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The effect of light vs dark coat color on thermal status in Labrador Retriever dogs.

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29 **Abstract**

30 Although dark coat color in dogs has been theorized as a risk factor for thermal stress,
31 there is little evidence in the scientific literature to support that position. We utilized 16 non-
32 conditioned Labradors (8 black and 8 yellow) in a three-phase test to examine effects of coat
33 color on thermal status of the dog. Rectal, gastrointestinal (GI), surface temperature, and
34 respiration rate measured in breaths per minute (bpm), were collected prior to (Baseline — phase
35 1) and immediately after a controlled 30-minute walk in an open-air environment on a sunny day
36 (Sunlight — phase 2). Follow up measurements were taken 15 minutes after walking (Cool
37 down – phase 3) to determine post-exposure return to baseline. No effect of coat color was
38 measured for rectal, gastrointestinal or surface temperature, or respiration ($P > 0.05$) in dogs
39 following their 30-minute walk. Temperatures increased similarly across both coat colors (rectal
40 1.88°C and 1.83°C ; GI 1.89°C and 1.94°C ; eye 1.89°C and 1.94°C ; abdominal 2.93°C and
41 2.35°C) for black and yellow dogs respectively during the sunlight phase ($P > 0.05$). All
42 temperatures and respiration rates decreased similarly across coat colors for rectal (0.9°C and 1.0
43 $^{\circ}\text{C}$) and GI (1.5°C and 1.3°C) for black and yellow dogs respectively ($P > 0.05$). Similarly, sex did
44 not impact thermal status across rectal, gastrointestinal or surface temperature or respiration rates
45 measured ($P > 0.05$). These data contradict the commonly held theory that dogs with darker coat
46 color may experience a greater thermal change when exposed to direct sunlight compared to
47 dogs with a lighter coat color.

48

49 **Keywords:** Canine, Labradors, Thermal Stress, Heat Stress, Dog, Thermal Imaging,
50 Temperature, Coat Color

51

52 **Introduction**

53 Darker coat color has been suggested as a potential risk factor for heat injury in dogs in
54 several publications [1-4] However, little evidence is available to support this theory, and a
55 majority of these claims appear in the introduction or discussion sections of publications, or in
56 review articles, with no supporting data. One study in Greyhounds reported higher rectal
57 temperatures in darker colored dogs following exercise but utilized greater numbers of males in
58 the darker coat participant group. These males were significantly larger in size than their female
59 cohorts, so it is not known if sex or size played a role in their results. In addition, the darker
60 colored group (n = 166) had more than twice the number of the light coated group (n = 63)
61 which may have impacted the outcome [5]. In another study using Newfoundland dogs, researchers
62 tested patches of white and black fur exposed to heat lamps. Authors measured the microclimate of the
63 dog's coat and reported no significant difference in temperature between white and black fur regions
64 on the dogs [6]. However, this study did not examine two separate groups of dogs with single coat
65 colors (i.e. solid black or white).

66 Work in cattle has demonstrated an impact on thermal status associated with coat color, but
67 this has not been thoroughly investigated in dogs. Increased solar absorption in darker coated cattle
68 has been demonstrated to increase overall heat gain [7]. Darker cattle exposed to direct sunlight had a
69 surface temperature gain of 4.8 °C, while lighter cattle only increased surface temperature by 0.7°C
70 [8]. Additionally, this study reported increased incidence of elevated surface temperature, respiration,
71 sweating, and heat stress signals in darker colored cattle compared to lighter colored cattle.

72 The risk of thermal injury to dogs is of significant concern to the veterinary community and is
73 considered a common occurrence especially during the summer months. Evidence to validate the

74 ideas surrounding coat color as a risk factor would be helpful in establishing a better understanding of
75 any increased danger facing dark coated dogs. Assessment of risk for heat injury can only be
76 accurately evaluated by studying dogs that incur heat injury in comparison to dogs that do not,
77 whether prospectively or retrospectively. Prospective studies of this nature are inherently difficult to
78 conduct as our current standards of ethics and animal stewardship generally preclude experimentally
79 induced heat injury in dogs. In addition, given the relatively low incidence of naturally occurring heat
80 injury in any given population of dogs, prospective studies relying on naturally occurring cases would
81 require a significant amount of time to complete. Thus, risk of heat injury is primarily based on
82 observations of normal thermoregulatory reactions to safe levels of thermal stress, typically induced
83 by exercise. In this study, we exposed dogs of light and dark coat colors to mild exercise (i.e. loose
84 leash walk) in direct sunlight to assess thermoregulatory reactions and measure various parameters
85 associated with body temperature and thermoregulation. The objective of this research was to identify
86 the impact of coat color on the thermal status of dogs exposed to direct sunlight and to measure the
87 increase in temperature experienced by black dogs as compared to yellow dogs.

88

89 **Materials and Methods**

90 **Animals and Diets**

91 Institutional Animal Care and Use approval (protocol #18-022) was received from
92 Southern Illinois University prior to initiation of the study. The study was conducted in mid-
93 June in Carbondale, Illinois with seasonally typical environmental conditions (mean outdoor
94 temperature 29.34 ± 1.76 °C, 84.81 ± 3.17 °F). Non-conditioned Labrador Retrievers (n = 16)
95 from a single kennel and with similar genetics were recruited for participation in this study.
96 “Non-conditioned” was determined as having daily exercise consisting of 4 ± 1 hours of daily

97 group turnout but the absence of a specific conditioning or exercise program. All dogs
98 utilized came from 2 litters to limit for genetic variability. Dogs had a mean age of 2.73 ± 1.86
99 years, mean weight 26.6 ± 3.32 kg and a mean BCS of 5.5 ± 1.5 . Study participants were maintained
100 on a commercial kibble diet (Victor High Energy, Mid America Pet Food Mount Pleasant, Texas)
101 and fed twice daily for 60 days prior to the study. All dogs were up to date on vaccinations (rabies,
102 bordetella, DHLPP) and received a monthly standardized parasite control regimen (Frontline Plus,
103 Merial France) (Interceptor Plus, Elanco, Greenfield, IN). All study participants received a health
104 screening by a licensed veterinarian prior to inclusion in the study and were also assigned a body
105 condition score (BCS) by a trained researcher (Nestle Purina Petcare Company, St. Louis, MO).
106 Following this exam, one canine was excluded from participation due to a previously undiagnosed
107 dermal condition. Dogs of opposite colors were paired according to sex and BCS for participation.

108 **Phases**

109 The study was separated into three phases. Phase 1 (Baseline) included housing of each dog
110 for 30 uninterrupted minutes in a climate-controlled room in individual crates. Phase 2 (Sunlight)
111 consisted of 30 minutes of loose leash walking at a controlled pace in an uncovered outdoor sandy
112 arena measuring 30m by 60m. The study concluded with Phase 3 (Cooling) and incorporated a 15-
113 minute rest in a climate-controlled room in individual crates. All dogs were monitored throughout the
114 study by veterinary staff stationed in the center of the outdoor arena and climate-controlled holding
115 area, and all dogs were allowed ad libitum access to water while in their crates during both the
116 Baseline and Cooling phases of the study.

117 Environmental conditions in the outdoor arena and in the climate-controlled room were
118 monitored (Accurite Wireless Weather Station, Chaney Instrument Co. Lake Geneva, WI) to record
119 temperature, humidity and heat index every five minutes.

