Cardiac Biomarker Release after Endurance Exercise in Male and Female Adults and Adolescents

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Objectives To compare the responses of high-sensitivity cardiac troponin T (hs-cTnT) and NH_2-terminal probrain natriuretic peptide (NT-proBNP) after 60 minutes of swimming in male and female adults and adolescents with different pubertal status.

Study design Adolescent swimmers (25 male and 25 female) and adult swimmers (7 male and 9 female) participated in a 60-minute maximal swimming test with serial assessment of hs-cTnT and NT-proBNP at rest, immediately postexercise, and at 1, 3, 6, 12, and 24 hours postexercise. Adolescents were classified according to pubertal status: Tanner stages 3 (n = 14), 4 (n = 22), and 5 (n = 14).

Results Exercise resulted in an increase in both biomarkers. hs-cTnT responses to exercise were similar in adolescents with different pubertal status and adults, although there was substantial individual variability in peak hs-cTnT, with the upper reference limit exceeding in 62% of the participants. Postexercise kinetics for hs-cTnT were largely consistent across all groups with a return to near baseline levels 24 hours postexercise. The male participants showed higher values of hs-cTnT at baseline and postexercise. All groups had similar NT-proBNP responses to acute exercise and recovery. One swimmer exceeded the upper reference limit for NT-proBNP.

Conclusions An exercise-associated increase in hs-cTnT and NT-proBNP occurred in response to a 60-minute maximal swimming test that was independent of pubertal status/adolescent vs adults. The present data also suggests that baseline and postexercise hs-cTnT values are higher in male compared with female, with no sex differences in NT-proBNP values. *(J Pediatr 2017;191:96-102).*

Cardiac biomarkers are established as part of standard evaluation for the diagnosis and prognosis of patients with myocardial infarction (cardiac troponin T [cTnT] and troponin I [cTnI])[1] and heart failure (NH_2-terminal pro-BNP [NT-proBNP]).[2] Both biomarkers are elevated after prolonged exercise, a physiological stimulus (eg, a marathon[3,4]) as well as shorter bouts of physical activity lasting 30-60 minutes.[5,6] The clinical relevance of these phenomenon is relevant for clinical investigations in athletes after exercise.[7,8]

Most cardiac biomarker data is derived from adults, however, there is a small but consistent dataset suggesting similar responses in adolescents completing prolonged exercise bouts.[9-13] Direct comparison of the release of cardiac biomarkers with exercise in adults and adolescents is limited.[10,14] In a well-controlled study,[10] adolescents demonstrated a peak high-sensitivity cTnT (hs-cTnT) that was 11 times higher than adults after a long-distance run and was still significantly elevated in adolescents at 24 hours of recovery. In contrast, López-Laval et al[14] observed no differences in peak cTnI and postexercise cTnI kinetics during 24 hours of recovery after a basketball match. These contradictory findings may be associated with differences in the pubertal status of adolescents as well as other personal differences (eg, size, fitness, sex) and/or differences in the exercise stimulus. The influence of pubertal status on the postexercise release of biomarkers has only been assessed in a small sample of male adolescent runners.[10] The authors observed a trend toward higher release of hs-cTnT in adolescents of lower Tanner stage, suggesting a role for maturity in mediating hs-cTnT release with prolonged exercise.

There is limited information on the influence of sex on exercise-induced cardiac biomarker release.[11,15,16] Traiperm et al[11] noted similar increases in male and female adolescent marathon runners, but data were limited by assay precision, the number of sampling times postexercise, and the lack of control of the duration/intensity of exercise and pubertal status. In contrast, in a recent study, although limited by

cTnI	Cardiac troponin I
cTnT	Cardiac troponin T
HR	Heart rate
hs-cTnT	High-sensitivity cTnT
NT-proBNP	NH_2-terminal probrain natriuretic peptide
URL	Upper reference limit

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assay precision and by the number of sampling times postexercise, it was observed that after a half-marathon cTnT elevation occurred in all runners but is higher in young male compared with female athletes.[15] No studies in adolescents have evaluated the influence of sex on NT-proBNP values.

We employed multiple sampling points during 24 hours of recovery from a 60-minute swimming time trial to examine the influence of high-intensity aerobic exercise on hs-cTnT and NT-proBNP appearance in male and female adults and adolescents with different pubertal status. Our hypothesis was that the release of hs-cTnT with exercise would be greater in male than in female adolescents, higher in adolescents than in adults, and with the highest values in adolescents with lower maturity status. We hypothesize no influence of sex or adolescent-adult and pubertal status on the release of NT-proBNP with exercise.

