ABSTRACT: This study aimed to evaluate temperature variations on the thighs in an incremental cycling test in healthy recreational cyclists with two different fat percentages. Thirty-two male recreational cyclists were measured in height, body mass, thigh skinfold and body fat percentage, and from the body fat percentage were divided into two groups, Group 1: 16 cyclists who presented body fat percentage < 24% and Group 2: 16 cyclists who presented body fat percentage > 24%. Three thermographic photos were taken, before (Pre), just after (Post) and after 10 min (Post10) of the incremental cycling test to determine mean temperature of right and left Vastus Lateralis, Rectus Femoris and Biceps Femoris. Temperature variations were defined as the difference among the three moments: (i) var1 = Post-Pre, (ii) var2 = Post10-Pre and (iii) var3 = Post10-Post. Differences between groups and moments were calculated using magnitude-based inferences. Group 1 evidenced a very likely large increase in the cycling peak power output. Group 2 showed a likely and most likely moderate, large and very large increase in age, body mass and fat. Group 1 depicted a very likely to likely moderate temperature increase in the right and left Vastus Lateralis, Rectus Femoris and Biceps Femoris on Post10 compared to Post effort moment. Both groups depicted a very likely and most likely moderate and large temperature decrease of right and left Biceps Femoris on Pre compared to Post effort. Percentage of fat seems to discreetly influence skin temperature response, finding that might not be observed when we evaluate trained cyclists exhibiting different percentages of fat.

Key Words: Infrared thermography; Fat percentage; Incremental cycling test.

RESUMO: Este estudo objetivou a avaliar as variações de temperatura das coxas em um teste incremental de ciclismo em ciclistas recreacionais saudáveis com dois diferentes percentuais de gordura. Trinta e dois ciclistas recreacionais do sexo masculino foram avaliados em estatura, massa corporal, dobras cutâneas da coxa e percentual de gordura corporal, e, a partir do percentual de gordura corporal, foram divididos em dois grupos, Grupo 1: 16 ciclistas que apresentaram percentual de gordura corporal < 24% e Grupo 2: 16 ciclistas que apresentaram percentual de gordura corporal > 24%. Foram tiradas três fotos termográficas, antes (Pré), logo após (Pós) e após 10 min (Pós10) do teste de ciclismo para determinar a temperatura média do Vasto Lateral, Reto Femoral e Bíceps Femoral direito e esquerdo. As variações de temperatura foram definidas como a diferença entre os três momentos: (i) var1 = Pós-Pré, (ii) var2= Pós10-Pré e (iii) var3= Pós10-Pós. Diferenças entre grupos e momentos foram calculadas usando inferências baseadas em magnitude. Grupo 1 apresentou um provável a muito provável aumento moderado da temperatura para os Vastos Laterais direito e esquerdo, o Reto Femoral e o Bíceps Femoral no Pós10 em comparação com o momento pós-esforço. Grupo 2 mostrou aumentos provável e muito provável moderado, grande e muito grande na idade, massa corporal e gordura. Ambos os grupos descreveram uma muito provável e mais provável moderada e grande queda de temperatura do Bíceps Femoral direito e esquerdo no Pré comparado ao Pós-esforço. Percentagem de gordura parece influenciar discretamente a resposta da temperatura da pele, resultado que poderá não ser observado quando avaliados ciclistas treinados que apresentam diferentes percentagens de gordura.

Palavras-chave: Termografia infravermelha; Percentual de gordura; Teste incremental de ciclismo.
Body fat percentage and lower limbs temperature in recreational cyclists

Introduction

Increases in the metabolic rate of human beings occur with physical exercise, which, consequently, raises internal body heat. Internal temperature rising is generated by metabolic energy convection into mechanical and thermal components, mainly due to the active muscle action, causing blood transport increasing in the skin surface. This transport causes the loss of heat to the environment by thermoregulatory processes such as conduction, convection, radiation and evaporation, being changes observed on the skin surface in various activities and sport disciplines.