120 **Data Collection**

121 Thermal status data for each dog were captured immediately following each of the three
122 phases utilizing four methods as shown in Fig 1. Gastrointestinal (GI) data were captured using an
123 ingestible thermistor orally administered (CorTemp, CorTemp Inc, Palmetto, FL) 30 minutes
124 (± 15) prior to the Baseline phase. GI temperatures were monitored with a handheld wireless
125 reader (CorTemp, HQInc Palmetto, FL.). GI temperature was recorded in triplicate for each data
126 collection period to ensure accuracy and the mean was utilized for statistical analysis. Rectal
127 measurements were collected in tandem, using calibrated, 8second digital thermometers
128 (American Diagnostics Company ADTEMP II model #413B) inserted to a depth of
129 approximately 2 cm with petroleum jelly to minimize canine discomfort. Thermal images of
130 participants were captured using a forward-looking infrared thermal camera (FLIR T400 thermal
131 camera) at an approximate distance of 2 meters from the canine to capture body surface
132 temperature as previously described [9-12]. To reduce the effects of environmental factors, all
133 images were captured in an enclosed area with no exposure to wind or direct sunlight. Thermal
134 images were analyzed using thermography software (ThermaCam Researcher Professional 2.9,
135 FLIR Systems Inc. Wilson, OR, USA) to determine body surface temperature at the left eye
136 and caudal abdomen as described previously [13-15] with examples shown in Fig 2.

137
138 **Fig 1.** Pictogram representing the phases and points of data collection.

139
140
141 **Fig 2.** Thermography¹ depicting Baseline² (left) and Sunlight³ (right) values for Labrador Black
142 6. The two areas of interest were left eye⁴ and left caudal abdomen⁵.

143
144
145 Digital video was utilized to record respiration rates (GoPro Camera, GoPro Inc. San
146 Mateo, Ca) for 30 seconds at the start of each data collection period prior to rectal temperature

147 monitoring. The head, face, and tongue were captured and later played back in slow motion to
148 count respiration during this 30 second period. A single independent observer was utilized
149 throughout all canine respiration videos to minimize observer bias. Respiration was calculated as
150 breaths per minute (BPM) = 30-second respiration x 2.

151 **Statistical Analysis**

152 All data were analyzed using SAS version 9.4 (SAS Institute Inc., Cary, NC). Each
153 phase (baseline, sunlight, cooling) was examined using a Proc Glm repeated measures test.
154 Baseline and Sunlight temperatures were examined using a paired t test to identify main effects
155 of coat color and sex for dependent variables including rectal, gastrointestinal, surface
156 temperature, respiration rate, and water consumption.

157 Additionally, a multivariate ANOVA was utilized to identify differences associated with the
158 interactions of coat color and sex on rectal, gastrointestinal, body surface temperature,
159 respiration, and water consumption. Water consumption throughout the data collection period
160 was calculated as: Water offered – Water remaining = Water consumed

161 Return to baseline was identified as having achieved a cooling phase temperature within 0.5°F of the
162 dog's initial baseline temperature using the below equations. If the cooling phase temperature had
163 fallen to within 0.5°F, it was deemed “yes” the dog returned to a baseline temperature. The following
164 equation was utilized:

$$165 \quad \text{Baseline} - \text{Cooling} \leq 0.5^{\circ}\text{F} = \text{Return to Baseline (Yes)}$$

$$166 \quad \text{Baseline} - \text{Cooling} \geq 0.5^{\circ}\text{F} = \text{Return to Baseline (No)}$$

167 Return to baseline was reported as Yes or No and was analyzed using the Proc Freq procedure of SAS
168 (chi square) to examine differences coat color and sex. Significance for all outcomes was established
169 at $P < 0.05$.

170

171 Results

172 Following 30 minutes of walking in direct sunlight, rectal temperatures increased by 1.88°C in
 173 black dogs, and 1.83 °C in yellow coated dogs (P< 0.0001). Similarly, GI temperatures
 174 increased by 1.89 °C in black coated dogs, and 1.94 °C in the yellow group, (P < 0.0001) as
 175 shown in Fig 3. Eye surface temperature increased by 2.8 °C black and 1.93 °C yellow (P <
 176 0.005) and abdominal surface temperature increased by 2.93 °C black and 2.35 °C yellow (P <
 177 0.0001). See Figs 3-4, Table 1. No significant temperature difference was noted between black
 178 and yellow Labradors across all phases.

179 **Fig 3.** Mean change in rectal¹ and gastrointestinal temperature (GI)² across three phases in non-
 180 conditioned Labradors.

181

182 **Fig 4.** Mean change in body surface temperature measured by thermography¹ at the eye² and
 183 abdomen³ in non-conditioned Labradors

184

185 **Table 1.** Mean values of thermal status indicators₁ across three phases (Baseline², Sunlight³, Cooling⁴) in
 186 Labradors grouped by coat color.

Variable	Color	Baseline	P-value	Sunlight	P-value	Cooling	P-value
Rectals₅	Black	38.44±0.37 °C ^a 101.2±0.7 °F	0.8404	40.3±0.41 °C ^b 104.5±0.8 °F	0.9354	39.46±0.34 °C ^c 103±0.6 °F	0.4673
	Yellow	38.51±0.52 °C ^a 101.3±1.0 °F		40.31±0.34 °C ^b 104.6±0.6 °F		39.43±0.30 °C ^c 102.8±0.4 °F	
GI₆	Black	38.76±0.25 °C ^a 101.8±0.5 °F	0.6279	40.68±0.47 °C ^b 105.2±0.9 °F	0.8286	39.2±0.6 °C ^c 102.6±1.1 °F	0.8153
	Yellow	38.66±0.48 °C ^a 101.6±0.9 °F		40.61±0.21 °C ^b 105.1±0.4 °F		39.29±0.26 °C ^c 102.6±0.5 °C ^c	
Eye₇	Black	36.09±0.57 °C ^a 97.0±1.1 °F	0.0934	38.89±0.42 °C ^b 102.0±0.8 °F	0.3004	37.4±0.5 °C ^c 99.3±0.96 °F	0.0973

	Yellow	36.68±0.55 °C ^a 98.0±1.1 °F		38.6±0.54 °C ^b 101.5±1.0 °F		36.9±0.51 °C ^c 98.4±1.0 °F	
Abdominal₈	Black	36.24±0.91 °C ^a 97.2±1.7 °F	0.7763	39.15±0.73 °C ^b 102.5±1.4 °F	0.0908	37.4±0.5 °C ^c 100.7±1.3 °F	0.1002
	Yellow	36.01±1.44 °C ^a 96.9±2.9 °F		38.4±0.75 °C ^b 101.1±1.5 °F		36.9±0.51 °C ^c 99.6±1.2 °F	
Respiration₉	Black	123.3±20.5 ^a	0.7206	270.5±40.2 ^b	0.744	241.7±24.5 ^c	0.2998
	Yellow	132.9±40.7 ^a		276.6±28.2 ^b		216.4±59.7 ^c	

187

188 *Notes a significant difference observed by coat color

189 ^{a,b,c}Notes a significant difference observed by phase

190 ¹Thermal status indicators including rectal, gastrointestinal, eye and abdominal temperature

191 ²Baseline occurred 30 minutes prior to sunlight exposure (sunlight) and recorded initial measurements

192 ³Sunlight phase consisted of 30 minutes of active walking in a sunny outdoor area on a leash

193 ⁴Cooling phase occurred 15 minutes after walking in a climate-controlled room with water

194 ⁵Rectal temperature was recorded by inserting thermometer to a depth of approximately 2 cm with petroleum jelly

196 ⁶GI (gastrointestinal) temperature was recorded with an ingestible thermistor CorTemp 30 minutes prior to baseline

198 ⁷Eye temperature was captured using thermography FLIR T400 at the left eye

199 ⁸Abdominal temperature was captured using thermography FLIR T400 at the left caudal abdomen

200 ⁹Respiration rate was captured for 30 seconds utilizing a GoPro, depicted as breaths per minute (bpm)

201

202 Similarly, all temperature measurements significantly decreased from sunlight to cooling

203 phase. Following cessation of cooling phase, rectal temperatures decreased by 0.84°C black and 1.0

204 °C yellow (P< 0.0001) and GI temperatures decreased 1.45 C in black dogs and 1.33 in yellow

205 dogs (P< 0.0001) as shown in Fig 3. Thermal eye surface temperature decreased 1.49 °C in black

206 and 1.71 °C in yellow dogs (P < 0.005), and abdominal surface temperature decreased by 1.0 °C

207 black and 0.85 °C yellow (P < 0.0001) as shown in Fig 4. A similar change in respiration rates

208 was shown across both coat colors of Labradors, meaning that coat color did not significantly

209 impact breathing rates across phases (P > 0.05), as shown in Fig 5.

