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Short communication

Core body temperature does not cool down with skin surface temperature during recovery at room temperature after acute heat stress exposure

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ABSTRACT

Identifying new methods of assessing livestock welfare is a growing area of research. Non-invasive methods such as infrared thermography are valuable for quick and accurate observations and could be utilized to monitor the thermal status of swine without direct contact. The study objective was to determine if infrared thermography could be used as a non-invasive, hands-off approach to accurately monitor the welfare of swine by comparing changes in skin surface temperature (SST), core body temperature (CBT), behavior, and heart rate during acute heat stress (AHS) and subsequent recovery in thermoneutral (TN) conditions. In eight replications, 16 pigs (n=8 barrows and 8 gilts) were subjected to AHS (39.3 ± 0.1 °C) for 30 min followed by TN (20.6 ± 0.1 °C) for 30 min. The SST, CBT, heart rate, and behavioral data were recorded throughout the entire experiment. During pre-treatment, ear base SST was greater ($P < 0.01$; 35.6 ± 0.3 °C) than all other locations. The SST at all locations increased ($P < 0.01$) linearly with duration of AHS exposure. During TN, maximum CBT was greater ($P < 0.01$; 40.6 ± 0.1 °C) compared to during AHS (40.3 ± 0.1 °C). Pigs spent more time standing during AHS ($P < 0.01$) and tended ($P = 0.10$) to lie more during TN; however, heart rate (141 ± 2.3 beats per minute) was not affected by treatment or duration. In summary, rapid TN exposure after an AHS challenge reduces SST; however, CBT was actually increased and this may have implications towards reduced activity and increased organ damage.

1. Introduction

Commercially raised pigs are subjected to multiple environmental stressors throughout their lifetime. Due to a lack of functional sweat glands (Fox et. al., 2013; Johnson et. al., 2013; Warriss et al., 2006), pigs are particularly susceptible to the effects of environmentally-induced heat stress (HS), which can result in production losses as well as morbidity and mortality (Johnson et al., 2015). Although the recommended temperature range for finishing and market weight pigs is 10–25 °C (FASS, 2010), pigs are often exposed to temperatures outside this range. In addition to HS, other stressors such as handling may increase heat production (Stewart et al., 2005) resulting in a greater body temperature and a subsequent increase in HS susceptibility (Addis et al., 1967). Therefore, elevated body temperature could be a potential tool to determine whether swine are stressed in a commercial setting (Brown-Brandl et. al., 2003; Kammersgaard et al., 2013).

The study objective was to determine if infrared thermography could be used as a non-invasive, hands-off approach to accurately monitor the welfare of swine by comparing changes in skin surface temperature (SST), core body temperature (CBT), behavior, and heart rate during acute heat stress (AHS) and subsequent recovery in thermoneutral (TN) conditions. We hypothesized that skin temperature in peripheral regions (ear, ear base) would be better suited to predict CBT than trunk regions (neck, shoulder, thorax, flank, rump, ham).

2. Materials and methods

2.1. Animals and study design

All experimental procedures using animals were approved by the Purdue University Animal Care and Use Committee (protocol #1406001096). In 8 repetitions (2 pigs per repetition), 16 crossbred pigs (n=8 gilts (nulliparous female) and 8 barrows (castrated male); 98.2 ± 2.0 kg BW; ¼ Large White × ¼ Landrace

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× ½ Duroc; 100 d of age) were housed in the Purdue University Swine Farm Environmental rooms and maintained in TN conditions (20.6 ± 0.1 °C and 78.6 ± 0.1% RH) to acclimate for 7 d. Pigs had ad libitum access to feed and water during the acclimation phase. The feed consisted primarily of corn and soybean meal and met or exceeded nutrient requirements (NRC, 2012). Light cycles were set at a 12 h light: 12 h dark cycle and all pigs were individually housed (1.8 m × 1.2 m pens with metal grate flooring) throughout the entire study.

On d 4, 5, and 6 of the acclimation period, pigs from each repetition were handled and individually moved into an identical environmental room across a corridor (6 m) set at 20.6 ± 0.1 °C and 70.6 ± 0.1% RH for 30 min (this room would later serve as the AHS room) and then returned to their room (to later serve as the TN room). This training occurred at similar times each day at 1000 h and the same groups of pigs were moved each time during acclimation period and during the experiment. The training was provided to minimize the effects of handling when pigs were moved into the AHS room for the experiment. Approximately 90 min prior to experimental AHS at 0800 h on d 7, temperature transmitters calibrated by the manufacturer (CorTemp™ T150002; accuracy: ± 0.1 °C; 2.0 cm × 0.5 cm; HQ Inc.; Palmetto, FL) were orally administered to the two pigs to monitor CBT and pigs were feed and water-restricted during the experiment period for 90 min. Pigs were fitted behind the forelimbs with an electrode-containing strap that was telemetrically connected to a receiver watch (Polar RS800CX, Finland) to collect heart rate data. Prior to data collection, pigs were allowed to rest in their home pen for 30 min to minimize any physiological changes due to handling. Baseline CBT and SST were collected every 1 min during the last 5 min of the 30-min rest period. Concurrently, heart rate was monitored for 5 min and average baseline beats per minute (bpm) was calculated. If the heart rate was higher than 250 bpm and less than 7 bpm, such data were considered noise and not included in analysis. This cleaning of data excluded 6.4% of total heart rate data.

