WILDERNESS & ENVIRONMENTAL MEDICINE, ▮, ▮▮▮–▮▮▮ (2017)

ORIGINAL RESEARCH

Blood Hemostatic Changes During an Ultraendurance Road Cycling Event in a Hot Environment

Brian R. Kupchak, PhD; Josh B. Kazman; Jakob L. Vingren, PhD; Danielle E. Levitt; Elaine C. Lee, PhD; Keith H. Williamson, MD; Lawrence E. Armstrong, PhD; Patricia A. Deuster, PhD, MPH

From the Department of Military & Emergency Medicine, Uniformed Services University of Health Sciences, Bethesda, MD (Drs Kupchak and Deuster, Mr Kazman); the Applied Physiology Laboratory, Department of Kinesiology, Health Promotion and Recreation, University of North Texas, Denton, TX (Dr Vingren and Ms. Levitt); the Human Performance Laboratory, Department of Kinesiology, University of Connecticut, Storrs, CT (Drs Lee and Armstrong); and the Department of Kinesiology, Midwestern State University, Wichita Falls, TX (Dr Williamson).

Objective.—This study aims to examine blood hemostatic responses to completing a 164-km road cycling event in a hot environment.

Methods.—Thirty-seven subjects (28 men and 9 women; 51.8±9.5 [mean±SD] y) completed the ride in 6.6±1.1 hours. Anthropometrics (height, body mass [taken also during morning of the ride], percent body fat [%]) were collected the day before the ride. Blood samples were collected on the morning of the ride (PRE) and immediately after (IP) the subject completed the ride. Concentrations of platelet, platelet activation, coagulation, and fibrinolytic markers (platelet factor 4, β-thromboglobulin, von Willebrand factor antigen, thrombin-antithrombin complex, thrombomodulin, and D-Dimer) were measured. Associations between changes from PRE- to IP-ride were examined as a function of event completion time and subject characteristics (demographics and anthropometrics).

Results.—All blood hemostatic markers increased significantly ($P < .001$) from PRE to IP. After controlling for PRE values, finishing time was negatively correlated with platelet factor 4 ($r = 0.40$; $P = .017$), while percent body fat (%BF) was negatively correlated with thrombin-antithrombin complex ($r = –0.35$; $P = .038$) and to thrombomodulin ($r = –0.36$; $P = .036$). In addition, male subjects had greater concentrations of thrombin-antithrombin complex (d = 0.63; $P < .05$) and natural logarithm thrombomodulin (d = 6.42; $P < .05$) than female subjects.

Conclusion.—Completing the 164-km road cycling event in hot conditions resulted in increased concentrations of platelet, platelet activation, coagulation, and fibrinolytic markers in both men and women. Although platelet activation and coagulation occurred, the fibrinolytic system markers also increased, which appears to balance blood hemostasis and may prevent clot formation during exercise in a hot environment.

Keywords: cycling, heat stress, platelet activation, coagulation, fibrinolysis

Introduction

Ultraendurance events represent an unusual opportunity to study human physiology under uncommon levels of exercise and environmental stress. Moreover, with the rising popularity of ultraendurance running and cycling over the last decade[1] it has become imperative to better understand the effects of these events on human physiology. Ultraendurance events (running, cycling, and triathlon) have been shown to induce changes in blood homeostasis, including platelet activation, coagulation, and fibrinolysis.[2–5] We followed subjects in the Hotter 'N Hell Hundred (HHH), which typically generates great physiological stress, seen by cyclists losing 2% of their body mass despite intaking fluids approaching 1 L/h,[6] as it consists of a 164-km bicycle ride in northern Texas during summer heat that annually exceeds 37°C.

Corresponding author: Brian R. Kupchak, PhD, Department of Military & Emergency Medicine, Uniformed Services University of Health Sciences, 4301 Jones Bridge Road, Bethesda, MD 20814, USA; e-mail: brian.kupchak@usuhs.edu.

Submitted for publication September 2016.
Accepted for publication May 2017.