210

211 **Fig 5.** Mean change in respiration rates¹ across three phases in non-conditioned Labradors.

212

213

214 Exposure to walking in sunlight significantly increased the rectal (1.84°C), GI (1.94°C), eye
 215 surface (2.41°C) and abdominal surface (2.67°C) temperatures of all dogs when Baseline and
 216 Sunlight temperatures were compared ($P < 0.0001$). Furthermore, returning to the climate-
 217 controlled room significantly decreased the rectal (0.7°C), GI (1.41°C), eye surface (1.58°C), and
 218 abdominal surface (0.92°C) temperature of all dogs ($P < 0.0001$).
 219
 220 After completion of 30 minutes in direct sunlight walking, both males and females saw a similar
 221 increase across all temperatures, rectal (1.83°C male, 1.84°C female), GI (2.04°C male, 1.87°C
 222 female), eye surface (2.3°C 2 male, 2.5°C female) and abdominal surface (2.93°C male and 2.5
 223 °C female). A similar fall in temperatures for both sexes was seen after 15 minutes of passive
 224 cooling, rectal (0.92°C male, 0.89°C female), GI (1.32°C male, 1.47°C female), eye surface
 225 (1.62°C male, 1.57°C female), and abdominal surface (1.0°C male, 0.87°C female) as shown in
 226 Figures 6-7, Table 2.

227
 228 **Fig 6.** Mean change in rectal¹ and gastrointestinal temperature (GI)² across three phases in non-
 229 conditioned Labradors.

230
 231 **Fig 7.** Mean change in surface temperature measured by thermography¹ at the eye² and
 232 abdomen³ in non-conditioned Labradors across three phases.

233
 234 **Table 2.** Mean values of thermal¹ status indicators across three phases (Baseline²,
 235 Sunlight³, Cooling⁴) in Labradors grouped by sex.

VARIABLE	SEX	BASELINE	P-VALUE	SUNLIGHT	P-VALUE	COOLING	P-VALUE
RECTAL ₅	Male	38.52±0.35 °C ^a 101.3±0.7°F	0.8536	40.35±0.31 °C ^b 104.6±0.6 °F	0.6991	39.43±0.3 °C ^c 103±0.6 °F	0.7511
	Female	38.44±.5 °C ^a 101.2±0.9 °F		40.28±0.41 °C ^b 104.5±0.8 °F		39.39±0.27 °C ^c 102.9±0.5 °F	
GI ₆	Male	38.68±0.36 °C ^a 101.7±0.7 °F	0.9407	40.72±0.21 °C ^b 105.3±0.4 °F	0.6005	39.4±0.41 °C ^c 102.9±0.8 °F	0.3736
	Female	38.73±0.39 °C ^a 101.7±0.7 °F		40.6±0.44 °C ^b 105.1±0.9 °F		39.13±0.49 °C ^c 102.4±0.9 °F	

EYE₇	Male	36.58±0.64 °C ^a 97.9±1.3 °F	0.2509	38.9±0.14 °C ^b 102.0±0.3 °F	0.3087	37.28±0.5 °C ^c 99.1±1.0 °F	0.5457
	Female	36.16±0.57 °C ^a 97.1±1.1 °F		38.66±0.62 °C ^b 101.6±1.2 °F		37.09±0.59 °C ^c 98.8±1.1 °F	
ABDOMINAL₈	Male	36.2±0.95 °C ^a 97.2±2.0 °F	0.8360	39.13±0.34 °C ^b 102.4±0.7 °F	0.1674	38.13±0.45 °C ^c 100.6±0.9 °F	0.9533
	Female	36.09±1.33 °C ^a 97.0±2.5 °F		38.58±0.97 °C ^b 101.4±1.9 °F		37.71±0.81 °C ^c 99.9±1.5 °F	
RESPIRATION₉	Male	124.0±50.3 ^a	0.8203	274.0±34.4 ^b	0.9533	225.3±33.9 ^c	0.8553
	Female	130.2±51.4 ^a		272.9±35.9 ^b		230.1±56.0 ^c	

236

237 *Notes a significant difference observed by sex

238 ^{a,b,c} Notes a significant difference observed by phase

239 ¹Thermal status indicators including rectal, gastrointestinal, eye and abdominal temperature

240 ²Baseline occurred 30 minutes prior to sunlight exposure (sunlight) and recorded initial measurements

241 ³Sunlight phase consisted of 30 minutes of active walking in a sunny outdoor area on a leash

242 ⁴Cooling phase occurred 15 minutes after walking in a climate-controlled room with water

243 ⁵Rectal temperature was recorded by inserting a thermometer rectally 2cm

244 ⁶GI (gastrointestinal) temperature was recorded with an ingestible thermistor CorTemp 30 minutes prior to baseline

245 ⁷Eye temperature was captured using thermography FLIRT400 at the left eye

246 ⁸ Abdominal temperature was captured using thermography FLIR T400 at the left caudal abdomen

247 ⁹Respiration rate was captured for 30seconds utilizing a GoPro, depicted as breaths per minute(bpm)

248

249

250 Across all phases of the study, sex did not show a significant effect on respiration rates

251 of the Labradors, with both sexes showing a similar increase and decrease in bpm ($P > 0.05$), as

252 shown in Fig 8.

253

254 **Fig 8.** Mean change in respiration rates¹ across three phases in non-conditioned Labradors.

255

256

257 No effect of coat color ($P = 0.5560$) or sex ($P = 0.9806$) was seen for water consumption

258 with black dogs consuming 173.75± 195.3 ml and yellow dogs consuming

259 221.21±57.1 ml.

260

261 No effect of coat color was noted when rectal temperatures were examined for a return to

262 baseline in 12.5% and 28.6% of black and yellow dogs respectively, ($P = 0.5692$). Similarly, GI

263 temperatures returned to baseline 50% of black and 42.9% of yellow dogs ($P = 1.00$) and

264 abdominal surface temperature with 12.5% black and 28.6% yellow dogs ($P = 0.6080$) returning

265 to baseline values. Conversely, coat color did impact the dog's return to baseline when eye
266 surface temperature was examined with 12.5% black and 71.4% yellow dogs achieving baseline
267 values after their Cooling phase, as shown in Table 3 (P = 0.0406).

268
269 **Table 3.** Return to baseline¹ rectal², gastrointestinal³ (GI), thermal eye⁴, and thermal abdominal⁵
270 temperatures by coat color and sex.

271

VARIABLE	BLACK	YELLOW	P-VALUE	MALE	FEMALE	P-VALUE
RECTAL	12.5%	28.6%	0.5692	16.7%	22.2%	1.00
GI	50%	42.9%	1.00	33.3%	55.6%	0.6084
EYE	12.5%	71.4%	0.0406*	50%	33.3%	0.2286
ABDOMINAL	12.5%	28.6%	0.6080	0%	33.3%	0.6080

272
273 *Notes a significant difference between groups
274 ¹Return to Baseline occurred when cooling temperature returned within 0.5°F of the initial baseline temperature
275 reading measured 30 min prior to sunlight exposure (sunlight
276 ²Rectal temperature was recorded by inserting a thermometer in 2cm rectally
277 ³GI (gastrointestinal) temperature was recorded with an ingestible thermistor CorTemp 30 minutes prior to baseline
278 ⁴Eye temperature was captured using thermography FLIR T400 at the left eye
279 ⁵Abdominal temperature was captured using thermography FLIR T400 at the left caudal abdomen

280
281 Sex did not influence cooling as rectal temperatures returned to baseline in 22.2% and 16.7% of
282 female and male dogs respectively (P =1.00). Temperatures for the GI tract returned to baseline
283 in 55.6% of female and 33.3% of male dogs (P =0.6084).