Skin temperature response depends on the physical activity type. In cyclic exercises, like running or cycling, skin temperature decreases in the initial effort instants due to the deviation of blood to the active muscles. However, on rest period skin temperature deviates from muscles to the skin, thus being lost to the environment. Contrarily, it has been noticed that skin temperature rises at the beginning of the exercise, which is followed by a decrease during the activity and an increase after the end of the exercise. This seems to occur due to athlete’s training level, which has already been pointed out as a skin temperature response influencing factor, as both alterations occur mainly on the regions where muscles have been elicited.

Physiological and biomechanical profile that change with the athlete’s conditioning level in cyclic sports might affect skin temperature responses. However, the percentage of body fat has also been mentioned as a skin temperature influencing factor in both during the rest and physical activity period. It might be explained by the percentage of body fat acting as thermal insulation and reducing skin temperature, implying that athletes with lower percentage of body fat achieve greater decreases in it. In fact, it has been thoroughly explained and accepted that fat percentage causes skin temperature changes, but, how it impacts on different cyclists’ percentage of body fat (fat percentage < and > than 24%) with similar cycling conditioning level at a specific temperature during a cycling test has been little explored. The evaluation of temperature variation in cycling is necessary since hyperthermia is normally observed in long competitions and may affect health and performance. Thus, it is paramount to fully understand the behavior of skin temperature during cycling. This study aimed to evaluate temperature variations on an incremental cycling test in healthy recreational cyclists with two different fat percentages.

Materials and methods

Participants

Thirty-two healthy recreational male cyclists volunteered to participate and were divided into two groups of 16 cyclists each: body fat percentage < and > 24% (Group 1, and Group 2, respectively) as shown in Table 1. These body fat percentages were established according to the health risk classification proposed by the American College of Sports Medicine. Based on this classification, body fat percentage < 24 was considered healthy and > 24 meant a high risk of fat percentage. Data collection was approved according to the Ethics and Research Committee of the Federal University of Amazonas (CAAE / CEP / UFAM 66458217.7.0000.5020), and all experimental procedures were conducted by the Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. Participants provided written informed consent before data collection.

Body composition

Body mass and density have been estimated by air displacement plethysmography (BOD POD; Body Composition System, Cosmed, Rome, Italy) following the equipment-standardized technique. The percentage of body fat was determined using the Siri’s equation ($\%G = [(4.95/D)-4.50] x 100; SIRI$), where "D" is the body density (D=mass/volume). Participants wore minimal fitting clothing, spandex shorts and a swim cap. To ensure quality control the equipment was calibrated on a daily basis according to supplier recommendations.

R. bras. Ci. e Mov 2019;27(3):150-157.
Cycling incremental test

Participants’ body posture on the stationary ergometric bicycle (CG4 Imbrasport, Co., Porto Alegre Brazil) was adjusted, being defined as the maximum extension of the knee during cycling between 25° and 30°. The incremental test started with an initial 105 W workload for 3 min and was followed by 35 W increments every 3 min until exhaustion. Pedaling cadence was maintained at 60 ± 5 revolutions per minute (RPM) by visual feedback of the ergometer bicycle software (Ergo-control, CG4 Imbrasport, Co., Porto Alegre Brazil). Exhaustion was defined when the participant was no longer able of maintaining a pedaling cadence of 55 RPM. Athletes’ peak power output was acquired by the correction of the power output on the last testing stage completed.

Skin surface temperature

Each participant was evaluated by the same examiner, went through a 10 min acclimatization in a standing position, wearing swimsuits, in a controlled room with temperature set at 22 ± 3°C and relative humidity of 50 ± 15%, without electronic equipment near the thermographic camera and avoiding measurement noise. Participants were instructed to prevent sunbathing or UVA rays on the test day, strenuous exercise in the previous 24 h and to abstain from skin creams, consuming hot or alcoholic beverages in the 12 h prior testing. An anti-reflective panel was positioned behind the participant during thermography photos acquisition, which minimized the effect from infrared radiation reflected by the participant on the wall, avoiding solar or electric energy irradiation.

