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Scoring of sweat losses in exercised horses – a pilot study

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Summary

Based on a series of exercise tests which included the estimation of sweat losses, this article proposes a novel sweat scoring system for exercising horses. This provides a practical estimate of individual animal exercise-induced sweat losses, based on visible appearance of sweat on the coat after work, which takes into account the effect of various influencing factors. In terms of accuracy and flexibility, the score seems to provide advantages over estimates based on current general recommendations from reference books. Additional studies are needed to validate this scoring system and its use under more diverse situations.

Keywords horse, sweat, temperature, relative humidity, scoring system

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Introduction

Exercise-induced sweat losses are primarily responsible for the additional electrolyte requirements of exercising horses and, thus, are very important to understand. Currently, sweat losses are commonly estimated as being linearly dependent on the changing energy requirements for work (GfE, 1994), although obviously different databases for the quantity of exercise-induced sweat losses are used in the key reference books (GfE, 1994; NRC, 2007). Physical work is inefficient from an energetic perspective. With around 80% of the expended energy being lost as heat (Marlin and Nankervis, 2002), this must be dissipated to prevent an undesirable increase in body temperature. Heat production during exercise can be calculated from the rate at which oxygen is being utilized and, thus, from the volume of inhaled oxygen (V_{O_2}): metabolic heat = V_{O_2} (litres per min) × k × exercise duration, where 'k' characterizes the amount of heat liberated per litre of consumed oxygen (McCutcheon and Geor, 2008). V_{O_2}, in turn, can be estimated by use of the heart rate (Coenen, 2008). Exposure to sunlight may further heat up the body with solar radiation being responsible of up to 15% of heat gained in a horse during exercise (Guthrie and Lund, 1998). From the available mechanisms of thermoregulation (conduction, convection, radiation, evaporation), evaporation is the most effective way for horses to eliminate the excess heat produced during exercise. The loss of water *via* the skin is therefore much more important than that *via* the respiratory tract (Heilemann et al., 1990; McCutcheon and Geor, 2008), at least at high body temperatures following exercise (Marlin and Nankervis, 2002). Sweat losses induced by a given exercise boot are furthermore greatly influenced by the weather/environmental conditions, which can significantly affect the efficacy of evaporation. These factors include ambient temperature (AT), relative humidity (RH), the extent of vapour pressure gradient between the skins surface, the rate of air movement and shower activity (Monteith, 1973; Geor et al., 1995; McCutcheon et al., 1995). Therefore, the rate at which heat is stored in the body when exercised in hot, humid conditions may be more than twice the rate during exercise at the same intensity in cool and dry conditions (Geor et al., 1995; Geor and McCutcheon, 1998a,b; Lindinger, 1999) thereby causing more thermal stress. Diverse indices (comfort index, wet bulb globe index) have been proposed to summarize and assess the totality (AT, RH, global radiation, air movement) or at least a substantial part of the environmental factors responsible for thermal stress in athletic horses (Schroter et al., 1996; Marlin and Nankervis, 2002). Difficulties arise, however, in that they may be misleading due to some factors cancelling each other out, for example, combinations of AT and RH in the case of the comfort index. The wet bulb globe index, however, has the disadvantage that it cannot be interpreted linearly because an increase from, for example, 20 to 25 has less of a clinical impact than that from 23 to 28 (Marlin and Nankervis, 2002). Furthermore, such indices do not consider factors that are difficult to quantify but are probably very important for the individual including the horses' athletic fitness, climatic adaptation, temperament and arousal as well as the interaction of the horse with the rider or driver. In conclusion, estimating the volume of sweat loss based on the type and often perceived level of exercise either with or without consideration of the weather and other environmental factors seems to be almost impossible under practical conditions and may lead to serious errors in individual cases. Practically, signs externally visible on horses, such as the intensity of sweating and the distribution of sweat on the body surface, may summarize the impact of all known and unknown factors relevant to thermal stress and, thus, enable a more accurate estimate of individual sweat losses to be made. We therefore hypothesized that 1) scoring the sweat loss *via* specific externally visible characteristics would be a practical way of estimating sweat losses in exercised horses and 2) this would be more accurate than conventional generic estimates based on work load and indices that take into account weather conditions. The aim of this study therefore was to estimate sweat losses through measuring exercise-induced body weight losses in Warmblood-type horses subjected to two different exercise protocols intensities and to use these results to develop a practical visual sweat scoring system (sweat score).