284 Similarly, no effect of sex was observed for cooling of surface temperatures measured at
285 the caudal abdomen with 33.3% of female and 0% of male dogs returning to baseline values (P
286 = 0.6080). Eye surface temperature returned to baseline in 33.3% female and 50% of male dogs
287 achieving baseline values after their Cooling phase (P = 0.2286), as shown in Table 3.

288 289 Discussion

290 Black dogs did not demonstrate a difference in temperature following exposure to
291 direct sunlight when compared to yellow dogs for any of the parameters we examined,

292 including rectal thermometer using a standard medical-grade predictive digital thermometer,
293 GI temperature using an ingestible thermistor, eye surface temperature and abdominal
294 surface temperature using forward-looking infrared thermography, respiration or water
295 consumption. Contradictory to currently held beliefs, all dogs experienced a similar rise
296 in rectal, GI, surface temperature, and respiration from the baseline to the sunlight
297 phase, with no difference shown between dark vs lighter coated dogs ($P > 0.05$) as shown
298 in Figures 3–5 and Table 1. Furthermore, no effect of sex was measured as both males
299 and females demonstrated similar responses to sunlight exposure and cooling based on
300 rectal, GI, eye surface, abdominal temperatures, and respiration rates ($P > 0.05$) shown
301 in Figures 6-8, and Table 2.

302 Contrary to the commonly held belief, our data demonstrated that black dogs did not
303 experience a greater heat gain than their yellow counterparts. Similarly, there was no
304 difference in the apparent thermoregulatory effect between dark and light dogs. This is
305 particularly noteworthy because of the relative short duration of the walk and the significant
306 temperature increase we observed in both dark and light-coated dogs. It is also interesting to
307 note that the 15-minute cooling period was inadequate for 80% of the dogs to achieve
308 baseline thermal status based on rectal measurements which are considered standard for
309 recording accurate temperature in animal species [16] .

310 Conversely, almost 50% of each group was able to return to a baseline values via
311 GI values after 15 minutes of cooling. This could be attributed to water consumption
312 during the cooling phase affecting the CorTemp capsule reading. [17] However, it is
313 important to note that all dogs did experience a significant decrease in their rectal, GI,
314 eye and abdominal temperatures, and respiration rates. Future work should include

315 studies with a longer cooling period to determine that time frame necessary for
316 non-conditioned dogs to achieve baseline thermal status following thermal stress.
317 The data presented here are inconsistent with the previous study examining racing
318 greyhounds with larger proportions of dark coated dogs having higher rectal
319 temperatures after racing [5] . Key differences between this study and the prior study on
320 Greyhounds include controlled coat color (black or yellow vs. multiple light or dark
321 colors), tighter grouping of age and sex, and a controlled time period and consistent
322 environment. However, there were fewer dogs in our study compared to the study on
323 Greyhounds (16 vs. 229). Power calculations indicate that it would take more than 500 dogs
324 to adequately test this question using an alpha of 0.05 and 80% power. That number of dogs
325 is beyond our capacity. Furthermore, the greyhounds utilized in the previous study were
326 considerably more fit than the non-conditioned dogs used in our study. Fitness level can
327 impact thermal response as previously demonstrated in working canines [18, 19] and
328 should be examined as a controlled factor in future work.

329 Infrared thermal cameras have been widely used in livestock species to identify
330 changes in the surface temperature of the animals. These studies focused on areas that
331 had more skin exposure for more accurate data, such as the flank, eye, and facial region.
332 In our canine study, thermal images were captured inside a building to reduce effects
333 from wind, sun, and other environmental exposures. Both yellow and black dogs showed
334 similar changes in body surface temperatures which does not support the idea that coat
335 color is a potential risk factor for thermal stress. A comparison of skin surface
336 temperature during exposure to sunlight in dogs is warranted. There were some
337 challenges associated with the capture of the thermal imaging. Although the baseline

338 photos were captured with little difficulty, many of the dogs were hot following the
339 sunlight exposure and several were non-compliant in assuming the same posture. More
340 obedient/compliant dogs would prove better subjects for this nature of study.

341 In designing the study, we considered that if body temperature measurements
342 were similar between the dark and light coated dogs, perhaps dark coated dogs simply
343 undertook increased efforts of thermoregulation such as increased respiration (i.e.
344 panting) or increased water consumption. However, we found no difference in these
345 parameters between the dark and light coated dogs, suggesting that the effort they
346 expended to thermoregulation was also similar. A key limitation in our study is that we
347 did not record heart rate, which would be important in assessment of thermoregulatory
348 response. More sophisticated instrumentation and monitoring would be important in
349 further studies to determine if more subtle physiological changes were occurring with
350 thermoregulation.

351 Novel data produced by this work include an absence of significant difference in
352 body temperature between black or yellow coated dogs. The techniques utilized to assess
353 temperature, panting and water consumption are non-technical, readily available methods
354 for canine handlers or owners to assess thermal status of dogs in the field, and thus are
355 important to prevention of heat related injury. These data provide critical evidence to dispute
356 the theory that dark coat color is a risk factor for thermal stress which is reported across
357 several forums including veterinary textbooks and previously published articles [1-4].
358 In this experiment, dark and light-colored dogs exposed to the same environment
359 showed a similar heat gain and loss (mean peak rectal 40.31 ± 0.37 °C and mean peak GI
360 temperatures 40.65 ± 0.37 °C respectively). This study also showed that when these non-

361 conditioned dogs reached rectal temperatures near 40.9 °C (105.62 °F), and
362 gastrointestinal temperatures near 42°C (106.16 °F), 15 minutes of rest in a cool room
363 with water available for consumption is adequate to begin to decrease the temperature,
364 although a return to baseline values may not be achieved within that time frame. No
365 medical intervention or active cooling method was needed to decrease the dogs’
366 temperature and nor heat-related negative health impacts were noted by the veterinary
367 team on site, despite dogs reaching temperatures as high as 42°C (106.16 F).

368

369 **Ethical Conflicts**

370 The authors declare that they had no conflict of interest.

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378

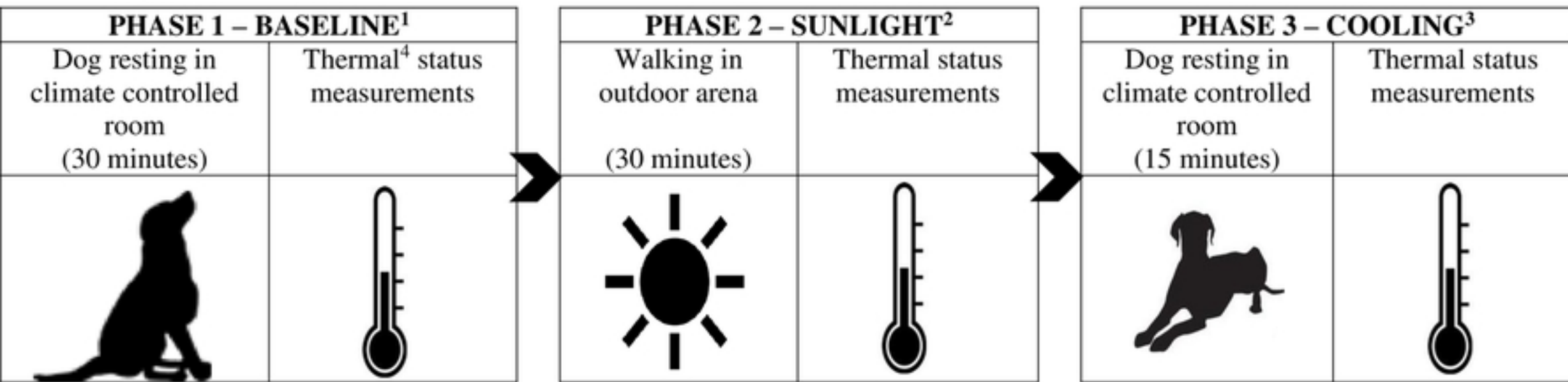
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- 424

Fig 1. Pictogram representing the phases and points of data collection.



