Thermoregulation Research Group. Dr. L. Verdegaal
Research Group of Comparative Physiology. Prof. Delesalle

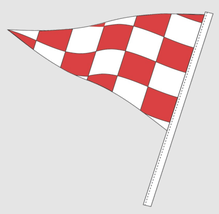
Overview of gastrointestinal pill temperature monitoring in mammals during exercise with emphasis on horses

Elisabeth-Lidwien J. M. M. Verdegaal[1,2], Todd J. McWhorter[1], Gordon S. Howarth[1], and Catherine J. G. Delesalle[1,2]

[1]School of Animal and Veterinary Sciences, Roseworthy Campus, University of Adelaide, Roseworthy, SA 5371, Australia; [2]Research Group of Comparative Physiology, Department of Translational Physiology, Infectiology and Public Health, Faculty of Veterinary Medicine, Ghent University, Ghent, Belgium.

Background: heat stress in exercising horses

Exercise & thermoregulation → **Hyperthermia & heat stress** → **Exertional Heat Illness (EHI)** → **May be fatal** → **Monitoring during exercise using a GI temp pill in the field**



Heat stress – EHI:
- Recent prevalence in racehorses: 0.09-1.1%[1,2,3]
- Increase with climate change & heatwaves

Photo showing collapsed horse with EHI. Courtesy of Dr. Brownlow, IGSRV website

Overall aim:
To improve equine welfare with strategic & protective management of athlete

Introduction: thermoregulation monitoring in equine athletes

Thermoregulation monitoring studies to investigate heat illness problems in human athletes during treadmill exercises have used several devices:
- rectal thermistors
- skin temperature sensors
- arterial blood thermistors
- telemetric gastrointestinal (GI) pills.

Advantages of using GI temperature pills in horses (Verdegaal et al. 2021)
- reliable, accurate and precise method to measure and monitor core body temperature (T_c)
- non-invasive method, highly practical for use during field exercise and real-life competitions as opposed to standard testing by treadmill exercise
- continuous recording of thermal response as opposed to serial rectal temperature measurements

GI pill (Jonah®)

Monitoring belt with data receiving device GI pill (Equivital®)

The main objective of this narrative review was to provide an overview of gastrointestinal temperature pills and examples of its use in horses and other mammals.

Gastrointestinal (GI) pills to monitor core temperature

The GI pill has been used to monitor T_c during field exercise in other mammals besides humans (athletes, military, defensive) such as elephants and dogs, and resting cattle in the field.

In horses:
- 2005, at rest and during 158 km transport using CorTemp®(Green et al., 2005; Green et al., 2008).
- 2017, Jonah pill® evaluated during exercise and real-life competitions comparing different exercise intensities (Verdegaal et al. 2017; Verdegaal et al. 2021)

Results: overview of GI pills & technical details

Name GI pill, country	Horse Y/N Horse exercise Y/N	Other mammals	**Transfer distance**	Manu-facturer accuracy***	Bias** (°C)	Reliability** (bias) (°C)	Inertia: response time (seconds, s)**	Battery life (h)	Remarks
Jonah® pill (Vitalsense, Phillips), USA	Y, Y	Human	Excellent, > 1m	0.17	-0.017°C ± 0.023°C	0.002°C ± 0.014°C#	39 ± 6 s	240	Connect with Equivital manager Discontinued
Smartpill® (Medtronic) USA	Ponies **only,** N (Stokes et al. 2012)	Human, dogs	Only transfer T_c in ponies with antenna	…	-	-	-	>120	Measures pH and intraluminal pressure
CorTemp®, USA	Y, N (Green et al., 2006)	Human, dogs	0.65 m	0.27	0.077°C ± 0.040°C	0.017°C ± 0.083°C	25 ± 4 s	168–240	Connect with CorTrack manager *Impractical in horses. Discontinued
Anipill/e-Celsius® (Bodycap), France	Y, N* (unpublished information)	Monkeys (rabbits, rats, mice)	<1m? *not usable horse	0.23	-0.081°C ± 0.055°C	-0.007°C ± 0.033°C	21 ± 13	480	Connect with Equivital and e-Performance manager
MyTemp, The Netherlands	N	Human athletes	1m	*In development*	-0.003°C ± 0.006°C	0.001°C ± 0.008°C#	19 ± 2 s	Infinite (no battery)	Commonly used in human athletes for last 5y. Future evaluation in horses

Table 1. Overview of gastrointestinal (GI) pills and their use. Overall size is small, varies minimally from 23-11 mm. *Authors' opinion after investigating in several horses in the field during exercise; **Comparison in vitro study based on temperature-controlled water baths from Bongers et al. (2018); ***manufacturer details; # values did not differ when GI temperature recording was repeated (reliability); & Discontinued.

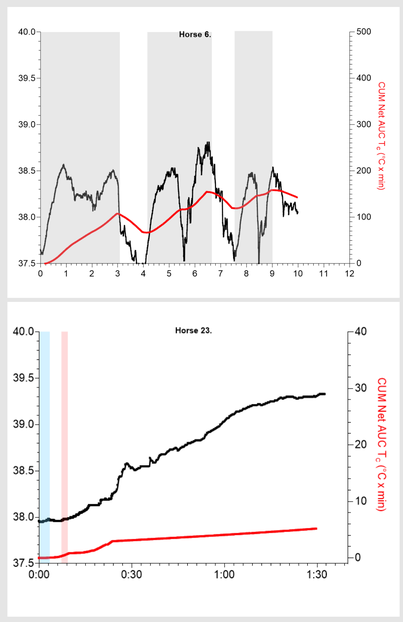


Figure 1. Two scatterplots of T_c (°C; left y-axis, black line) and cumulated net AUC (°C x min); right y-axis, red line) over time (h) during exercise periods & recovery. Above graph T_c endurance horse per 40 km exercise loop (grey blocks) & cool down (10 min). Lower graph T_c in trotters, warm-up exercise – blue blocks and trotter exercise - light-red blocks.

Discussion

- GI pill is a unique method to monitor T_c during competition in the open air as opposed to earlier laboratory-based studies using treadmill and invasive temperature measurement methods.
- Only one make of pill was accurate and reliably used in exercising horses[3]
- Authors have trialed Anipill & CorTemp pills without success.
- In larger mammals such as horses, reliability depends on transfer distance of GI pill

Conclusions

i. Evidence suggests that the GI pill is commonly used in human athletes but faces challenges in other larger mammals
ii. Further studies and new technology are required to implement GI pill monitoring in the field
iii. Further investigations using the GI temp pill will be useful for the equine industry to prevent EHI, improve performance, welfare and social image of the industry, in addition to assessing welfare of other mammals including human athletes.

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Elisabeth-Lidwien Verdegaal MVM, DVM, PhD, Dip ECEIM
Specialist Equine Medicine, University of Adelaide, Australia
Thermoregulation Research Group. Dr. L. Verdegaal
Research Group of Comparative Physiology. Prof. Delesalle
Email: Lidwien.Verdegaal@Adelaide.edu.au