Material and methods

The protocol of the study was approved by the LALLF (Landesamt für Landwirtschaft, Lebensmittelsicherheit und Fischerei) Mecklenburg-Western Pomerania. The study was carried out in Dummerstorf (Germany) under typical weather conditions for the summer season in a temperate climate zone. Ambient temperature and relative humidity were measured every day when the horses were exercised. The study consisted of two parts, the first in which the horses undertook light work (LW: 10 min speedy walk, 10 min posting, 5 min canter, 5 min trot, 10 min slow walk) and the second where they undertook medium exercise (MW: 15 min speedy walk, 10 min posting, 10 min canter including some medium canter and gallop, 5 min trot, 10 min canter, 10 min slow walk). For LW and MW, 8 (age 7.5 ± 4.0 years; 590 ± 37.9 kg body weight, bwt) and 9 (age 9.5 ± 4.3 years; 634 ± 73.2 kg bwt) Warmblood-type mares were used respectively. The horses were selected so that they met the requirements of the tests with regard to their state of training. Two mares were used in both studies. For LW and MW, the horses received meadow hay (58.00 or 66.00 g/kg bwt$^{0.75}$/d respectively), cereal grains (oats: barley in a 3:2 ratio at 21.86 or 24.75 g/kg bwt$^{0.75}$/d respectively) and a mineral balancer at a feeding level to provide 115% or 130% maintenance (GfE, 1994; NRC, 2007) requirements respectively. The horses were housed individually in boxes with wooden shavings as bedding and had free access to water. During the study period, the horses were ridden on separate days by two professional riders each (rider A: 61 kg bwt; rider B: 75 kg bwt). In MW, one mare was ridden three times (once by rider A and twice by rider B) and one horse performed the exercise protocol twice, but on the lunge rather than being ridden. Data on exercise-induced changes of bwt and RT from the horse exercised at the lunge were nearly in the middle of that from the other horses, and therefore, it has been decided to include the data from that horse into analysis. The LW exercise tests were performed one day after the other, but the MW exercise tests were carried out over a 3-week time period with at least 1 week between each exercise test for an individual horse. The exercise tests were performed in an arena with sandy subsoil. The rectal temperature (RT) was measured before and immediately after the exercise tests. After the exercise tests had been finished, the horses were photographed enabling the sweaty areas on the body surface to be documented. To help develop the sweat scoring system and to describe the associated phenotypes, the appearance of all horses after all exercise tests (total number of observations = 35) was used. For this, the horses were visually inspected immediately after exercise, but without their saddle. To determine exercise-induced bwt losses, the horses were thoroughly cleaned and weighed on a calibrated weighbridge (accuracy of the scale: 0.5 kg) before the start of each exercise test and 3 h after finishing the test when the horses were completely dried and cleaned. The optimal duration of the recovery period was determined in preliminary studies (with the same horses exercised according to identical protocols used in the current study) to ensure that the horses by the

Table 1 Weather conditions throughout exercise tests at low and medium exercise intensity, respectively, as well as exercise-induced changes in rectal temperature and body weight as well as estimated sweat losses*

		Low exercise intensity	Medium exercise intensity
Ambient temperature	[°C]	25 ± 2.6 (22–28)	22 ± 3.4 (18–27)
Relative humidity	[%]	46^{b} ± 5.1 (39–51)	71^{a} ± 8.9 (60–84)
Rectal temperature before exercise	[°C]	37.7^{B} ± 0.217	37.7^{B} ± 0.197
Rectal temperature after exercise	[°C]	38.6^{Ab} ± 0.393	39.7^{Aa} ± 0.549
Body weight (bwt) loss	[kg]	4.4^{b} ± 3.6 (1.8–8.8)	12.1^{a} ± 3.55 (3.50–18.4)
bwt loss relative to the initial bwt	[%]	0.75^{b} ± 0.31 (0.32–1.5)	1.9^{a} ± 0.54 (0.54–2.5)
Sweat loss	[L]	4.2^{b} ± 1.9 (1.6–8.6)	11.7^{a} ± 3.55 (3.2–18.0)
Sweat loss relative to the initial bwt	[%]	0.71^{b} ± 0.31 (0.29–1.4)	1.8^{a} ± 0.54 (0.49–2.5)