¹Baseline occurred 30 minutes prior to sunlight exposure (sunlight) and recorded initial measurements

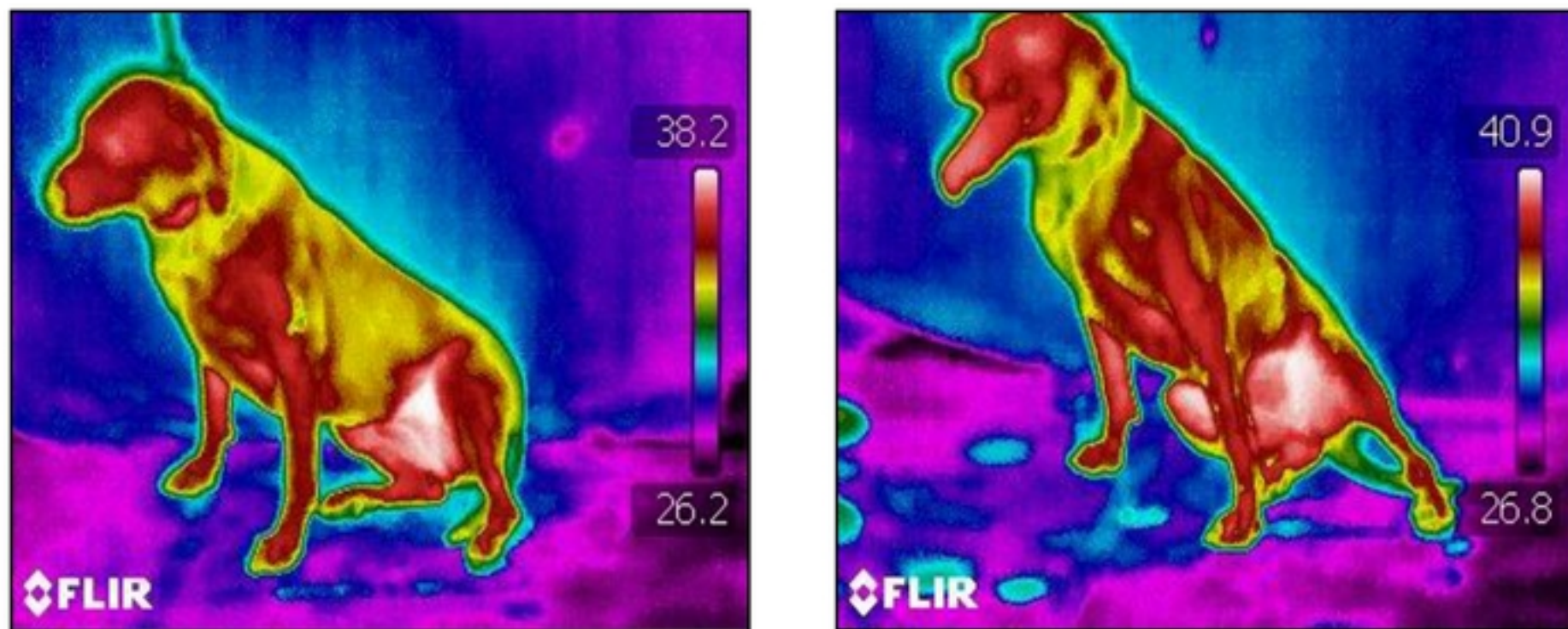
²Sunlight phase consisted of 30 minutes of controlled pace walking in a sunny outdoor area on a leash

³Cooling phase occurred 15 minutes after walking in a climate-controlled room with water

⁴Thermal status measurements consisted of rectal, gastrointestinal, eye surface, abdominal surface temperature, and respiration rate

Figure 1

Fig 2. Thermography¹ depicting Baseline² (left) and Sunlight³ (right) values for Labrador Black 6. The two areas of interest were left eye⁴ and left caudal abdomen⁵.



¹Thermography captured using FLIR T400. Peak values noted at the top of the color legend at the right of each image.

²Baseline occurred 30 minutes prior to sunlight exposure (sunlight) and recorded initial measurements

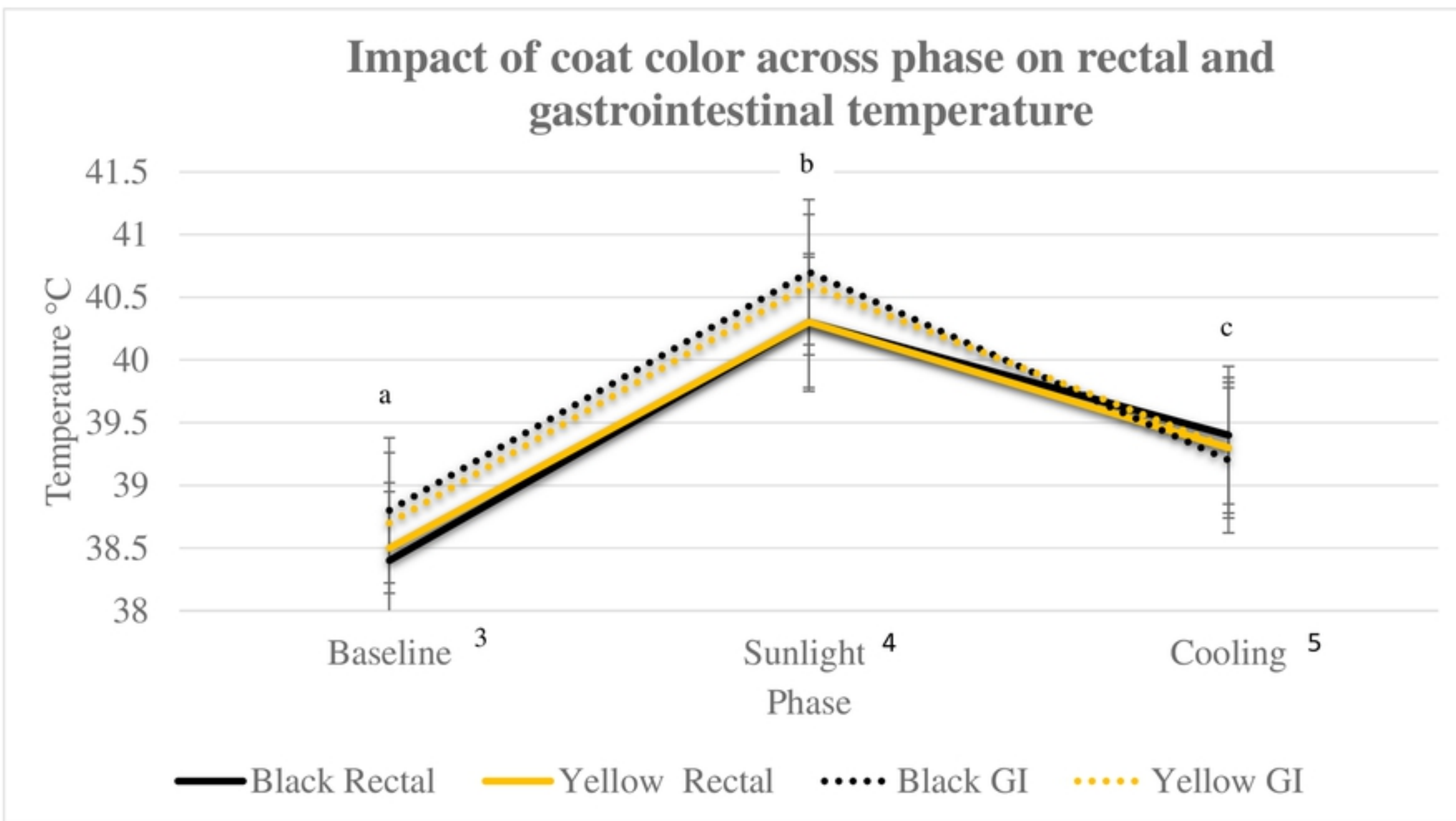
³Sunlight phase consisted of 30 minutes of active walking in a sunny outdoor area on a leash

⁴Eye thermal temperature has been correlated with rectal temperature.