Each participant took two thermography photos, one in the anterior and one in the posterior plane through a thermographic camera (FLIR T4xx series, FLIR, Luxemburgstraat, Belgium) with lens positioned parallel to the ground at 1 m away from the participant. Three test moments during the incremental cycling test were selected for thermal images analysis: (i) before the exercise, after 10 min of acclimatization in laboratory environment (Pre); (ii) just after the end of the incremental protocol after sweat removal (Post) and (iii) after 10 min rest (Post10). According to previous studies, high skin temperature alterations have been observed in these moments, denoting human body most substantial thermoregulation process changes.

ThermCAM Researcher Pro 2.0 software (FLIR, Luxemburgstraat, Belgium) was used to acquire average temperatures for each region of interest (Vastus Lateralis, Rectus Femoris and Biceps Femoris) on both, right and left sides of the body. Differences between the mean temperatures of each region of interest at different moments were calculated as following: (i) var1: Post vs. Pre; (ii) var2: Post10 vs. Pre; (iii) var3: Post10 vs. Post.

Statistical analysis

All data presented normality evaluated by the Shapiro–Wilk’s test, and homogeneity of the variances evaluated by the Levene’s tests. Descriptive statistics was used in data analysis, means and standard deviation. Changes in age, height, body mass, body fat, thigh skinfold, peak power output between groups and the differences between moments in each group and muscle were analyzed using Standardized Mean Difference (SMD) and Effect Size (ES).

The Hopkins scale (www.sportsci.org/resource/stats) was used for their interpretation: 0-0.2 trivial, > 0.2-0.6 small, > 0.6-1.2 moderate, > 1.2-2.0 large, and > 2.0 very large. Effects with 90% Confidence Interval (CI) overlapping zero and/or the smallest worthwhile change (i.e., 0.2 standardized units) were unclear. Inference and precision based on magnitude were performed to analyze the odds of true modifications being clear or trivial. The probability of finding differences between variables was solved by assessing them qualitatively through the scale: < 1%, almost certainly not; 1-5%, very unlikely; 5-25%, unlikely; 25-75%, possible; 75-95%, likely; 95-99%, very likely; > 99%, most likely. Probabilities were also calculated to identify whether the true differences were lower, similar or greater than the smallest difference or change, 0.2 x standard deviation between subjects. If the chance of having higher and lower differences were both > 5%, the true difference was determined to be unclear.
153 Body fat percentage and lower limbs temperature in recreational cyclists

Results

Table 1 depicts mean and standard deviation of age, height, body mass, body fat, thigh skinfold, peak power output and SMD, 90% CI and probabilities of comparison between groups. Group 1 has evidenced a very likely large increase in the peak power output. Group 2 has shown a likely and most likely moderate, large and very large increase in age, body mass and body fat.

Table 1. Mean and standard deviation of age (AGE), height (Hgt), body mass (BM), body fat (BFT), thigh skinfold (TSF), peak power output (PPO) and Standardized Mean Difference (SMD), 90% Confidence Interval (CI), Effect Size (ES) and Probabilities of comparison (PC) between Groups 1 and 2.