*Estimated from the measured bwt loss by correcting for water intake, faeces and urine losses and respiratory water losses, the latter according to Heilemann et al. (1990) and Meyer et al. (1990).
Different lower case letters indicate with $p < 0.05$ different means between exercise tests at low and medium intensity.
Different uppercase letters indicate with $p < 0.05$ different means between rectal temperature before and after exercise.

end of the recovery period were no longer obviously sweating and had evidently dried areas on the skin. The measured exercise-induced bwt differences were corrected for water intake as well as losses by faeces and urine. To catch any losses of urine and faeces during the exercise test and the 3 hrs lasting post-exercise period, buckets were used. To estimate sweat losses, the above exercise-induced bwt losses were also corrected for estimated respiratory water losses, which were taken to be 0.5 ml/kg bwt loss x hr of exercise (Heilemann et al., 1990; Meyer et al., 1990). Statistical analysis of data was accomplished by use of the software package SPSS 20.0 for windows (SPSS, Chicago, IL, USA). Results are given as means ± sd. Wilcoxon test was used to investigate differences of means between weather conditions and exercise-induced changes in RT and bwt between LW and MW and between RT before and after exercise within both types of exercise test. Pearson's correlation coefficient was calculated to analyse the relationships between exercise-induced sweat loss and either AT or RH, and further between both weather factors. The level of significance was preset at $p < 0.05$.

Results

During LW and MW, the AT varied in a similar manner across a range of 18–28 °C (Table 1). RH, however, was clearly lower ($p < 0.05$) during the LW (39–51%) protocol than the MW (60–84%). In both trials, AT and RH were negatively correlated (LW: $r = -0.74$, $p < 0.001$; MW: $r = -0.89$, $p < 0.001$).

During LW and MW exercise tests, the horses' rectal temperature rose ($p < 0.05$) by a mean of 0.9 and 2.0 °C respectively (Table 1). The exercise-induced bwt loss, in absolute terms and relative to the initial bwt, as well as the estimated sweat losses are given in Table 1. The exercise-induced bwt losses varied between 0.3% and 2.5% of the horses' bwt prior to exercise with the mean losses being lower than 1.0% in LW compared with nearly 2% in MW (LW vs. MW: $p < 0.05$). This corresponded to a mean sweat loss of approximately 4 and 12 litres in LW and MW respectively (LW vs. MW: $p < 0.05$). Neither AT nor RH influenced the volume of sweat loss ($p > 0.05$) when the horses were exercised at the low intensity. However, during medium work, AT had a positive impact ($r = 0.94$, $p = 0.007$) and RH a negative effect ($r = -0.58$, $p = 0.009$) on the sweat loss. Based on a visual inspection of the horses following exercise, 5 distinct 'sweat' phenotypes could be determined and could be associated with a defined sweat loss range (Table 2).

Discussion

The horses, their breed, level of conditioning, and the exercise intensity used in the current study were considered to be representative of that undertaken by the majority of leisure and low to medium level sport horses under German conditions. The climatic conditions, however, spanned the typical summer season in a temperate climate zone and in part what happens in spring and autumn. Due to the known impact of ambient temperature, which was confirmed here with medium but not with low work, it is to be expected that sweat losses during the winter season would be lower than those measured in this study. However, the phenotypic expression of sweating may not necessarily be different from that observed here.

Currently, there are several methods for measuring sweat losses in exercised horses including application of absorbent material over a known area of the skin, the so-called sealed pouch or ventilated capsule

Table 2 Sweat scores with assigned phenotypic descriptions (observed immediately after exercise without the saddle), their associated sweat losses based on the current study and sweat loss ranges proposed for practical use

Sweat score	Phenotypic peculiarities	Sweat losses [L] determined in the study	*n**	Sweat losses [L] (in % of bwt) proposed for practical use
1	Area under the saddle partly dry, but partly dark, sticky and moist Sticky throat area Flanks darker than normal	1.6–4.0	9	1–$\leq$ 4 (0.2–0.7)
2	Wet area under the saddle and on the throat Small white areas at the edges of the saddle corners may occur through foaming Friction surfaces between throat and reins as well as on the posterior inner limbs (with heavily muscled or fat horses) may be white coloured due to foaming	–7.2	7	> 4–$\leq$ 7 (> 0.7–1.2)
3	Snaffle leaves a clear wet impression on the head (often with foam on the back piece and noseband) Throat and areas under saddle and girth consistently wet Flanks clearly wet	7.2–9.3	4	> 7–$\leq$ 9 (> 1.2–1.5)
4	Throat and flanks completely wet Moist, dark wrinkles above the eyes In heavily muscled or fat horses white coloured between posterior inner limbs because of pronounced foaming	9.6–11.8	6	> 9–$\leq$ 12 (> 1.5–2)
5	Horses additionally dripping fluid above the eyes and under the belly	12.7–18.0	9	> 12–18 (> 2–3)