⁵Abdominal temperature has been correlated with rectal temperature.

Figure 2

Fig 3. Mean change in rectal¹ and gastrointestinal temperature (GI)² across three phases in non-conditioned Labradors.



^{a,b,c} Notes significant difference by phase

* Notes significant difference by color

¹ Rectal temperature was recorded by inserting thermometer to a depth of approximately 2 cm with petroleum jelly

² GI (gastrointestinal) temperature was recorded with an ingestible thermistor CorTemp 30 minutes prior to baseline

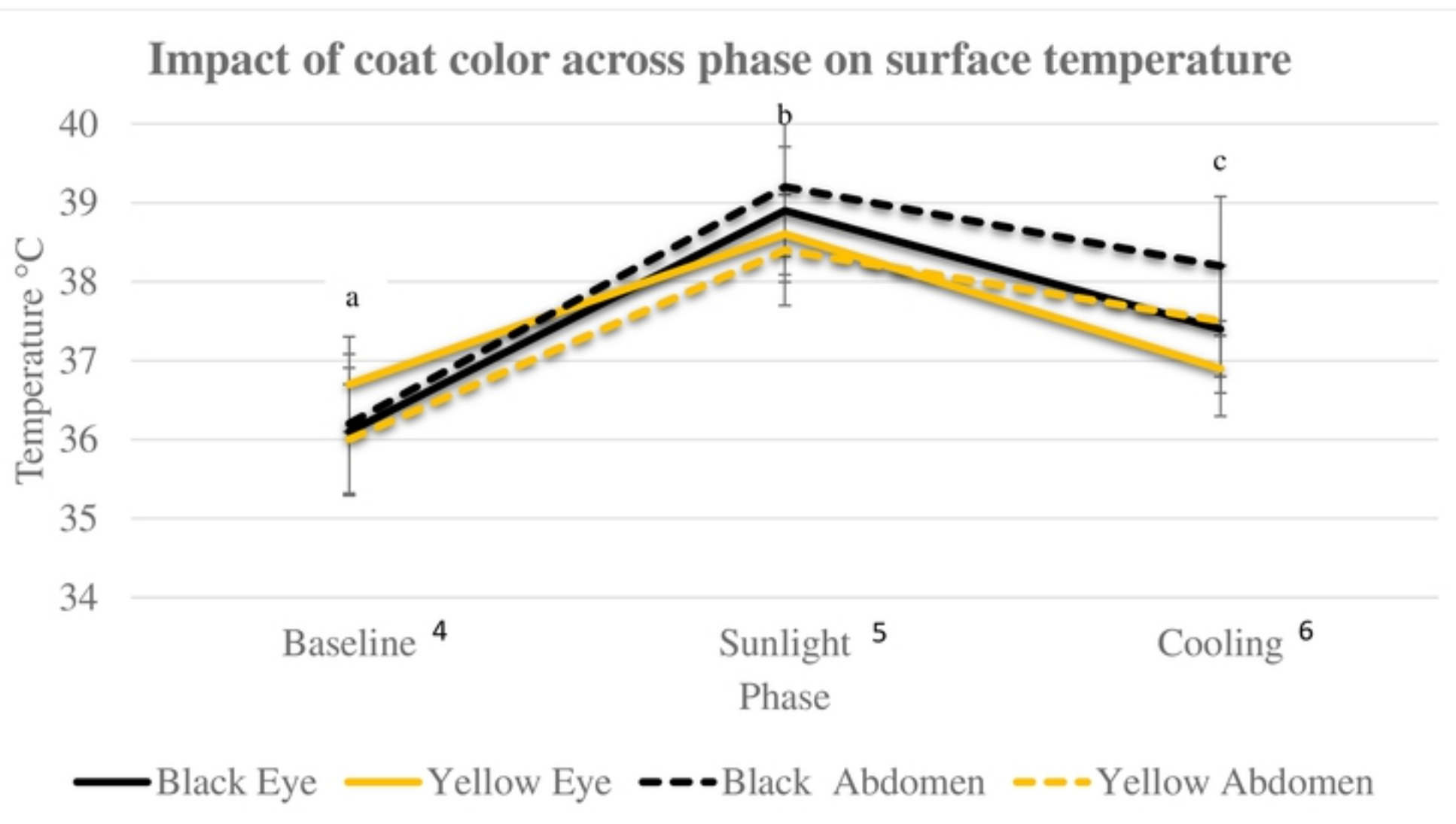
³ Baseline occurred 30 minutes prior to sunlight exposure (sunlight) and recorded initial measurements

⁴ Sunlight phase consisted of 30 minutes of active walking in a sunny outdoor area on a leash

⁵ Cooling phase occurred 15 minutes after walking in a climate-controlled room with water

Figure 3

Fig 4. Mean change in body surface temperature measured by thermography¹ at the eye² and abdomen³ in non-conditioned Labradors



^{a,b,c} Notes significant difference by phase

* Notes significant difference by coat color

¹Thermography captured using FLIR T400

²Eye temperature was captured using thermography focusing on left eye

³Abdomen (Ab) temperature was captured using thermography focusing on left caudal abdomen

⁴Baseline occurred 30 minutes prior to sunlight exposure (sunlight) and recorded initial measurements

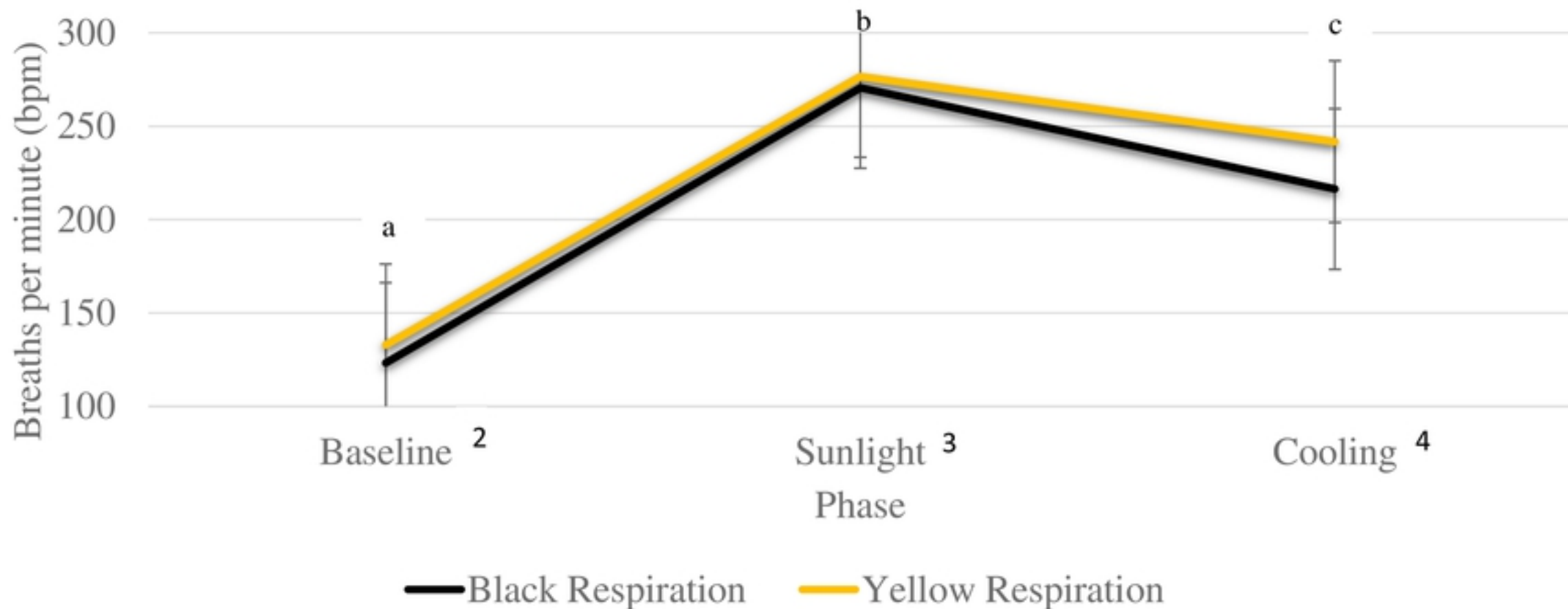
⁵Sunlight phase consisted of 30 minutes of active walking in a sunny outdoor area on a leash