| Variables | Group 1 | Group 2 | Group 1 vs. Group 2 |
|-----------|---------|---------|---------------------|
|           | SMD (90% CI) | ES | % greater/similar/lower values (PC) | % greater/similar/lower values (PC) |
| AGE       | 28.56 ± 5.50 | 32.50 ± 8.45 | 0.73 (0.16; 1.37) | Moderate | 93/6/1 (Likely) |
| Hgt (cm)  | 172.91 ± 7.28 | 174.58 ± 8.01 | 0.22 (-0.38; 0.81) | Small | 64/27/9 (Unclear) |
| BM (kg)   | 72.85 ± 9.56 | 88.37 ± 13.86 | 1.23 (0.63; 1.83) | Large | 100/0/0 (Most likely) |
| BFT (%)   | 16.07 ± 5.50 | 29.83 ± 4.13 | 1.68 (1.19; 2.16) | Very large | 100/0/0 (Most likely) |
| TSF (cm)  | 17.63 ± 4.24 | 20.81 ± 5.82 | 0.62 (-0.04; 1.27) | Moderate | 86/12/2 (Likely) |
| PPO (W.Kg⁻¹) | 3.91 ± 1.04 | 2.92 ± 0.85 | -1.09 (-1.68; 0.51) | Large | 0/1/99 (Very likely) |

Table 2 presents mean and standard deviation of Vastus Lateralis, Rectus Femoris, and Biceps Femoris temperature of lower limbs on Pre, Post, Post10, Group 1 and 2.

Table 2. Mean and standard deviation of skin temperature of Vastus Lateralis (VL), Rectus Femoris (RF) and Biceps Femoris (BF) on both, right and left lower limbs, Group 1 and 2 on Pre, Post, Post10.

| Variables | Right (R) | Left (L) |
|-----------|-----------|----------|
|           | Pre (ºC) | Post (ºC) | Post10 (ºC) | Pre (ºC) | Post (ºC) | Post10 (ºC) |
| Group 1 VL | 31.70 ± 1.09 | 31.01 ± 0.96 | 32.13 ± 1.13 | 31.21 ± 0.91 | 31.06 ± 0.91 | 32.10 ± 1.14 |
| Group 2 VL | 29.94 ± 1.21 | 29.01 ± 1.30 | 30.48 ± 1.75 | 29.88 ± 1.07 | 28.77 ± 1.22 | 30.34 ± 1.77 |
| Group 1 RF | 31.31 ± 0.37 | 31.05 ± 0.97 | 32.23 ± 0.96 | 31.26 ± 0.97 | 31.14 ± 0.87 | 32.13 ± 1.08 |
| Group 2 RF | 29.96 ± 1.24 | 29.07 ± 1.30 | 30.50 ± 1.74 | 29.98 ± 1.18 | 28.91 ± 1.20 | 30.48 ± 1.69 |
| Group 1 BF | 31.21± 0.98 | 30.20 ± 1.51 | 31.20 ± 1.07 | 31.20± 0.87 | 30.14± 1.59 | 31.12 ± 1.13 |
| Group 2 BF | 30.38± 1.21 | 28.33 ± 1.18 | 29.72 ± 1.40 | 30.40± 1.34 | 28.40± 1.23 | 29.56 ± 1.35 |

Figures 1, 2 and 3 have shown SMD, 90% CI, ES and probabilities of the comparison of temperature among Post vs. Pre (var1); Post10 vs. Pre (var2); Post10 vs. Post (var3) for both groups and sides of the body on Vastus.
Lateralis, Rectus Femoris and Biceps Femoris, respectively. Considering right Vastus Lateralis, Group 1 has evidenced a very likely and likely moderate temperature increase at Post10 compared to Pre and Post moments. Group 2 has shown an unclear moderate increase at Post10 compared to Post moment. Group 1 has displayed on left Vastus Lateralis a likely moderate temperature increase at Post10 compared to Post. Considering right and left Rectus Femoris, Group 1 has depicted a likely moderate temperature increase at Post10 compared to Post effort. Group 2 has shown an unclear and moderate temperature increase in the right Rectus Femoris. Right and left Biceps Femoris have shown a very likely and most likely moderate and large temperature decrease in both groups at Pre compared to Post effort. Moreover, a likely moderate increase in Group 1 has been noticed at right and left Biceps Femoris and Group 2 right Biceps Femoris at Post10 compared to Post test.