Data loggers (HOBO; Onset ®; Bourne, MA) were used to record temperature and humidity in TN (20.6 ± 0.1 °C; 78.6 ± 0.2% RH) and AHS (39.3 ± 0.1 °C; 38.2 ± 0.2% RH) rooms. After the 30-min rest period, two pigs were moved into the AHS room and CBT and SST were recorded every 1 min for the first 5 min, and then every 5 min for the final 25 min. After the 30 min of AHS, pigs were returned to their home pen in TN conditions and CBT and SST were recorded as in the AHS room.

2.2. Thermal imaging

Skin surface temperature was determined by taking a broadside photo from a similar distance (1.5 m) and position perpendicular to the camera optical axis of individual pigs using an infrared thermal camera (FLIR-T62101; −20 °C to 1200 °C temperature range with ± 2% accuracy; NETD: < 0.045 °C @30° C; 320 × 240 pixels infrared resolution; 120° swivel lens and 25° × 19° field of view with 1–8 × continuous zoom; FLIR Systems Inc., Wilsonville, OR) with emissivity set at 1 and photos were analyzed using FLIR Tools software (version 2.1). Because pigs were housed within closed and clean environmental rooms without windows to the outside and water was not available during the experiment, no reflections or infrared radiation could influence measured surface temperatures and pigs remained dry and clean throughout the study. Temperatures at nine anatomical locations were recorded in each photo. The locations (Fig. 1) included ear (back of pinna), ear base (transition between pinna and neck), neck (above the vertebrae), shoulder (across the scapula), thorax (posterior to elbow over the fore ribs), flank (past the ribs and in front of the stifle muscle), rump (dorsal to hip), ham (below tail and above hocks), and body average (included the majority of the side profile). Body parts were selected manually using software function of the camera. An area of approximately 2 cm^2 within the parts as shown in Fig. 1 was selected to record the skin temperature for all body parts except ear base (approximately 1 cm^2) and body average (approximately 1300 cm^2). When the body parts were covered or enough areas were not exposed, those body parts were considered missing for analysis purpose.

2.3. Behavior observations

Pig behavior was recorded while pigs were in the AHS and TN room using ceiling mounted cameras (Panasonic WV-CP254H, Matsushita Electric Industrial Co. Ltd., Osaka, Japan) attached to the digital video recorder system. Video files were analyzed in Observer XT 11.5 (Noldus, The Netherlands) by one trained individual using continuous sampling technique. Postures included standing (when a pig was up on its four legs without running or jumping), lying (sternum or side in contact with floor), sitting (fore-legs extended, hind legs flexed and sternum off ground), and hyperactive (standing on its four legs but with running and attempts to jump within the pen). Behaviors included attempted feeding (head in feeder), attempted drinking (snout in contact with nipple drinker), activity (sham chewing, moving, chewing on pen objects), and inactive (absence of any of the previously noted behaviors). Percent of time each pig displayed a posture and a behavior was calculated. The 10 possible behaviors and postures were lying and no activity, lying and activity, sitting and no activity, sitting and drinking, sitting and eating, sitting and activity, standing and no activity, standing and drinking, standing and feeding, standing and activity, and hyperactivity. However, pigs did not display the combination of sitting and eating while they were in AHS or TN rooms.

2.4. Statistical analysis

Core body temperature data and skin surface temperature data were analyzed using the PROC MIXED procedure in SAS 9.4 (SAS Institute Inc., Cary, NC). Data within the AHS and TN periods were analyzed separately and were conducted with time (0–30 min) as the statistical model component. The statistical model was: $Y_{ijk} = \mu + T_i + e_{ij}$. Where, Y = parameter of interest, μ = mean, T = time, and e = residual. For repeated analyses of time within period, CBT and SST for each pig were analyzed using repeated measures with an auto-regressive covariance structure with time within the AHS or TN periods as the repeated effect. To analyze differences between periods, CBT and SST data within each period were averaged for individual pigs and the statistical model component was period (AHS, TN). The statistical model for period analyses was: $Y_{ijk} = \mu + {}_{Pi} + e_{ik}$. Where, Y = parameter of interest, μ = mean, P = period, and e = residual. Repetition was used as a random effect and CBT and SST during the pre-treatment period were used as a covariate for all CBT and SST analyses, respectively. Sex was included as a random variable for all analyses; however, because no differences were detected for any parameter it was removed from the final analysis.

Average percent of time spent in displaying a particular posture and behavior while in AHS and TN rooms were compared using general linear model. For data cleaning, only heart rate data between 75 and 250 bpm were considered for analysis. Average heart rates during the 10-min intervals when the pigs were in AHS and TN rooms were compared to baseline heart rate. Results are presented as mean ± SE where possible and $P < 0.05$ was considered significantly different and $0.05 \leq P \leq 0.1$ was considered to be a tendency.