⁶Cooling phase occurred 15 minutes after walking in a climate-controlled room with water

Figure 4

Fig 5. Mean change in respiration rates¹ across three phases in non-conditioned Labradors.

Impact of coat color across phase on respiration rate



^{a,b,c} Notes significant difference by phase

^{*} Notes significant difference by coat color

¹ Respiration rate was captured for 30 seconds by a GoPro camera

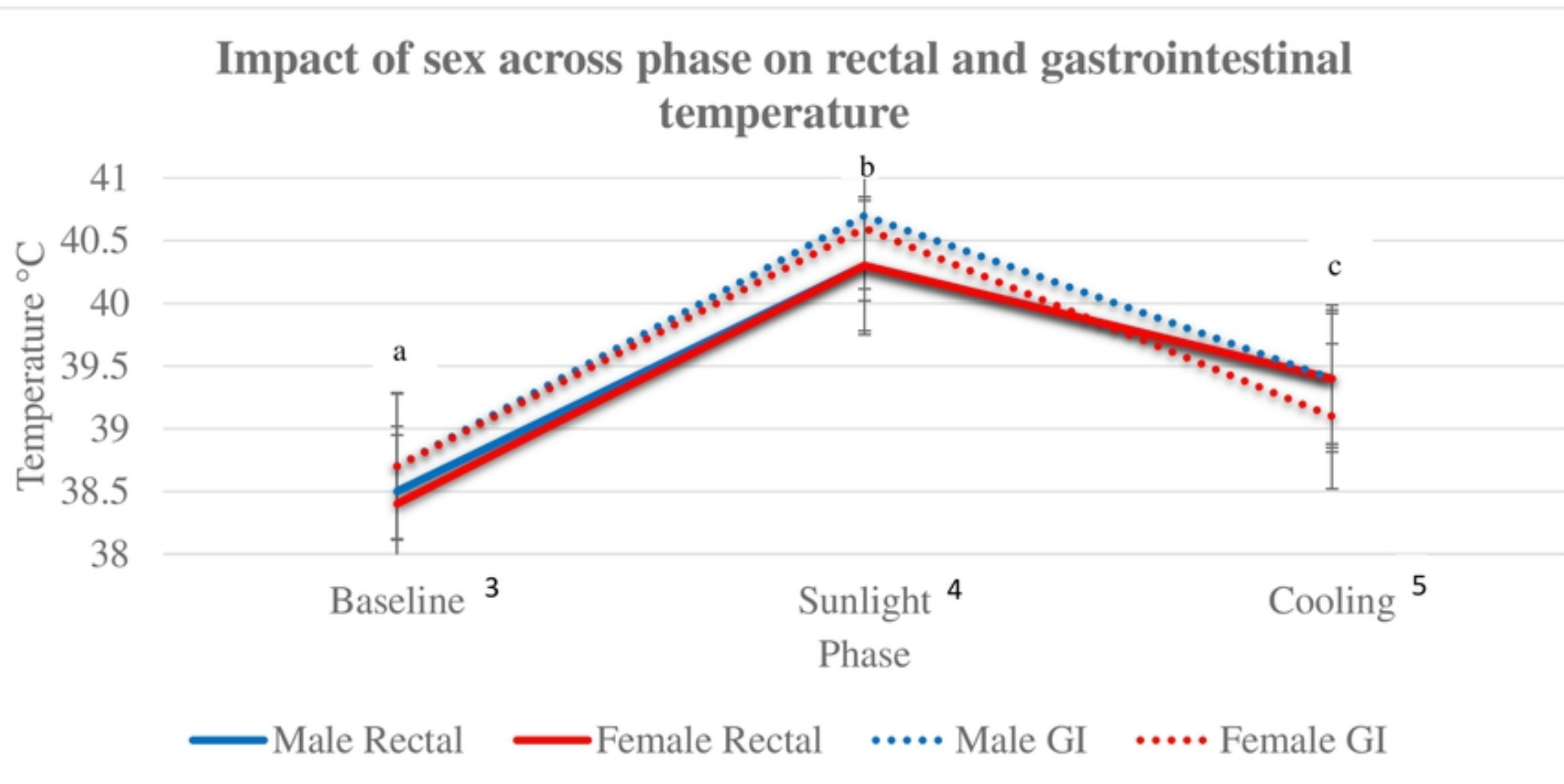
² Baseline occurred 30 minutes prior to sunlight exposure (sunlight) and recorded initial measurements

³ Sunlight phase consisted of 30 minutes of active walking in a sunny outdoor area on a leash

⁴ Cooling phase occurred 15 minutes after walking in a climate-controlled room with water

Figure 5

Fig 6. Mean change in rectal¹ and gastrointestinal temperature (GI)² across three phases in non-conditioned Labradors.



^{a,b,c} Notes significant difference observed by phase

* Notes significant difference observed by sex

¹ Rectal temperature was recorded by inserting thermometer to a depth of approximately 2 cm with petroleum jelly

² GI (gastrointestinal) temperature was recorded with an ingestible thermistor CorTemp administered 30 minutes prior to baseline