![Figure 1](image1.png)

**Figure 1.** Temperature differences among Post vs. Pre (var1), Post10 vs. Pre (var2) and Post10 vs. Post (var3) in Groups 1 and 2 on right and left Vastus Lateralis. Error bars indicate 90% Confidence Interval (CI) of Standardized Mean Difference (SMD) between time points. The probabilities of the differences between the moments being greater, similar or lower are presented in percentages and classified according to these percentages (PC).

![Figure 2](image2.png)

**Figure 2.** Temperature differences among Post vs. Pre (var1), Post10 vs. Pre (var2), Post10 vs. Post (var3) in Groups 1 and 2 on right and left Rectus Femoris. Error bars indicate 90% Confidence Interval (CI) of Standardized Mean Difference (SMD) between time points. The probabilities of the differences between the moments being greater, similar or lower are presented in percentages and classified according to these percentages (PC).
Body fat percentage and lower limbs temperature in recreational cyclists

Figure 3. Temperature differences among Post vs. Pre (var1), Post10 vs. Pre (var2), Post10 vs. Post (var3) in Groups 1 and 2 on right and left Biceps Femoris. Error bars indicate 90% Confidence Interval (CI) of Standardized Mean Difference (SMD) between time points. The probabilities of the differences between the moments being greater, similar or lower are presented in percentages and classified according to these percentages (PC).

Discussion

The present study has analyzed the effect of body fat of Group 1 and 2 on kineanthropometric and performance data, variation among Pre, Post and Post10 tests during an incremental cycling protocol on body skin temperature at right and left Vastus Lateralis, Rectus Femoris and Biceps Femoris in each group. Group 2 was older than Group 1 and had a greater body mass and body fat. Group 1 has demonstrated an increase on temperature on all muscles from Post to Post10 and a decrease from Pre to Post on Biceps Femoris. Group 2 has demonstrated a temperature increase from Post to Post10 only on the right limb in all muscles and a decrease from Pre to Post on both limbs on Biceps Femoris.

Quadriceps Femoris muscles are the most requested for cycling and have previously demonstrated a temperature decrease from Pre to Post exercise and an increase from Pre and Post to Post10 min of exercise. The only muscle that behaved similarly was the right Vastus Lateralis of Group 1 in the variation Pre to Post 10. This difference in Group 1 can be explained by the smaller percentage of fat, since it can facilitate the dissipation of heat to the environment. Another explanation can be the greater peak power output in this group (Table 1), which can demonstrate a greater muscle elicitation, which would be responsible for a greater heat generation. Differences between Post to Post10 in Groups 1 and 2 on Vastus Lateralis and Rectus Femoris resemble what was previously presented with a temperature increase after the end of the activity, demonstrating greater transportation of temperature from the muscles to the skin after the exercise.

Right and left Biceps Femoris presented a decrease from Pre to Post and an increase from Post to Post10, except the left Biceps Femoris in Group 2, corroborating with previous studies. However, Priego Quesada et al. have already noticed a different finding, evidencing a small temperature increase from Pre to Post on Biceps Femoris, during a cycling effort. This may be due to sample selection in each study, as in the first study were selected highly trained cyclists, whereas in the other were chosen a group of low trained cyclists and a group of recreational cyclists very similar to ours. The clear difference being presented only in one limb in Group 2 may be an indicative of a greater right limb muscles use throughout, which causes greater heat production after an activity.

An explanation for our findings considering temperature variations may be related to a raise of catecholamine and other vasoconstrictors, which increases the vasoconstrictor response of blood vessels, these variables were not evaluated in this study. Because of this occur the transport of warmer circulating blood from the muscles in activity to the skin for losing temperature to the environment, thus increasing participants’ temperature. As to the response of metabolic factors, anthropometry and type and level of training can also explain that difference. Different
cutaneous temperature types presented are caused by different percentages of body fat. This difference is due to the percentage of fat that can be observed in both trained and untrained groups, and can be noticed at rest and during exercise.