*Number of observations.

methods and, as applied here, the examination of exercise-induced body weight changes (Marlin and Nankervis, 2002). Although generally accepted, each of these methods has disadvantages. When corrected for faecal and urinary losses, however, body weight differences provide very similar values to the more direct method using absorbent material (Meyer et al., 1990). Even though sweat losses constitute the substantial majority of total evaporative fluid losses and contribute to 75–85% and more of total heat losses through thermoregulation of horses during exercise (McCutcheon and Geor, 2008), measuring sweat losses *via* body weight changes leads to a systematic overestimation mainly due to respiratory water losses. Under climatic conditions similar to those in the current study, the respiratory water loss of exercised horses was estimated to be 0.5 ml/kg of body weight/hr, which can be used to correct body weight changes for its respiratory contribution (Heilemann et al., 1990; Meyer et al., 1990). This correction, however, does not take into account that the relationship between the fluid losses *via* the skin vs. the respiratory tract may be variable depending on exercise intensity and environmental conditions, as well as being influenced by the recovery period (Nadel, 1988). Despite these uncertainties, apart from extreme exercise intensities or climatic conditions, correcting data for respiratory fluid losses allows a more credible estimate of the quantity of exercise-induced sweat losses to be made (Heilemann et al., 1990; Meyer et al., 1990). Mean sweat losses for light and moderate work measured in the current study came to 4.2 and 11.7 litres, respectively, which superficially appears to be in good agreement with the reference book of the GfE (GfE, 1994; per 600 kg of bwt: light work 4.5, moderate work 9.0), but not with the NRC (NRC, 2007; per 600 kg of bwt: light work 1.5, moderate work 3.0). However, the compliance with the GfE-reference book (GfE, 1994) is only apparently satisfactory because sweat losses measured in the current study include those occurring in the recovery period, but the data of Meyer et al. (1990) which form the foundation of the GfE-information to our knowledge do not. This is an important point as sweat losses during 1 hr of recovery after 20 min of exercise at 50% V_{O_2max} under hot and humid conditions contributed to 49–66% of the total bwt losses in horses losing between 3.8 and 4.5 L of sweat during exercise (without recovery) (Geor et al., 2000). Although in the current study, exercise was performed at two different intensities under the more moderate conditions of a temperate climate zone each individual test lasted longer and recovery period which has been included in the measurement of bwt losses took clearly longer than in the exercise tests reported by Geor et al. (2000). Therefore, it can be assumed that sweat losses during the recovery period under the conditions of the current study also were a significant proportion of the total sweat losses. As sweat losses including both exercise and recovery period represent the physiologic fluid loss caused by exercise, they are likely to be more representative of the requirements.

Although variability in sweat losses is mentioned in the comments of GfE- and NRC-reference books (GfE, 1994; NRC, 2007), the tables for practical use contain fixed data only for a given work load and energy need, respectively, which precludes a flexible assessment of individual situations. For more abstract calculations, this may serve as a general orientation, but often this general guide may not be sufficiently accurate. For example, the range of estimated individual sweat losses was approximately 7 (1.6–8.6) and 15 (3.2–18) litres in light and medium work for a 600 kg horse (similar breed/fitness/diet/exercise intensity etc), respectively, in the current study. There is no possibility of overcoming this problem, however, if one continues to assume a strong linear dependency of the quantity of exercise-induced sweat losses and the partial energy need for exercise as currently suggested by the GfE (1994) and NRC (2007). As previously mentioned, other important factors which are difficult to quantify can also have significant influence on sweat losses (e.g. athletic fitness, climatic adaptation, hair length, temperament, arousal, interaction between horse and rider, depth and character of the subsoil) and, therefore electrolyte requirements.

The results of this study indicate that it should be possible to estimate exercise-induced sweat losses on an individual basis with a substantially higher accuracy by use of a sweat score, which is based on phenotypic characteristics and therefore takes into account more of the key influencing factors for an individual than existing methods. Further studies are required to verify the score proposed here and to check whether it can be applied to other conditions (different breeds and types of exercise; diverse weather conditions).

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