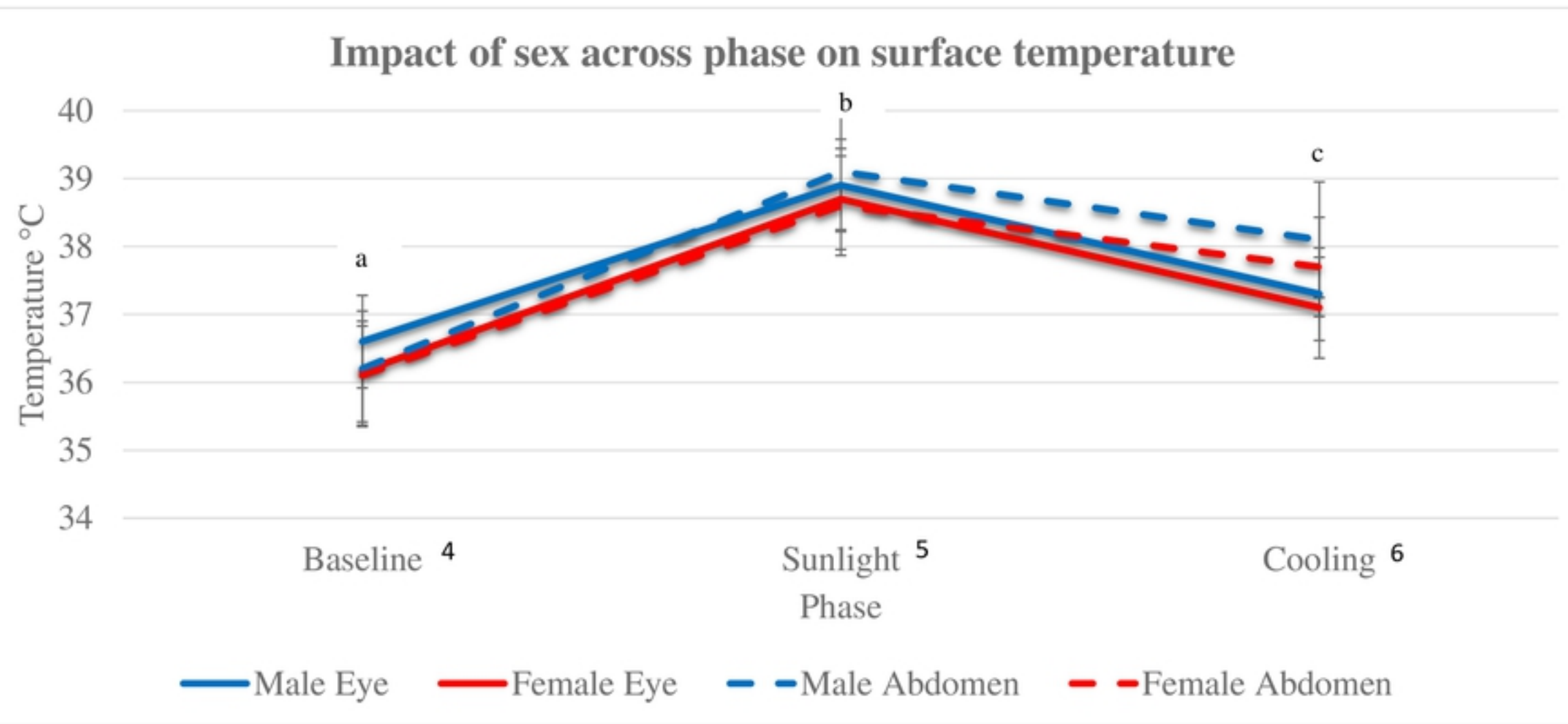
³ Baseline occurred 30 minutes prior to sunlight exposure and recorded initial measurements

⁴ Sunlight phase consisted of 30 minutes of active walking in a sunny outdoor area on a leash

⁵ Cooling phase occurred 15 minutes after walking in a climate-controlled room with water

Figure 6

Fig 7. Mean change in surface temperature measured by thermography¹ at the eye² and abdomen³ in non-conditioned Labradors across three phases.



^{a,b,c} Notes significant difference observed by phase

* Notes significant difference observed by sex

¹Thermography captured using FLIR T400

²Eye temperature was captured using thermography focusing on left eye

³Abdomen (Ab) temperature was captured using thermography focusing on left caudal abdomen

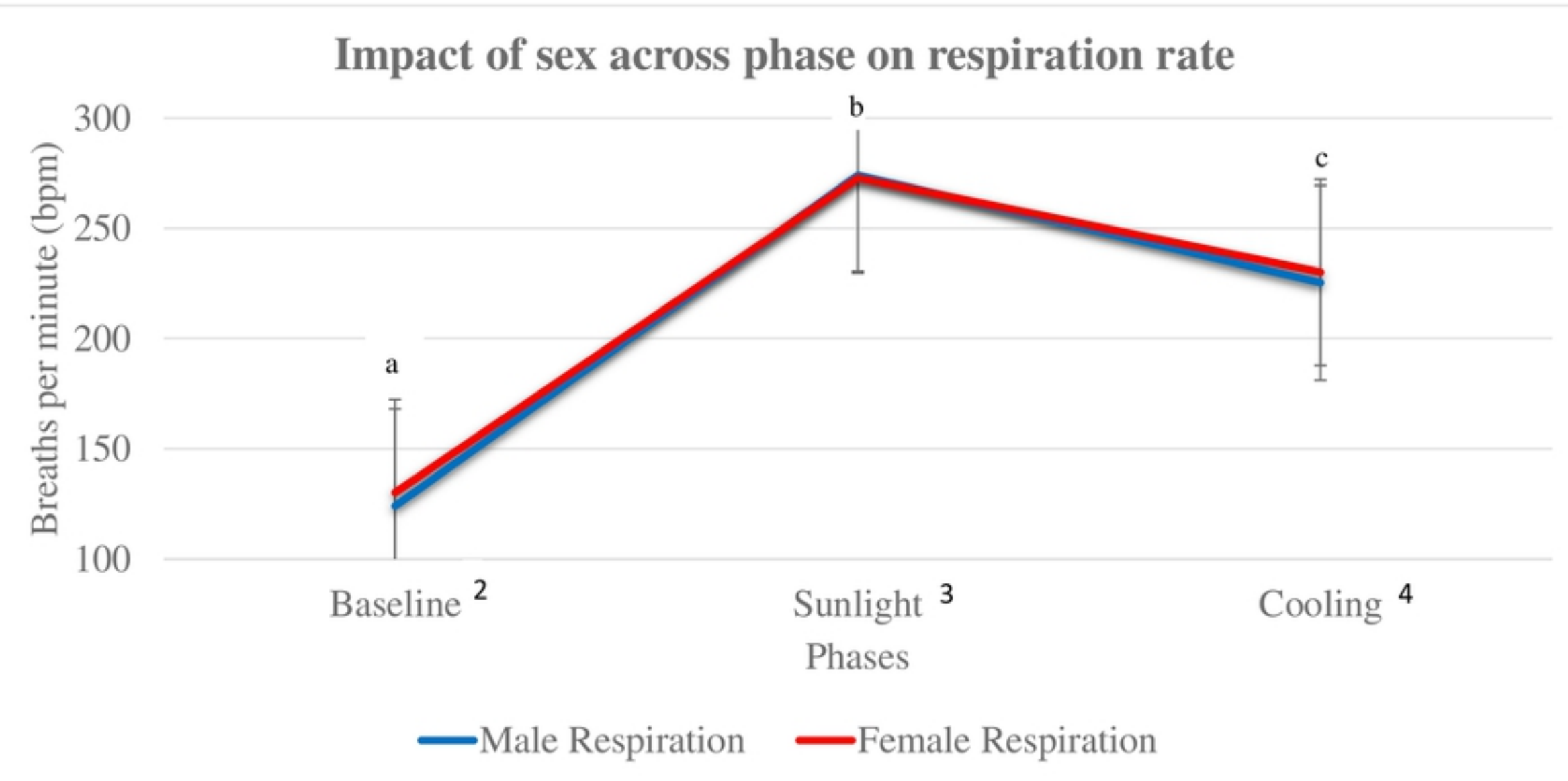
⁴Baseline occurred 30 minutes prior to sunlight exposure and recorded initial measurements

⁵Sunlight phase consisted of 30 minutes of active walking in a sunny outdoor area on a leash

⁶Cooling phase occurred 15 minutes after walking in a climate-controlled room with water

Figure 7

Fig 8. Mean change in respiration rates¹ across three phases in non-conditioned Labradors.



^{a,b,c} Notes significant difference observed by phase
^{*} Notes significant difference observed by sex
¹ Respiration rate was captured for 30 seconds by a GoPro camera
² Baseline occurred 30 minutes prior to sunlight exposure and recorded initial measurements
³ Sunlight phase consisted of 30 minutes of controlled pace walking in a sunny outdoor area on a leash
⁴ Cooling phase occurred 15 minutes after walking in a climate-controlled room with water

Figure 8