Due to this diversity of factors that may influence skin temperature we have evaluated a group with the same training level, but with different body fat percentages on skin temperature. Unlike other studies, this group demonstrated a greater skin temperature decrease, a smaller skinfold and body fat percentage, showing that, although different percentages of fat affect the behavior of skin temperature, when we evaluate individuals with the same level of training in cycling, the behavior of skin temperature does not change.

Notwithstanding the originality and relevance of the current data, limitations should be addressed. Further studies should research on the type of activity, considering submaximal exercises with the same level of intensity and work for all participants. In the current study cyclists have presented a difference in the peak power output, which generated more heat due to muscle mechanical activity. But even with differences in the mentioned variables, individuals’ frequency and level of training were controlled to guarantee the same level of capacity on cycling.

**Conclusions**

Our study can show that individuals with different fat percentage but with the same level of training on cycling exhibit similar behavior of temperature in lower limb muscles. However, differently from what has been discussed in other studies, body fat percentage influences skin temperature response, but these differences decrease when we evaluate individuals trained in a cyclical modality even if they have depicted different body composition. New studies with higher trained cyclist groups with different body fat percentages may show more pronounced temperature differences on the lower limbs, since in individuals with a higher training level the body fat percentage may have a greater influence on the cutaneous temperature responses.

**Acknowledgments**

The authors want to thank PROPESP (Pró-Reitoria de Pesquisa e Pós-Graduação) for supporting this study and for the availability of space and equipment for research want to thank the Human Performance Laboratory (LEDEHU) of Federal University of Amazonas (UFAM).

**References**

1. Lim CL, Byrne C, Lee JKW. Human thermoregulation and measurement of body temperature in exercise and clinical settings. Ann Acad Med Singapore. 2008; 37(4): 347-53.
2. González-Alonso J. Human thermoregulation and the cardiovascular system. Exp Physiol. 2012; 97(3): 340-6.
3. Taylor NAS. Principles and practices of heat adaptation. Journal of the Human Environment System. 2000; 4(1): 11-22.
4. Balci GA, Basaran T, Colakoglu M. Analysing visual pattern of skin temperature during submaximal and maximal exercises. Infrared Phys Technol. 2016; 74: 57-62.
5. Ouzzahra Y, Havenith G, Redortier B. Regional distribution of thermal sensitivity to cold at rest and during mild exercise in males. J Therm Biol. 2012; 37(7): 517-23.
6. Priego Quesada JI, Martínez N, Salvador Palmer R, Psikuta A, Annaheim S, Rossi RM et al. Effects of the cycling workload on core and local skin temperatures. Exp Therm Fluid Sci. 2016; 77: 91-9.
7. Merla A, Mattei PA, Di Donato L, Romani GL. Thermal imaging of cutaneous temperature modifications in runners during graded exercise. Ann Biomed Eng. 2010; 38(1): 158-63.
8. Neves EB, Moreira TR, Lemos RJ, Vilaça-Alves J, Rosa C, Reis VM. The influence of subcutaneous fat in the skin temperature variation rate during exercise. Res Biomed Eng [Internet]. 2015; 31(4): 307-12.
9. Priego Quesada JI, Carpes FP, Bini RR, Salvador Palmer R, Pérez-Soriano P, Cibrián Ortiz de Anda RM.
Relationship between skin temperature and muscle activation during incremental cycle exercise. J Therm Biol [Internet]. 2015; 48: 28-35.

10. Priego Quesada JI, Sampaio LT, Bini RR, Rossato M, Cavalcanti V. Multifactorial cycling performance of Cyclists and Non-Cyclists and their effect on skin temperature. J Therm Anal Calorim. 2017; 127(2): 1479-89.

11. Akimov EB, Son’kin VD. Skin temperature and lactate threshold during muscle work in sportsmen. Fiziol Cheloveka. 2011; 37(5): 120-8.

12. Priego Quesada JI, Lucas-Cuevas AG, Salvador Palmer R, Pérez-Soriano P, Cibrián Ortiz de Anda RM. Definition of the thermographic regions of interest in cycling by using a factor analysis. Infrared Phys Technol. 2016; 75: 180-6.