Methods

Sixty-six highly trained swimmers were recruited from a large water polo club in Mexico through an open invitation to all of its members. Volunteers included adolescent (25 male and 25 female, age range = 12-18 years) and adult (7 male and 9 female, age range = 22-46 years) swimmers (**Table I**). None of the subjects had any clinical evidence or personal history of cardiac disease or arterial hypertension, and all had a normal 12-lead electrocardiogram at rest. All swimmers provided written informed consent (and parental consent for adolescents). The study followed the ethical guidelines of the Declaration of Helsinki and was approved by the Research Ethics Committee of the Universidad Autónoma de Nuevo León (Autonomous University of Nuevo Leon).

All participants visited the laboratory and swimming pool on 2 occasions. During the first laboratory visit, subjects underwent anthropometric assessment. Body height was measured to the nearest 0.1 cm (SECA 225; SECA, Hamburg, Germany). Body mass was determined to the nearest 0.05 kg (SECA 861; SECA). The percentage of total body fat was calculated according to Faulkner.[17] A questionnaire was use to obtain training and medical history. Pubertal status was assessed directly by 2 experienced pediatricians according to the standardized Tanner stages based on external primary and secondary sex characteristics.[18] The adolescents were categorized in the middle of puberty, Tanner stage 3 (4 male and 10 female), or late puberty, Tanner stage 4 (11 male and 11 female) and 5 (10 male and 4 female). Finally, maximal heart rate (HR) was recorded using a specific protocol commonly used in training of swimmers consisting of the execution of 6 repetitions of 25 m swimming at maximum intensity with 10 seconds of rest in between repetitions.

In the second visit, the swimmers completed a self-paced 5-minute warm-up (<60% of %HRmax) followed by a 60-minute "all-out" swimming test. All participants were accustomed to the 60-minute all-out swimming test protocol and were asked to abstain from strenuous exercise for 48 hours before the exercise test. During the exercise test, swimmers made a continuous effort without periods of rest time to complete the maximum possible distance at self-paced velocity. The swimming test took place at 8:00 a.m. in a 50-m indoor pool (water temperature 26°C, air temperature 29°C, relative humidity 75%). Pairs of subjects competed side-by-side to provide motivation and competition, and strong verbal encouragement was provided during the test. Subjects were constantly aware of the time and distance covered. Water intake was allowed ad libitum. HR was recorded continuously during the tests via a Polar HR monitor (Polar Team 2; Kempele, Finland). The distance covered was recorded every 10 minutes. The 6-20 ratings of perceived exertion[19] were recorded immediately after the test was completed. Repeated venous blood samples were taken before, immediately after (5 minutes), and at 1, 3, 6, 12,

Table I. Subject characteristics and exercise data

	Adolescents			
	Tanner stage 3 (n = 4 male; 10 female)	Tanner stage 4 (n = 11 male; 11 female)	Tanner stage 5 (n = 10 male; 4 female)	Adults (n = 7 male; 9 female)
Subject characteristics				
Age, y	14.8 ± 1.8†,‡	15.1 ± 1.3†,‡	16.4 ± 1.6‡	31.1 ± 7.9
Height, m	1.59 ± 5.9*,†	1.65 ± 7.6	1.71 ± 7.6‡	1.64 ± 7.0
Weight, kg	51.9 ± 7.6*,†,‡	62.8 ± 12.9†	69.4 ± 12.0	67.5 ± 10.8
Body fat, %	17.5 ± 5.2	18.8 ± 7.3	17.4 ± 6.6	18.4 ± 6.3
Maximum HR, bpm	194 ± 8‡	194 ± 8‡	194 ± 7‡	185 ± 7
Training history, y	2.3 ± 1.6†,‡	2.7 ± 2.0‡	4.8 ± 3.6	7.1 ± 6.4
Training volume, h/wk	18.0 ± 0.0‡	18.0 ± 0.0‡	18.0 ± 0.0‡	14.5 ± 9.5
60-min performance				
Velocity, km/h	3.3 ± 0.4	3.4 ± 0.4	3.5 ± 0.3	3.3 ± 0.4
Mean HR, bpm	163 ± 13	165 ± 16‡	171 ± 11‡	152 ± 16
%HRmax	84 ± 7	85 ± 8	88 ± 6‡	82 ± 9
RPE	18 ± 1	18 ± 1	18 ± 1	18 ± 1

RPE, ratings of perceived exertion.
Values are presented as means ± SD.
*Significantly different from Tanner stage 4.
†Significantly different from Tanner stage 5.
‡Significantly different from adults.