Activation of blood coagulation results from increased platelet activity, formation of thrombin and, ultimately, the formation of fibrin. Fibrinolysis increases due to a rise in tissue-type plasminogen activator and decrease in plasminogen activator inhibitor. If these 2 systems become unbalanced, risk of stroke and deep vein thrombosis significantly rises. The effects of such imbalance can be seen in complications from several medical conditions, including cancer and trauma. Other risk factors include older age, surgery, immobilization (as with prolonged bed rest, orthopedic casts, and sitting on long flights), combined oral contraceptives, pregnancy, the postnatal period, and genetic factors.[7–9]

Heat stress has been shown to have the potential to affect blood homeostasis, and has been shown to be regulated within a narrow range of temperatures.[10] In response to hyperthermic environmental conditions, subjects in several studies have exhibited increased levels in platelet counts (PC)[11,12] and stimulation of platelet activity, made evident by changes in the levels of platelet factor 4 (PF4) and β-thromboglobulin (β-TG).[13] Furthermore, exposure to hyperthermic conditions can increase the concentration of thrombin-antithrombin (TAT) complexes,[11] which indicates potential for coagulation. However, it is also apparent that the human body tries to protect blood homeostasis by activating the fibrinolytic system, as evident in increases in D-Dimers.[11,14,15] Thus, prolonged strenuous exercise and heat stress may independently affect blood homeostasis to increase the risk of clot formation, including risk of stroke or deep vein thrombosis.

The benefits of habitual endurance exercise have been shown to include reduced occurrence of ischemic heart disease and lower cardiovascular mortality. However, acute exercise stresses the cardiovascular system, resulting in increased platelet activation, coagulation, and fibrinolysis, among other physiological effects. The activation of the coagulation and fibrinolytic systems are dependent on the duration and intensity of the exercise, which can either accelerate clot formation or lead to the dissolution of clot.[16] The hematologic effects of this systematic stress are especially marked in individuals participating in ultraendurance events. Specifically, PC increase during marathon runs,[17,18] ultramarathon runs,[19] and prolonged bicycle rides,[5] while markers of platelet activation (β-TG and PF4) have been found to either increase[20,21] or not change[22,23] during endurance exercise. Additionally, prolonged endurance exercise produces both a hypercoagulable state (increased TAT),[4,5,22,23] which is usually balanced by fibrinolytic activation (increased tissue-type plasminogen activator and D-Dimers).[4,5,22,23]

Many studies have examined the effect of prolonged exercise on blood homeostasis,[4,5,22,23] but to our knowledge no published investigation has examined the combination of heat stress and prolonged exercise on platelet activation. The purpose of this study was therefore to examine blood hemostatic responses to completing a 164-km road cycling event performed in a hot environment. In addition, this investigation, compared with our previous study, examines a larger sample size and includes women.[5] We hypothesized that platelet activation, coagulation, and fibrinolysis would increase during the event.

Methods

SUBJECTS

Subjects were recruited through the HHH website, via emails sent to all HHH entrants, and in person at the Multi-Purpose Event Center (Wichita Falls, TX) during the HHH Exposition held on the days before the event (August 27–28, 2015). To be included in the study, subjects had to be healthy, aged 21–65 years, and have previously completed an organized bicycle ride of at least 164 km. Exclusion criteria consisted of the following: 1) inability to speak or understand English; 2) current tobacco use; 3) use of cholesterol-lowering, vasoactive, and/or anticoagulant medications (eg, Coumadin, aspirin); 4) current musculoskeletal injury; 5) diagnosis of cardiovascular, liver, kidney, blood, or gastrointestinal disease or severe metabolic or endocrine disorders (eg, type 2 diabetes); 6) presence of a known medical condition or currently taking medication that could alter fluid balance; 7) history of exertional heatstroke or exercise-heat intolerance; and 8) self-reported use of anabolic or catabolic hormonal substances including testosterone, anabolic steroids, growth hormone, or cortisone.

The methods and procedures of this study were reviewed and approved by the institutional review board of the Uniformed Services University before recruitment of subjects. Potential subjects attended a mandatory information session where the study's risks and benefits were carefully explained and questions were answered by the investigators. All subjects provided written informed consent after completing the information session. Each subject also completed a medical history form that was reviewed by the event's medical director.

ANTHROPOMETRICS, MONITORING GASTROINTESTINAL TEMPERATURE, AND ENVIRONMENTAL CONDITIONS

Anthropometric measurements were completed 1 to 2 days before the event at the Wichita Falls Convention Center, using procedures previously described.[24] Briefly, hip