13. Priego Quesada JI, Martínez Guillamón N, Cibrián Ortiz de Anda RM, Psikuta A, Annaheim S, Rossi RM et al. Effect of perspiration on skin temperature measurements by infrared thermography and contact thermometry during aerobic cycling. Infrared Phys Technol. 2015; 72: 68-76.

14. Chudecka M, Lubkowska A. Temperature changes of selected body’s surfaces of handball players in the course of training estimated by thermovision, and the study of the impact of physiological and morphological factors on the skin temperature. J Therm Biol [Internet]. 2010; 35(8): 379-85.

15. Savastano DM, Gorbach AM, Eden HS, Brady SM, Reynolds JC, Yanovski JA. Adiposity and human regional body temperature. Am J Clin Nutr. 2009: 90: 1124-31.

16. Claesens-van Ooijen AMJ, Westerterp KR, Wouters L, Schoffelen PFM, van Steenhoven AA, van Marken Lichtenbelt WD. Heat production and body temperature during cooling and rewarming in overweight and lean men. Obesity (Silver Spring) [Internet]. 2006; 14(11): 1914-20.

17. Ansley L, Cangley P. Determinants of “optimal” cadence during cycling. Eur J Sport Sci. 2009; 9(2): 61-85.

18. Rodriguez NR, Di NM, Langley S. American College of Sports Medicine position stand. Nutrition and athletic performance. Med Sci Sports Exerc. 2009; 41(3): 709-31.

19. Siri W. Body volume measurement by gas dilution. Techniques of measuring body composition. Washington, DC: National Academy of Sciences, National Research Council; 1961. p. 108-117.

20. Fields DA, Hunter GR, Coran MI. Validation of the BOD POD with hydrostatic weighing: Influence of body clothing. Int J Obes. 2000; 24(2): 200-5.

21. Denadai BS, Figuera TR, Favaro ORP, Gonçalves M. Effect of the aerobic capacity on the validity of the anaerobic threshold for determination of the maximal lactate steady state in cycling. Brazilian J Med Biol Res. 2004; 37(10): 1551-6.

22. González-Haro C. Differences in physiological responses between short- vs.long-graded laboratory tests in road cyclists. J Strength Cond Res. 2015; 29(4): 1040-8.

23. Hildebrandt C, Raschner C, Ammer K. An overview of recent application of medical infrared thermography in sports medicine in Austria. Sensors. 2010; 10(5): 4700-15.

24. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. Med Sci Sports Exerc. 2009; 41(1): 3-12.

25. Kautz SA, Neptune RR. Biomechanical determinants of pedaling energetics: Internal and external work are not independent. Exerc Sport Sci Rev. 2002; 30(4): 159-65.

26. Chudecka M, Lubkowska A, Kempitiska-Podhorodecka A. Body surface temperature distribution in relation to body composition in obese women. J Therm Biol. 2014; 43: 1-6.

27. Vainer BG. FPA-based infrared thermography as applied to the study of cutaneous perspiration and stimulated vascular response in humans. Phys Med Biol. 2005; 50(23).

28. Schlader ZJ, Prange HD, Mickleborough TD, Stager JM. Characteristics of the control of human thermoregulatory behavior. Physiol Behav [Internet]. 2009; 98(5): 557-62.

29. Sampaio L, Bezerra E, Paladino K, dos Santos JOL, Priego Quesada JL, Rossato M. Effect of training level and blood flow restriction on thermal parameters: Preliminary study. Infrared Phys Technol. 2016; 79: 25-31.

30. Salamunes ACC, Stadnik AMW, Neves EB. The effect of body fat percentage and body fat distribution on skin surface temperature with infrared thermography. J Therm Biol [Internet]. 2017; 66(December 2016): 1-9.

R. bras. Ci. e Mov 2019;27(3):150-157.