle carbohydrate use during exercise. This concern was resolved in all affected horses by the end of the ride, indicating that these horses did manage to take in adequate feeds after stage E.

Plasma Na^+ and Cl^- concentrations both increased – something that was not seen in any of the other groups and is a result that is rare in endurance horses. It is likely that this reflects the supplementation of electrolyte products in the early stages of the ride. It is usual that plasma Cl^- decreases during endurance exercise, not increases as seen in this group. Thus it appears that the riders / crews were effective with electrolyte supplementation but somewhat inadequate with respect to provision of water to properly balance the amount of electrolytes administered.

50-5: Indices of muscle or other tissue injury

The increases in these values were mild and exercise-normal (Table 50-5) and somewhat less than those seen in the 50 mile fast horses. There are no obvious signs of muscle or other tissue injury.

50-6. Indices of immune function and inflammation.

The changes in these values were also mild and exercise-normal (Table 50-6).